Landscape thresholds for the conservation of biodiversity in rural environments

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Abstract

The maintenance of ecological processes and the effective conservation of plants and animals in agricultural landscapes depend on a sound understanding of how natural systems respond to human land-use at the landscape scale. In this study we examined the relationship between the status of birds and mammals and the extent and pattern of native vegetation in rural landscapes, by using data from a field study in northern Victoria and from the New Atlas of Australian Birds. The field research involved surveys of birds and mammals, and the occurrence of mistletoe parasitism (a natural ecological process) in 24 landscapes, each 10 km x 10 km, representing a gradient in tree cover from 60% down to 2% cover. There was a marked threshold response in the richness of woodland-dependent bird species. Below 10% tree cover, there was a disproportionate loss of species as the bird community 'crashed'. The total extent of vegetation was the most significant influence on species richness, with the configuration (or pattern) of the vegetation having little influence at the landscape scale. The richness of native mammals showed a similar response with disproportionate loss of species in landscapes with less than 10-12% cover. Configuration of vegetation was a significant factor for mammals, with a higher richness in landscapes in which vegetation was aggregated. The occurrence of mistletoes in these rural landscapes was also significantly influenced by vegetation cover (positive relationship), although a distinct threshold level of vegetation was not evident. Individual species of woodland birds displayed a range of types (shapes) of responses to landscape change, including linear decline, curvilinear, quadratic, step-threshold and no change. This is the first time such responses have been demonstrated with empirical data at the landscape level. These showed that the process of decline for many species commences well above the threshold level of tree cover, and that at 10% cover multiple species are reaching the endpoint of their decline (i.e. local extinction). Our results indicate that while 10-15% native vegetation cover is a useful intermediate goal for restoration of landscapes which currently have little native vegetation (<5%), a long-term goal of 30-35% native vegetation is needed in rural landscapes to maintain resilient populations of most bird and mammal species. Vegetation on public land (e.g. stream frontages, roadsides, conservation reserves, state forests) can complement habitats on private land to achieve this restoration goal at landscape and regional scales.

1. Results and implications in relation to project objectives

Objective 1. To measure indicators of biodiversity in landscapes that have differing levels of vegetation cover (from < 2% to > 50%) and vegetation pattern (clumped vs dispersed vegetation).

Two approaches were used to measure indicators of biodiversity in landscapes with differing levels of vegetation cover. These are described, together with a summary of data collected.

a) Data from the Second Atlas of Australian Birds

Large data sets on birds are available as a result of the efforts of hundreds of volunteer observers with Birds Australia. We selected two regions, Gippsland Plains and Northern Victoria, for analysis, and collated observations of bird species for 'landscapes' represented by grid cells of 10' latitude by longitude. Other attributes of landscapes including total tree cover, configuration of tree cover, proportions of vegetation types, elevation, rainfall and land-uses, were also collated.

In the Gippsland Plains, a total of 165 species of landbirds (i.e. excluding water birds) was recorded from 57 landscapes (grid cells). By plotting the relationship between an occurrence index for species (derived from the reporting rate) and the breadth of distribution (number of landscapes in which a species was recorded), we were able to objectively identify bird species as common (40 spp), widespread but uncommon (65 spp) and rare and restricted (60 spp). Birds were also grouped by their habitat use, and foraging and nesting behaviours. Species regarded as being of conservation concern (as assessed by expert ornithologists) were disproportionately represented in woodland and heathland habitat groups, in the hollow-nesting group, and in the bark-foraging group of birds. This analysis has been accepted for publication (Radford and Bennett in press) and demonstrates the way in which Atlas data can be used for regional analyses.

The number of species of different ecological groups of birds in each Gippsland landscape (e.g. total bird species, woodland-dependent species, species of conservation concern) were also collated as indicators of biodiversity. Models of the relationship between these measures of species richness and landscape attributes were then developed.

In Northern Victoria, over 200 species of landbirds were recorded from 166 landscapes (grid cells). Attributes for each landscape were collated in similar manner as for Gippsland. This data set has been used primarily to test the relative importance of the extent of tree cover (wooded habitat) vs the configuration of tree cover in determining the number of woodland-dependent species (see below).

b) Field research in northern Victoria

Atlas data has a number of inherent limitations, such as variation in the number of observers, observer effort, observer skills, and the location of observations. Consequently, a field study was undertaken in northern Victoria (450-600 mm rainfall zone) to systematically collect data from a carefully selected set of landscapes. A total of 24 landscapes were selected, each 10 x 10 km (100 km^2) in size, and ranging in tree cover from 2% to 60%, with most having <20% cover. Landscapes were also selected such that in half the tree cover was 'aggregated' into one or a few large blocks while in the others it was 'dispersed' across the landscape. Ten survey sites were set out in each landscape, located in large (>40 ha) or small (<40 ha) blocks, along roadsides or streams, or among scattered trees of low canopy cover (detail in Radford *et al.* in press). Rainfall, geographic location (east-west), range in elevation, land use and other attributes were recorded for each landscape.

Birds were surveyed at each site in each landscape on four occasions (twice in breeding and non-breeding season) in a year. Data were collected within a 2 ha plot (to allow estimates of density) but off-site observations were also recorded as these were relevant when pooling data at a landscape level. A total of 189 species of birds, including 156 species of land-birds, was recorded, of which 80 species were considered to be woodland-dependent species typical of the region. The number of woodland species per landscape ranged from 12 to 53, with a mean of 38.4 species. The mean number of species per landscape for those recorded from at least two sites in each landscape was lower (mean 22.5 species). A list of all woodland species is given in Appendix 3, together with their frequency of occurrence at sites and in landscapes.

Mammals were surveyed at each site in each landscape using spotlight observations, hair-sampling tubes (10 tubes per site), searches for scats and signs, and incidental observations. Bats were not surveyed in this study due to limited resources. Mammal surveys were undertaken in half of the landscapes as part of an Honours research project (Naomi Best, Deakin University), and in the other half the survey work was financially supported by a CRGS grant from Deakin University. A total of 13 species of native mammals and 6 species of introduced feral mammals was recorded. The number of native mammals species per landscape ranged from 3 to 9. The occurrence of mammal species recorded in the study landscapes is summarised in Appendix 4.

Mistletoe occurrence was studied as an example of how a complex ecological process might be influenced by landscape change. This part of the project was conducted by Lindy MacRaild as part of her PhD research. Mistletoes are native plants which are hemi-parasites of trees (they obtain water and nutrients from host but are capable of photosynthesis). They depend on birds for dispersal of seeds between host trees. The Mistletoebird is the main dispersal vector for mistletoes in this region. Mistletoes were surveyed in 0.8 ha plots at 15 sites in each landscape. In each plot the number of mistletoes was recorded along with the tree species on which they were present, their relative size and position, and whether the mistletoe plant was alive or dead. A total of five species of mistletoes were recorded for the study, the most abundant being Box Mistletoe *Amyema miquelli*. Others were Grey Mistletoe *Amyema quandong,* Buloke Mistletoe *Amyema linophyllum*, Creeping Mistletoe *Muellerina eucalyptoides* and Fleshy Mistletoe *Amyema miraculosum*. The occurrence of mistletoes was patchy: they were detected in 20 of the 24 landscapes, and Box Mistletoe was recorded at 80 of the 360 sites surveyed.

Significance:

- Data was collected at the landscape-level to allow analysis of the way in which different sets of species (woodland birds, mammals) and an ecological process (mistletoe parasitism) are influenced by landscape change.
- This is one of the first empirical studies of the occurrence of species and processes at the landscape scale, using 'whole landscapes' as the unit of study.
- A large data set on the occurrence of birds and mammals was obtained, including records of threatened species. This data will contribute to the databases of the Atlas of Victorian Wildlife as a resource for wider use.
- Analysis of data from the New Atlas of Australian Birds (Birds Australia) (Radford and Bennett in press) has provided an innovative approach and methodology that can be used for regional analyses of the avifauna throughout Australia.

Objective 2. To test the idea of ecological 'thresholds' of landscape cover and pattern, below which there is disproportionately rapid decline in species, faunal groups or ecological processes.

The concept of identifying ecological 'thresholds' and using them in land management is a relatively new approach. An ecological threshold refers to a point or zone at which relatively rapid change occurs from one ecological condition to another, often indicating a 'breakdown' in the system. The idea is that if thresholds exist and can be identified, this can assist in setting goals for management to maintain the system at 'safe' levels.

In this project our objective was to test whether there is a threshold relationship between native fauna and the extent of wooded vegetation in rural landscapes. In particular, we wished to know whether there is a level of vegetation cover in rural landscapes below which there is a disproportionately rapid loss of species, or rapid decline in the occurrence/abundance of an individual species. The field data collected in northern Victoria on the occurrence of birds, mammals and mistletoe parasitism provided several different measures of biodiversity for this analysis.

The richness of woodland birds in the 24 study landscapes showed a distinct threshold response to the amount of tree cover (Fig. 1). A series of models were fitted to the data and the models with the best statistical fit were those that showed a marked decline in richness below 10% tree cover (Radford *et al*. in press). The 'broken-stick' regression model shown in Fig. 1, clearly demonstrates the threshold concept. Above 10% tree cover there was little variation in richness of woodland bird species in relation to tree cover, but below 10% there was a rapid loss of species.

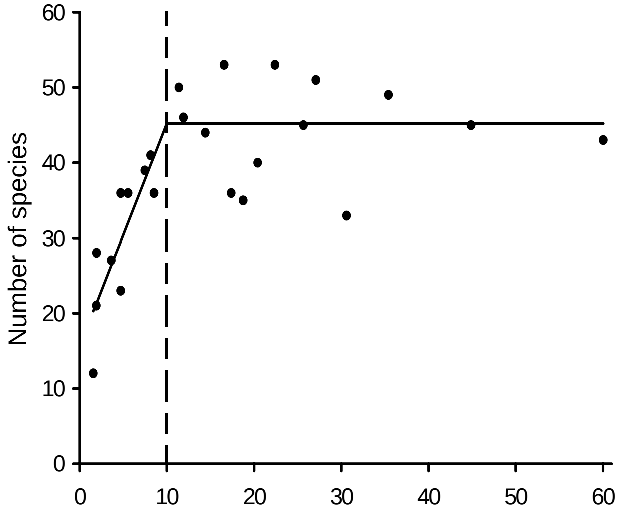


Fig. 1. The relationship between tree cover and species richness of woodland-dependent birds in 24 landscapes (each 100 km2) in northern Victoria. The solid line represents the line of best fit for a broken-stick regression model. The dashed line indicates the threshold in this relationship. Tree cover was the most significant predictor of bird species richness, alone accounting for 55% of the variation between landscapes.

The threshold in species richness equates to the local extinction of many species of woodland birds in these landscapes: that is, multiple species have reached the end point of their process of decline at around 10% tree cover. Clearly, the threshold represents the point of breakdown in the bird community – management goals need to be well above this point.

The relationship between species richness of native mammals and tree cover also showed a marked decline in the number of mammal species in landscapes with tree cover of approximately 10-12% cover (Fig. 2), and little change for landscapes with greater than approximately 15% cover. Further analysis will be carried out on this relationship. The frequency of occurrence of Box Mistletoe in landscapes (number of sites out of 15 at which they were present) was also modelled against tree cover. This showed a curvilinear relationship, but a distinct threshold response was not evident. The patchy occurrence of mistletoes meant that tree cover accounted for only 30% of the variation between landscapes.

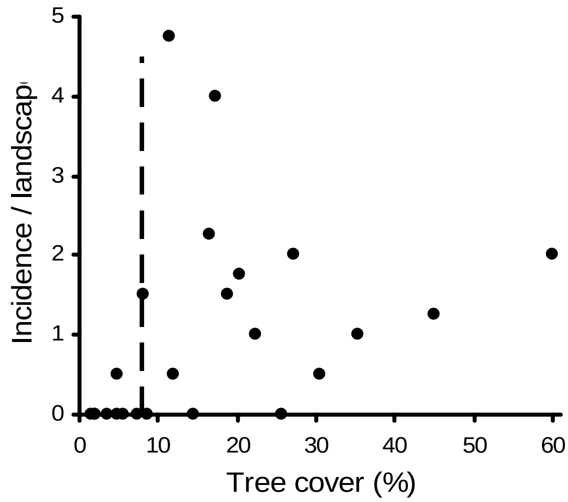


Fig. 2. Relationship between tree cover and richness of native mammal species in 24 landscapes (each 100 km²) in northern Victoria. The solid line represents the line of best fit for a logarithmic model.

Fig. 3. Relationship between incidence of the White-browed Babbler and tree cover in 24 landscapes in northern Victoria. The dashed line represents a threshold below which the species seldom occurs. Above this level it is present in most landscapes.

The relationship between the incidence of individual species and tree cover in the study landscapes was also examined for 57 species of woodland-dependent birds for which adequate data was available. This was important in demonstrating that there are a number of *different types of responses* to landscape change. Five types of responses identified include:

a) linear response – the rate of population decline is constant as tree cover declines (e.g. Little Lorikeet, Crimson Rosella)

b) curvilinear response – the rate of decline increases as tree cover declines. For some species the incidence of occurrence reaches an asymptote (e.g. Grey Shrike-thrush, Rufous Whistler) while for others it continues to increase with increasing tree cover in the landscape (e.g. Crested Shrike-tit, Brown-headed Honeyeater, Eastern Yellow Robin)

c) step-threshold response – the species does not occur below a particular threshold of tree cover, but is present above that level although there is no clear relationship with tree cover (e.g. White-browed Babbler (Fig 3), Hooded Robin).

d) quadratic response – the greatest incidence is in landscapes with mid-levels of tree cover with a lower incidence in both low and high cover landscapes (e.g. Jacky Winter, Brown Treecreeper)

e) no response – the incidence of the species is similar in all landscapes (e.g. White-winged Chough)

Significance:

- This study has provided empirical evidence of a landscape-level threshold in the richness of woodland-dependent bird species. Below 10% tree cover there is a disproportionate loss of species as the bird community 'crashes'. The richness of native mammals in rural landscapes shows a similar response, with disproportionate loss of species below 10-12% tree cover. These results indicate that a goal well in excess of 10% vegetation cover is required to retain woodland-dependent birds and mammals in rural landscapes.
- The occurrence of mistletoe in rural landscapes was significantly influenced by vegetation cover (positive relationship), although a distinct threshold was not evident. It is likely that many other ecological processes, such as plant-animal relationships, will also be modified by landscape change.
- Individual species of woodland birds displayed a range of types (shapes) of responses to landscape change, including a step-threshold. This is the first time such responses have been demonstrated with empirical data at a landscape level. It highlights the variation in the way native biota respond to landscape change, and shows we must not assume a single type of response by native fauna to landscape change.

Objective 3. To describe the relationship between the fauna and landscape pattern, and examine the extent to which landscape thresholds differ among different species' groups and ecological processes.

The influence of landscape pattern

Landscapes in the field study were selected to represent those in which tree cover was 'aggregated' and those in which it was more 'dispersed' through the landscape. We wished to test the relative importance of vegetation pattern versus vegetation extent as influences on the occurrence of species. Several different analyses all point to the primary importance of the extent of vegetation at the landscape scale, with vegetation pattern generally being of much less influence.

a) Species richness of woodland birds. An analysis of covariance for richness of woodland birds vs landscape pattern (aggregated vs dispersed) taking into account tree cover as the co-variate, showed that while tree cover was a highly significant influence on richness ($P < 0.001$) and there was no evidence of a main effect of pattern ($P > 0.1$), the interaction between landscape pattern and tree cover only just failed to reach significance ($P = 0.07$) (Radford *et al*. in press). However, the trend from this analysis and from fitting separate models to dispersed and aggregated landscapes, respectively, suggested that in landscapes with aggregated cover, woodland birds persisted at lower levels of cover, while in dispersed landscapes the loss of species was more gradual and commenced at higher levels of tree cover (see Appendix 5).

A multivariate model of factors influencing the richness of woodland-dependent birds included four significant factors: extent of tree cover, average patch shape, range in elevation and geographic location. Tree cover accounted for most of the variance in species richness (55%), with the others explaining a further 6.5%, 5.8% and 8.0%, respectively. Patch shape is one indicator of landscape pattern. Richness was greater in landscapes with decreasing regularity in patch shape (i.e. a greater proportion of elongated patches). This was most evident in landscapes with low to moderate tree cover (5-15%), and probably reflects greater richness in low-cover landscapes with high connectivity from roadside and streamside vegetation.

Multivariate models of factors influencing the incidence or occurrence of *individual* species of birds in landscapes were developed for 56 species of woodland-dependent birds. The extent of tree cover was the factor most commonly included in the models. However, one or more measures of the pattern (or configuration) of vegetation in the landscape were incorporated in the 'best' model for 27 of the 56 species. The measure most commonly included in models was the variable representing average patch shape. These modelling results suggest that the pattern of vegetation has a significant, but less important, influence than the extent of habitat for many species of birds.

b) Mammals. Both extent and configuration of tree cover were significant influences on the richness of native mammals in study landscapes. The model predicts that for a similar level of tree cover, landscapes in which the wooded vegetation is aggregated are likely to have a greater species richness than those where the vegetation is dispersed. This can be attributed to a number of species (e.g. Echidna, Black Wallaby, Yellow-footed Antechinus) depending on larger intact blocks of woodland for their occurrence.

c) Mistletoe. The extent of tree cover was the only significant variable in a model of the incidence of mistletoe (no. of sites at which present) in study landscapes.

d) Bird Atlas data. Bird Atlas data from 10' latitude/longitude grids in northern Victoria were used to further probe the relative importance of extent vs configuration of vegetation in the landscape as influences on species richness of woodland birds. Landscapes were ranked in relation to their configuration of wooded vegetation and a set of those with the highest and lowest levels of habitat aggregation were selected. The richness of bird species was then compared between these sets of landscapes, controlling for observer effort (number of bird lists submitted) and with tree cover as a covariate. Again, the results highlighted the importance of tree cover as the most significant predictor of species richness. The pattern of vegetation in the landscape had relatively little influence.

e) Landscape vs site level considerations. It is important to note that while configuration of tree cover has only moderate influence on fauna and ecological process (mistletoe parasitism) at the landscape scale, the type, size and location of remnant vegetation has a strong influence on the biota at a site scale. For example, there was a highly significant difference ($P<0.001$) in the mean number of woodland bird species per site in different types of landscape elements, ranging from a mean of 25.7 species in large blocks (>40 ha) to 7.8 species for roadside sites. Likewise, there was marked variation in the frequency of occurrence of many species between different landscape elements (Fig. 4 below).

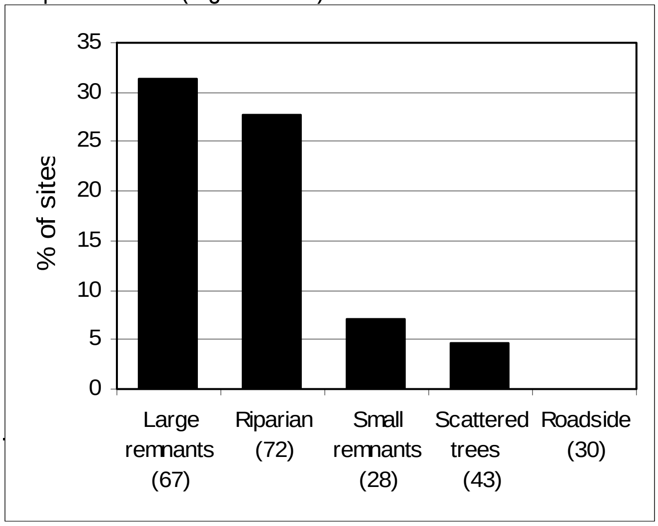


Fig. 4. Frequency of occurrence (% of sites) of the Olive-backed Oriole between different landscape elements in study landscapes in northern Victoria. This species was primarily recorded at survey sites in large blocks (>40 ha) or riparian vegetation.

The dispersal of mistletoes was also influenced by landscape pattern at the site-level. The occurrence of mistletoes at survey sites was strongly correlated with the distance from a large forest block (>100 ha).

Mistletoes were recorded from approx. 33% of sites within a large block or within 1 km, but were never recorded at sites >3 km from a large block (*n*=61 sites).

The extent to which landscape thresholds differ

It is important to note that a threshold response is only *one kind* of response to landscape change. Analyses of the responses of individual bird species highlighted the range of response types that occur – linear, curvilinear, quadratic, step-threshold and no response. Further, the level of tree cover at which different species experience decline, and at which they became locally extinct, differed between species. Eastern Yellow Robins, for example, were predicted to have declined to <50% of maximum incidence at around 15% tree cover, whereas for Grey Shrike-thrush this was at about 5% cover. This has important implications for conservation management. We must not assume that all responses will be a threshold response, or that all species will respond in the same way to land-use and loss of tree cover in rural landscapes.

Second, this study *did* provide strong empirical evidence of a threshold response in the richness of woodland birds and suggested a threshold response in richness of mammal species. For both taxa, the threshold was around 10% tree cover, consistent with previous analyses by Bennett and Ford (1997) based on Atlas data. The incidence of mistletoes showed a curvilinear decline with tree cover, with no obvious threshold of landscape cover at which dramatic loss occurred.

Other factors that influence native fauna

Our research focussed primarily on the influence of vegetation cover and pattern on the occurrence and richness of fauna at the landscape scale. It is important to recognise other factors that may also influence the occurrence of particular species or the richness and composition of assemblages. For example:

- Habitat condition. We recorded habitat condition at survey sites using the 'habitat hectare' approach, for compatibility with the DSE land managers. While we know that aspects of habitat condition are important at a site-level (e.g. large trees, tree hollows, shrubs) there was little evidence of its importance when averaged across all sites in a landscape.
- Fire. Almost nothing is known about fire regimes and their impact on fauna in these dry woodlands and forests.
- Predation. Predation by foxes and cats can influence mammals and ground-nesting/foraging birds.
- Pest plants and animals. Weeds and feral animals (Rabbits, Hares, House Mouse, Common Starling, Honey Bees etc) can affect the suitability of habitats for native fauna but were not explicitly studied here.

Significance:

- The extent of native vegetation (tree cover) had the greatest influence on the richness of faunal assemblages at the landscape scale. Measures that increase the overall extent of habitat in rural landscapes should therefore be an important goal for landscape managers. The extent of habitat determines the overall size and viability of populations.
- The pattern (configuration) of native vegetation also influences the richness of faunal groups and the incidence of particular species at the landscape scale, but is especially important at the site scale. Large blocks of vegetation and riparian vegetation are particularly rich habitats for birds and important for many species of birds and mammals.
- The influence of habitat isolation on mistletoe occurrence at survey sites can be attributed to the effect of isolation on the Mistletoebird, the vector that disperses seeds between host trees. Other ecological processes that involve plant-animal interactions will also be sensitive to the effect of landscape change on animal partners.
- Pattern (configuration) of vegetation is important because it can influence movement and connectivity for species, edge effects, and local population sizes.

Objective 4. To propose levels of vegetation cover for the maintenance and conservation of biodiversity at a landscape scale;

Our research in rural landscapes of northern Victoria identified a threshold level of native vegetation cover (tree cover) of around 10% at which there was disproportionate loss of woodland birds and native mammals. Clearly, a conservative level of vegetation cover is above this point at which the faunal community 'crashes'. Models of the incidence of individual species shows that the process of decline for many species commences well above this level, and that the richness threshold represents the stage at which multiple species reach the endpoint of their decline. But at what level of population decline do we become concerned about the status of a species? In presenting results to land managers, we identified the point at which species declined to 75% of their maximum predicted incidence (based on models of species incidence vs tree cover), and then to 50% of maximum predicted incidence (Radford *et al*. 2004). These points differ for different species.

A key conclusion for land managers is that there is no single 'correct' or universal answer to 'How much habitat is enough?'. Rather, an appropriate question is 'What will happen to the native fauna in *this landscape* if we manage it in *this way*?' We developed a set of three scenarios and used data and models to summarise their conservation values (Radford *et al*. 2004).

Scenario 1. Less than 5% native vegetation cover.

Scenario 2. Approx. 10-15% native vegetation cover.

Scenario 3. Approx. 30-35% native vegetation cover.

We make two main recommendations for land managers.
a) Rural landscapes with 10-15% vegetation cover represent an intermediate goal for landscapes that presently have very low cover of native vegetation (many have < 5%). If 10-15% can be achieved, a high diversity of native species are potentially able to occur, although the future sustainability of all species is not assured. Restoration along streams and the protection or creation of larger blocks of vegetation are high priorities; these are important elements for many species.

b) Rural landscapes with approximately 30-35% native vegetation (and 65-70% land for agricultural production) represents a balance likely to provide for most faunal species, and sustain more-resilient populations capable of withstanding environmental fluctuations. Large blocks of habitat are a key feature of such landscapes, and support area-sensitive species unlikely to occur in landscapes with low cover. The conservation value of these large blocks (and other habitats) depends on their integrity or 'completeness', which must be preserved from degrading land uses or fragmentation. It is not practical to have uniform cover of 30% on all farms or landscapes, but we must ensure that areas with higher vegetation cover are interspersed among those where native vegetation has been heavily cleared. Vegetation on public land within the rural land mosaic (e.g. stream frontages, bushland reserves, roadside vegetation, conservation reserves) can complement habitats on private land to reach a goal of 30-35% native vegetation.

Objective 5. To communicate this knowledge to stakeholders involved in planning, management and restoration of vegetation.

We made a strong commitment to communicating information about the project and its outcomes to stakeholders and others throughout the study, particularly in its final phase. A full list of communication activities is set out in Appendix 6.

1. Regional presentations of project outcomes to land managers and other interested people
Two-hour presentations were given at 13 locations in regional Victoria. *Locations*: Echuca, Bendigo (morning and evening), Melbourne -Victoria Pde, Melbourne-Deakin University (evening), Benalla (morning and evening), Wodonga, Traralgon, Stratford (evening), Leongatha, Warragul, Ballarat. A total of ~ 500 people attended these presentations representing a wide range of organisations and interests (see Appendix 7). A colour booklet (*How Much Habitat is Enough?,* 8 pp) (see Appendix 9) was prepared and printed (5000 copies) and widely distributed at these talks. Many people took away bundles of booklets for others in their groups. This was the most concentrated and successful effort to communicate with land managers, and much postive response was received to the research outcomes.

2. Seminars and conference presentations. At least 15 presentations have been made (listed in Appendix 6), at regional meetings, Universities, national conferences (e.g. Ecological Society of Aust) and internationally (UK).

3. Publications Scientific publications (4 mss to date, others in preparation) and 10 other articles in magazines and newsletters etc are listed below (see Publications).

4. Media.
At least 5 radio interviews and several articles in local papers (see Appendix 6). An email newsletter was also initiated for a range of land managers and interested persons, and four newsletters sent.

5. Other. Letters were sent on two occasions to landholders (~90 people) on whose properties we had survey sites, to inform them about the project and to provide specific feedback on bird species recorded on their property. Other talks (>8) were made in a variety of local and regional situations to groups (Appendix 6).

2. Publications from this project

Scientific papers (to date – others in preparation)

Bennett, A.F. and Radford, J.Q., 2004. Landscape-level requirements for the conservation of woodland birds: are there critical thresholds in habitat cover? pp. 117-124 in *Landscape Ecology of Trees and Forests* (Ed. R. Smithers). International Association for Landscape Ecology–UK Region and The Woodland Trust.

Radford, J.Q., Bennett, A.F. and Cheers, G.J. (2005 in press). Landscape-level thresholds of habitat cover for woodland birds. *Biological Conservation*

Radford, J.Q. and Bennett, A.F. (accepted). Avifauna of the Gippsland Plain and Strzelecki Ranges, Victoria, Australia: insights from Atlas data. *Wildlife Research* .

Radford, J.Q. (accepted). Variation in tree cover estimates using geographic information systems. *Ecological Management & Restoration*

Popular articles, magazine, newspapers etc

Jelinek, A. 2002. Clues to survival in agricultural landscapes. *Thinking Bush* Issue 1: 16-18.

Bennett, A. and Radford, J. 2003. 'Know your ecological thresholds'. *Thinking Bush* Issue 2: 1-3.

Bennett, A.F. and Radford, J.Q. 2004. From bush blocks to landscapes: wildlife conservation at different scales. *Thinking Bush* 3: 4-5.

Bennett, A. and Radford, J. 2002. Landscape patterns for biodiversity conservation. *Land for Wildlife News* 5(2): 11.

Radford, J.Q. 2002. A 'birds-eye' perspective of biodiversity conservation. *News and Views* 12(1): 26. (DSE magazine distributed to landholders in north-central Victoria)

Radford, J.Q. 2004. Species extinction: the tyranny of incremental habitat loss. *Parkwatch* 218: 10-11.

Radford, J.Q. 2004. Lessons from the landscape. *News and Views* 14(3): 16-17.

Radford, J.Q. 2004. Let sleeping logs lie. *Land for Wildlife News* 5(7): 13.

Radford, J.Q. 2004. Lessons from the landscape. *Landcare* magazine.

Radford, J., Bennett, A. and MacRaild, L. 2004. *How Much Habitat is Enough? Planning for wildlife conservation in rural landscapes*. Deakin University. 8 pp. [colour booklet distributed with regional presentations].

3. Student projects

The project has provided opportunities for two student research projects.

Naomi Best (Honours project, Deakin University, 2003): *The response of native mammals to a gradient in tree cover in landscapes across north-central Victoria.*

Lindy MacRaild (PhD, 2002-2005): *The effect of landscape cover and pattern on tree dieback and mistletoe parasitism in fragmented rural landscapes.*

4. Acknowledgements

We are most grateful to Land and Water Australia (Native Vegetation R&D Program) and the Dept Sustainability and Environment (DSE) for funding that made this project possible. Deakin University (School of Ecology and Environment) also provided much support, and a grant from the Deakin University CRGS scheme allowed completion of mammal surveys. The Holsworth Wildlife Trust provided financial support for PhD research by Lindy MacRaild. The Bendigo office of DSE (and Rob Price, FF Manager) provided essential office facilities, vehicle use and logistic support for Jim Radford, which greatly assisted the project. Initial collation of GIS vegetation data was carried out under contract by Spatial Vision, and further support was provided by Craig Feuerherdt and Steve Williams (Primary Industries Research Victoria). Birds Australia granted access to data sets from Gippsland and northern Victoria.

Many other people assisted in a variety of ways. Members of the Reference Committee (including Kim Lowe, Adam Muir, Jenny Wilson, Kate Bell, Rob Price, Alison Opperman, Geoff Park, Dale Tonkinson, Sally Murray, Elvyne Hogan, Karen Barton) provided discussion and feedback on progress; Naomi Best and Lindy MacRaild undertook student research projects which have greatly enhanced the study; capable field assistance has been provided by Garry Cheers, Andrew Carter, Geoff Nevill, Roger MacRaild and others; Hans Brunner provided expert skills with hair identification; and Ian Higgins and Aaron Gay (NCCMA) assisted with data base management. Karen Barton and Kim Lowe (DSE Melbourne) were instrumental in initiating this project and the latter provided valuable support throughout. We also wish to acknowledge the supportive research environment provided by Land and Water Australia, especially the annual Co-ordination Meetings of the Native Vegetation Program: thanks also to Jason Alexandra, Gill Whiting and Trudi Ryan.

We are particularly indebted to the many landholders who granted access to their properties, and to Forestry Victoria and Parks Victoria (Research Permit 10002099) for permission to conduct this research in State Forests and Parks.

Appendices

1. The Gippsland Plains study area used for analysis of Bird Atlas data. The gridlines represent 'landscapes' of 10' latitude by 10' longitude.

2a The location of study landscapes in northern Victoria used for field investigations

2b. Tree cover (shaded) in the study landscapes in northern Victoria. This represents a gradient from 2% to 60% cover.

3. Woodland-dependent species of birds recorded in study landscapes, north-central Victoria, 2002/03. The percentage of surveys, sites and landscapes in which each species was detected are presented.

4. Mammal species recorded in the 24 study landscapes in northern Victoria. The percentage of sites and landscapes at which each species was recorded are presented.

5. Univariate models of best-fit (solid line) and 95% confidence intervals (broken line) for the relationship between species richness of woodland-dependent birds and tree cover in landscapes with (a) aggregated and (b) dispersed habitat configuration.

6. Summary of communication activities (2001-2004) associated with this project.

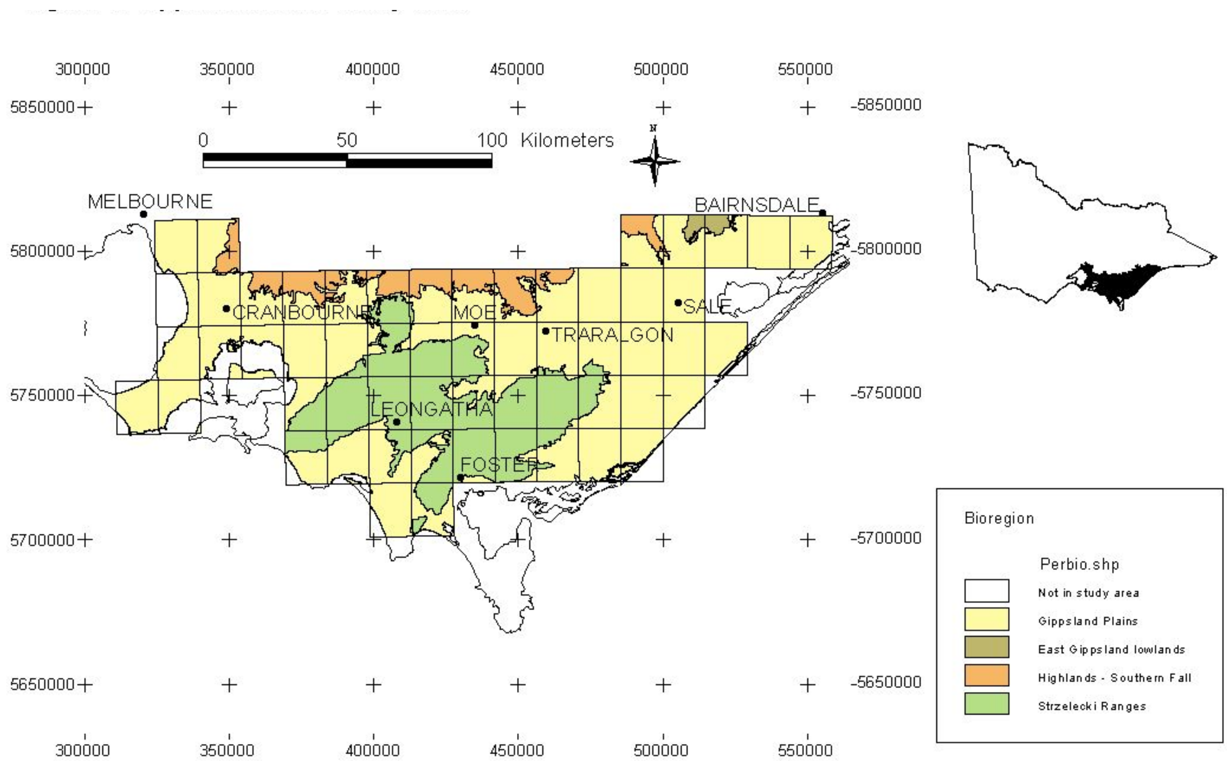
7. Summary of affiliations of attendees at regional presentations, Nov-Dec 2004

8. Copies of scientific publications arising from this research (four manuscripts)

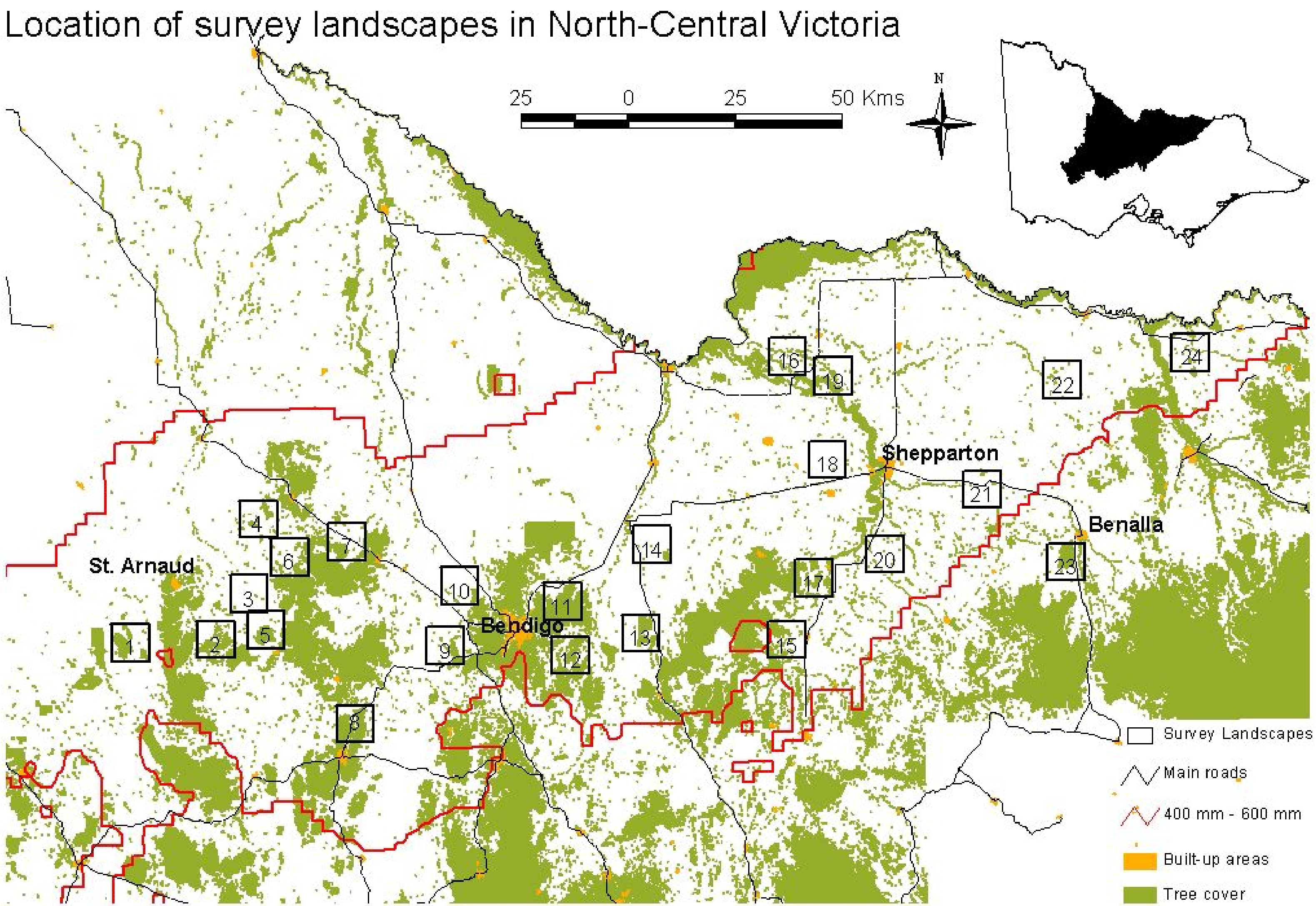
9. Copy of the colour booklet (8 pp) summarising research outcomes, for distribution at regional presentations

10. Copies of other articles and reports relating to the project.

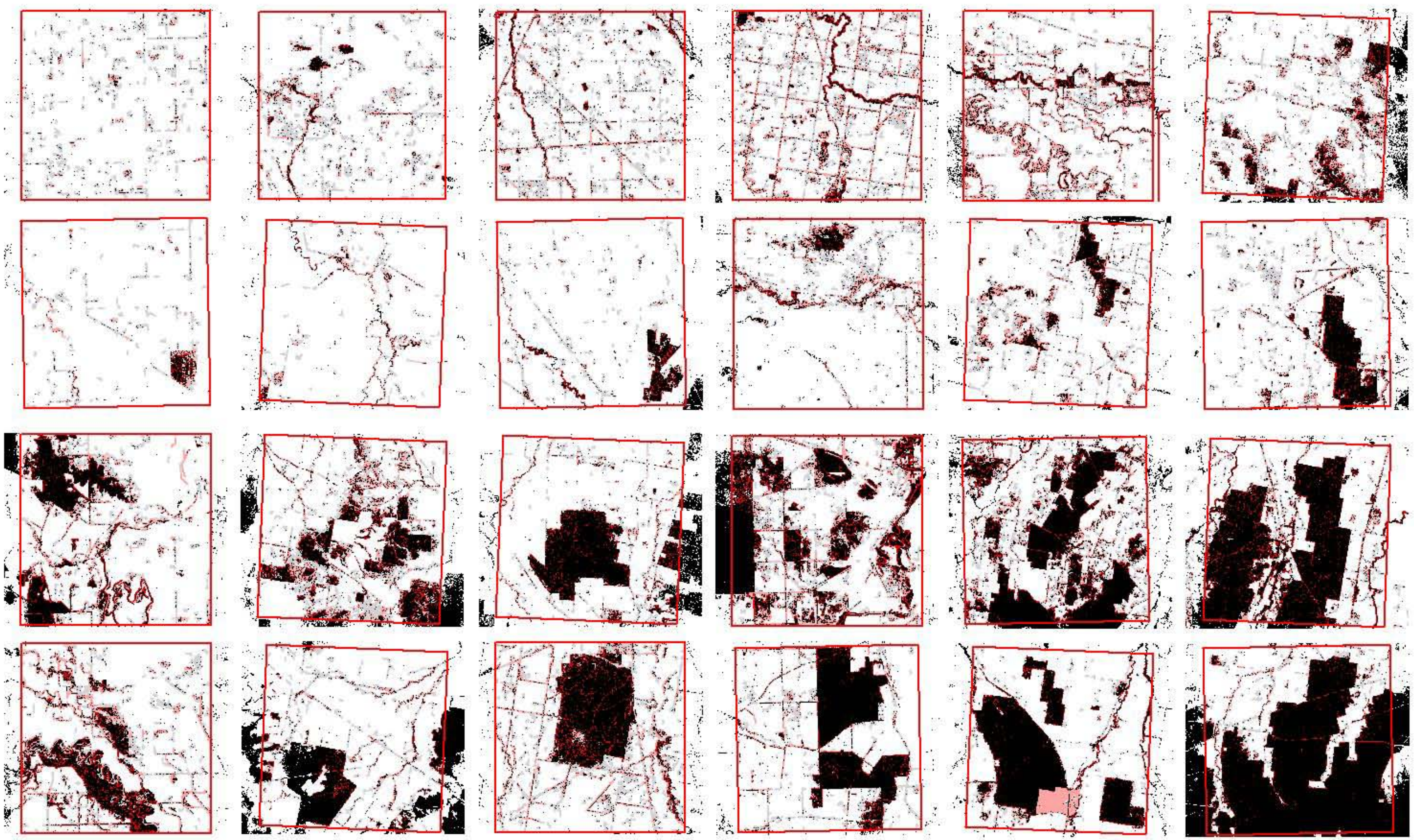
Appendix 1. The Gippsland Plains study area used for analysis of Bird Atlas data. The gridlines represent 'landscapes' of 10' latitude by 10' longitude.



Appendix 2a. The location of study landscapes in northern Victoria used for field investigations



Appendix 2b. Tree cover (shaded) in the study landscapes in northern Victoria, representing a gradient from 2% to 60% cover. .



Appendix 3. Woodland-dependent species of birds recorded in study landscapes, north-central Victoria, 2002/03. Percentage of surveys, sites and landscapes in which each species was detected are presented.

Common name	Scientific name	No. of surveys (n = 960)	No. of sites (n = 240)	No. of landscapes (n = 24)
Brown quail	*Coturnix australis*	0.42	1.67	16.67
Painted button-quail	*Turnix varia*	0.42	1.67	16.67
Peaceful dove	*Geopelia striata*	7.60	20.42	66.67
Common bronzewing	*Phaps chalcoptera*	12.71	37.08	91.67
Bush stone-curlew	*Burhinus grallarius*	0.52	1.25	12.50
Southern boobook	*Ninox novaeseelandiae*	0.83	2.50	16.67
Barking owl	*Ninox connivens*	0.10	0.42	4.17
Musk lorikeet	*Glossopsitta concinna*	42.19	65.83	75.00
Purple-crowned lorikeet	*Glossopsitta porphyrocephala*	11.35	36.25	79.17
Little lorikeet	*Glossopsitta pusilla*	4.17	13.75	58.33
Superb parrot	*Polytelis swainsonii*	0.10	0.42	4.17
Crimson rosella	*Platycercus elegans*	5.73	15.42	50.00
Yellow rosella	*Platycercus elegans flaveolus*	1.04	2.92	12.50
Swift parrot	*Lathamus discolor*	4.06	14.58	50.00
Tawny frogmouth	*Podargus strigoides*	0.31	1.25	12.50
Australian owlet-nightjar	*Aegotheles cristatus*	1.56	5.42	45.83
Dollarbird	*Eurystomus orientalis*	1.04	4.17	29.17
Azure kingfisher	*Alcedo azurea*	0.42	1.25	8.33
Sacred kingfisher	*Todiramphus sanctus*	7.71	21.25	75.00
Fan-tailed cuckoo	*Cacomantis flabelliformis*	0.21	0.83	8.33
Black-eared cuckoo	*Chrysococcyx osculans*	0.10	0.42	4.17
Horsfield's bronze-cuckoo	*Chrysococcyx basalis*	4.38	16.67	83.33
Shining bronze-cuckoo	*Chrysococcyx lucidus*	0.21	0.83	8.33
Tree martin	*Hirundo nigricans*	7.50	20.42	70.83
Grey fantail	*Rhipidura fuliginosa*	8.65	19.58	66.67
Leaden flycatcher	*Myiagra rubecula*	0.21	0.83	8.33
Jacky winter	*Microeca fascinans*	13.33	27.50	87.50
Scarlet robin	*Petroica multicolor*	1.04	3.75	20.83
Red-capped robin	*Petroica goodenovii*	3.85	10.00	54.17
Hooded robin	*Melanodryas cucullata*	2.19	5.00	29.17
Eastern yellow robin	*Eopsaltria australis*	7.60	15.42	58.33
Golden whistler	*Pachycephala pectoralis*	5.42	19.17	83.33
Rufous whistler	*Pachycephala rufiventris*	12.19	32.50	87.50
Gilbert's whistler	*Pachycephala inornata*	1.25	3.75	25.00
Grey shrike-thrush	*Colluricincla harmonica*	40.94	65.42	95.83
Crested shrike-tit	*Falcunculus frontatus*	14.79	36.25	95.83
Crested bellbird	*Oreoica gutturalis*	7.40	14.58	50.00
White-bellied cuckoo-shrike	*Coracina papuensis*	3.23	10.83	54.17
White-winged triller	*Lalage sueurii*	4.06	14.17	58.33
Spotted quail-thrush	*Cinclosoma punctatum*	0.42	1.67	16.67
Grey-crowned babbler	*Pomatostomus temporalis*	1.67	3.33	16.67
White-browed babbler	*Pomatostomus superciliosus*	10.21	18.33	58.33
Western gerygone	*Gerygone fusca*	3.02	8.33	41.67
Weebill	*Smicrornis brevirostris*	15.21	28.75	79.17
Southern whiteface	*Aphelocephala leucopsis*	1.77	4.17	33.33

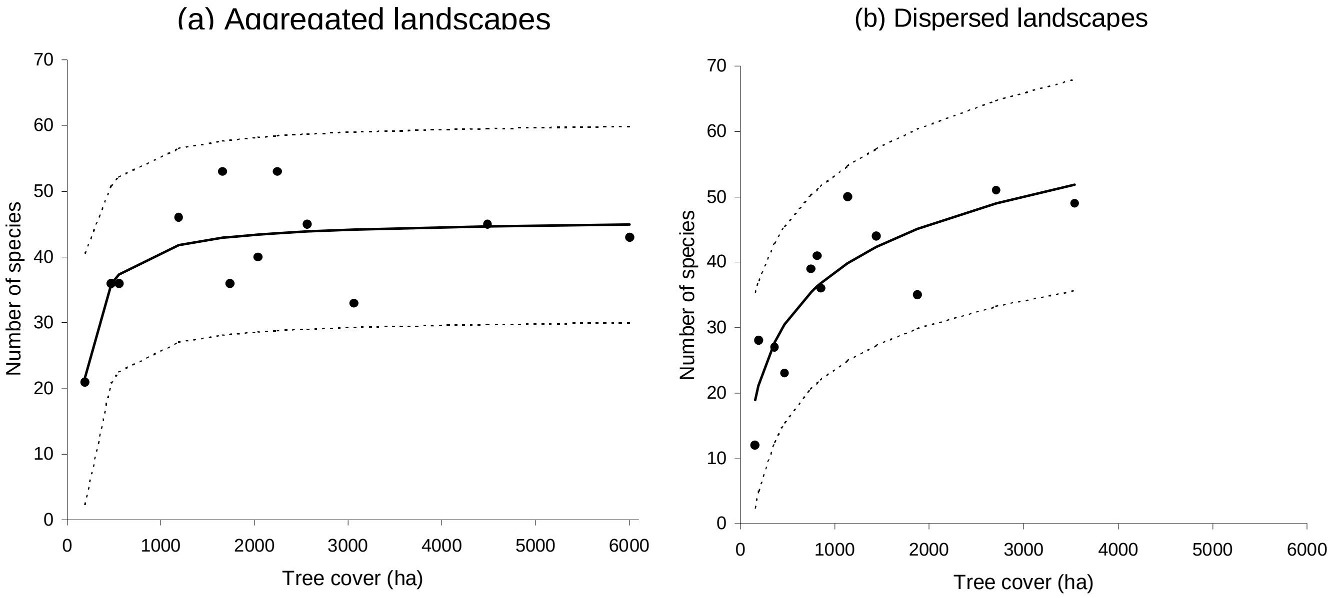
Common name	Scientific name	No. of surveys	No. of sites	No. of landscapes

		(*n* = 960)	(*n* = 240)	(*n* = 24)
Striated thornbill	*Acanthiza lineata*	2.40	6.25	37.50
Yellow thornbill	*Acanthiza nana*	6.98	15.42	66.67
Brown thornbill	*Acanthiza pusilla*	0.73	2.50	16.67
Chestnut-rumped thornbill	*Acanthiza uropygialis*	0.31	1.25	12.50
Buff-rumped thornbill	*Acanthiza reguloides*	4.27	7.92	37.50
White-browed scrubwren	*Sericornis frontalis*	1.67	2.92	20.83
Chestnut-rumped heathwren	*Hylacola pyrrhopygia*	0.21	0.83	8.33
Speckled warbler	*Chthonicola sagittata*	0.42	1.67	12.50
Superb fairy-wren	*Malurus cyaneus*	19.27	30.00	87.50
Dusky woodswallow	*Artamus cyanopterus*	12.60	31.25	83.33
Varied sittella	*Daphoenositta chrysoptera*	3.23	10.00	62.50
Brown treecreeper	*Climacteris picumnus*	45.10	55.83	95.83
White-throated treecreeper	*Cormobates leucophaeus*	13.65	21.67	75.00
Mistletoebird	*Dicaeum hirundinaceum*	5.94	19.17	75.00
Spotted pardalote	*Pardalotus punctatus*	12.08	30.42	79.17
White-naped honeyeater	*Melithreptus lunatus*	4.48	17.50	70.83
Black-chinned honeyeater	*Melithreptus gularis*	21.35	41.25	87.50
Brown-headed honeyeater	*Melithreptus brevirostris*	15.52	33.75	91.67
Eastern spinebill	*Acanthorhynchus tenuirostris*	0.21	0.83	8.33
Painted honeyeater	*Grantiella picta*	0.10	0.42	4.17
Fuscous honeyeater	*Lichenostomus fuscus*	18.02	27.08	62.50
Yellow-faced honeyeater	*Lichenostomus chrysops*	2.40	8.33	45.83
White-eared honeyeater	*Lichenostomus leucotis*	1.56	5.42	37.50
Yellow-tufted honeyeater	*Lichenostomus melanops*	15.31	21.67	58.33
White-plumed honeyeater	*Lichenostomus penicillatus*	60.31	75.42	100.00
Red wattlebird	*Anthochaera carunculata*	52.81	73.75	91.67
Blue-faced honeyeater	*Entomyzon cyanotis*	1.25	5.00	33.33
Noisy friarbird	*Philemon corniculatus*	5.21	17.92	66.67
Little friarbird	*Philemon citreogularis*	3.02	7.92	33.33
Diamond firetail	*Stagonopleura guttata*	2.40	7.08	29.17
Red-browed finch	*Neochmia temporalis*	1.88	5.00	29.17
Olive-backed oriole	*Oriolus sagittatus*	5.63	18.75	66.67
Apostlebird	*Struthidea cinerea*	0.63	1.67	4.17
White-winged chough	*Corcorax melanorhamphos*	30.42	57.92	95.83
Pied currawong	*Strepera graculina*	2.08	7.08	33.33

Appendix 4. Mammal species recorded in study landscapes, north-central Victoria. Percentage of sites and landscapes in which each species was detected are presented. (* introduced species)

Common name	Scientific name	% of landscapes (n=24)	% of sites (n=240)
Platypus	*Ornithorynchus anatinus*	8.3	0.8
Short-beaked Echidna	*Tachyglossus aculeatus*	79.2	30.0
Yellow-footed Antechinus	*Antechinus flavipes*	87.5	29.2
Brush-tailed Phascogale	*Phascogale tapoatafa*	25.0	4.2
Koala	*Phascolarctos cinereus*	25.0	6.3
Common Brushtail Possum	*Trichosurus vulpecula*	100.0	70.0
Sugar Glider	*Petaurus breviceps*	62.5	13.3
Squirrel Glider	*Petaurus norfolcensis*	8.3	1.7
Common Ringtail Possum	*Pseudocheirus peregrinus*	100.0	48.3
Western Grey Kangaroo	*Macropus fuliginosus*	8.3	0.8
Eastern Grey Kangaroo	*Macropus giganteus*	100.0	67.9
Bl Wallaby	*Wallabia bicolour*	75.0	27.9
Water rat	*Hydromys chrysogaster*	12.5	1.3
House Mouse*	*Mus domesticus*	62.5	14.2
Black Rat*	*Rattus rattus*	33.3	5.8
Red Fox*	*Vulpes vulpes*	100.0	53.3
Cat*	*Felis catus*	45.8	6.3
Brown Hare*	*Lepus europeus*	95.8	25.0
European Rabbit*	*Oryctolagus cuniculus*	100.0	59.2

Appendix 5. Univariate models of best-fit (solid line) and 95% confidence intervals (broken line) for species richness of woodland-dependent birds versus tree cover (ha) in landscapes with (a) aggregated (inverse model) and (b) dispersed (logarithmic model) habitat configuration. Solid circles are observed values. Models were not extrapolated beyond the range of the data



Appendix 6. Summary of communication activities (2001-2004) associated with this project.

Land and Water Australia

- Communication Plan (Dec 2001) - accepted by LWA
- Fact Sheet 5 for the Native Vegetation Research and Development Program
- Presentations at Native Vegetation R&D Program meetings in 2001, 2002, 2003 and 2004, including 2 page summaries.

Reports in magazines and newsletters

Jelinek, A. 2002. Clues to survival in agricultural landscapes. *Thinking Bush* Issue 1: 16-18. (contributed ideas and information)

Bennett, A. and Radford, J. 2002. Landscape patterns for biodiversity conservation. *Land for Wildlife News* 5(2): 11.

Radford, J.Q. 2002. A 'birds-eye' perspective of biodiversity conservation. *News and Views* 12(1): 26.

Bennett, A. and Radford, J. 2003. 'Know your ecological thresholds'. *Thinking Bush* Issue 2: 1-3

Bennett, A.F. and Radford, J.Q. 2004. From bush blocks to landscapes: wildlife conservation at different scales. *Thinking Bush* Issue 3: 4-5.

Radford, J. 2004. Species extinction: the tyranny of incremental habitat loss. *Parkwatch* 218: 10-11.

Radford, J. 2004. Lessons from the landscape. *News and Views* 14(3): 16-17.

Radford, J. 2004. Let sleeping logs lie. *Land for Wildlife Newsletter* 5(7): 13.

Radford, J. 2004. Lessons from the landscape. *Landcare* magazine.

Booklet

Radford, J., Bennett, A. and MacRaild, L. 2004. *How Much Habitat is Enough? Planning for wildlife conservation in rural landscapes*. Deakin University, Melbourne. 8 pp

Scientific papers

Bennett, A.F. and Radford, J.Q., 2004. Landscape-level requirements for the conservation of woodland birds: are there critical thresholds in habitat cover? pp. 117-124 in *Landscape Ecology of Trees and Forests* (Ed. R. Smithers). International Association for Landscape Ecology–UK Region and The Woodland Trust.

Radford, J.Q., Bennett, A.F. and Cheers, G.J. 2005 in press. Landscape-level thresholds of habitat cover for woodland birds. *Biological Conservation*

Radford, J.Q. and Bennett, A.F. (accepted). Avifauna of the Gippsland Plain and Strzelecki Ranges, Victoria, Australia: insights from Atlas data. *Wildlife Research* .

Radford, J.Q. (accepted). Variation in tree cover estimates using geographic information systems. *Ecological Management and Restoration*

in preparation (for 2005)

Radford, J.Q. and Bennett, A.F. Using Atlas data to model factors that influence avifaunal species richness: a case study from the Gippsland Plain, south-east Australia.

Radford, J.Q. and Bennett, A.F. Response of woodland-dependent birds to gradients of tree cover at the landscape level: an empirical evaluation of landscape thresholds.

Bennett, A.F. and Radford, J.Q. An empirical assessment of the response of the native mammal fauna to landscape change in northern Victoria.

Bennett, A.F. and Radford, J.Q. Landscape factors influencing distribution and abundance of woodland-dependent birds in northern Victoria.

MacRaild, L., Bennett, A.F. and Radford, J.Q. Factors affecting mistletoe occurrence at the landscape scale.

Email newsletter

An email newsletter was initiated and sent to a range of stakeholder individuals and groups, and interested individuals. This was sent out four times, mainly to inform people about the project and early progress. It is an effective communication tool, but was not used in the final stages of the project.

Media

'Bendigo Advertiser' (15 May 2002) describing the project
ABC Goldfields radio (91.1 FM): Breakfast show – interview, July 23, 2004. (Jim Radford)
3RPP radio: extended interview (20 minutes) during "Green Room" program – Nov 11, 2004 (Jim Radford)
ABC Goldfields radio (91.1 FM): Breakfast show – interview, November 15, 2004 (Jim Radford)

ABC radio - interview for the Country Hour (Dec 2004) (Andrew Bennett)

Landholders and local groups

2002. Written outline of the project to four naturalists groups, and requesting their assistance in completing bird censuses in key landscapes for this study

2003 (March) - Letter to private landholders where study sites are located with feedback on the first round of bird surveys.

2004 (March) – Letter to private landholders with feedback on project progress and 'personalised' list of birds observed on their property.

Regional presentations of project outcomes (Nov-Dec 2004)

Two-hour presentations at 13 locations in regional Victoria.
Locations: Echuca, Bendigo (morning and evening), Melbourne -Victoria Pde, Melbourne-Deakin University (evening), Benalla (morning and evening), Wodonga, Traralgon, Stratford (evening), Leongatha, Warragul, Ballarat.

A total of approximately 500 people attended these presentations representing a wide range of organisations and interests (see Appendix 7). The presentations generated much positive response and feedback. A colour booklet (8 pp) was prepared and printed (5000 copies) and widely distributed at these talks. Many people took away bundles of the booklets for others in their groups. These presentations were the most successful communication exercise undertaken for the project, coming near the completion of the research when a series of results were available.

Booklet: Radford, J., Bennett, A. and MacRaild, L. 2004. *How Much Habitat is Enough? Planning for wildlife conservation in rural landscapes*. Deakin University, Melbourne. 8 pp

Seminars and conference presentations

A number of scientific presentations have been made at state, national and international forums. Some of these were mainly to describe the project and its aims, while others (particularly in 2004) presented scientific outcomes from the research.

2002

Sustainable landscapes for people and wildlife: directions in research. Deakin University, Faculty Seminar, Burwood (2002) .

2003

Landscape level thresholds in habitat cover: empirical evidence for an effect of configuration. Arthur Rylah Institute, Dept Sustainability & Environment, Heidelberg, (Dec 2003). .

Vanishing Jewels of the Forest: Birds of Victoria's Box-Ironbark Region. Presented at Box Ironbark: True treasures of the goldfields. 6th Annual Wimmera Biodiversity Seminar, Stawell, October 23, 2003.

Vanishing Jewels of the Forest: Birds of Victoria's Box-Ironbark Region. Presented at North-Central CMA Biodiversity Workshop, Castlemaine, November 6, 2003.

Mammals of the Box-Ironbark Region. North-Central CMA Biodiversity Workshop, Castlemaine, November 6, 2003.

Landscape level thresholds for conservation of biodiversity in rural environments. Presented at North-Central Natural Resource Management Research Forum, La Trobe University, Bendigo, December 3, 2003.

Landscape level thresholds in habitat cover for woodland bird diversity: empirical evidence for an effect of habitat configuration. Presented at Ecological Society of Australia Annual Meeting, University of New England, Armidale, December 2003. (Symposium on ecological thresholds)

Relationship between landscape structure and mistletoe parasitism in rural fragmented environments. Presented at Ecological Society of Australia Annual Meeting, University of New England, Armidale, December 2003.

Application of Atlas data to identify thresholds in vegetation cover: a case study from the Gippsland Plain, south-east Victoria. Presented at Australasian Ornithological Conference, Australian National University, Canberra, December 13, 2003.

2004

Ecological responses to changes in vegetation pattern: are thresholds a useful tool for land management and restoration? Presented at New Dimensions in Agricultural Landscape Planning: Asking the Right Questions. Symposium andWorkshop, Ballarat, February 16-17, 2004.

Landscape-level requirements for the conservation of woodland birds: are there critical thresholds in habitat cover? International Association for Landscape Ecology – UK region, Cirencester, England (June 2004) (Symposium on "Landscape Ecology of Trees and Forests')

Landscape level thresholds for conservation of biodiversity in rural environments. Presented at Greening Australia Knowledge Exchange Forum "Restoring Biodiversity … the rest of the ecosystem", Bendigo, June 24-25, 2004.

New concepts in landscape 'makeovers'. Invited keynote address to the Annual Meeting of the Ballarat Environment Network (World Environment Day, June 2004).

Wildlife conservation in rural environments: new perspectives from landscape ecology. University of Ballarat seminar series, Ballarat, July 2004.

Landscape-level responses to habitat cover in woodland bird species: different strokes for different (bird)folks. Ecological Society of Australia Annual Meeting, University of Adelaide, Adelaide, December 7-10, 2004.

Mistletoe occurrence: a landscape perspective. Ecological Society of Australia Annual Meeting, University of Adelaide, Adelaide, December 7-10.

Other community involvement

January 10 (2003) – Guest speaker on Wycheproof Landcare Group Bus Tour
September 21 (2003) – Guest speaker at Land For Wildlife Open Day, Sartori property, Franklinford.
October 10 (2003) – Guest speaker on Wedderburn CMN Bus Tour.
October 12 (2003) – Guest speaker (biodiversity) at DSE Forest Tour for development of Forest Management Plan, Bendigo FMA.
January 6 (2004) – Guest speaker for NC CMA Environmental Management Systems program (Birchip).
March 4 (2004) – Expert advice on restoration options for NC CMA funding (Elmore district).
April 14 (2004) – Guest speaker for Bendigo Field Naturalist's Club (Bendigo).
August 19 (2004) – Guest speaker at Land for Wildlife Statewide Co-ordinator's meeting (Goornong).

Appendix 7. Summary of affiliations of attendees at regional presentations, Nov-Dec 2004

Presentations: at 13 locations: Echuca, Bendigo (morning and evening), Melbourne -Victoria Pde, Melbourne-Deakin University (evening), Benalla (morning and evening), Wodonga, Traralgon, Stratford (evening), Leongatha, Warragul, Ballarat

Attendance: approximately 500 (at least 460 signed attendance book or were estimated)

Groups represented (based on affiliations listed in the attendance book – this is an incomplete listing as at several presentations names and affiliations were not recorded).

Government agencies:
Dept Sustainability and Environment, and Arthur Rylah Institute (many)
Dept Primary Industries (many), and PIRVIC (Primary Industries Research Victoria)
Dept of Infrastructure
DIPNR (NSW)
Parks Victoria
VicRoads

Other organisations
Greening Aust Vic
Trust for Nature
Royal Botanic Gardens (Cranbourne)
The Wilderness Society
Environment Victoria
Victorian National Parks Association
VFF
City West Water

Superb Parrot Project
Echuca and District Bird Observers Club
Bendigo Field Naturalists Club
Wildlife Rescue
Wellsford Watch
Goldfields Revegetation
Regent Honeyeater Project
Conservation Management Network, Gippsland
Greenlink Box Hill
Blackburn Tree Preservation Society
Radio 3RPP
South West (Cobbobonee) Woodlands
Teachers for Forests
Murray ROC
Landcare – many groups represented and numerous Landcare facilitators (typically assoc with 10-15 Landcare groups)

Education sector
Deakin University
La Trobe (Bendigo, Albury and Bundoora Campuses)
Monash (Churchill, ?)
University of Melbourne, and Australian Research Centre for Urban Ecology
TAFE Thurgoona
RMIT
Charles Sturt University
Research students and prospective environment students

Catchment Management Authorities

North Central CMA
Goulburn-Broken CMA
North East CMA
West Gippsland CMA
East Gippsland CMA
Glenelg Hopkins CMA
Corangamite CMA
Wimmera CMA
Murray (NSW)

Local government
Loddon Shire
City of Greater Bendigo
Benalla Rural City Council
Rural City of Wangaratta
City of Casey
City of Melbourne SERCO??
Albury City
Wellington Shire
LaTrobe City Council

Individuals
Many individuals from wide range of backgrounds (farmers, conservation interest etc)

Environmental consultants
at least 7 different consultants

Appendix 8. Copies of scientific publications arising from this research (four manuscripts)

Bennett, A.F. and Radford, J.Q., 2004. Landscape-level requirements for the conservation of woodland birds: are there critical thresholds in habitat cover? pp. 117-124 in *Landscape Ecology of Trees and Forests* (Ed. R. Smithers). International Association for Landscape Ecology–UK Region and The Woodland Trust.

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Radford, J.Q. (accepted). Variation in tree cover estimates using geographic information systems. *Ecological Management and Restoration*

Appendix 9. Copy of the colour booklet (8 pp) summarising research outcomes, for distribution at regional presentations

Appendix 10. Copies of other articles and reports relating to the project.