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**A comparison of the avifaunal diversity on native hardwood plantations and
pastureland in north-east Victoria**

1999-2001

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1. INTRODUCTION

The potential for hardwood plantations to contribute to the biodiversity of an agricultural landscape has generated widespread interest, although any increase in biodiversity from plantations is yet to be quantified. Few studies have been conducted into the functionality of native hardwood plantations as ecosystems (Woinarski 1979, Kavanagh and Turner 1994, Law and Kavanagh 1998, and Kavanagh *et al.* 2001). The difficulties in determining the biodiversity values of farm forestry is attributed to the limited research work that has been conducted to compare species and habitat richness between cleared agricultural land and farm forestry (Ive and Lambeck. 1997). It is well known that cleared pastureland supports fewer native bird species than native forests (Green and Caterall 1998). Yet it is generally assumed that remnant vegetation has a higher biodiversity value than pastureland landscapes. Further more, few studies have compared the functionality of native hardwood plantations to that of pastureland land (Kavanagh *et al.* 2001).

This report presents the results of a two-year study designed to quantify the effects of plantations on biodiversity, using birds as a biological indicator. Biological indicators are those species which indicate the condition of the environment (Spellerberg, 1991). Studying biological indicators will assist in documenting changes in faunal assemblages following an environmental change (in this case, altering habitat from pastureland to developing native hardwood plantations).

This study was funded jointly by the Victorian Department of Natural Resources and Environment (DNRE) and the Natural Heritage Trust Program. It is being managed by the DNRE with Charles Sturt University and Ettamogah Research Consultants contracted to advise on survey techniques and undertake the bird surveys and reporting.

This study documents the changes in bird populations that have occurred following the conversion of pastureland to native hardwood plantations. A further aim of this study is to establish how ageing of the hardwood plantation, management techniques and neighbouring vegetation influences bird use of the areas.

Three properties in north-east Victoria established under the Farm Forestry of North East Victoria (FFORNE) were chosen as study sites. On each property bird surveys were conducted in the plantation, on the edge, pastureland and in nearby remnant vegetation. Each property was surveyed over a two-day period, every six weeks from August 1999 to July 2001.

2. STUDY AREA

The study area was located in the Benalla region, which is part of the broader north-east region of Victoria (Figure 1). Three properties were chosen from the FFORNE project for the study, each containing similar hardwood plantations of one or more species Southern Blue Gum *Eucalyptus globulus globulus*, Sydney Blue Gum *E. saligna* and Shinning Gum *E. nitens*. The three study sites (properties) chosen each shared the following characteristics:

- the plantations were established in 1996;
- plantations greater than 10 ha in size;
- all plantations were more than one kilometre from associated remnant sites;
- associated pastureland areas were at least 200 m away from the edge of the plantation site; and
- plantations were roughly square.

The locations of the three study sites is shown in Figure 2. The climate in terms of rainfall and temperature for the region is summarised in Table 2.

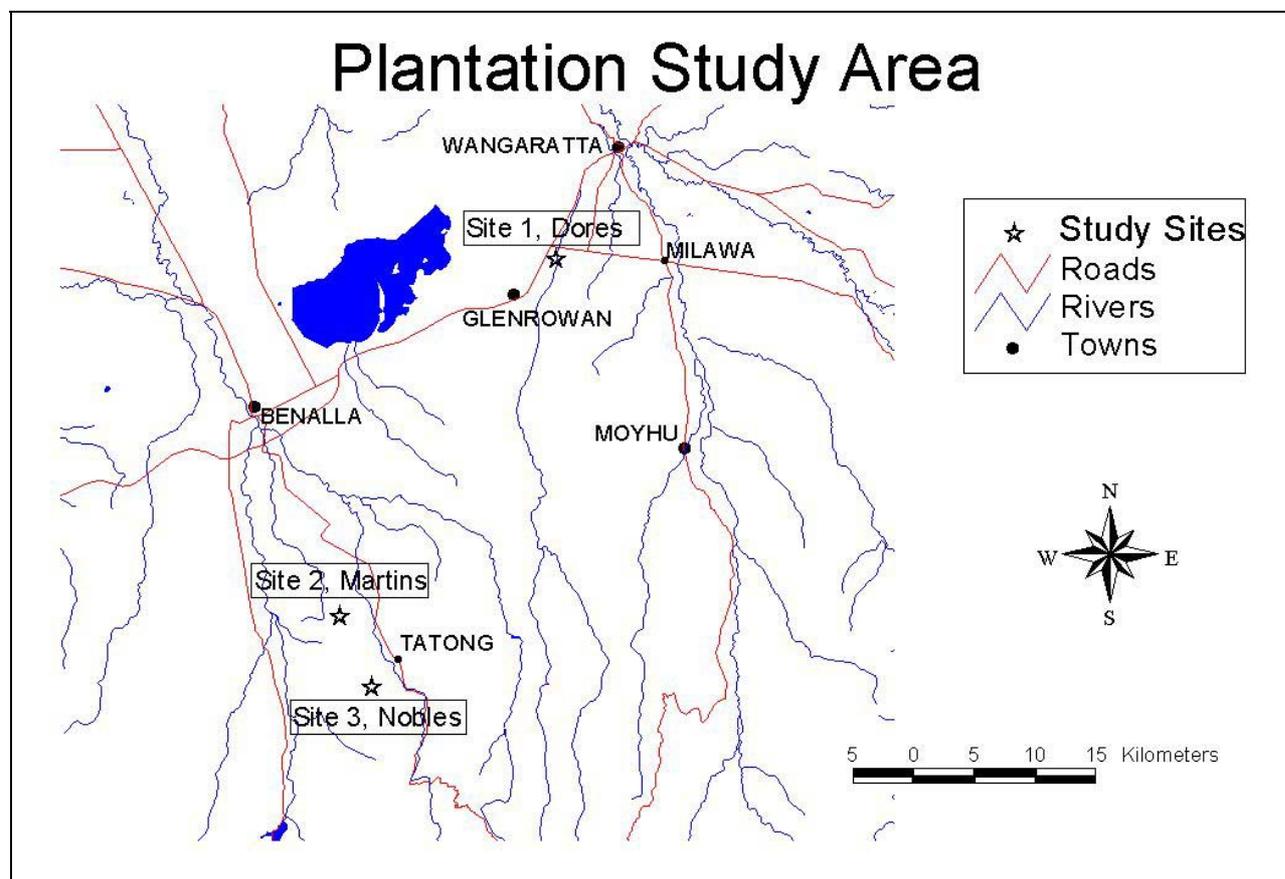


Figure 1. Study Area.

Study Site 1- Dores property

The Dores property is located east of Glenrowan, 2 km south of the Hume Highway. It contains *E. globulus* and *E. saligna* in separate adjacent blocks. The topography of the site is generally flat, with the low-lying country acting as a catchment basin for the surrounding mountain ranges. Creeks and other watercourses border the property. Pasturelands with some narrow riparian remnant zones and linear corridors of remnant vegetation surround the site. The remnant vegetation associated with this site is located one kilometre south of the property in the form of an open woodland consisting of Grey Box *Eucalyptus microcarpa* and White Box *E. albens* with a very sparse understorey of native and introduced shrubs and groundcover species.



Figure 2. Dores plantation (December 2000). Note dense understorey of Phalaris, which was consistent throughout the survey.

Study Site 2 - Martins property

The Martins property is located south of Benalla off Martins Road, near Tatong. The plantation consists solely of *E. globulus*, located at the top of a gentle slope, which leads into the adjacent pastureland site. The plantation is bordered on one side by a belt of remnant vegetation, which extends through the property. The site is surrounded by pastureland with a number of farm dams and belts of remnant vegetation. The remnant vegetation associated with this site is in the form of closed woodland consisting of Red Stringybark *E. macrorhyncha*, Grey and White Box with a sparse, predominately native shrubby understorey. It is located off Samaria Road approximately 5 km from the property.



Figure 3. Martins Plantation (January 2001), two months after final pruning and thinning was completed. Stocking rate is now 400 trees per hectare.

Study Site 3 – Nobles property

Located south of Benalla off Larkin Road between Tatong and Samaria, Nobles property has a plantation of *E. globulus* and *E. nitens* in separate blocks. It is located on a steep easterly-orientated slope with the associated pastureland further down slope. The immediate area surrounding the site is generally characterised by pastureland with some remnant vegetation. The property is largely surrounded by mountainous country consisting of remnant vegetation and some *Pinus radiata*. Remnant vegetation associated with the site is located off Larkin Road more than 1 km south of the site, and consists of Box/Callitris woodland, with a modified understorey of predominately introduced species.



Figure 4. Nobles property, edge study area showing plantation (January 2001). Note the minor pruning of the trees to the right. All plantations are typically this dense before pruning and/or thinning.

Table 1 details the changes within each of the three plantations prior to and during the course of the study as a result of the management of each plantation.

3. METHODOLOGY

Field sampling methodology

The three study sites were each considered to contain four study areas: the native hardwood plantation itself, edge of the plantation, pastureland and local remnant vegetation sites. The remnant vegetation sites were surveyed in order to establish a benchmark for the bird species potentially occurring within the region.

Bird surveys were conducted in each area (plantation, edge, pastureland and remnant) at each site, using the following methodology. A permanent point was selected within each area (see Figure 4). The sight and sound of all birds were recorded over a 15-minute period within a 25 m radius of the permanent point. The permanent point for all edge areas was placed 10 m into the plantation.

Counts of bird calls and sightings were conducted at each site (four areas per site) for two consecutive days every six weeks (August 1999 – July 2001), yielding four surveys per season, per site. Weather conditions, time and other variables were also recorded.

A regional species list was compiled consisting of all birds seen or heard outside the 25 m radius or designated 15-minutes survey time. Only birds regarded as utilising the habitat of the study area, (e.g. foraging, social interaction, breeding, as temporary refuge, hunting) were recorded. Birds flying over or directly through a study area were not recorded. All surveys were conducted within the first few hours of sunrise.

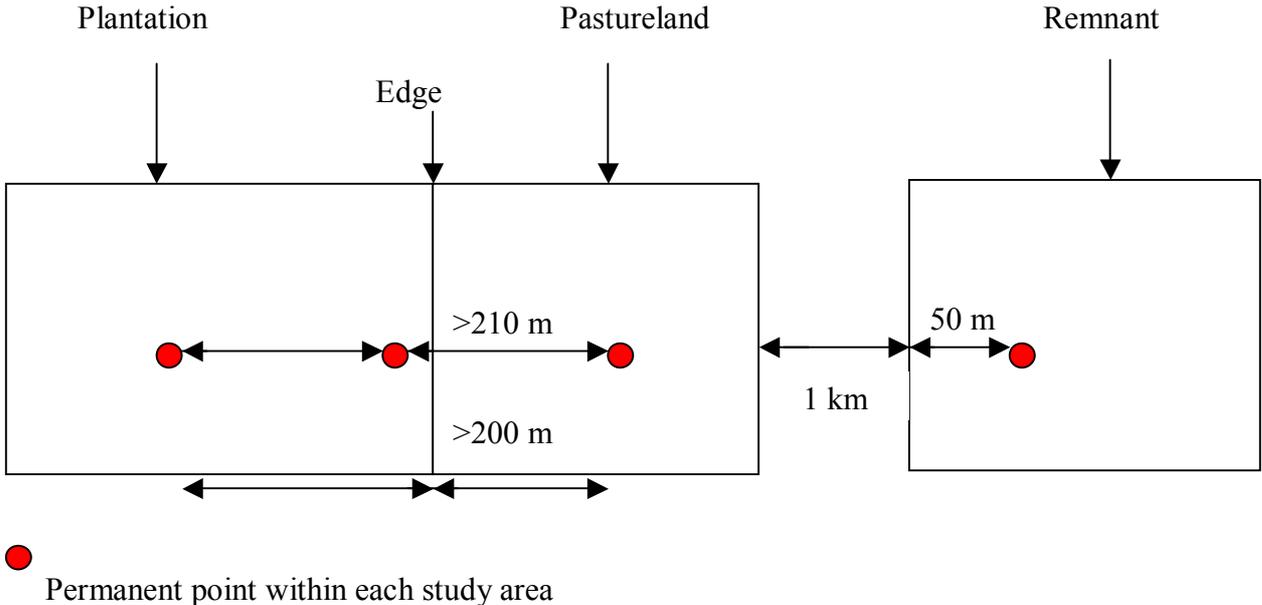


Figure 5. The locations of the study areas within each study site.

Analysis of data

We were keen to understand how numbers of individuals and numbers of species varied among properties, treatments (study areas) and date. Initially, the research was designed to use the three different properties as replicates of the four treatments (remnant, edge, pastureland and plantation) across seventeen dates. However, the properties were subjected to different management regimes (see earlier), so could not be considered to be true replicates in the subsequent statistical analyses. Instead, a three-factor ANOVA (without replication) was conducted using repeated measures on the third factor (date). Such analyses assume there is no three-way interaction (among date, property and treatment); an assumption that was valid in this study (see later results). The data were transformed prior to analysis, with numbers of species square-rooted and numbers of individuals log transformed to improve normality. A Tukey's Test was used to determine the nature and significance of any differences recorded.

Table 1. Modifications to each plantation of the study.

	Year Planted	Stem density at stocking rate	Approximate height	Modifications/Changes
Sites	Dores	1000	6 – 8 m	No pruning or thinning during or before study. Only occasional grazing of the understorey to reduce fire hazard.
	Martins	1000	8 – 10 m	<ul style="list-style-type: none"> ▪ first pruned November 1999 up to 2-3 m ▪ pruned up to 4-5 m and thinned to stocking rate of 400 stems per ha (sph) October - November 2000 ▪ occasional grazing of the understorey (sheep and cattle) to reduce fire hazard
	Nobles	1000	8 – 10 m	<ul style="list-style-type: none"> ▪ first pruned up to 2-3 m March 1998 ▪ first thinned April 1999 to 600 sph ▪ pruned up to 4 m March and August 2000 ▪ pruned up to 6 m and thinned to 400 sph April 2001 ▪ occasional grazing of the understorey (sheep and cattle) to reduce fire hazard

Table 2. Temperature and precipitation values for the Benalla region.

Year	Name and Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1999	Mmax Air Temperature (°C)	33.8	30.6	26.5	21.5	18.1	14.9	14.9	16	19.7	21.7	23.7	27.1	22.4
1999	Mmin Air Temperature (°C)	18.9	15.6	12.9	6.6	5.9	3.8	3.6	4.5	7.1	9.4	9.1	13.5	9.2
1999	Total Monthly Precipitation (mm)	28.8	4.6	83	56	104.2	60.6	32	99.8	37.2	58.2	58.8	73	696.2
2000	Mmax Air Temperature (°C)	28.1	32.4	27.8	22.9	16.1	13.3	13.2	14.7	17.6	19.7	26.6	29.6	21.8
2000	Mmin Air Temperature (°C)	13.9	17.1	14.5	8.8	5.7	3.6	3.3	4	6.6	8	13.7	13.1	9.4
2000	Total Monthly Precipitation (mm)	8.4	49.6	27.6	37.8	70.6	60.2	73.4	89.4	90.4	76.8	88.2	7.8	680.2
2001	Mmax Air Temperature (°C)	33.8	31.8	26.5	23.1	18.3	15.1	15	—	—	—	—	—	—
2001	Mmin Air Temperature (°C)	18.5	17.3	11.9	8.1	4.7	4.8	3.6	—	—	—	—	—	—
2001	Total Monthly Precipitation (mm)	62.6	54.2	37.6	49.6	11.4	58.6	42	54.6	48.8	—	—	—	—

Source: Prepared by John Cornell-Reilly, Climate & Consultancy Section in the Victorian Regional Office of the Bureau of Meteorology October 2001.
Mmax = Mean max, Mmin = Mean Minimum

4. RESULTS

A total of 126 bird species were recorded during the study, including the incidental sightings within the study area (see Appendix 1). Eighty-two of the 126 species were recorded during the systematic surveys of the study sites.

4.1 Comparison of the vegetation areas

The majority of species (85.4%) and majority of all individuals (58.9%) were recorded in remnant vegetation areas. More species and individuals were observed using edge areas (58.5% and 18.2% respectively) and plantation areas (52.4% and 14.8% respectively) than using pastureland (30.5% of all species and 8.1% of all individuals), as shown in Table 3 and 4.

Table 3. Number of *species* recorded per area for each study site.

Study Sites	Study Area			
	Plantation	Edge	Pastureland	Remnant
Dores	19	19	15	37
Martins	24	29	14	48
Nobles	33	32	11	56
Average no. of species for each area	14.33	16	8.33	23.33
Total no. of species for each area	43	48	25	70

Although the remnant vegetation supported larger bird diversity than the native hardwood plantation areas on all properties, the fact that native hardwood plantations supported greater species diversity than the pastureland is significant (Figure 5). Within all three properties, the number of species recorded within the plantation and edge areas exceeded the number of species recorded within pastureland areas. The number of species recorded within the Nobles plantation and edge areas more than doubled the number of species recorded within pastureland (Table 3). The number of species recorded within the edge area of the Martins property was also more than double the number of species recorded within their pastureland. The number of species recorded within the Martins plantation area, also significantly exceeded the number of bird species recorded within pastureland.

The number of bird species recorded in native hardwood plantations (Table 3) ranged from 19-33 with an average of 14.3 for plantation areas, and from 19-32 species with an average of 16.0 for edge areas. In contrast, species richness of pastureland ranged from 11-15 species with an average of 8.3. Remnant sites displayed a species richness ranging from 37-56 species with an average of 23.3.

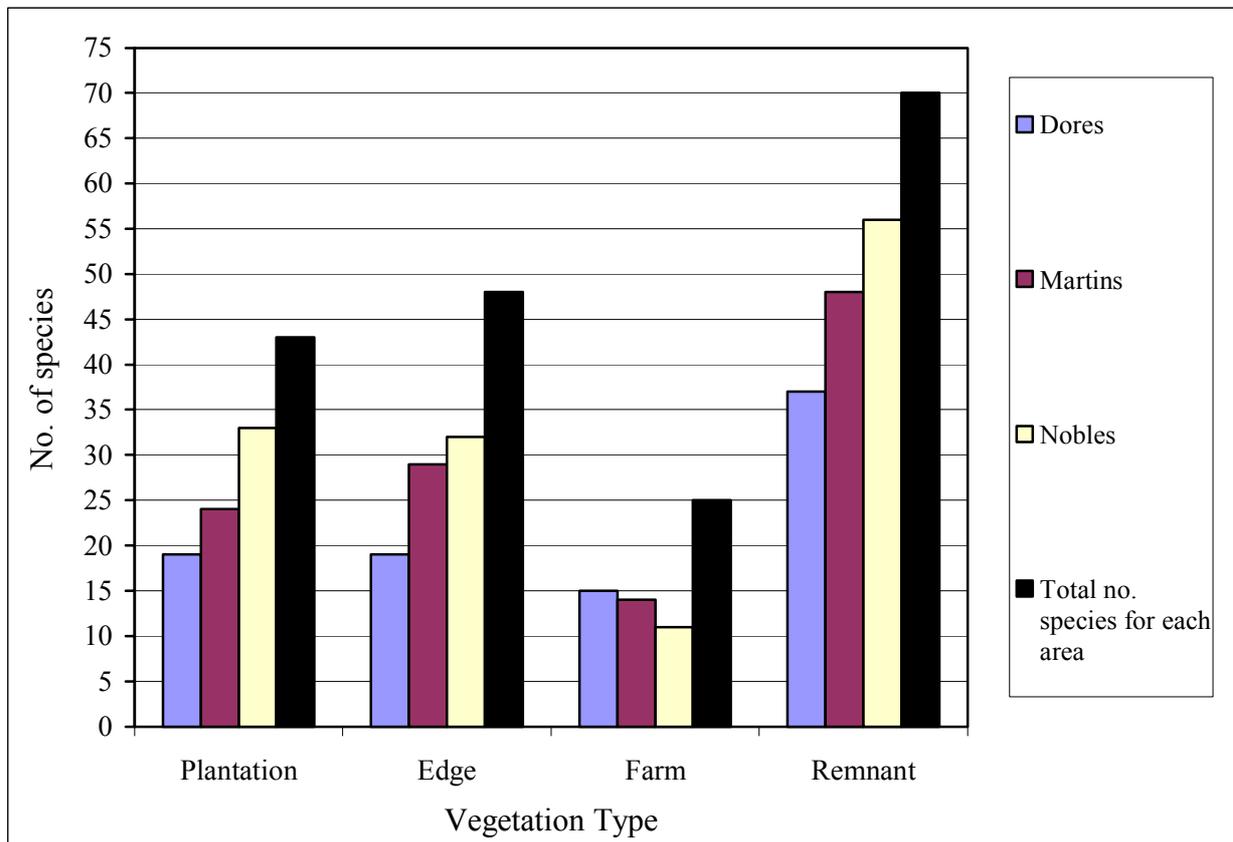


Figure 6. Number of *species* observed in each study area at each study site (property).

The number of individuals recorded within each area (plantation, edge, pastureland, remnant) broadly reflects the number of species recorded within each area. Remnant vegetation contained more than triple the number of individuals recorded in other vegetation types (Table 4 and Figure 7). Indeed, the number of individuals recorded within each remnant vegetation area exceeded all other vegetation types for each property. The number of individuals recorded within all edge areas always exceeded the number of individuals recorded within all pastureland and all plantation areas except for one. The number of individuals recorded within plantation and edge areas always significantly exceeded the number of individuals recorded within pastureland by at least 30% and sometimes more than 200%.

Table 4. Number of *individuals* recorded for each area at each study site.

Study Sites	Study Area				Total no. of individuals for each site
	Plantation	Edge	Pastureland	Remnant	
Dores	126	168	87	888	1269
Martins	224	183	137	562	1106
Nobles	254	395	106	958	1713
Total no. of individuals for each area	604	746	330	2408	
No. of surveys	33	33	33	33	

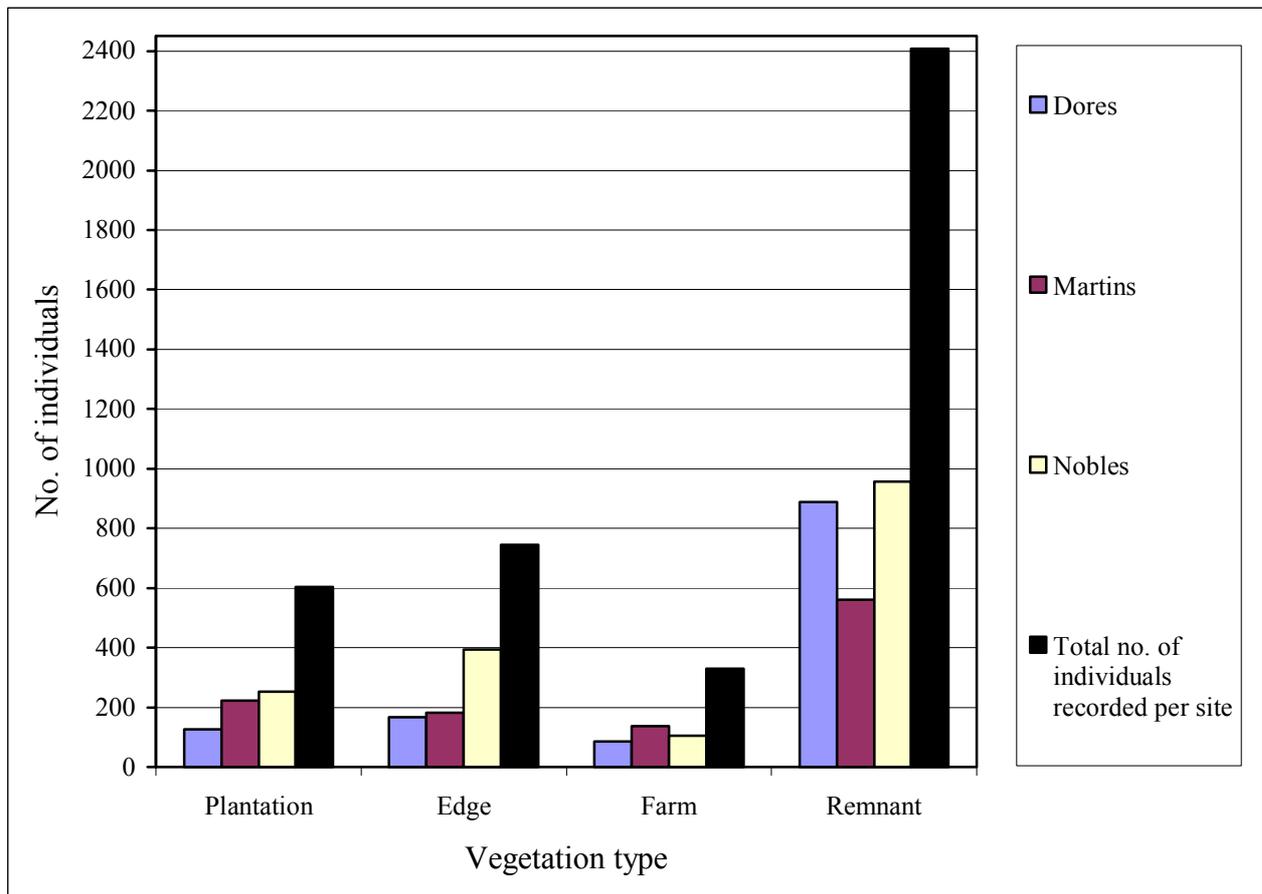


Figure 7. Number of *individuals* observed for each area at each study site (property).

4.2 Comparison of the study sites (properties)

The Noble's property had the greatest number of bird species present during the surveys (67 species). This property recorded the greatest number of species for all plantations (33), more than doubling the average of 14.3. The Noble's property also recorded the greatest number of species for all edge areas (32) and the lowest species diversity of all pastureland areas (11). The Dores property had the greatest number of species present of all pastureland areas (15) and, although above average, it had the fewest species of all edge (19) and plantation areas (19).

4.3 Seasonal variations

A number of seasonal trends in numbers of bird species became obvious over the two years of the study. It can be seen in Figure 8 that the number of species within the plantation and edge areas generally increased during the September-February period, which is likely to be a response to the commencement of spring and warmer months of the year. Species numbers generally decreased within the plantation and edge areas during the cooler months. This is also generally characteristic of species diversity within remnant areas. Almost the opposite occurred within pastureland areas. Although numbers of species in pastureland areas are at their greatest during late August and September, with the onset of spring, species numbers are at their lowest during the warmest months of the year and only start to increase again during late March.

4.4 Interactive effects of management and biodiversity

The various management practices implemented in each plantation may affect bird species diversity and abundance. As can be seen in Figure 9, after thinning and pruning was conducted at the Martins plantation in order to manipulate the plantation to its final stocking rate, a change in species abundance occurred. The number of new species (species not previously recorded within the study area) recorded within the plantation after final pruning and thinning (October-November 2000) increased by 37.5% over a 10-month period (October 2000-July 2001). Other plantation areas only experienced minor increases in species numbers (<22%) compared to the Martins plantation over a 12 month period (Table 5).

Table 5. Increase in the number of bird species recorded from July 2000 – July 2001. Numbers in brackets represent number of new species recorded from July 2000 – July 2001.

Study Sites	Study Area			
	Plantation	Edge	Pastureland	Remnant
Dores	21.05% (4)	21.05% (4)	6.66% (1)	5.41% (2)
Martins	50% (12)	24.14% (7)	28.57% (4)	20.83% (10)
Nobles	21.21% (7)	31.25% (10)	18.18% (2)	19.65% (11)

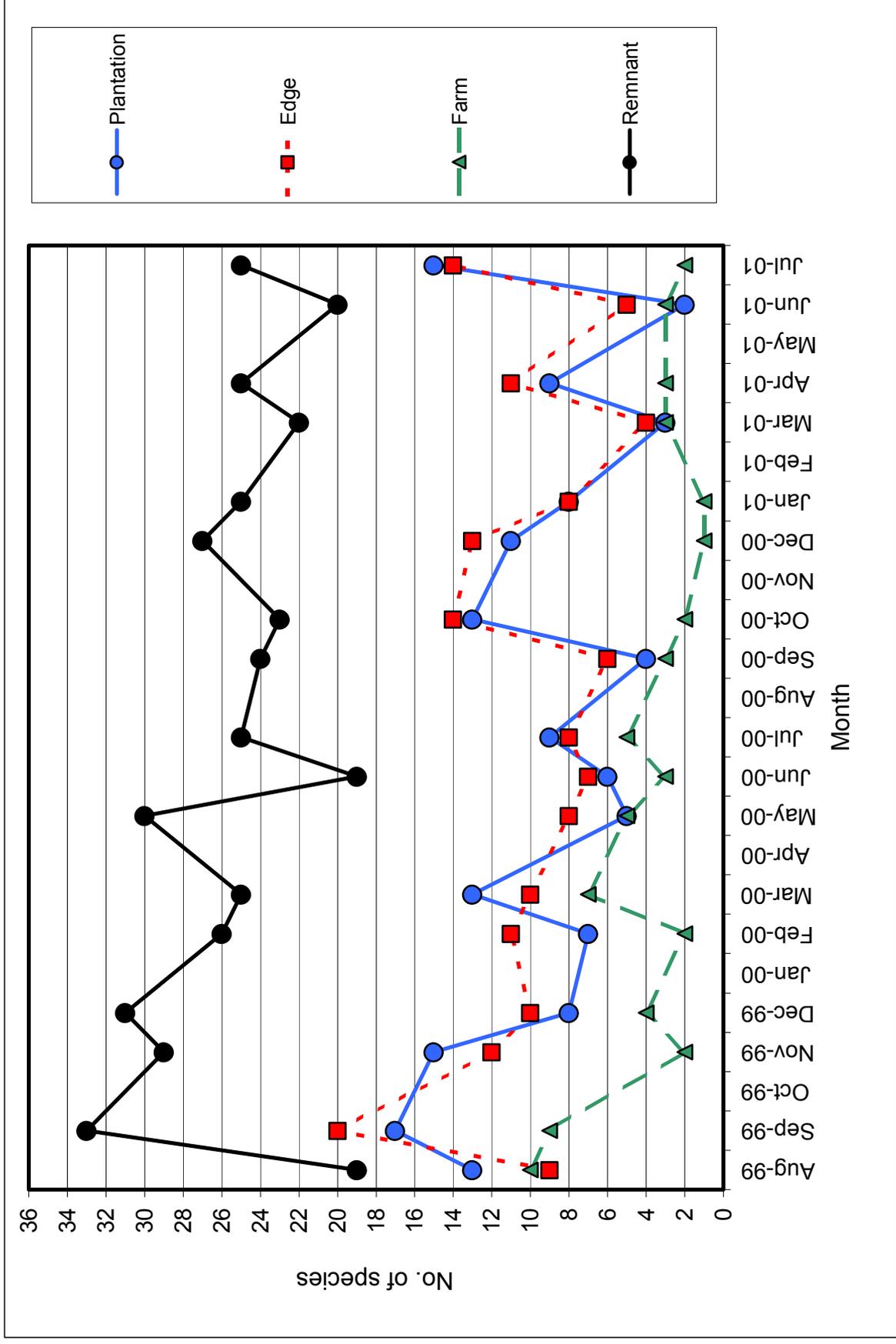


Figure 8. Seasonal changes in numbers of bird species in each area (study sites combined).

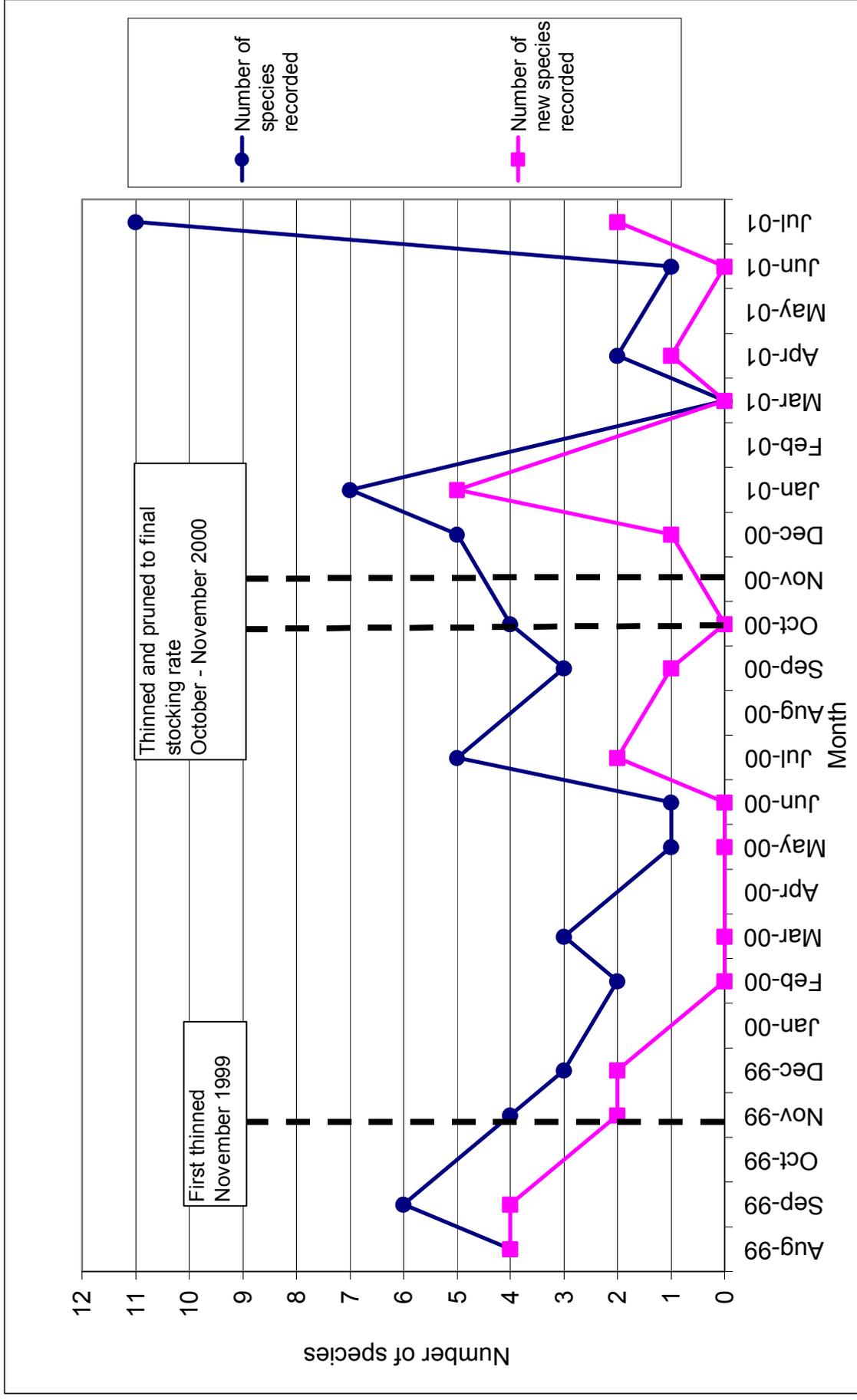


Figure 9. Number of species recorded within the plantation area of Martins throughout the course of the survey. Note timing of thinning and pruning in plantation.

The differences in numbers of birds (species and individuals) among the three properties were consistent across the two years ($F_{16, 96} = 1.14, P=0.33$), but the differences in species observed among the three properties were dependent on the treatment ($F_{16, 96} = 7.47, P<0.0001$). This means that we can determine the effect of the treatments (remnant, edge, pastureland and plantation) on the number and variety of birds as the time of the year does not influence the results.

The following tables present the results of the follow-up Tukey's Multiple Comparison Tests (with Tukey's correction) performed on these data. It can be seen that the remnant vegetation study areas supported significantly more birds (species and individuals) than the other areas. The edge and plantation study areas supported significantly more avifauna than pastureland areas.

Table 6. The mean number of bird *species* in the different treatments (study areas) and properties (all data combined). Lines connect the treatments that do not differ significantly.

Treatment	Property	Mean	
Remnant	Nobles	3.861	
Remnant	Dores	3.720	
Remnant	Martins	3.408	
Edge	Nobles	2.510	
Plantation	Nobles	2.297	
Plantation	Martins	1.935	
Edge	Martins	1.887	
Edge	Dores	1.811	
Plantation	Dores	1.794	
Pastureland	Dores	1.565	
Pastureland	Martins	1.561	
Pastureland	Nobles	1.309	

Table 7. The mean number of *individual* birds in the different treatments (study areas) and properties (all data combined). Lines connect the treatments that do not differ significantly.

Treatment	Property	Mean
Remnant	Nobles	1.735
Remnant	Dores	1.705
Remnant	Martins	1.475
Edge	Nobles	1.346
Plantation	Nobles	1.097
Plantation	Martins	0.945
Edge	Martins	0.921
Edge	Dores	0.839
Plantation	Dores	0.801
Pastureland	Dores	0.775
Pastureland	Martins	0.651
Pastureland	Nobles	0.575

4.5 Species most commonly recorded within the plantation

The majority of birds recorded within each of the plantation and edge areas were insectivorous (see Table 8). All native species found within the plantation areas, apart from the Eastern Rosella and, to a lesser extent, the White-plumed and Yellow-faced Honeyeaters rely almost entirely on insects for feeding. A number of foraging techniques are adopted by different species to utilise the various resources of the plantation. The Grey Fantail hovers and hawks (bird and prey in the air) for insects in the air, whilst other species glean (picking prey of substrate) insects from branches and leaves on the ground (e.g. the Superb Fairywren). The Brown and Striated Thornbill's both glean insects from the foliage of trees at various height levels (Ford 1989)

The two parrot species found within the plantation and edge areas are both primarily seed eaters. The Eastern Rosella forages for seeds on the ground and probably within the plantation, while the Red-rumped Parrot forages for seeds on the ground. The Eastern Rosella may eat more insects in winter and spring, when seeds are not as abundant (Ford 1989). No other granivorous species were recorded within the plantation or edge sites, apart from occasional records of the Crested Pigeon, Common Bronzewing, Red-browed Firetail and Crimson Rosella.

The diversity of species recorded within the plantation is a reflection of the overall structural and floristic diversity of the plantation. The plantations are structured simply when compared to the higher floristic diversity and multiple layers found within the remnant areas.

Table 8. The five most commonly recorded bird species within each vegetation type for each property. Numbers in brackets are the number of times each species was recorded for the 17 surveys (e.g. the Grey Fantail was recorded during 11 of the 17 surveys in the Dores Plantation).

	Plantation	Edge	Pastureland	Remnant
Dores	<ol style="list-style-type: none"> 1. Grey Fantail (11) 2. Superb Fairywren (9) 3. Eastern Rosella (5) 4. Flame Robin, Rufous Whistler, Yellow-rumped Thornbill & Striated Thornbill (3) 5. Grey Shrike-thrush & Brown Thornbill (2) 	<ol style="list-style-type: none"> 1. Superb Fairy-wren (11) 2. Willie Wagtail (5) 3. Red-rumped Parrot, Singing Bushlark & Magpie (3) 4. Eastern Rosella, Flame Robin, Restless Flycatcher & Yellow-rumped Thornbill (2) 5. Black-faced Cuckoo-shrike, Striated Pardalote (1) and others 	<ol style="list-style-type: none"> 1. Mapie (12) 2. Australian Raven (4) 3. Magpie-lark, Willie Wagtail, Welcome Swallow & Eastern Rosella (3) 4. All other species recorded (1) 	<ol style="list-style-type: none"> 1. Superb Fairy-wren & White-plumed Honeyeater (17) 2. Magpie (15) 3. Willie Wagtail (14) 4. Noisy Miner (12) 5. Eastern Rosella, Striated Pardalote Magpie-lark (11)
Martins	<ol style="list-style-type: none"> 1. Grey Fantail (10) 2. White-winged Chough (7) 3. Brown Thornbill (5) 4. Striated Thornbill & White-plumed Honeyeater (4) 5. Eastern Rosella, Golden Whistler & Superb Fairywren (3) 	<ol style="list-style-type: none"> 1. Grey Fantail (9) 2. White-plumed Honeyeater & White-winged Chough (5) 3. Grey Shrike-thrush & Mistletoebird (4) 4. Willie Wagtail & Striated Pardalote (3) 5. Richard's Pipit, Black-faced Cuckoo-shrike, Rufous Whistler & Yellow-rumped Thornbill (2) 	<ol style="list-style-type: none"> 1. Magpie (15) 2. Magpie-lark (4) 3. Sulphur-crested Cockatoo & Welcome Swallow (3) 4. Crested Pigeon (2) 5. All other species recorded (1) 	<ol style="list-style-type: none"> 1. Superb Fairy-wren & White-throated Treecreeper (16) 2. Grey Fantail (11) 3. Brown Treecreeper (10) 4. Magpie (9) 5. Laughing Kookaburra & Magpie-lark (8)
Nobles	<ol style="list-style-type: none"> 1. Grey Fantail (12) 2. Grey Shrike-thrush & Striated Thornbill (8) 3. Brown Thornbill (7) 4. Yellow-faced Honeyeater (6) 5. Blackbird (5) 	<ol style="list-style-type: none"> 1. Superb Fairy-wren & Brown Thornbill (12) 2. Grey Fantail (11) 3. Striated Thornbill (8) 4. Yellow-faced Honeyeater (7) 5. Striated Pardalote (5) 	<ol style="list-style-type: none"> 1. Mapie (11) 2. Sulphur-crested Cockatoo (4) 3. Galah (2) 4. All other species recorded (1) 	<ol style="list-style-type: none"> 1. Superb Fairy-wren (17) 2. White-plumed Honeyeater (16) 3. Eastern Rosella (14) 4. Laughing Kookaburra, Willie Wagtail & White-throated Treecreeper (12) 5. Crimson Rosella, Restless Flycatcher & Magpie (11)

5. DISCUSSION

Throughout this report an emphasis has been placed on comparing the number of species recorded, as opposed to the number of individual birds. The number of individuals do not give an accurate representation of the diversity within a site and can be easily influenced by a single flock of birds. Hence, the results of this study should largely be interpreted by comparing numbers of bird species within different properties, treatments and seasons.

The results to date indicate a preference by birds for remnant vegetation. This can be largely attributed to the structural complexity of the remnant vegetation, compared to the simple, single layer, monoculture plantings of the native hardwood plantations. Remnant vegetation not only displays a higher level of structural diversity, but also a higher level of floristic diversity than all other areas. However, it is important to note the native hardwood plantations in this study were found to support greater species diversity than the pastureland on which they were established. All plantation and edge areas displayed a higher level of species diversity than the associated pastureland areas.

Species diversity is influenced by the management practices applied to each plantation. The Martins plantation recorded a significant increase in bird species, following intensive pruning and thinning of the plantation during October–November 2000. Numbers of species increased by more than one third over a ten-month period following pruning, while other plantation study areas, recorded less than a 20% increase in the number of new species over a longer period of time. Given that no other plantation underwent such a sudden change, it is likely that the increase in bird species is a result of (or at least largely influenced by) the type of management within this plantation. Thinning and pruning results in a large accumulation of ground debris in the form of large branches and leaves, which attracts and insectivorous birds. The fallen debris also offers temporary refuge for a number of smaller bird species (e.g. Thornbill species).

The Nobles plantation was also pruned and thinned during the study. This was conducted at a slower rate. No significant changes to bird species diversity occurred during this management. The changes in species composition over time was largely a result of seasonal influences rather than minor management practices. It is also likely that the bird diversity of pastureland study areas is influenced by the agricultural practices undertaken by the property owners. All property owners slashed or grazed their pastureland study areas at different times of the year. Grazing of pasturelands and the understorey within the plantations occurred continuously throughout the duration of the study.

The topography, rainfall, proximity to other native vegetation and other land characteristics of the study site can also have an influence on species diversity. The Dores property, which is located in flat, low-lying country, supported a relatively low number of species in both edge and plantation areas. The two other study sites were located in sloping, undulating country and displayed much higher species diversity for both plantation and edge areas.

It is evident from the results of this survey that the conversion of pastureland into native hardwood plantations has increased the number of bird species and, thus, overall biodiversity within the properties. The lower species diversity found in pastureland can be largely attributed to the lack of structurally suitable habitat for some species and, to a lesser extent, floristically suitable habitat. By introducing the native hardwood plantations onto pastureland, additional vegetation layers have been created, hence increasing overall structural diversity and avifaunal diversity of the study area.

It is more than likely that further changes in species diversity and composition will be seen in the next few years as the plantation further develops and further pruning and thinning occurs to improve the growth rate of selected trees.

6. CONCLUSION AND RECOMMENDATIONS

Native hardwood plantations have the potential to significantly increase the conservation of avifaunal diversity in agricultural landscape. However there are still significant differences between avifauna diversity of native hardwood plantations and native remnant vegetation. Ultimately, the protection of areas of remnant vegetation will have the greatest influence on bird diversity in the landscape.

It is likely that plantation age, plantation size, proximity to native vegetation and the number and diversity of trees and shrubs planted are among the most important factors influencing bird diversity in eucalyptus plantations (Kavanagh *et al.* 2001). Further studies could be conducted to determine the plantation characteristics which are most attractive to birds.

Further studies

In order to provide a greater understanding of the use of plantations by bird species further studies are recommended. This type of information is not obtained during standard bird surveys. Such studies could also use birds as indicators of the overall biodiversity of the plantations.

1. Existing data could be used to determine bird assemblages across the four study areas and three study sites. Analysis could be conducted into the relationship between woodland-dependent species and other species. This could further help determine how native hardwood plantations contribute to biodiversity.
2. The bird diversity found in plantation edges was very similar to that found in the plantation, but the effect of tree planting in strips increasing the overall edge effect was not investigated.
3. The management of plantations for sawlogs by thinning and pruning of trees will have an effect on bird biodiversity. The initial effect seems to be an increase in bird species due to the increased leaf and branch litter. The longer term effects on birds of thinning a plantation of around 200 trees per hectare (pruned to six metres) needs further investigation.
4. Time budgeting studies are required to determine which species feed in the plantation and edge areas. How plantations support specialist feeders and/or generalist feeders, which strata levels are preferred by different bird species, and which food and prey items are obtained by birds in altered landscapes.

Potential management practices to be undertaken by plantation owners

Native hardwood plantations tend to consist of a monoculture (single species) and are largely managed for timber production, so there is little opportunity for many bird habitats to develop within the plantation. The emphasis should therefore be placed on enhancing the existing habitat provided by the plantation. Habitat values (characteristics) may be enhanced by modification to the size, shape or location of the plantation (Bennett *et al.* 2000). Increasing the size and width of a plantation and connecting the plantation with other nearby areas of vegetation can be expected to enhance the habitat value of the plantation. Opportunities also exist to increase the diversity of the habitat structure and habitat resources of the plantation by adding local understorey and groundcover species between rows, and by planting trees at intervals to ensure a variety of age classes.

The following guidelines have been provided as an option for plantation owners to increase the habitat value of their plantation for birds (as adopted from Abel *et al.* 1997 and Bennett *et al.* 2000):

- Use locally indigenous species for ground cover and understorey planting. Priority must be given to planting locally indigenous species to an area as they are most likely to provide natural habitat resources (foods, foraging substrates, refuge, etc) that local species require.
- Establish natural layers in the vegetation where possible. Different layers provide for different types of foraging substrate, nesting locations and shelter for animal species. This can be achieved by planting species of different heights (i.e. ground cover, shrubs, mid-storey species etc). Where possible, mimic patches of natural bushland. In addition, ground layer components can be added as resources for wildlife. Hollow logs, branches and leaf litter provide shelter, refuge and living space. Leaving branches and fallen trees after thinning and pruning operations can assist in the development of ground layers.
- Patchiness of vegetation. In natural bushland areas plants occur in a patchy manner. This may include areas containing open clearings, dense thickets and areas of sparse cover. To mimic patchiness within plantations, shrubs and trees of a variety of species can be planted at irregular distances and at different stages (to create patches of vegetation of different ages) along the outside row or outside the plantation.
- Management of vegetation. The way in which a plantation is managed will influence the habitat quality for bird species. Maintaining habitat resources (i.e. fallen timber and multiple layers of vegetation) requires management to ensure that these resources are not completely removed when harvesting or tidying the plantation.
- Existing remnant vegetation. Retaining remnant vegetation during plantation establishment has the potential to increase bird diversity within a plantation. Older remnant trees (habitat trees) offer a range of foraging, sheltering and breeding opportunities. This is a reflection of the different structure of habitat provided by the older trees, compared to the simple, often single-layer monoculture of the native hardwood plantations.

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Appendix 1. Total species list of all birds seen or heard during the study, including incidental recordings.

(* denotes introduced species)

<i>Coturnix pectoralis</i>	Stubble Quail
<i>Coturnix ypsilophora</i>	Brown Quail
<i>Phalacrocorax melanoleucos</i>	Little Pied Cormorant
<i>Phalacrocorax carbo</i>	Great (Black) Cormorant
<i>Phalacrocorax sulcirostris</i>	Little Black Cormorant
<i>Tachybaptus novaehollandiae</i>	Australasian Grebe
<i>Anas superaliosa</i>	Pacific Black Duck
<i>Anas castanea</i>	Grey Teal
<i>Anas castanea</i>	Chestnut Teal
<i>Chenonetta jubata</i>	Maned Duck
<i>Ardea pacifica</i>	Pacific Heron
<i>Ardea novaehollandiae</i>	White-faced Heron
<i>Ardea intermedia</i>	Intermediate Egret
<i>Egretta garzetta</i>	Little Egret
<i>Threskiornis aethiopica</i>	Australian White Ibis
<i>Threskiornis spinicollis</i>	Straw-necked Ibis
<i>Platalea flavipes</i>	Yellow-billed Spoonbill
<i>Vanellus miles</i>	Masked Lapwing
<i>Elseyaornis melanops</i>	Black-fronted Dotterel
<i>Elanus notatus</i>	Black-shouldered Kite
<i>Milvus sphenurus</i>	Whistling Kite
<i>Aquila audax</i>	Wedge-tailed Eagle
<i>Hieraaetus morphnoides</i>	Little Eagle
<i>Accipiter fasciatus</i>	Brown Goshawk
<i>Accipiter cirrhocephalus</i>	Collared Sparrowhawk
<i>Falco peregrinus</i>	Peregrine Falcon
<i>Falco longipennis</i>	Australian Hobby
<i>Falco berigora</i>	Brown Falcon
<i>Falco cenchroides</i>	Australian Kestrel
<i>Geopelia placida</i>	Peaceful Dove
<i>Geopelia cuneata</i>	Diamond Dove
<i>Phaps chalcoptera</i>	Common Bronzewing
<i>Phaps elegans</i>	Brush Bronzewing
<i>Geophaps lophotes</i>	Crested Pigeon
<i>Callocephalon fimbriatum</i>	Gang-Gang Cockatoo
<i>Cacatua roseicapilla</i>	Galah
<i>Cacatua pastinator</i>	Little Corella
<i>Cacatua galerita</i>	Sulphur-crested Cockatoo
<i>Glossopsitta pusilla</i>	Little Lorikeet
<i>Alisterus scapularis</i>	Australian King-Parrot
<i>Platycercus elegans</i>	Crimson Rosella
<i>Platycercus eximus</i>	Eastern Rosella
<i>Psephotus haematonotus</i>	Red-rumped Parrot
<i>Cuculus pallidus</i>	Pallid Cuckoo
<i>Chrysococcyx basalis</i>	Horsefield's Bronze-Cuckoo
<i>Podargus strigoides</i>	Tawny Frogmouth
<i>Hirundapus caudacutus</i>	White-throated Needletail
<i>Dacelo novaguineae</i>	Laughing Kookaburra

<i>Todirhampus sancta</i>	Sacred Kingfisher
<i>Merops ornatus</i>	Rainbow Bee-eater
<i>Eurystomus orientalis</i>	Dollarbird
<i>Daphoenositta chrysoptera</i>	Varied Sittella
<i>Cormobates leucophaea</i>	White-throated Tree-creeper
<i>Climacteris picumnus</i>	Brown Treecreeper
<i>Malurus cyaneus</i>	Superb Fairy-wren
<i>Pardalotus punctatus</i>	Spotted Pardalote
<i>Paerdalotus striatus</i>	Striated Pardalote
<i>Sericornis frontalis</i>	White-browed Scrubwren
<i>Sericornis sagittatus</i>	Speckled Warbler
<i>Smicrornis brevirostris</i>	Weebil
<i>Gerygone fusca</i>	Western Gerygone
<i>Gerygone olivacea</i>	White-throated Gerygone
<i>Acanthiza pusilla</i>	Brown Thornbill
<i>Acanthiza lineata</i>	Striated Thornbill
<i>Aphelocephala leucopsis</i>	Southern Whiteface
<i>Acanthiza reguloides</i>	Buff-rumped Thornbill
<i>Acanthiza chrysorrhoa</i>	Yellow-rumped Thornbill
<i>Anthochaera carunculata</i>	Red Wattlebird
<i>Philemon corniculatus</i>	Noisy Friarbird
<i>Philemon citreogularis</i>	Little Friarbird
<i>Entomyzon cyanotis</i>	Blue-faced Honeyeater
<i>Manorina melanocephala</i>	Noisy Miner
<i>Lichenostomus chrysops</i>	Yellow-faced Honeyeater
<i>Lichenostomus leucotis</i>	White-eared Honeyeater
<i>Lichenostomus malanops</i>	Yellow-tufted Honeyeater
<i>Lichenostomus fuscus</i>	Fuscous Honeyeater
<i>Lichenostomus pencillatus</i>	White-plumed Honeyeater
<i>Melithreptus brevirostris</i>	Brown-headed Honeyeater
<i>Melithreptus lunatus</i>	White-naped honeyeater
<i>Phylidonyris pyrrhoptera</i>	Crescent Honeyeater
<i>Phylidonyris novaehollandiae</i>	New Holland Honeyeater
<i>Acanthorhynchus tenuirostris</i>	Eastern Spinebill
<i>Petroica phoenica</i>	Flame Robin
<i>Petroica multicolor</i>	Scarlet Robin
<i>Petroica goodenovii</i>	Red-capped Robin
<i>Eopsaltria australis</i>	Eastern Yellow Robin
<i>Microeca leucophaea</i>	Jacky Winter
<i>Falcunculus frontatus</i>	Crested Shrike-tit
<i>Colluricincla harmonica</i>	Grey Shrike-thrush
<i>Pachycephala pectoralis</i>	Golden Whistler
<i>Pachycephala rufiventris</i>	Rufous Whistler
<i>Rhipidura fuliginosa</i>	Grey Fantail
<i>Rhipidura leucophrys</i>	Willie Wagtail
<i>Myiagra inquieta</i>	Restless Flycatcher
<i>Grallina cyanoleuca</i>	Australian Magpie-lark
<i>Oriolus sagittatus</i>	Olive-backed Oriole
<i>Corancina novaehollandiae</i>	Black-faced Cuckoo-shrike
<i>Lalage tricolor</i>	White-winged Triller
<i>Artamus personatus</i>	Masked Woodswallow
<i>Artamua superciliosus</i>	White-browed Woodswallow
<i>Artamus cuanopterus</i>	Dusky Woodswallow

<i>Cracticus nigrogularis</i>	Pied Butcherbird
<i>Gymnorhina tibicen</i>	Australian Magpie
<i>Strepera graculina</i>	Pied Currawong
<i>Corvus coronoides</i>	Australian Raven
<i>Corvus mellori</i>	Little Raven
<i>Corcorax melanorhamphos</i>	White-winged Chough
<i>Hirundo neoxena</i>	Welcome Swallow
<i>Hirundo nigricans</i>	Tree Martin
<i>Hirundo amel</i>	Fairy Martin
<i>Anthus novaeseelandiae</i>	Richard's Pipit
<i>Mirafra javanica</i>	Singing Bushlark
<i>Alauda arvensis</i>	Skylark*
<i>Cincolorhamphus crucalis</i>	Brown Songlark
<i>Passer montanus</i>	Tree Sparrow*
<i>Passer domesticus</i>	House Sparrow*
<i>Carduelis chloris</i>	European Greenfinch*
<i>Carduelis carduelis</i>	European Goldfinch*
<i>Neochemia temporalis</i>	Red-browed Firetail
<i>Stagonopleura guttata</i>	Diamond Firetail
<i>Dicaeum hirundinaceum</i>	Mistletoebird
<i>Zosterops lateralis</i>	Silvereye
<i>Turdus merula</i>	Blackbird*
<i>Sturnus vulgaris</i>	Common Starling*
<i>Acridotheres tristis</i>	Common Mynah*

Appendix 2. Number of individual birds for each study area and presence of species for each study area (all sites combined) August 1999 – July 2001.

(* denotes introduced species)

Species	Plantation	Edge	Pastureland	Remnant
Pacific Black Duck	0	1	0	1
Maned (Wood) Duck	0	0	1	6
Brown Goshawk	0	0	0	1
Collared Sparrowhawk	1	0	1	1
Australian Hobby	0	0	0	1
Brown Falcon	0	0	1	0
Common Bronzewing	0	1	0	2
Brush Bronzewing	0	0	0	1
Crested Pigeon	0	3	3	1
Gang-Gang Cockatoo	0	0	1	2
Galah	0	1	3	13
Sulphur-crested Cockatoo	0	0	8	23
Australian King Parrot	0	0	0	1
Crimson Rosella	1	2	0	12
Eastern Rosella	9	4	4	32
Red-rumped Parrot	1	3	2	4
Pallid Cuckoo	0	1	0	0
Laughing Kookaburra	1	2	0	29
Sacred Kingfisher	0	0	0	3
Rainbow Bee-eater	0	0	0	4
Dollarbird	0	0	0	3
Singing Bushlark	1	3	1	3
Welcome Swallow	0	1	7	12
Tree Martin	0	0	0	2
Richard's Pipit	0	2	1	0
Black-faced Cuckoo-shrike	2	4	0	14
Blackbird*	5	2	0	0
Flame Robin	5	3	1	5
Scarlet Robin	1	3	0	2
Eastern Yellow Robin	0	1	0	4
Jacky Winter	0	0	0	7
Eastern Shrike-tit	0	1	0	2
Golden Whistler	3	1	0	5
Rufous Whistler	6	5	0	15
Grey Shrike-thrush	12	7	0	24
Restless Flycatcher	1	2	0	7
Grey Fantail	33	31	0	21
Willie Wagtail	3	9	4	30
Superb Fairy-wren	16	25	0	50
White-browed Scrubwren	3	5	0	2
Speckled Warbler	0	1	0	2

Appendix 2 cont: Species	Plantation	Edge	Pastureland	Remnant
Western Gerygone	0	0	0	5
White-throated Gerygone	0	0	0	0
Brown Thornbill	14	13	0	8
Buff-rumped Thornbill	2	3	0	5
Yellow-rumped Thornbill	4	5	0	3
Striated Thornbill	15	9	0	7
Southern Whiteface	1	0	0	0
Varied Sittella	0	0	0	1
White-throated Treecreeper	1	0	0	38
Brown Treecreeper	1	0	0	21
Red Wattlebird	4	3	1	7
Noisy Friarbird	3	2	0	9
Noisy Miner	1	0	2	16
Little Friarbird	0	0	0	1
Yellow-faced Honeyeater	7	7	0	7
Yellow-tufted Honeyeater	1	0	0	3
Fuscous Honeyeater	1	0	0	1
White-plumed Honeyeater	6	7	0	38
Brown-headed Honeyeater	2	1	0	2
White-naped Honeyeater	2	2	0	4
Crescent Honeyeater	0	0	0	1
New Holland Honeyeater	0	1	0	0
Eastern Spinebill	0	1	0	5
Mistletoebird	3	5	0	2
Spotted Pardalote	0	2	0	6
Striated Pardalote	5	9	2	24
Silveryeye	4	1	0	0
Diamond Firetail	0	0	1	0
Red-browed Firetail	2	0	0	13
Common Straling*	0	1	0	0
White-winged Chough	8	5	1	16
Australian Magpie-lark	1	0	7	15
Dusky Woodswallow	0	0	0	6
Australian Magpie	4	12	38	35
Pied Currawong	0	0	1	6
Australian Raven	3	0	5	20
White-eared Honeyeater	2	2	1	0
Little Raven	0	1	1	0
Olive-backed Oriole	0	0	0	1
White-winged Triller	0	0	0	1
Peaceful Dove	0	0	0	1
Total number of species recorded for each study area (all sites combined)	43	48	25	70

Appendix 3. Presence of bird species in the different study sites (properties) August 1999 – July 2001 (all areas combined excluding remnant areas).

(* denotes introduced species)

Species	Dores	Martins	Nobles
Pacific Black Duck	X		
Maned (Wood) Duck	X	X	X
Brown Goshawk			X
Collared Sparrowhawk	X		X
Australian Hobby			X
Brown Falcon	X		
Common Bronzewing		X	X
Brush Bronzewing			X
Crested Pigeon	X	X	X
Gang-Gang Cockatoo		X	
Galah	X	X	X
Sulphur-crested Cockatoo	X	X	X
Australian King Parrot			X
Crimson Rosella	X	X	X
Eastern Rosella	X	X	X
Red-rumped Parrot	X	X	
Pallid Cuckoo		X	
Laughing Kookaburra	X	X	X
Sacred Kingfisher	X	X	
Rainbow Bee-eater	X		
Dollarbird	X		
Singing Bushlark	X	X	X
Welcome Swallow	X	X	X
Tree Martin	X		
Richard's Pipit		X	
Black-faced Cuckoo-shrike	X	X	X
Blackbird*			X
Flame Robin	X	X	X
Scarlet Robin		X	X
Eastern Yellow Robin		X	X
Jacky Winter	X	X	X
Eastern Shrike-tit		X	
Golden Whistler		X	X
Rufous Whistler	X	X	X
Grey Shrike-thrush	X	X	X
Restless Flycatcher	X	X	X
Grey Fantail	X	X	X
Willie Wagtail	X	X	X
Superb Fairy-wren	X	X	X
White-browed Scrubwren	X	X	X

Appendix 3 cont: Species	Dores	Martins	Nobles
Speckled Warbler	X	X	
Western Gerygone			
White-throated Gerygone			
Brown Thornbill	X	X	X
Buff-rumped Thornbill	X	X	X
Yellow-rumped Thornbill	X	X	X
Striated Thornbill	X	X	X
Southern Whiteface			X
Varied Sittella		X	
White-throated Treecreeper	X	X	X
Brown Treecreeper	X	X	X
Red Wattlebird	X	X	X
Noisy Friarbird	X	X	X
Noisy Miner	X	X	X
Little Friarbird	X		
Yellow-faced Honeyeater		X	X
Yellow-tufted Honeyeater			X
Fuscous Honeyeater			X
White-plumed Honeyeater	X	X	X
Brown-headed Honeyeater		X	X
White-naped Honeyeater		X	X
Crescent Honeyeater			X
New Holland Honeyeater			X
Eastern Spinebill		X	X
Mistletoebird		X	X
Spotted Pardalote	X	X	X
Striated Pardalote	X	X	X
Silvereeye	X	X	X
Diamond Firetail			X
Red-browed Firetail	X		X
Common Straling*			X
White-winged Chough	X	X	X
Australian Magpie-lark	X	X	X
Dusky Woodswallow	X		X
Australian Magpie	X	X	X
Pied Currawong	X	X	X
Australian Raven	X	X	X
White-eared Honeyeater			X
Little Raven			X
Olive-backed Oriole			X
White-winged Triller			X
Peaceful Dove			X
Total number of species for each property	48	54	67