Effects of patch area and habitat on bird abundances, species numbers and tree health in fragmented Victoria forests.

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CHAPTER 6

Effects of Patch Area and Habitat on Bird Abundances, Species Numbers and Tree Health in Fragmented Victorian Forests

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Data were analysed on birds in 56 forest patches (0.1 to 1771 ha) that had been isolated by clearing for agriculture or pine plantations in the Latrobe Valley of southeastern Victoria.

Positive relationships were found for forest and total bird species and abundance with patch area or its logarithm, and several other variables made additional contributions, e.g. grazing intensity. Habitat indices were closely correlated and explained almost as much variation. Forest bird abundance did not increase with area above 10-30 ha. Numbers of forest species continued to increase with patch area but medium-sized patches (10-150 ha) supported a higher proportion of species than expected. The species present depended on habitats represented. Large reserves may be needed by some species but other forest species occurred only on medium-sized patches. More complex relationships were found for farmland birds and water birds.

Small heavily grazed patches (less than 10 ha) supported few forest birds and more farmland birds, including noisy miners *Manorina melanocephala* which aggressively excluded other species. Few birds fed on insects in the canopy in these patches, which showed signs of dieback due to insect damage. Protection of understorey habitat can have wide benefits in maintaining the health of the rural ecosystem.

INTRODUCTION

WHEN forests are cleared many plant and animal species become confined to remnant patches of native vegetation, especially when land is permanently altered for uses such as agriculture. These patches and their fauna can continue to play a role in the local ecology, protecting land from erosion, salinity and other degradation and providing habitat for wildlife including species that benefit from clearing (farmland species) (e.g. Breckwoldt 1983). Hence it is important to know how to design and manage systems of remnant vegetation, and how to conserve plant and animal species in these fragmented systems.

This chapter deals with a study of birds on 56 fragmented forest patches in the Latrobe Valley of southeastern Victoria, following a similar study of mammals on the same patches (Suckling 1980, 1982, 1984). Some preliminary data on birds have already been presented (Loyn 1984, 1985); the latter paper included a list of species with details of habitats occupied. Here more attention is paid to mathematical relationships and a subsequent paper is planned to analyse effects of fragmentation on individual species.

STUDY REGION

A large part of eastern Victoria is hilly or mountainous and remains as forested public land. The Latrobe Valley is an exception, as it has become a major centre for agriculture and industry.

Much of the study region has been cleared for agriculture and pine plantations over the last 100 years and in 1978 about 34% remained as fragmented native forests and woodlands, with 52% as agricultural land and 14% as pine plantations (Suckling 1982). By 1983 an additional 4% had been cleared (mainly for a new coal-fired power-station at

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Loy Yang), including three of the 59 original fragments. The fragments studied ranged in size from 0.1 to 1771 ha and were scattered through the region mostly on private property. They had been isolated for periods from 7 to 100 years and three had been partly cleared for use as shire rubbish tips. The largest area has subsequently been converted to pine plantations. No fragment was further than 1.5 km from another patch of native forest. Two were isolated by as little as a main road; details are given in the Appendix. More extensive forests still exist on public land in the hills and coastal sand-plain south of the region, and continuous forest occurs on higher ground north of the Latrobe Valley.

The 56 fragments contained mixed-species dry sclerophyll forest including stands of narrow-leaf peppermint *Eucalyptus radiata,* manna gum *E. viminalis* and yertchuk *E. consideniana*. The understorey was dominated either by heathy shrublands, swards of austral bracken fern *Pteridium esculentum* or in heavily grazed patches by introduced grasses. Thickets of burgan *Leptospermum phylicoides* occurred frequently and some gullies contained tall gully shrubs, though generally the region was too low (60 to 360 m above sea level) and dry (about 750 mm mean annual rainfall at 180 m) for gully vegetation to be well developed. More information on individual study areas is given by Suckling (1980) and Loyn (1984).

METHODS

All 56 fragments were searched in each of three spring/summer seasons from November 1980 to March 1983. All birds observed were recorded, and numbers seen or heard on 20-minute counts were used as measures of abundance (Loyn 1986). On the smallest patches one or two counts were sufficient to cover the whole area on each visit, whereas on larger patches up to 19 counts were made on a visit with the aim of searching all habitats. Areas of about 3 ha could be covered in each count, so birds per count on smaller patches do not give a true reflection of bird density. At the end of the study, counts were continued until few extra species could be found. Basic observations were made on the use birds were making of their habitats.

ANALYSIS

Data were tabulated and statistics calculated for each patch (numbers of bird species, and bird abundances expressed as individual birds per count). Depending on their known use of habitats elsewhere, the 132 bird species observed in the region were classified as 78 forest species, 28 farmland (open-country) species and 26 water bird species. Most of the farmland species used trees for nesting or roosting, and some such as noisy miners *Manorina melanocephala* also fed among trees as well as pasture.

Values for bird species and abundance were regressed against characters of the individual patches, listed in Table 1. Variables 1 to 8 were described by Suckling (1982). The habitat indices 10 to 13 were derived from data in the Appendix; it was realised that they were coarse and that habitats of individual species depended on combinations of these features and more subtle features, which could often be described verbally but not numerically.

Initially regressions were run against A (area) or log A alone, and then against variables 2 to 8 together in a forward, stepwise, multiple linear regression package (SPSS, Nie *et al.* 1975). Then the variables 9 to 13 (altitude and habitat indices) were added as appropriate, and finally variable 14 (noisy miner abundance, considered in a separate section). Variables were only included in equations if they improved regressions significantly ($P < 0.05$).

Some of the characters were intercorrelated and hence hard to separate, especially in the enlarged package. Small patches tended to be heavily grazed, at low altitude, widely scattered, isolated for long periods, occupied by noisy miners and with few remaining forest habitats. Some other combinations were tested to allow for intercorrelation (see Nie *et al.* 1975), in case stepwise inclusion of one variable obscured effects of a correlated variable, or failed to maximize explained variance. When considering bird abundance, water birds were included with farmland birds as they were not abundant enough in the forest fragments to warrant separate analysis, and depended on farm dams or pasture for feeding.

RESULTS

Numbers of bird species and bird abundances on individual forest patches are shown in the Appendix. Bivariate correlations between these parameters and patch characters are shown in Table 2; stepwise contributions of patch variables to multiple regression equations are considered in Table 3, and the predictive equations for lines of best fit are shown in Table 4.

Bird Abundances

The patches fell clearly into two groups with high or low population densities of forest birds (Appendix). All but two patches larger than 10 ha supported reasonably high densities of forest birds (16.6 to 39.8 birds per count), making over 85% total populations. The exceptions were a long narrow patch, heavily grazed by sheep and cattle from surrounding pasture (F4) and a ring of remnant forest, much of it grazed, around the main rubbish tip for Traralgon (T29). In those patches densities of forest birds were low, making only 39 and 32% of total populations (11.5 and 12.7 birds per count). Two other disturbed patches retained a shrubby native understorey despite disturbance and they supported higher

Table 1. Measured characters of forest fragments.

Character	Brief description	Mean value
1. A:	its area in ha (0.1 to 1771)	69.3
2. log A:	the log to the base ten of A	0.93
3. Years isolated:	the time since isolation in years (7 to 100 years)	33.2
4. Dist:	the distance from the nearest other patch in km to (0.03 to 1.43)	0.24
5. LDist:	the distance from the nearest larger patch in km (0.03 to 4.43)	0.74
6. Graze:	an index of grazing history from 1 (very light) to 5 (very heavy)	2.98
7. Fire:	an index of fire history from 1 (no recent fires) to 5 (frequent or recent)	2.23
8. Timber:	an index of logging and other disturbance from 1 (light) to 5 (heavy)	1.86
9. Alt:	the mean altitude in metres above sea level (60 to 250)	146
10. Hab:	an index of the number of habitats on a patch, including eucalypt communities, types of understorey, special features and types of edge (0 to 17)	4.5
11. Forhab:	an index of the number of forest habitats on a patch, as above but taking rubbish tips, cattle-degraded understorey and pasture-edge as negative (-3 to 14)	1.7
12. Farmhab:	an index of the number of farmland habitats on a patch (0 to 6)	1.7
13. Waterhab:	an index of the number of water habitats on a patch (small dam, creek, or proximity to a large swamp, 0 to 3)	0.3
14. Noisy miners:	the measured abundance of aggressive noisy miners *Manorina melanocephala*, in birds per count (0 to 12)	2.8

Variable 14 was not used with abundances of farmland birds or total birds, as noisy miners were included in those categories. Variables 11-13 were only used with their respective groups of birds.

Table 2. Correlation coefficients (r) for regressions of bird numbers against patch characters.

Dependent variable: Patch character — independent variable	Forest bird species	Farmland bird species	Water bird species	Total bird species	Forest bird abundance	Farmland and water bird abundance	Total bird abundance	Noisy miner abundance
1. A	0.427***	0.053^{NS}	0.130^{NS}	0.428***	0.256^{NS}	–0.193^{NS}	0.116^{NS}	–0.168^{NS}
2. log A	0.861***	0.276*	0.237^{NS}	0.900***	0.740***	–0.402**	0.548***	–0.365**
3. Dist	0.284*	0.211^{NS}	0.142^{NS}	0.330*	0.238^{NS}	–0.078^{NS}	0.246^{NS}	–0.149^{NS}
4. LDist	0.191^{NS}	0.425***	0.202^{NS}	0.295*	0.097^{NS}	0.155^{NS}	0.356***	0.068^{NS}
5. Fire	0.294*	–0.103^{NS}	0.124^{NS}	0.268*	0.348**	–0.274*	0.142^{NS}	–0.214^{NS}
6. Timber	–0.056^{NS}	0.044^{NS}	0.095^{NS}	0.051^{NS}	–0.097^{NS}	0.155^{NS}	0.067^{NS}	0.042^{NS}
7. Graze	–0.700***	0.093^{NS}	–0.007^{NS}	–0.642***	–0.683***	0.639***	–0.140^{NS}	0.500***
8. Years	–0.500***	0.147^{NS}	0.101^{NS}	–0.430***	–0.516***	0.551***	–0.014^{NS}	0.398***
9. Alt	0.362**	–0.442***	–0.111^{NS}	–0.240^{NS}	0.382**	–0.501***	–0.118^{NS}	–0.364***
10. Hab	0.735***	0.234^{NS}	0.212^{NS}	0.756***	0.702***	–0.431***	0.452***	–0.416***
11. Forhab	0.821***	–	–	–	0.818***	–	–	–
12. Farmhab	–	0.428***	–	–	–	0.542***	–	0.427***
13. Waterhab	–	–	0.550***	–	–	–	–	–0.134^{NS}
14. Noisy miners	–0.659***	0.272*	0.265*	–0.557***	–0.710***	(0.709)$_{\dagger}^{***}$	(–0.378)$_{\dagger}^{**}$	–

– = not calculated. Correlations marked † were calcualted after subtracting noisy miner abundance from farmland or total bird abundance.
* = P <0.05 ** = P <0.01 *** = P< 0.001.

densities of forest birds (39.8 and 24.9 birds per count). One (F6) was the site of the smaller Gormandale rubbish tip, and the other (T18) was partly used as a trail-bike course; neither had been heavily grazed.

In contrast, many patches of 10 ha or less had been grazed or slashed for fire protection and they supported low densities of forest birds and high densities of farmland birds (Appendix). Of the 31 patches of this size class, forest birds made less than 20% of total populations in eleven, and more than 85% in only six, all of which had received a degree of protection from stock through fencing or being bounded by pine plantations rather than pasture. In those patches, densities of forest birds appeared

Table 3. Stepwise contribution of variables to multiple regression equations.

Dependent variable	Variables tested (see Analysis)	Independent variable added at each step (and significance of adding it) Step 1	Step 2	Step 3	Step 4	Step 5	Variance explained at each stem ($r^2 \times 100\%$) Step 1	Step 2	Step 3	Step 4	Step 5
Forest bird species	2-8, 2-10	log A***	–Graze**	–Years*	–	–	74.2	81.1	82.7		
	2-11	log A***	Forhab***	–Years**	–	–	74.2	82.5	85.2		
	2-14	log A***	–Noisy miners***	–Years**	–	–	74.2	87.9	90.0		
Farmland bird species	2-8	L Dist**	–	–	–	–	18.1				
	2-13, 2-14	–Alt***	log A***	Farmhab**	–	–	19.6	36.6	44.6		
Water bird species	2-8	–	–	–	–	–	no significant relationship				
	2-13	Waterhab***	–Hab*	–Alt*	Fire*	–	30.2	38.4	44.3	49.0	
	2-14	Waterhab***	Noisy miners**	–	–	–	30.2	41.9			
Total bird species	2-8, 2-13	log A***	–Years**	–	–	–	81.1	84.1			
	2-14	log A***	–Noisy miners*	–Years*	–	–	81.1	87.1	88.1		
Forest bird abundance	2-8, 2-10	log A***	–Graze***	–	–	–	54.7	65.3			
	2-11, 2-14	Forhab***	log A**	–Years*	–	–	66.8	71.5	74.5		
	2-8+14	log A***	–Noisy miners***	–Years**	–	–	54.7	77.0	79.9		
Farmland (+ water) bird abundance	2-8	Graze***	–	–	–	–	40.8				
	2-13, 2-14	Graze***	Farmhab**	–Hab**	LDist*	–	40.8	50.3	57.1	62.6	
	2-14 (not 5)	Graze***	Farmhab**	–Hab**	Timber*	–Alt*	40.8	50.3	57.1	60.7	63.9
Noisy miner abundance	2-8	Graze***	–	–	–	–	25.0				
	2-13	Graze***	Farmhab*	–Hab*	–	–	25.0	31.0	40.4		
	2-13 (not 6)	Farmhab***	–Hab***	–	–	–	18.2	39.6			
Total bird abundance	2-8	log A***	–	–	–	–	30.1				
	2-13	log A***	–Alt*	–	–	–	30.1	37.9			

* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$. – = additional variables made no further significant contribution.

only slightly lower than in larger patches (Appendix). The apparent reduction in patches smaller than 3 ha may be partly an artefact of the study method which was designed to search areas of about 3 ha on each count.

Signs of eucalypt dieback associated with insect attack were evident in all patches lacking understorey, which contained low densities of insectivorous forest birds (Appendix).

Forest Bird Abundance — Because population densities of forest birds were low in the smallest patches, significant regressions were found for abundance against area for forest birds (Table 2). The relationship was improved greatly by considering log A not A, explaining 54.7% of variance, but was clearly not linear and for patches larger than 30 ha there was little difference in density with increasing patch size (Appendix). The relationship with log A was better mainly because large patches received less weighting in the equations.

Addition of the grazing index improved the relationship significantly, in a negative sense, explaining an additional 10.6% of variance (Table 3). No other variable in the first package (variables 2 to 8) made significant additional contributions, though several were strongly correlated (Table 2). In the enlarged package the variable most strongly correlated with forest bird abundance was the index of forest habitats, and its positive effect superseded the negative effect of the grazing index in the predictive equation. The years isolated also entered this equation (negatively), suggesting a progressive degradation of these patches as habitat for forest birds, apart from any effects of area reduction or changes in other measured variables. The equation explained 79.9% of variance (Table 3).

Farmland and Water Bird Abundance — Abundances of farmland and water birds were negatively correlated with log A (Table 2), but the regression only explained 16.0% of variance. The grazing index superceded the effect of log A, in a positive sense, explaining 40.8% of variance. Farmland birds were only abundant in heavily grazed patches, regardless of size but generally these patches were small. No other variable in the first package made additional contributions. In the enlarged package, 63.9% of variance was explained by including additional terms for farm habitats and the timber index (positively) and total habitats and altitude (negatively) (Table 3). This was the only equation where the timber index (effects of logging and other disturbance) made a significant contribution.

Total Bird Abundance — As abundances of forest and farmland birds responded in opposite ways to most measured variables (Table 2), the regressions for total birds were weaker, explaining only 37.9% of variance with the enlarged package, 30.1% from log A (positively, through the forest component) and the additional 7.8% from altitude (negatively, through the farmland component).

Numbers of Species

Numbers of forest species and total species increased with size of patch over the range of sizes studied, whereas numbers of farmland species showed little change (see Figure 2 in Loyn 1985).

Table 4. Regression equations for predictive lines of best fit.

Groups of birds	Variables tested	Bird species (numbers of species on patch) =	Bird abundance (individual birds per count) =
Forest birds	2, 2-8	16.04 log A + 12.78	9.78 log A + 10.40
	2-10	13.05 log A − 2.06 (Graze) − 0.09 (Years isolated) + 24.8	6.89 log A − 2.86 (Graze) + 21.61
	2-11	as above	4.33 log A + 2.30 (Forhab) − 0.081 (Years isolated) + 14.08
	2-8 + 14	12.83 log A − 1.29 (Noisy miners) − 0.09 (Years isolated) + 22.43	6.92 log A − 1.19 (Noisy miners) − 0.074 (Years isolated) + 18.88
	2-14	as above	as with 2-11
Farmland birds	2	1.06 log A + 6.34	− 4.89 log A + 13.81
	2-8	1.45 LDist + 6.24	4.29 (Graze) − 3.55
	2-13	1.59 log A − 0.033 (Alt) + 1.19 (Farmhab) + 8.59	1.54 (Graze) + 5.79 (Farmhab) − 3.07 (Hab) + 2.76 (LDist) + 6.57
	2-13 (not 5)	as above	1.60 (Graze) + 5.16 (Farmhab) − 2.14 (Hab) + 2.22 (Timber) − 0.046 (Alt) + 12.32
	2-14	as above	not tested
Waterbirds	2-8	no significant relationship	not tested
	2-13	1.48 (Waterhab) − 0.23 (Hab) − 0.007 (Alt) + 0.21 (Fire) + 1.72	not tested
	2-14	0.98 (Waterhab) + 0.077 (Noisy miners) − 0.014	
Noisy miners	2	0 or 1	− 1.80 log A + 4.49
	2-8	0 or 1	1.36 (Graze) − 1.26
	2-13	0 or 1	0.35 (Graze) + 2.14 (Farmhab) − 1.09 (Hab) + 3.05
	2-13 (not 6)	0 or 1	2.44 (Farmhab) − 1.29 (Hab) + 4.46
(Total mammals)	2	(6.09 log A + 2.11)	
Total birds	2	17.36 log A + 19.6	4.89 log A + 24.21
	2-13	16.34 log A − 0.11 (Years isolated) + 24.0	5.61 log A − 0.048 (Alt) + 30.61
	2-14	15.15 log A − 0.88 (Noisy miners) − 0.064 (Years isolated) + 26.25	not tested

Table 5. Comparison of three regression models of bird (and mammal) statistics against patch area.

Model:	Sign of correlation	Variance explained (r^2x100%) Linear	Exponential	Power function	Slope of power function (z)
Dependent variable:		Number of species	Number of species	log (Number of species)	
Independent variable:		A	log A	log A	
Forest bird species:	+	18.3***	74.2***	54.9***	.34
Farmland bird species:	+	2.8^{NS}	7.6*	5.2*	.06
Water bird species:	NS	0.17^{NS}	5.6^{NS}	6.6^{NS}	–
Total bird species:	+	18.3***	81.0***	69.1***	.24
(Total mammal species):	+	–	86.0**	–	.37

* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$; NS = not significant; – = not calculated.

Hence for forest and total birds, area terms explained more variance for numbers of species than they had done for abundance (Table 3). Three regression models (linear, exponential and power function) of species numbers against area are compared in Table 5. All gave highly significant positive relationships for total bird species and forest bird species, but the linear model (untransformed species numbers against area) explained far less variance than the other two. The exponential model explained almost 20% more variance for forest birds than did the power function (74.2% for forest species, 81.1% for total species) (Table 5). All models overestimated numbers of species in the largest patches, but this effect was least in the exponential model, which gave least weighting to the large patches. To look at it another way, if it were proposed to reduce the size of a large patch of forest containing a given number of species, all models would overestimate the initial loss of species with decreasing patch size, but the exponential model would do so less than the others.

Forest Bird Species — The relationship of forest bird species with area was closer than for abundance and log A accounted for 74.2% of the 85.2% of variance explained in the enlarged package (Table 3). The grazing index made a significant additional contribution (in a negative sense) with the first package, but was superceded by the index of forest habitats (in a positive sense) in the enlarged package, suggesting that grazing acted on forest bird species by removing specific forest habitats. The years isolated contributed in a negative sense with both packages, and the multivariate equations (Table 4) suggest that about nine forest species would be lost from patches of constant size in the first century of isolation. Further extrapolation would be unwarranted without more evidence about whether this was happening at a steady linear rate.

No other variable contributed significantly. Altitude was positively correlated (Table 2), probably because the smallest, most degraded patches were lowest in the valley. Factors such as fire and logging are known to affect forest bird species and abundance elsewhere, but in this study fire and logging histories did not differ greatly between patches, and distances of isolation also covered a narrow range (Appendix). These variables were not strongly correlated with forest or total bird species (Table 2).

The index of forest habitats explained almost as much variance (67.4%) as the most strongly correlated variable log A (74.2%), but as these two variables were themselves intercorrelated ($r = 0.723$, $r^2 = 52.3\%$, $p < 0.01$), the contribution of the habitat index was masked by the area effect. Large patches contained more habitats than small ones and the area of a patch (or its log) may be a better measure of habitat diversity than the coarse habitat indices measured.

Farmland Bird Species — Numbers of farmland species were positively correlated with log A (although their abundance was negatively correlated), but the relationship was weak (Table 2). Few species occurred in patches that lacked a farmland boundary. In the first package the closest correlation was with distance from the nearest larger forest patch, suggesting that isolation between patches (or the amount of surrounding farmland) helped determine numbers of farmland species. It was thought that a better measure could be the square or log of this distance term, but they gave even weaker relationships. A stronger regression was found with the enlarged package, explaining 44.6% of variance (still far less than for forest birds). The contributing variables were altitude (in a negative sense) and log A and the index of farmland habitats (in a positive sense) (Table 3). The negative effect of altitude reflects the greater degree of agricultural clearing in the valley, which has provided habitats for more farmland bird species.

Water Bird Species — Only a few water bird species made more than incidental use of the forest patches, although some small and large patches provided important nesting and roosting sites for them. No significant relationship was found with area terms or the first package of variables 2 to 8. Inclusion of terms for altitude and habitats gave a regression explaining 49.0% of variance (Table 3). The contributing variables were water habitats and the fire index (in a positive sense) and total habitats and altitude (in a negative sense).

The effect of altitude reflects the greater extent of natural and artificial wetlands in the valley, on a broader scale than considered in the habitat variables. The fire index made a significant contribution to no other equation and its positive effect may be a quirk of intercorrelation; the least fire-prone patches were the small heavily grazed patches in farmland containing dams and swamps.

Total Bird Species — As forest species, farmland species and water bird species all increased with log A, the relationship was even stronger for total species, explaining 81.1% of variance (Table 3). Forest bird species responded in different ways to most other variables (Table 2), and only years isolated made a significant additional contribution (in a negative sense), explaining a further 3.0% of variance. The multivariate equation (Table 4) suggests that about eleven species would be lost from patches of constant size in the first century of isolation.

Noisy Miners — A Special Factor

The most conspicuous bird in many of the small, grazed patches was an aggressive honeyeater, the noisy miner, which breeds communally and defends territories against all other bird species (Dow 1977). Noisy miners compounded the effects of understorey removal by physically expelling small birds that attempted to encroach on their territories.

The only other birds that were able to nest in noisy miner territories were larger farmland species (e.g. Australian magpie *Gymnorhina tibicen*), some large raptors and water birds (e.g. at T28 a pair of brown goshawks *Accipiter fasciatus* and a pair of yellow-billed spoonbills *Platalea flavipes),* a predatory forest passerine (grey butcherbird *Cracticus torquatus*) and a few hole-nesting species (e.g. eastern rosella *Platycercus eximius*, laughing kookaburra *Dacelo novaeguineae*, tree martin *Cecropis nigricans* and introduced common starling *Sturnus vulgaris*). Occasionally striated pardalotes *Pardalotus striatus* nested in tree hollows in small patches or isolated trees in paddocks, making raids into noisy miner colonies to snatch food before expulsion. Noisy miners fed in pasture and in the canopy (on larger invertebrates, exudates, etc.), and the other farmland birds fed primarily on insects and seeds in surrounding pasture. Apart from the pardalotes, few birds remained to feed on small invertebrates in the canopy of patches dominated by noisy miners, all of which suffered dieback and defoliation by insects. Noisy miners did not occur in those forest patches where intact understorey provided cover for competing birds. In large patches noisy miners occurred only locally, always on the edge of pasture and usually in grazed peninsulas of forest that required defence on only one edge.

Because noisy miners were locally dominant, regressions were run for their abundance against log A and other patch variables. Noisy miner abundance proved to be negatively correlated with log A (Table 2), but the regression only explained 13.3% of variance. The grazing index superseded the effect of log A, in a positive sense, explaining 25.0% of variance. In the enlarged package, 40.4% of variance was explained by including additional terms for farm habitats (in a positive sense) and total habitats (in a negative sense) (Table 3). These two terms superseded the effect of the grazing index with little loss in explained variance (Table 3), and a slight gain in significance of regression. This suggests that the substantial contribution of the grazing index was almost entirely reflected in the habitat indices. The other relationships were similar to those for farmland birds generally, except that less variance was explained and no extra contribution was made by altitude (despite a strong negative correlation, Table 2) or the timber index. A few farmland birds, but not noisy miners, entered larger forest patches after logging. Farmland birds and water birds generally favoured similar forest patches to noisy miners, and numbers were positively correlated despite aggression between them (Table 2).

When noisy miner abundance was included as a patch character in multiple regressions, it improved the best previous relationships for forest bird abundance, forest bird species and total bird species, but not for farmland or water bird species (Table 3). (Noisy miner abundance could not be regressed against farmland or total bird abundance as it formed a substantial part of each.) For forest birds, noisy miner abundance superseded the grazing index in the same negative sense, but was superseded by the forest habitat index in a positive sense (Table 3). These three characters were too closely intercorrelated to be separated easily (Table 2). It is likely that forest birds would be scarce wherever grazing had reduced the understorey, though not as scarce as when noisy miners compounded the effect through their evident aggression.

Observations on two patches suggest separate effects of these variables. One 1 ha patch (M8) retained dense swamp paperbark *Melaleuca ericifolia* thickets despite grazing, and it supported no noisy miners and a fairly high abundance of forest birds (Appendix), including species that fed in the eucalypt canopy as well as in the paperbark. On one 4 ha patch with heathy understorey (MF), noisy miners were initially resident on the edge and in nearby roadside trees. During a drought in late 1982 a few cattle were admitted to the patch and noisy miners encroached further, reducing populations of forest birds even where understorey remained intact. Thus a shifting balance was evident even in the short time-scale of the study.

DISCUSSION

Changes in Species with Clearing

Before European settlement the study region was almost entirely forested and present-day farmland birds would have been confined to a few open areas of woodland in the valley; it is certain that they are now more abundant and probable that more species are represented. It is also certain that forest birds are less numerous, as only 30% of forest habitat remains and population density was no higher in small patches than in more extensive forest (Appendix).

Historical records are not adequate to determine whether any forest species have been lost from the region but an assessment can be made from knowledge of current distribution. In a survey of a 30,000 ha block of forest nearby, only two additional bird species were found (Gilmore 1977); they were brown quail *Coturnix australis* and southern emu-wren *Stipiturus malachurus*, and both were confined to small areas of swampy heathland not represented in the study region. It is not known whether such heathland might have been represented before clearing. A similar situation held for mammals (Suckling 1982), with only one extra species found in the 30,000 ha block, also in a special localised habitat (Gilmore 1977).

A few extra forest bird species were found further away from the study region, but all were in different habitats such as coastal forest or wetter forest at higher altitude on either side of the Latrobe Valley, above the rainshadow of the study region (pers. obs.; Blakers *et al.* 1984; Loyn *et al.* 1980; Norris *et al.* 1979).

Those most likely to have had suitable habitat in the study region before clearing are superb lyrebird *Menura novaehollandiae* (wetter forests and gullies), flame robin *Petroica phoenicea* (now a passage migrant, breeding in slightly wetter forests at higher altitude), brown treecreeper *Climacteris picumnus* (dry forest including river red gums, but in SE Victoria mainly box woodland), bell miner *Manorina melanophrys*, yellow-tufted honeyeater *Lichenostomus melanops* and satin bowerbird *Ptilonorhynchus violaceus* (all in broad foothill gullies) and pied currawong *Strepera graculina* (slightly wetter forests, but rarely breeding south of the Latrobe Valley). In an American study, Bond (1957) found that birds of wet forest habitats were the most susceptible to fragmentation, but here the point is rather that the study region would only have contained small areas of suitable or marginal habitat (if any), while wetter forests nearby (especially north of the Valley) have not been greatly fragmented. Conversely, four forest species (and many farmland and water birds) were markedly more common in the study region than in continuous forest nearby. The forest species were emu *Dromaius novaehollandiae*, white-bellied cuckoo-shrike *Coracina papuensis*, leaden flycatcher *Myiagra rebecula* and noisy friarbird *Philemon corniculatus*. All are typically birds of dry forest, and were present because their habitats were represented not because they benefited from fragmentation. Indeed, the cuckoo-shrike was only found on the largest patches, and emus are absent from more heavily cleared parts of Victoria. As indicated by Lynch and Wigham (1984) from American studies, the regional distribution of habitat should be considered. In the Latrobe Valley, clearing has been concentrated in the more open forest and woodland habitats, so the more critical need locally is to conserve species associated with those habitats. This can now only be done by conservation of fragmented patches.

Most species whose habitats were represented in the study patches were recorded on them, and it seems that most if not all species have survived there despite the 70% reduction in area of forest habitat.

Distribution of Species Between Patches; Species not on Large Patches

Generally the distribution of species reflected their particular habitat requirements (Loyn 1985). No single patch supported all species, but the largest patch (F11, 1771 ha) supported the greatest number of forest species with 62 of the 79 recorded. This is a slightly lower proportion than for mammals where the same patch supported 18 of the 20 species recorded (Suckling 1982). Eight of the forest bird species missing from that patch were merely occasional or irregular visitors to other patches, and three others were observed on the second largest patch (M11, 973 ha). The remaining six apparently depended on smaller patches for survival in the study region. The six species and their main local habitats were emu (heathy woodland), rose robin *Petroica rosea* (silver wattles *Acacia dealbata*), spotted quail-thrush *Cinclosoma punctatum* (drier forest with open understorey), chestnut-rumped hylacola *Sericornis pyrrhopygius* (heathy woodland), noisy friarbird *Philemon corniculatus* (river red gums *E. camaldulensis*, forest red gums *E. tereticornis* and banksias) and white-winged chough *Corcorax melanorhamphos* (drier woodland with open understorey). Several other species occurred in the two largest patches only in very small numbers, and smaller patches were also important for their local survival; these species included birds of drier habitats such as leaden flycatcher. Elsewhere in the state all occurred in continuous forest, though little or no extensive habitat remains for some of them (notably noisy friarbird) in this region of southern Victoria. There appears to be no reason for these species to avoid larger patches of forest, but in this region their habitats were only represented in small patches.

Species only on Large Patches

No species was confined to the largest patch. At least one pair of powerful owls *Ninox strenua* was resident there and otherwise the species was not recorded except occasionally on the second largest patch (M11, 973 ha). Another forest bird, the beautiful firetail *Emblema bella*, was only observed once outside the largest study patch where small numbers were resident in heathy gullies. Just one other species, the white-bellied cuckoo-shrike, was recorded only in the three largest patches (F11, M11 and M2, 144 ha) where a few pairs occurred as regular summer migrants.

Just as some species (at least six in this study) had habitats that by chance were only represented on small forest patches, others would be expected to have habitats only represented on large forest patches. Therefore it would be wrong to conclude that the three birds mentioned above necessarily need large reserves. If the patches were reduced in size their particular habitats might be lost, but if the habitats remained the species might remain as well.

No obvious reason can be suggested for white-bellied cuckoo-shrikes to need large reserves. Their absence from extensive forest nearby suggests that they need particular habitats (undefined) that happened to be represented in this study region solely on large patches. However, possible reasons can be suggested for the other two species.

Powerful owls have large territories, sometimes in the order of 800 to 1000 ha (Fleay 1968; Seebeck 1976) though this would depend on prey availability. Resident pairs were studied by Tilley (1982) in fragmented forest patches of 142 ha and 165 ha, where their diet included common farmland birds as well as arboreal mammals. It is not known whether smaller areas could be used, or combinations close together, but in this study they did not appear to be.

Beautiful firetails inhabit flammable understoreys and may need large reserves to provide successions of suitable habitat after fires. They are slow to return after wildfires and have not been seen flying across open country, though they may do so.

Hence three reasons for species to be associated with large patches may be exemplified by these three species: white-bellied cuckoo-shrikes by chance, powerful owls needing large areas for hunting and beautiful firetails needing continuous regeneration of successional habitats.

Species/area Relationships

Many studies have attempted to explain variations in numbers of species on habitat islands in terms of the equilibrium theory of biogeography (MacArthur and Wilson 1967; Diamond 1975). This theory has provided a framework for discussing important conservation issues but suffers from a paucity of experimental evidence, and many of the observed relationships can be described well with other models (Connor and McCoy 1979). The theory has also been used wrongly to argue that single large reserves necessarily conserve more species than series of several small reserves (the SLOSS debate) whereas the theory itself has been shown not to answer the question (Simberloff and Abele 1976, 1982). A full analysis of the present data with respect to SLOSS is planned, but a comparison of five 50 ha combinations with varying degrees of fragmentation revealed very similar numbers of forest bird species (Loyn 1985), implying that the observed reduction in species numbers with reducing patch size was a basic consequence of patch area rather than an effect of fragmentation. This use of SLOSS to separate 'passive' area effects from effects of fragmentation *per se* has been overlooked and clouded by arguments about general answers to the SLOSS question.

All studies have shown that large habitat patches support more species than small patches, but the form of the relationship varies according to geographical factors and the taxonomic or ecological group concerned. The present data fitted an exponential model best, and this model has generally been associated with systems that are not fully isolated and where numbers of species are determined mainly by habitats represented. All birds observed on this study were capable of moving easily between patches and most were observed doing so, including the only flightless species (emu); it was observed more often in pine plantations and pasture than in natural habitat. However, the graphs sloped steeply with the power function model (z=0.34 for forest birds), which has been taken as typical of more isolated systems and the equilibrium model. High z values and good exponential fits have also been reported for mammals on the same patches (Suckling 1982) and lizards, birds and mammals in the wheatbelt of Western Australia (Kitchener *et al.* 1980a, b, 1982; Humphreys and Kitchener 1982). The explanation in all cases is probably that habitats decline rapidly with decreasing patch size.

In the Latrobe Valley, the three models overestimated numbers in larger forest blocks nearby (as they did for mammals, Suckling 1982). For example, extrapolation of the exponential equation predicted 65 diurnal forest species on the largest patch (1771 ha) and 85 forest species on the 30,000 ha forest block studied by Gilmore (1977), whereas numbers actually found were 59 and 52 respectively. If instead the graphs were fitted to extensive forest nearby, they would underestimate numbers of forest species currently surviving in medium or large forest patches.

All equations were improved significantly by including terms other than log A, and the entry of a term for years isolated suggests that numbers of species were declining at about ten species per century (mainly forest birds) and could be collapsing towards lower equilibrium levels fitting another model. The equations for farmland and water birds suggested their species numbers depended primarily on factors external to the patches, whereas their abundance on patches depended mainly on grazing intensity, reflecting their use of these habitats. Nevertheless, the patches provided essential nesting and roosting sites for many of these species. Farmland and water birds were most common at low altitude, probably because the greater extent of clearing in the valley has provided more diverse habitats for both groups. It should also be noted that many farmland species were originally confined to open habitats at low altitude or inland, and would have been even rarer in the forested ranges before clearing.

The grazing and habitat indices made major contributions despite their coarseness. Few bird species were absent from patches where their habitats were well represented, so that a more careful (but subjective) calculation of habitat indices might have yielded near-perfect correlations. Noisy miner abundance was correlated with these variables and may have been a more sensitive (indirect) measure of grazing effects on small patches than the other indices, though noisy miners had a special impact of their own (on small grazed patches), as described.

Hence in this study, habitat representation emerges as a prime factor contributing to species-area relationships, with grazing as a prime factor reducing habitats, specially on small patches. Noisy miners may reduce forest bird populations and species further on small heavily grazed patches. Fragmentation acts mainly by reducing area of habitat, though when patches are reduced below 10 ha they appear to become more susceptible to effects of grazing and noisy miners.

Ecological Interactions and Tree Health

It was noticed that eucalypt dieback from defoliating insects was more severe in small, heavily grazed patches than in forest patches with intact understorey and higher populations of forest birds. Similar observations were made elsewhere in eastern Australia (New England tablelands) by Ford and Bell (1981) and Davidson (1984), although in higher rainfall parts of Victoria there is less evidence of dieback in grazed forest patches.

Many factors can be involved in rural dieback (e.g. see Old *et al.* 1981; Marks and Idczak 1976) including climate, effects of stock on trees and soil compaction, increased exposure to weather and pollutants (the Latrobe Valley study region was downwind from a major industrial centre) and hydrologic changes.

Insects are often an important factor affecting the health of trees and birds can play a major role in controlling them. This was demonstrated recently when common forest birds controlled psyllid infestations after experimental removal of aggressively territorial bell miners, resulting in improved tree health (Loyn *et al.* 1983). In the Latrobe Valley noisy miners may exert a similar influence to bell miners, maintaining high populations of insect prey through territorial defence, despite other differences in the ecology of the two miners. Even without noisy miners, it seems that populations of forest birds would be low in small heavily grazed patches lacking understorey, and hence such patches would be relatively unprotected against insect attack.

Mammals such as sugar gliders *Petaurus breviceps* also consume substantial numbers of insects (Nagy and Suckling 1985) and benefit from understorey protection (Suckling 1980, 1984). The importance of understorey was discussed by Davidson (1984), as habitat for predatory and parasitic insects as well as birds, all of which can reduce pest insects. The solution is to protect small patches from grazing, improving both species diversity and tree health.

Implications for Conservation and Management

The message for conservation is that small and large patches of remnant forest have value, depending on the habitats represented. In a region such as the Latrobe Valley, some important habitats are represented on medium-sized patches (10-150 ha) and not on larger patches as well as *vice versa*. These patches also have value in maintaining regional populations of birds and other wildlife, including common forest and farmland species which can help maintain the health of the forest patches and probably pasture as well.

Good management of small and scattered forest patches presents logistic problems for a central agency (e.g. government), and can best be achieved by individual landholders with suitable incentives and encouragement. Conservationists and government should recognize the complementary value of scattered forest remnants as well as large reserves for wildlife conservation and other reasons.

Trees and patches of forest on farmland have value for many purposes apart from wildlife conservation. They provide shelter for stock, protection from erosion and salinity, and supplies of firewood and fencing material. When patches smaller than 10 ha are heavily grazed by stock, they do not regenerate and old trees senesce rapidly, at least in part through inadequate natural control of insect populations. The survival of these patches, and to some extent the whole landscape, may depend on greater attention to animal habitat including protection and encouragement of understorey as well as tree regeneration.

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REFERENCES

Blakers, M., Davies, S. J. J. F. and Reilly, P. N., 1984. The Atlas of Australian Birds. Melbourne University Press, Melbourne.

Bond, R. R., 1957. Ecological distribution of breeding birds in the upland forests of southern Wisconsin. *Ecol. Monogr.* 27: 351-84.

Breckwoldt, R., 1983. Wildlife in the Home Paddock. Angus and Robertson, Sydney.

Connor, E. F. and McCoy, E. D., 1979. The statistics and biology of the species — area relationship. *Am. Nat.* 113: 791-833.

Davidson, R. L., 1984. The unique value of natural areas to agriculture. Symposium on Small Natural Areas, their conservation and management. National Trust of Australia (NSW), University of Newcastle, 103-12.

Diamond J. M., 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. *Biol. Conserv.* 7: 129-45.

Dow, D. D., 1977. Indiscriminate interspecific agression leading to almost sole occupancy of space by a single species of bird. *Emu* 77: 115-21.

Fleay, D., 1968. Nightwatchmen of Bush and Plain. Jacaranda Press, Brisbane.

Ford, H. A. and Bell, H., 1981. Density of birds in eucalypt woodland affected by varying degrees by dieback. *Emu* **81**: 202-8.

Gilmore, A. M., 1977. A survey of vertebrate animals in the Stradbroke area of South Gippsland, Victoria. *Vic. Nat.* **94**: 123-8.

Humphreys, W. F. and Kitchener, D. J., 1982. The effect of habitat utilization on species — area curves: implications for optimal reserve area. *J. Biogeogr.* **9**: 391-6.

Kitchener, D. J., Chapman, A., Dell, J., Muir, B. G. and Palmer, M., 1980a. Lizard assemblage and reserve size and structure in the Western Australian wheatbelt — some implications for conservation. *Biol. Conserv.* **17**: 25-62.

Kitchener, D. J., Chapman, A., Muir, B. G. and Palmer, M., 1980b. The conservation value for mammals of reserves in the Western Australian wheatbelt. *Biol. Conserv.* **18**: 179-207.

Kitchener, D. J., Dell, J., Muir, B. G. and Palmer, M., 1982. Birds in Western Australian wheatbelt reserves — implications for conservation. *Biol. Conserv.* **22**: 127-63.

Loyn, R. H., 1984. Bird diversity in isolates. Pp. 49-61. *in* Symposium on Small Natural Areas, their conservation and management. National Trust of Australia (NSW), University of Newcastle.

Loyn, R. H., 1985. Birds in fragmented forests in Gippsland, Victoria. Pp. 323-31 *in* Birds of eucalypt forests and woodlands — ecology, conservation, management ed by A. Keast, H. F. Recher, H. Ford and D. Saunders. Surrey Beatty and Sons, Sydney.

Loyn, R. H., 1986. The 20-minute search — a simple method for counting forest birds. *Corella* **10**: 58-60.

Loyn, R. H., Macfarlane, M. A., Chesterfield, E. A. and Harris, J. A., 1980. Forest utilization and the flora and fauna in Boola Boola State Forest in southeastern Victoria. *Forests Commision Victoria, Bulletin* 28.

Loyn, R. H., Runnalls, R. G., Forward, G. Y. and Tyers, J., 1983. Territorial bell miners and other birds affecting populations of insect prey *Science* **221**: 1411-3.

Lynch, J. P. and Whigham, D. F., 1984. Effects of forest fragmentation on breeding bird communities in Maryland, USA. *Biol. Conserv.* **28**: 287-324.

MacArthur, R. H. and Wilson, E. O., 1967. The Theory of Island Biogeography. Princeton University Press, Princeton.

Marks, G. C. and Idczak, R. M., 1976. Eucalypt dieback in Australia. Report of a seminar held at Lakes Entrance, Victoria. Forests Commission, Victoria.

Nagy, K. A. and Suckling, G. C., 1985. Field energetics and water balance of sugar gliders, *Petaurus breviceps* (Marsupialia: Petauridae). *Aust. J. Zool.* **33**: 683-91.

Nie, N. H., Hadlae Hull, C., Jenkins, J. G., Steinbrenner, K. and Bent, D. H., 1975. Statistical Package for the Social Sciences. 2nd ed. McGraw-Hill.

Norris, K. C., Gilmore, A. M. and Menkhorst, P. W., 1979. Vertebrate fauna of South Gippsland, Victoria. *Mem. Nat. Mus. Vic.* **40**: 105-99.

Old, K. M., Kile, G. A. and Ohmart, C. P. (eds.), 1981. Eucalypt dieback in forests and woolands. C.S.I.R.O. Melbourne.

Seebeck, J. H., 1976. The diet of the Powerful owl (*Ninox strenua*) in Western Victoria. *Emu* **76**: 167-70.

Simberloff, D. S. and Abele, L. G., 1976. Island biogeography theory and conservation practice. *Science* **191**: 285-6.

Simberloff, D. and Abele, L. G., 1982. Refuge design and island biogeographic theory: effects of fragmentation. *Am. Nat.* **120**: 41-50.

Suckling, G. C., 1980. The effects of fragmentation and disturbance of forest mammals in a region of Gippsland, Victoria. Ph.D. Thesis, Monash University.

Suckling, G. C., 1982. Value of reserved habitat for mammal conservation in plantations. *Aust. For.* **45**: 19-27.

Suckling, G. C., 1984. Population ecology of the sugar glider, *Petaurus breviceps*, in a system of fragmented habitats. *Aust. Wildl. Res.* **11**: 49-75.

Tilley, S., 1982. The diet of the powerful owl (*Ninox strenua*) in Victoria. *Aust. Wild. Res.* **9**: 157-75.

Appendix: Habitats and birds on study patches.

Area	Size (ha)	Habitats: Distance from nearest patch (m)	Distance from nearest larger patch (m)	Grazing index* (1-5)	Date of isolation	Altitude (m)	Main Vegetation †	Other features	Boundaries with #	Numbers of bird species: Forest bird species	Farmland bird species	Water bird species	P Total bird species (diurnal)	Numbers of individual birds: Forest birds per count	Total birds per count	Forest birds as % of total birds	Noisy miners as % of total birds
M5	0.1	39	39	2	1968	160	N,o		O	8	4	0	12	5.3	10.7	50	34
M6	0.5	104	311	5	pre 1900	140	N,o		O	4	6	1	11	1.5	15.5	10	38
T27	0.5	234	234	5	pre 1920	60	N,o		O	3	7	0	10	2.0	10.6	19	21
M8	1	246	246	5	1890-1918	140	N,o,t		O	21	8	0	29	13.8	22.6	61	0
M10	1	234	285	3	1960-1965	130	N,o		O	22	10	0	32	14.1	36.3	39	10
M13	1	156	156	4	1960-1965	130	N,o		O	3	6	1	10	3.3	22.4	15	50
M21	1	311	571	5	-1900	130	N,o		O	4	9	1	14	3.0	23.8	13	1
ME	1	467	467	5	1955	90	N,o		O	6	11	0	17	3.8	25.6	15	27
T26	1	66	66	3	1966	160	N,o		P,O	21	3	0	24	17.1	18.1	94	0
T28	1	284	1829	5	1920	60	N,o		O	5	8	1	14	2.2	24.2	9	22
F10	2	402	402	1	1972	210	Y,h		P	27	3	0	30	14.6	15.5	95	0
F21	2	93	93	5	1890	160	Y,o		O	3	5	0	8	1.8	26.8	7	43
M7	2	130	623	5	pre 1900	145	Y,b,o	T	O	4	8	1	13	3.5	31.6	11	30
MB	2	259	259	5	pre 1900	120	N,o		O	10	7	0	17	8.0	27.8	29	17
T25	2	66	332	3	1926	210	N,b,o		P,O	23	4	0	27	27.6	29.8	93	0
M19	2	39	39	2	1973	210	Y,b,h		P,S	26	7	0	33	21.2	23.2	91	2
MD2	3	26	26	3	1962	110	Y,h,g,t		O	28	8	0	36	29.0	38.7	75	0
M15	3	26	26	3	1960-1965	140	N,o		O	10	8	0	18	2.9	26.9	11	41
F25	4	40	40	3	pre 1960	190	Y,h		O,R	32	5	0	37	24.3	25.9	94	0
M20	4	26	2205	5	pre 1923	120	N,o	E	O	7	10	3	20	5.0	39.6	13	38
M18	4	234	519	2	1973	220	Y,h,b	M	P,S	25	4	0	29	24.4	26.1	94	3
MF	4	259	259	2	1953	90	N,Y,h		O	25	10	0	35	19.4	32.0	61	17
M14	5	39	39	3	1960-65	130	N,b,o,t		O	20	10	0	30	15.8	32.8	48	25
TE	5	372	372	1	1967	100	Y,h		P,O	33	3	0	36	25.3	27.3	93	0
F20	6	93	226	3	1890	170	Y,h (sparse)		O,W	26	5	1	32	19.5	32.6	60	18
T11	6	159	1009	3	1960	150	N,b		P,S	31	2	0	33	20.9	21.2	99	0
M9	7	285	882	3	1960-65	130	N,o		O	29	10	0	39	16.3	37.9	43	23
TB	7	133	133	4	1960	210	Y,b		S	32	2	0	34	18.8	19.3	98	0
F8	8	266	266	4	1973	120	N,b,o		P,O	25	4	0	29	19.9	25.2	79	3
T31	9	350	1868	5	pre 1910	90	R,o		O	11	12	0	33	13.0	34.4	38	18
MD1	10	337	519	3 but slashed often	1962	110	N,o	D	O	13	10	4	27	6.8	36.0	18	29
F24	11	27	27	4	pre 1960	175	Y,h,g		O,R	35	3	0	38	21.7	22.7	96	0
F23	12	133	133	4	pre 1960	200	Y,h		O,S,W	33	8	1	42	26.8	30.4	88	1
F9	12	159	159	4	1963	110	N,b,g		P,O	40	7	0	47	27.8	28.5	98	0
M1	13	146	146	2	1968	190	N,b,o		O	24	5	0	29	16.6	18.9	88	1
T2	15	146	398	3	1966	120	Y,b,o		P,O	42	4	2	48	30.4	31.8	96	0
F4	17	389	2595	5	pre 1920	100	N,o,b		O	28	10	0	38	11.5	34.1	34	28
T19	18	40	3188	2	1966	190	N,b,h	recently reduced from 57 ha	P,O,W	31	6	0	37	26.0	28.5	90	1

Appendix — Continued.

Area	Size (ha)	Habitats: Distance from nearest patch (m)	Distance from nearest larger patch (m)	Grazing index* (1-5)	Date of isolation	Altitude (m)	Main Vegetation †	Other features	Boundaries with #	Numbers of bird species: Forest bird species	Farmland bird species	Water bird species	P Total bird species (diurnal)	Numbers of individual birds: Forest birds per count	Total birds per count	Forest birds as % of total birds	Noisy miners as % of total birds
F7	19	266	1302	4	1973	150	N,b		P,O	34	7	0	41	25.7	28.8	89	3
T29	22	311	2672	5	pre 1918	90	N,b,o	T major rubbish near Traralgon	O	29	13	1	43	12.7	40.1	32	9
F12	26	597	597	1	1963	140	Y,h		P,O	40	4	0	44	23.5	24.2	97	0
T18	29	545	770	3	1965	130	Y,h,b		P,O	42	8	0	50	24.9	27.3	91	1
M3	32	208	208	1	1974	170-210	Y,h		P,O	41	5	0	46	29.0	29.8	97	0
T10	34	66	345	1	1965	110	Y,h		P,O	33	9	1	43	28.3	30.5	93	1
M14A	40	285	178	2	1962	120	Y,N,h		O	45	13	1	59	28.3	33.5	85	5
F19	44	93	93	3	1960	190	N,h,g		P,O,W	37	5	1	43	32.0	33.9	95	3
M13A	48	259	1297	3	1928	120	N,G,b,g,t	C	O	47	12	1	60	37.7	41.1	92	1
F6	49	1427	1557	1	1972	180	Y,h	T,E	P	44	10	2	56	[illegible]	43.0	92	1
T1	50	398	1461	1	1967	100-180	Y,S,G,h	C	P,O	44	4	0	48	29.6	29.9	99	0
M23W	57	467	467	1	1963	120-210	Y,G,h	D	P,O	46	6	0	52	31.0	32.5	95	0
M4	96	39	519	2	1976	150-200	N,G,b,g	D	P,O	46	12	0	58	34.4	38.9	89	0
F1	108	402	4426	1	1964	70	N,R,G,b,t	D	P,O	46	12	1	59	27.3	32.1	85	2
M23E	134	467	2213	1	1964	120-200	Y,b,h	C	P,O	49	9	0	58	30.5	32.3	95	0
M2	144	146	319	1	pre 1940	160-220	Y,S,G,h	D,C	O	49	12	2	63	33.0	35.0	94	0
M11	973	337	1323	1	pre 1970	140-240	Y,S,G,h	D,C	P,O	52	12	3	67	29.5	31.3	94	0
F11	1771	332	332	1	1933	160-360	Y,S,G,h,t	C	P,O	59	5	0	64	30.9	31.6	98	0

Key to Appendix:

* Grazing pressure is indicated on a scale of 1 (little or no grazing by domestic stock) to 5 (heavy grazing pressure, little or no natural understorey remaining).

† The Main vegetation includes:

N — stands dominated by Narrow-leaf Peppermint *Eucalyptus radiata*, usually with Manna Gum *E. viminalis*, and But-but *E. bridgesiana*, and sometimes Swamp Gum *E. ovata* and other species.
Y — stands dominated by Yertchuk *E. consideniana*, with some of the species above and various stringybarks.
S — stands dominated by various stringybarks, specially Messmate *E. obliqua*, often with Narrow-leafed Peppermint and Mountain Grey Gum *E. cypellocarpa* in gullies and on wetter slopes, and an understorey containing Forest Wire-grass *Tetrarrhena juncea* and various shrubs.
R — stands dominated by River Red Gum *E. camaldulensis* or Forest Red Gum *E. tereticornis*.
G — some well developed gully vegetation.
b — understorey dominated by Bracken *Pteridium esculentum*.
t — thickets of tea-tree, specially Burgan *Leptospermum phylicoides*.
h — heathy understorey (e.g. with Common Heath *Epacris impressa* or *Banksia* spp), as well as Bracken, Burgan and various shrubs.
o — heavily grazed open understorey of introduced grasses.
g — naturally open understorey of native and introduced grasses.

Other features include rubbish tips (T), small dams (D), a small ephemeral swamp (E) or a permanently running creek (C). One area with unusually sparse trees and abundant Mistletoe is marked M (though Mistletoe also occurred in many patches).

\# Boundaries with pine plantations (P), open farmland (O) or scrub, e.g. regenerating farmland (S). Patches separated from other forest only by a road are marked R. Patches with extensive water nearby are marked W.

P Numbers of species exclude nocturnal birds, of which four species were resident with up to three on individual patches.