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The Responses of Birds to Restoration of Riparian Habitat on Private Properties

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Bibliography.
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Note: This work was completed in partial fulfilment of the requirements of the degree of Honours in Bachelor of Applied Science (Environmental Science) by Leigh Thompson, with Amy Jansen and Alistar Robertson as supervisors.

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1. EXECUTIVE SUMMARY

Riparian areas provide vital habitat for bird species. Since settlement 150 years ago, the Murrumbidgee Catchment in south-eastern Australia has suffered extensive clearing and the effects of grazing practices. The introduction of non-native livestock to riverine areas has resulted in severe reduction in riparian habitat quality because livestock activity is concentrated near water and shade. Restoration efforts within the Murrumbidgee Catchment currently focus mainly on the exclusion of livestock by fencing-off riparian habitats. This study used 27 sites in the south west slopes region of the Murrumbidgee catchment to investigate whether the number of years since riparian areas were fenced-off (range of years 1-10+yrs) and the size of the fenced areas (range of sizes 1-4+ha) affected 1) the probability of occurrence of the Superb Fairy-wren (*Malurus cyaneus)* and the Brown Treecreeper (*Climacteris picumnus*), and 2) the species composition of riparian bird communities.

The number of years since riparian areas were fenced to exclude livestock was a significant factor in the probability of occurrence of the Superb Fairy-wren and the Brown Treecreeper. Within-site habitat features such as fallen logs, branches and the amounts of leaf litter were also significant factors in the probability of occurrence of the two bird species. Restoration may be accelerated by the artificial enhancement of woody debris stocks in fenced-off areas. The total bird community also varied significantly with time since fencing of the riparian areas, with grazing-sensitive species increasing and grazing-tolerant species declining in diversity with time since fencing. The size of the fenced-off areas was generally not a significant factor in the probability of occurrence of the Superb Fairy-wren, nor did it appear to affect bird community composition. However, Brown Treecreepers were unlikely to occur at most sites of <4 ha, and were significantly more likely to occur at larger sites if they had been fenced >10 years ago. Thus, it appeared that the Superb Fairy-wren was responding mainly to changes in habitat quality while the Brown Treecreeper was also responding to the area of habitat available.

Fenced-off remnants and plantings of riparian vegetation provide vital habitat for avifauna. As habitat quality increased with time since riparian areas were fenced off, the probability of occurrence of grazing sensitive bird species like the Superb Fairy-wren and the Brown Treecreeper increased. Currently, fenced riparian areas are scattered on private lands across the landscape. Management of these fenced riparian areas should now aim at connecting these remnants to form a continuous habitat with reduced exposure to intensive agricultural practices. As woodland bird species abundance and diversity steadily decrease in southern Australia, the continued fencing-off of riparian areas to exclude livestock is essential in helping to increase habitat quality and subsequently halt the decline of woodland bird species.

2. INTRODUCTION

This report presents the findings from a one-year (2001) field project where bird species in the southwest slopes of the Murrumbidgee Catchment were monitored in riparian areas where livestock had been excluded.

The project aimed to assess the efficacy of government-funded fencing initiatives in increasing local biodiversity by excluding livestock. Level of success was gauged using indicator bird species (Superb Fairy-wren and Brown Treecreeper) as well as bird community composition in privately owned, fenced riparian areas. Many factors influence bird abundance in riparian areas. This study focused on the following factors and questions:

1. SITE AGE (number of years since fenced to exclude livestock) - How did the number of years since fenced affect the probability of occurrence of indicator species and bird community composition?
2. SITE SIZE (total area fenced to exclude livestock in hectares) - How did the total area fenced affect the probability of occurrence of indicator species and bird community composition?

3. BACKGROUND

3.1. Decline of woodland birds in Australia

Globally, bird abundance and diversity are decreasing as a result of habitat clearance and fragmentation with bird species extinction rates currently 50 times higher than natural rates (Barrett, Ford & Recher 1994).

Over 75% of Australia's native vegetation habitats have been cleared, or become fragmented as a result of clearing (Backhouse & Clarke 1995). At present more than 20% of Australia's vertebrate fauna are considered to be at risk (Recher & Lim 1990; Backhouse & Clarke 1995). In the last 20 years, 10 million hectares of native vegetation has been cleared in Australia, resulting in the loss of an estimated 150 million individual birds (Barrett 2000).

Within New South Wales, current clearing rates of native vegetation are approximately 150000 hectares per year resulting in vegetation loss in some areas in excess of 90% (NPWS 2000). In the Murray-Darling Basin, tree loss has been extensive and currently 25 bird species are considered to be threatened, with one quarter of the remaining species declining in numbers (Robinson & Traill 1996).

3.2. Livestock and riparian areas

Some of the most modified habitats are those at land-water interfaces. Human settlement has focused on land-water margins and therefore human induced disturbances are more intense in riparian areas (Jansen & Robertson 2001*a*). Riparian areas in Australia and elsewhere are now highly degraded (Fleischner 1994; Belsky, Matzke & Uselman 1999; Jansen & Robertson 2001*a*). In particular, livestock indirectly affect faunal communities by altering habitat structure and production patterns in and around riparian areas (Jansen & Robertson 2001*a*).

Livestock are closely tied to water supplies, which leads to a gradient of grazing pressure decreasing with distance from water (Wilson 1990; Robertson 1997). Intense grazing and trampling by livestock has led to riparian zones often being the most degraded areas within catchments, and the ecological costs of grazing are magnified at these sites (Fleischner 1994).

Riparian habitats are particularly important as refuges during drought periods (Morton, Short & Barker 1995). Recent work in Australia has shown that bird species richness and community composition is greater in riparian habitats than adjacent hillslope habitats (Fisher & Goldney 1997; MacNally 1997).

Riparian woodlands in south-eastern Australia form critical habitats for woodland bird communities. Loss of forested habitat (by clearing) and changes in understorey composition (by grazing) may influence bird community abundance and diversity (Fisher & Goldney 1997; Jansen & Robertson 2001*b*). Exclusion of livestock from riparian areas by fencing increases the abundance of understorey vegetation and coarse woody debris (Robertson & Rowling 2000), and the provision of alternative watering points and periods of rest from grazing in sites that are not fenced also increase habitat quality (Jansen & Robertson 2001*a*) and woodland bird diversity (Jansen & Robertson 2001*b*).

In the hillslope region of the Murrumbidgee River Catchment in south-eastern Australia, rehabilitation of riparian habitats is usually based on the fencing of remnants to exclude livestock and the planting of native tree species. Usually these fencing initiatives have the twin aims of retarding erosion and enhancing local biodiversity. Although fencing to exclude livestock prevents further habitat degradation, little research has been conducted to determine how elements of the biota are responding to these rehabilitation efforts. Thus the main objective of this study was to determine if these rehabilitation efforts were affecting woodland bird species.

Within the Murrumbidgee Catchment, Jansen & Robertson (2001*b*) identified a range of bird species sensitive to the variable effects of grazing pressure in riparian habitats. Of these species, the Superb Fairy-wren (*Malurus cyaneus*) and the Brown Treecreeper (*Climacteris picumnus*) were identified as possible indicator species that could be used to monitor the effectiveness of grazing exclusion as a riparian management tool without having to survey the whole bird community. Subsequently, these two bird species were chosen to act as indicators of riparian restoration efforts.

4. METHODS

4.1. Study Region

The study region was located in southern New South Wales, within the upper Murrumbidgee River catchment, and was bounded by the towns of Cookardinia, Adelong, Harden and The Rock (Figure 4.1) The catchment in this region is dominated by rolling hills and ridges in the southeast, to undulating alluvial plains in the west. Maximum altitude within the study region was 521m asl with gradients from less than 3° on the flats to as high as 45° in ridge areas. The geology of the upper catchment is predominately intrusions of limestone, slate, sandstones and granitic rock into meta-sediments (Environmental Protection Authority (EPA) 1995).

Average annual rainfall ranges from 800mm in the south to 615mm in the north and rainfall increases from west (500-600mm) to east (700-800mm). Mean annual temperatures at Harden range from 15-30°C in the summer to 1-13°C in the winter. Mean annual temperatures in Adelong range from 13-30°C in summer to 1-12°C in the winter (Bureau of Meteorology 2001).

Since settlement in the mid 1800s, the upper catchment of the Murrumbidgee has been extensively cleared of native vegetation for sheep and cattle grazing. Subsequently large areas of the catchment are now subject to gullying and wind erosion (EPA 1995). Clearing of native vegetation has resulted mainly in the survival of only small remnant woodlands located on private lands and larger areas in government reserves (DLWC 2000). Since the early 1990s, there has been extensive government and community-driven action to address stream bank erosion and biodiversity loss in the upper catchment (EPA 1995). Government agencies, including The New South Wales Environmental Protection Authority (EPA), New South Wales Department of Land and Water Conservation (DLWC) and Greening Australia have identified areas of remnant vegetation requiring conservation efforts. In addition, these agencies have developed plans for revegetation of other areas. Emphasis within the Murrumbidgee River catchment is on the revegetation of public and private riparian areas.

Riparian vegetation in the study region is dominated by Blakely's Red Gum (*Eucalyptus blakleyi*), River Red Gum (*Eucalyptus camaldulensis*) as well as White and Grey Box woodlands (*Eucalyptus albens* and *E. microcarpa).* Scatterings of Mugga Ironbark (*Eucalyptus sideroxylon)* and Red Stringybark (*Eucalyptus macrorhyncha)* are also evident. Pasture and understorey surrounding remnant areas consists of predominately introduced grasses such as Phalaris (*Phalaris paradoxa*), as well as Tussock Grass (*Poa labillardieri*) and Blackberry (*Rubus fruticosus*) (DLWC 2000). Current land management practices within riparian zones are aiming to promote the return of regional native plant species. These practices include fencing to exclude stock, the promotion of understorey growth and the provision of off river watering points. Extensive tree plantings are being promoted to create buffer strips around riparian areas, often with the combined aims of increasing the filtering capacity of riparian habitats for nutrients and sediments as well as promoting the return of regional wildlife.

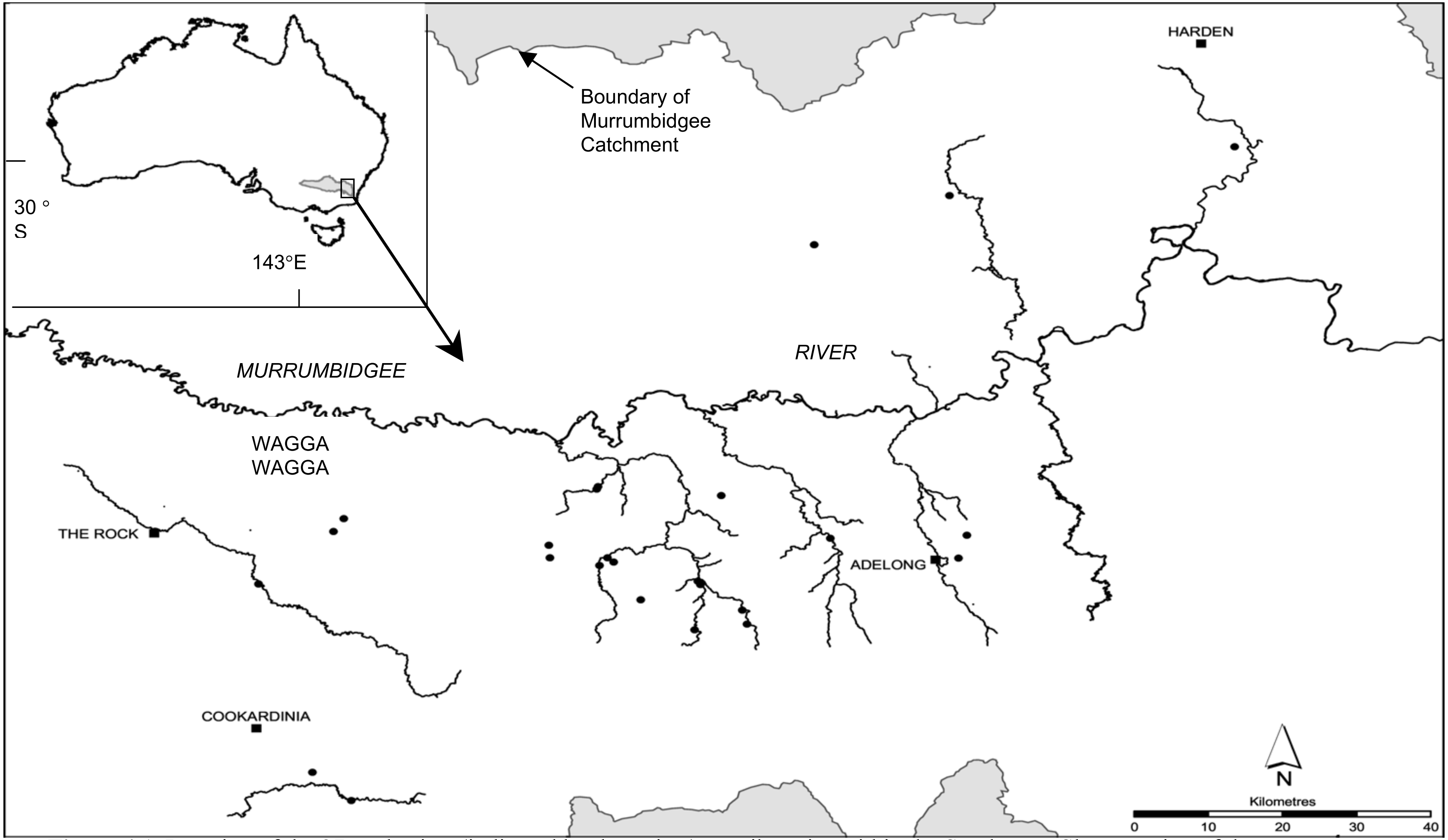


Figure 4.1. Location of the 27 study sites (indicated by dot points) on tributaries within the South-west Slopes region of the Murrumbidgee Catchment. Towns bordering the study area are also shown. N. B. some sites are close together and separate dot points are indistinguishable

4.2. Site Selection

All sites used to investigate relationships between riparian land management and bird diversity (see below) were located on small tributaries of the Murrumbidgee River, with each varying in degrees of permanency of flow. Fenced riparian sites were chosen to investigate the relationship between site age (number of years since riparian sites were fenced off) and site size (area in hectares) and how these two factors affect the abundance and presence of regional woodland bird species.

Locations of government-funded fenced riparian areas were obtained from Landcare, Greening Australia and the *National Heritage Trust* (NHT) funded Bidgee Banks project. Following discussions with landholders and government agency staff, preliminary site visits were conducted from which 27 sites were chosen for study based on size and time since fencing (age) (see below). Sites were all >20 meters in width. Studies of bird communities in southern Australian windbreaks and shelterbelts on farms found that species density and diversity are consistent at 20m in width but will increase as width increases above 20m (Kinross 2000). The smallest site used in this study was 1ha in area.

4.3. Study Design

Sites were chosen in three size (0-2 hectares, 2-4 hectares, and 4+ hectares) and three age (1-5 years since fencing, 5-10 years since fencing and 10+ years since fencing) categories. The study involved a balanced design, with three sites in each of the three size categories and three age categories making a total of 27 (3x3x3) sites (Table 4.1).

Table 4.1. A summary of the study design with the 27 study sites in 9 combinations of time since fencing (age) and size (hectares). See Figure 4.1 for location of sites in the upper Murrumbidgee catchment. (See Appendix 1 for pictures of representative sites)

	AGE		
SIZE	1-5y	>5-10y	10+y
0-2ha	n = 3	n = 3	n = 3
2-4ha	n = 3	n = 3	n = 3
4+ha	n = 3	n = 3	n = 3

Surveys of birds and habitat structure at each of the 27 sites were carried out in three seasons: autumn (mid March), winter (mid June) and spring (late September). Surveys were carried out in a random order with each site being visited at a different time of day in each season of surveying (see below). For logistical reasons some sites were visited on the same day in each round of surveying, though the time of day of surveying in each season was different (see below). All surveys were carried out under fine or slightly overcast conditions.

4.4. Indicator Bird Species

Two species, the Superb Fairy-wren (*Malurus cyaneus*) and the Brown Treecreeper (*Climacteris picumnus*) were used as indicator species of riparian restoration effort in this study (see 3.2 above). Under the study design, changes in the abundance of either or both species in response to fencing initiatives in riparian habitats may indicate the critical time period for recovery (number of years since fencing) and the minimum size of the fenced area required to promote the recovery of bird populations.

Because the activity of birds will vary with daily temperature the appropriate time period for obtaining counts of the target species in each season was determined prior to each visit to the 27 sites (see Figure 4.2). To do this, all-day surveys from 7:00am to 7:00pm (autumn), 7:00am to 5:00pm (winter) and 7:00am to 6:00pm (spring) were carried out to determine the optimal observation time for the indicator species. Three surveys were undertaken at the North Wagga Wagga Reserve, a large (10ha) riparian area close to the CSU Wagga Wagga campus. Twenty-minute counts, in which I covered 300-400m, were taken at hourly intervals for both indicator species. Each hourly count was taken within a different area of the reserve to minimise the effects of disturbance. Hourly abundance data revealed that in autumn counts should be completed by 12:00pm, while in winter and spring the activity of birds remained the same throughout the course of the day (see Figure 4.2).

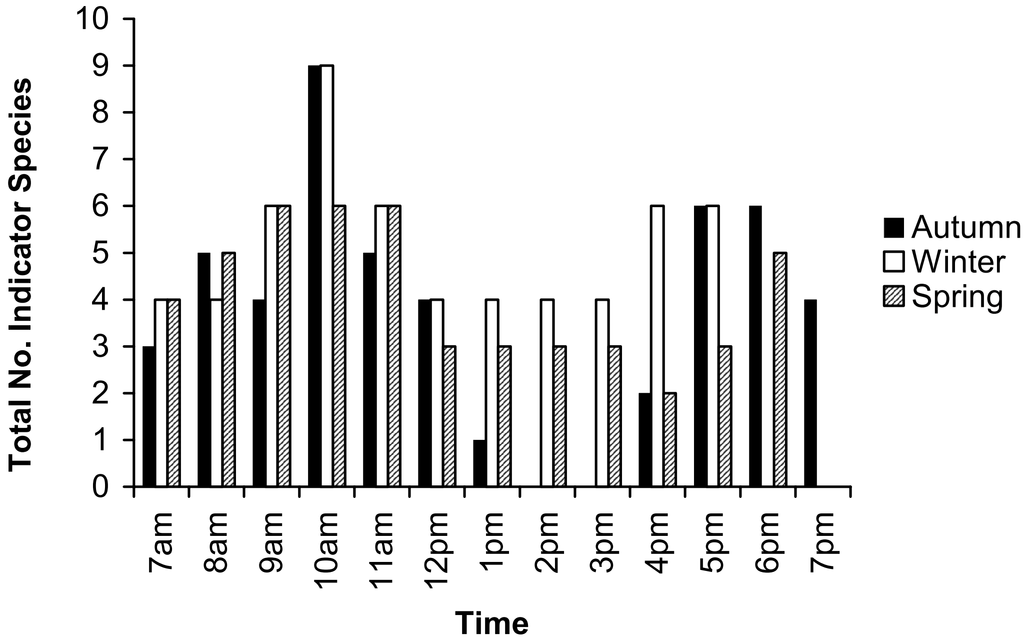


Figure 4.2. Total numbers of indicator species; Superb Fairy-wren (*Malurus cyaneus*) and Brown Treecreeper (*Climacteris picumnus*) counted each hour during the pilot survey of bird activity in autumn, winter and spring.

To determine the effects of fenced area size and age on indicator bird species, the abundance of wrens and treecreepers were recorded at each of the 27 sites in each of three seasons. In each season, the total numbers of the indicator bird species were recorded in at least three plots per site. A plot was a circle with a 10-meter radius in which measurements of vegetation variables and bird abundance were taken. The number of plots in each site was dependant upon site area. In most cases the following regime for the number of plots was used: 0-2ha = 3-4 plots, 2-4ha = 5-6 plots and 4+ha = 7-8 plots. Each plot was randomly selected with each plot not sharing the 10m-radius area with previous plots. Five minutes was allocated to count numbers of individual wrens and treecreepers within each plot. Counts of birds were based on all individuals seen and heard within the plot during the 5-minute time period. The first author performed all bird counts.

4.5. Bird Community Composition

In order to determine how the composition of the complete bird community was related to the size of sites and time since fencing, I used woodland bird community counts at the 27 sites in winter and spring. Woodland birds were deemed to include any regional bird species that were not raptors or waterbirds. The list of regional bird species likely to be present at these sites was complied from a previous study (Jansen & Robertson 2001*b*) (see Appendix 2). In each survey, three groups of volunteer bird watchers were provided with the target bird species list and randomly assigned to a selection of the 27 sites with sites then surveyed over a 2-day period. All sites were visited by two or three observers in each season. At each site, each observer recorded the presence or absence of all bird species seen within the site, as well as recording those occurring at site edges as incidentals. Regardless of the size of the sites, every observer carried out 30-minute meandering walks (not including time spent on reading identification books) at each site. In order to determine if each observer had equal abilities in bird identification, an ordination was performed of community compositions based on observations from different observers. This was followed by an analysis of similarities (ANOSIM, see below for details of statistical methods), which was used to determine if bird identification abilities differed between observers. There was no significant difference in observers' abilities to identify bird communities (Winter ANOSIM, Global R = 0.062, P = 0.13. Spring ANOSIM, Global R = 0.068, P = 0.14) (see Figure 4.3). Thus all counts were used to investigate the influence of site size and age on bird community composition.

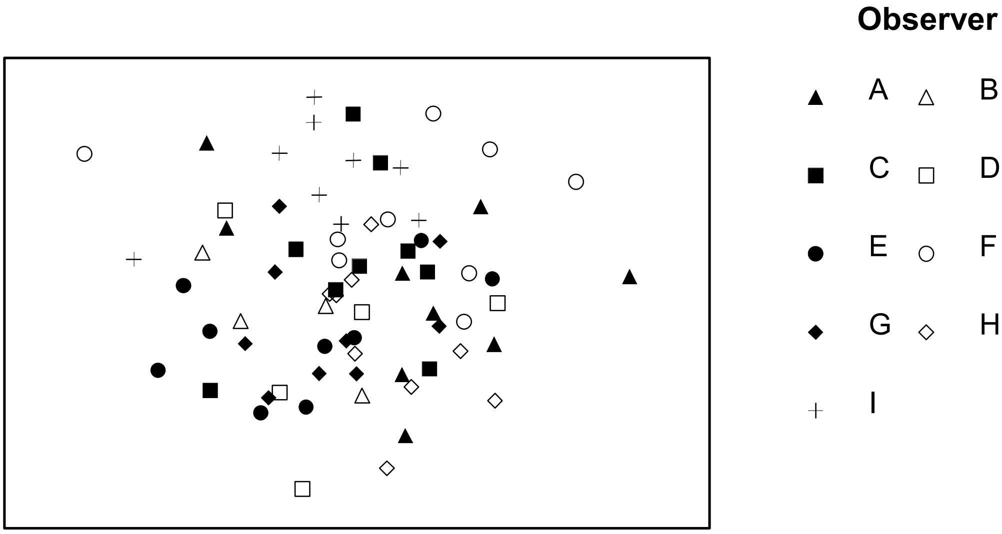


Figure 4.3. Ordination (non-metric multidimensional scaling) of bird community composition based on identifications by different observers for winter.

4.6. Habitat Variables

Many factors other than the size and age (years since fencing) of sites may influence bird numbers. In order to determine the relative importance of other factors as sources of variance in the abundance of indicator bird species, I collected information on a number of plot-scale and site-scale variables (see Tables 4.2 and 4.3).

Within each of the 27 sites, plot-scale habitat variables (Table 4.2) were measured during each trip in the same plots used for the collection of indicator species abundance data. Equal time was spent measuring habitat variables and counting species within a plot. A spacing of at least 10 m existed between plots, to ensure that the same features were not measured twice.

Site-scale variables (Table 4.3) were recorded only in autumn 2001, because they do not change with season. These variables included measures of the condition of the site prior to fencing (obtained from assessment of an adjacent site), length and width of fenced areas, the distance to the closest permanent water source, distance to closest large remnants of forest and aspects of site management. To obtain information on site management all landholders were interviewed.

Table 4.2. Plot-scale habitat variables recorded at each of the 27 sites over the three seasons.

Habitat Measure	**Description**
No. fallen logs	No. fallen logs >50cm diameter & >2m long
No. fallen branches	No. fallen branches 10-50cm diameter &>2m long
No. snags	No. standing dead trees
Canopy cover (%)	% canopy cover overhead within plot
Shrub cover (%)	% shrub cover on ground within plot
Leaf litter (%)	% leaf litter cover within plot
Understorey cover (%)	% understorey cover relative to bare ground
Large trees	No. large trees standing >50cm dbh and species
Small trees	No. small trees standing 10-50cm dbh and species
Saplings	No. saplings standing <10cm dbh & >1m tall

Table 4.3. Site-level variables measured at each site in autumn 2001.

Variable	Description
Length	Approximate length of fenced area.
Width	Approximate width of fenced area.
Slope	Approximate slope in degrees.
Distance to closest permanent water source	Distance to permanent water (eg. dam). Approximate distance in most cases. If none visible from site topographic maps were used to determine closest water source.
Degree of creek permanence	Whether the stream was ephemeral or permanent. If ephemeral, landholder was questioned as to how many months of the year it usually ran.
Distance to closest large remnant	Distance to significant large remnant. Measurements were taken from topographic maps with remnants at least 2km in width.
Weed control and management techniques	Management techniques utilised within the site, including weed control with each given a score (see Appendix 3a)
Prior Condition	Condition of the site prior to being fenced off. Each site was given a score (see Appendix 3b) according to present land management activities directly adjacent to the site.
Corridor presence	Whether there is a corridor of overstorey vegetation present between the fenced off area and the nearest large remnant.
Planting or remnant	Whether the site is predominately plantings or remnant vegetation.
2 or 1 side fenced	Whether the riparian site is fenced on one or two sides of the creek.

4.7. Statistical Analysis

Initially 2-way Analysis of Variance (ANOVA) models were used to test for differences between the abundance of indicator bird species with size and age of sites. However, abundances of Treecreepers were often very low and raw transformed data were heteroscedastic. To overcome this, I used the presence or absence of the bird species at the plot scale in binary logistic regressions (SPSS Inc. 1999) to test for the effects of size and age of sites.

The logistic regression technique is used for binary data (in this case indicator species either present or absent) for independent observations. The independence assumption is satisfied in that all plots were randomly selected within each site so that habitat variables and indicator species in each site are likely to be accounted for only once by random plot selection.

Before logistic regressions were performed, scatter plots for the abundance of each indicator species and habitat variables (see examples in Appendix 4) were plotted to determine which variables might influence indicator species presence or absence. Before analysis was undertaken bird species abundance data was coded as binary data with 0=absent and 1=present.

Ordinations of community composition based on presence/absence data were made using non-metric Multidimensional Scaling (MDS) in the PRIMER package based on Bray-Curtis similarities (Clarke & Warwick 1994). Tests for differences among observers (see 4.5 above) were made using 1-way analysis of similarities (ANOSIM) procedures in PRIMER. Tests for differences between age and size classes based on the Bray-Curtis similarity matrix were made using 1-way ANOSIM procedures.

The adequacy of a two dimensional representation of the multidimensional scaling ordination is provided by a stress factor (Clarke & Warwick 1994). It is accepted that stress values <0.1 are ideal while values <0.2 will normally provide an adequate representation. In the present study stress values for tests between observers was 0.25 and for tests of age and size were 0.24. However, since the number of samples was large, the MDS still gives an adequate representation (Clarke & Warwick 1994).

Species responsible for significant differences in bird community composition between sites of different size or age were identified using the SIMPER procedure in PRIMER (Clarke & Warwick 1994).

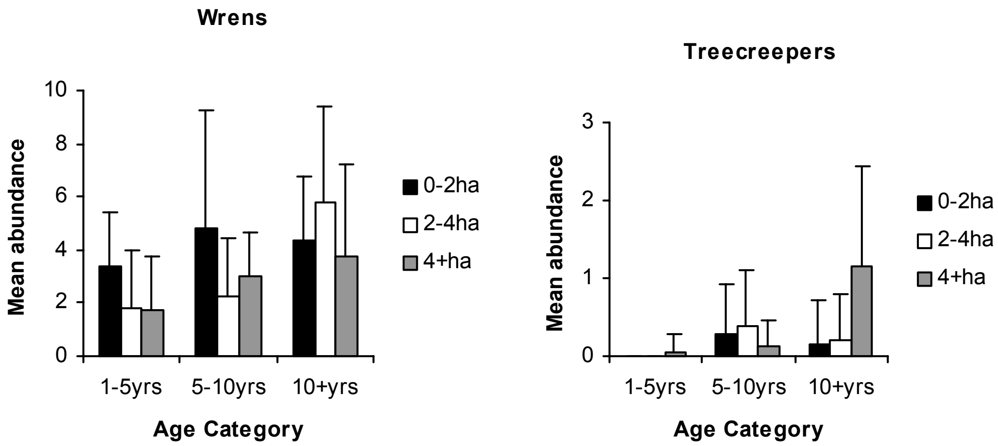
5. RESULTS

5.1. Indicator Bird Species

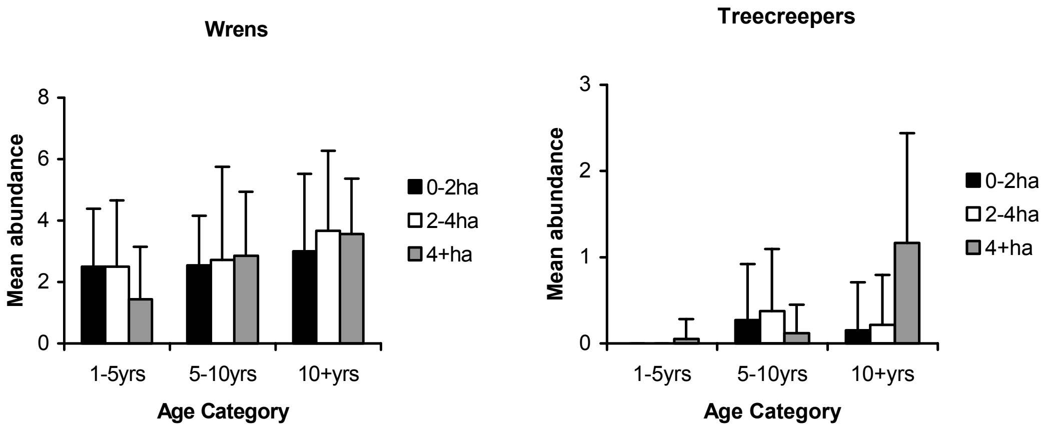
The probability of occurrence of the Superb Fairy-wren did not vary according to season and there was no effect of site size in any season. However, the probability of occurrence of the Superb Fairy-wren increased significantly with site age across all seasons and site sizes (Figure 5.1.a-c; Table 5.1).

Brown Treecreepers showed a seasonal change in probability of occurrence, being more likely to be found in Autumn and Spring than in winter. However, the effects of site age and size were consistent across all three seasons. There was a significant interaction between site age and size for the Brown Treecreeper (Table 5.1), such that they were unlikely to be found in recently fenced plots of any size, were slightly more likely to be found in sites in the middle age class, regardless of size, and their probability of occurrence in the oldest fenced sites increased significantly with site size (Figure 5.1.a-c).

a)



b)



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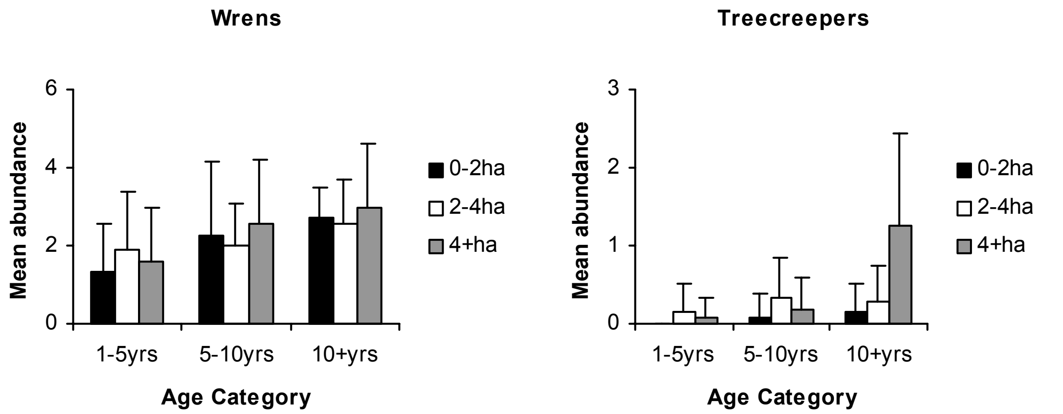


Figure 5.1. Mean (+1s.d.) abundance of wrens and treecreepers in riparian sites of different age and size in (a) autumn, (b) winter and (c) spring.

Table 5.1. Logistic regression analyses of the effects of size and age of sites on the presence or absence of indicator bird species.

Variable	d.f.	P
Wrens		
Age	2	<0.0001
Treecreepers		
Age	2	<0.0001
Size	2	<0.0001
Age*Size	4	<0.0001

The importance of site- and plot-level habitat variables in determining variations in abundances of birds was investigated using logistic regression analyses. Site-level habitat variables were measured and analysed only once at each site with analyses applying only to the autumn bird data. There was no significant effect of any site-level habitat variable on the presence of birds (Table 5.2), although distance to the closest large remnant and whether one or two sides of a site were fenced were close to significant for the Brown Treecreeper.

Table 5.2. Logistic regression analyses of the effect of site level habitat variables on the presence/absence of indicator bird species from the first visit in autumn.

Variable	**B**	**d.f.**	**P value**
Prior Condition			
Wrens	1.872	5	0.977
Treecreepers	-0.693	5	0.988
Length			
Wrens	0.001	1	0.430
Treecreepers	0.001	1	0.109
Width			
Wrens	0.000	1	0.911
Treecreepers	0.003	1	0.245
Length + width			
Wrens	0.001	1	0.341
Treecreepers	0.005	1	0.157
Closest permanent water			
Wrens	-0.001	1	0.432
Treecreepers	0.000	1	0.689
Closest large remnant			
Wrens	0.065	1	0.771
Treecreepers	-0.389	1	0.082
Weed control methods			
Wrens	2.565	3	0.482
Treecreepers	-0.588	3	0.977
Corridor presence			
Wrens	-7.210	1	0.918
Treecreepers	-0.575	1	0.696
Planting or remnant			
Wrens	-0.182	1	0.888
Treecreepers	1.268	1	0.172
1 or 2 sides fenced			
Wrens	-7.357	1	0.869
Treecreepers	-2.367	1	0.052

At the plot level, based on data pooled across seasons (Table 5.3), it is clear that for the Superb Fairy-wren, numbers of fallen logs and branches as well as the percentage of canopy cover are important in determining plot-level abundance patterns. Similarly, numbers of logs, branches, snags and percentage of canopy cover are important plot level variables in determining the abundance of the Brown Treecreeper. In addition, the percentage of leaf litter is close to significant in determining the presence of Brown Treecreeper at the plot level.

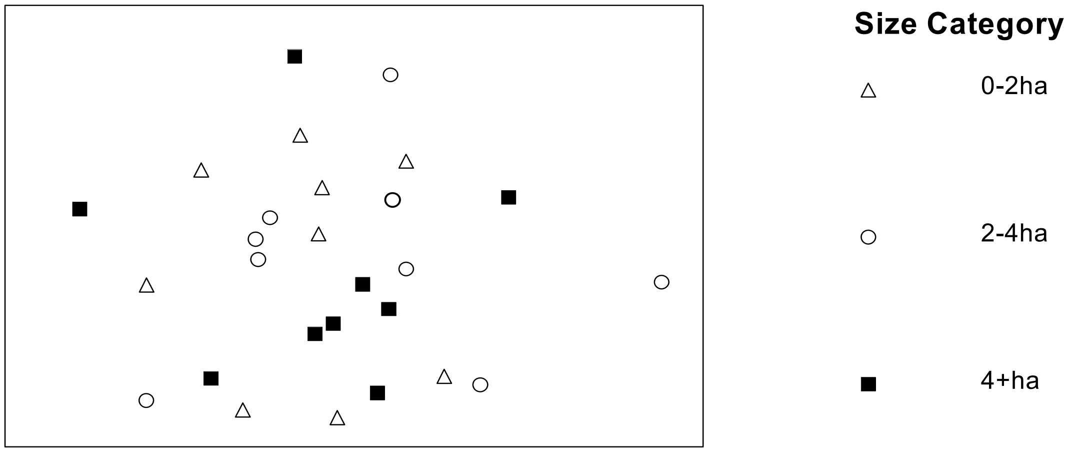
Table 5.3. Logistic regression analyses of the effect of plot-level habitat variables on the presence/absence of indicator bird species pooled over the three survey seasons.

Variable	B	d.f.	P value
Fallen logs			
Wrens	0.298	1	0.022
Treecreepers	0.609	1	0.000
Fallen branches			
Wrens	0.121	1	0.031
Treecreepers	0.330	1	0.000
No. Snags			
Wrens	-0.022	1	0.452
Treecreepers	0.135	1	0.002
% Canopy cover			
Wrens	0.009	1	0.043
Treecreepers	0.022	1	0.000
% Shrub cover			
Wrens	0.022	1	0.770
Treecreepers	-0.007	1	0.464
% Leaf litter			
Wrens	0.007	1	0.225
Treecreepers	0.011	1	0.057
% Understorey cover			
Wrens	0.012	1	0.163
Treecreepers	-0.003	1	0.756
No. Large trees			
Wrens	0.186	1	0.319
Treecreepers	-0.008	1	0.908
No. Small Trees			
Wrens	-0.37	1	0.275
Treecreepers	-1.33	1	0.090
No. Saplings			
Wrens	-0.26	1	0.489
Treecreepers	-0.33	1	0.480

5.2. Bird community composition

In winter and spring, there were no significant differences in bird community composition between sites of different size (Figure 5.2. a and b, and Table 5.4.). In contrast, there were differences in bird community composition between sites of different age in both seasons (Figure 5.3. a and b, and Table 5.4.). As sites became older (number years since fenced off increased) bird communities tended to become more different.

a)



b)

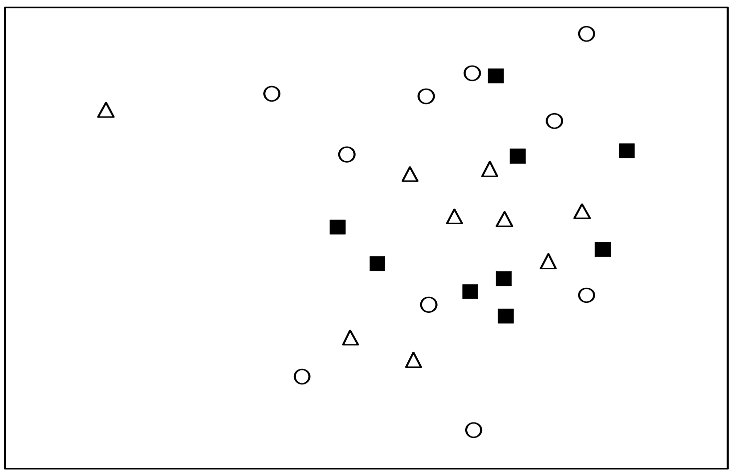


Figure 5.2. Ordination of bird community composition in (a) winter and (b) spring for sites of different size. Stress level = 0.24.

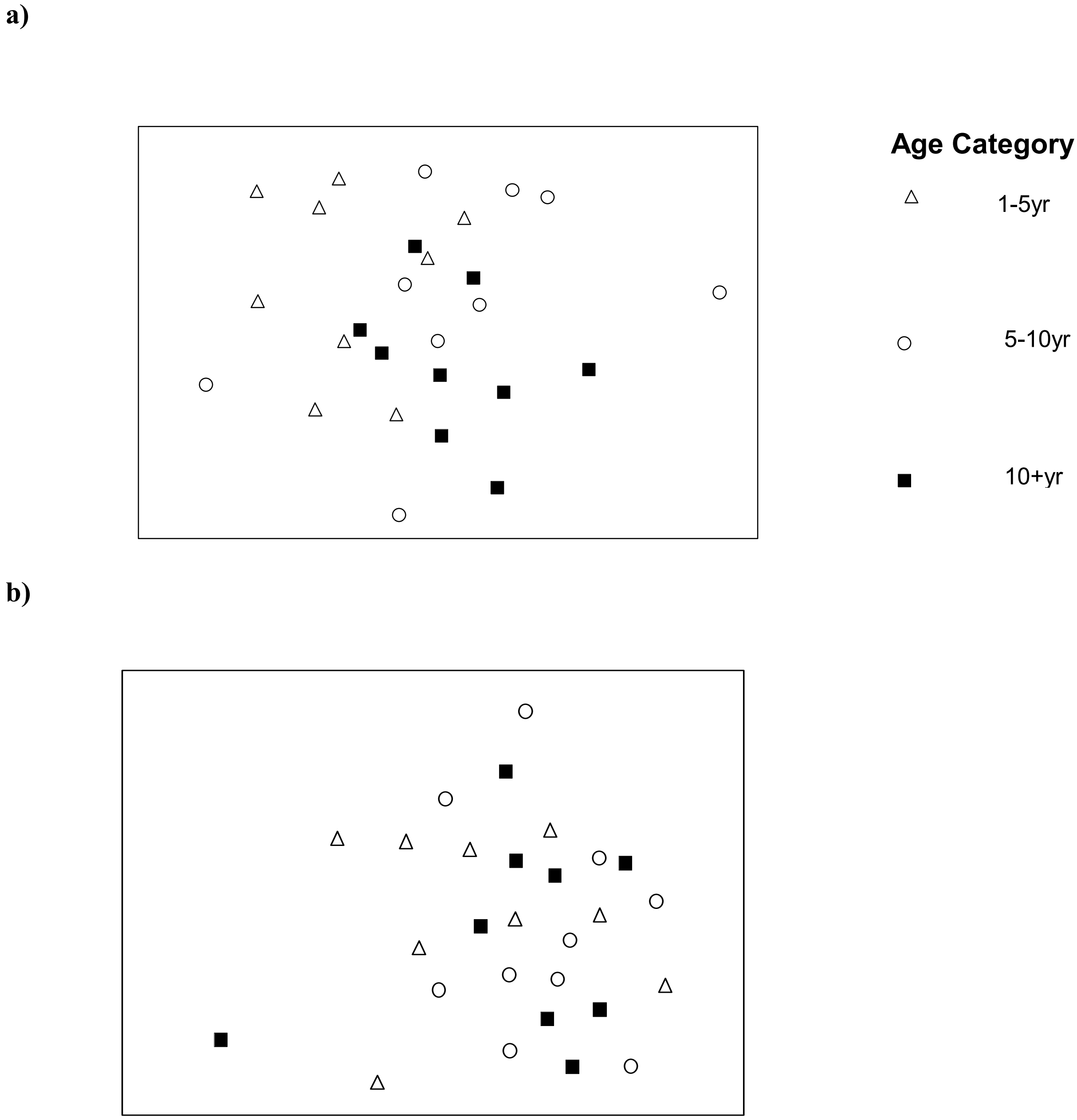


Figure 5.3. Ordination of bird community composition in (a) winter and (b) spring for sites of different age. Stress level = 0.24.

Table 5.4. Summary of analyses of similarities (ANOSIM) for bird community composition in sites of different age and size in winter and spring.

Variable	Global R	P value
Winter		
Effect of size	-0.024	>0.05
Effect of age	0.208	0.02
Spring		
Effect of size	0.07	>0.05
Effect of age	-0.015	0.042

The 70% cumulative cut-off level for average dissimilarity between species composition across all site age combinations was utilised to identify bird species that contributed most to significant differences between sites of different age. In each site age group pairing, the first 5-8 species account for approximately 30% of all dissimilarity with the first half of the species accounting for 70% of all dissimilarity of total bird abundance. (Table 5.5; see Appendix 2 for full scientific names).

Table 5.5. Bird species that contributed most to differences in community bird species counts for sites of different age.

Winter	% Contribution age group (yrs)			Spring	% Contribution age group (yrs)		
	1-5 & 5-10	1-5 & 10+	5-10 & 10+		1-5 & 5-10	1-5 & 10+	5-10 & 10+
Galah	4.74	3.09	4.56	White-plumed Honeyeater	4.10	3.99	2.01
Australian Raven	4.70	3.28	3.26	Eastern Rosella	3.78	3.43	3.76
Magpie-lark	3.94	2.57	3.88	Superb Fairy-wren	2.94	2.65	2.77
Superb Fairy-wren	3.50	3.97	2.03	Grey Shrike-thrush	3.55	3.77	3.44
Kookaburra	3.10	4.06	4.50	Australian Magpie	3.21	3.78	3.36
Sulphur-crested cockatoo	2.75	3.90	4.83	Galah	2.96	4.00	3.45
Eastern Rosella	3.14	3.65	3.49	Willie Wagtail	3.16	3.49	2.98
White-plumed Honeyeater	3.47	3.83	3.05				

6. DISCUSSION

6.1. Effects of time since fencing (site age)

Grazing of livestock in Australian over the past 150 years has resulted in the current landscape being fragmented and wildlife habitats becoming more simplified. Clearance of woodland in southern Australia has resulted in the loss of almost 90% of vegetation in some areas (Robinson & Traill 1996). Subsequent grazing by livestock has lead to a loss of understorey, reduced tree regeneration potential and the alteration of the grass and herb layer (Ford *et al.* 2001). This in turn has resulted in the widespread disappearance of local mammal populations and increased abundance of unpalatable woody plant species (Wilson 1990). For woodland birds, typically grazing alters understorey composition and removes shrubs that are important nest sites (Ford *et al.* 2001).

Because livestock congregate in riparian areas, the impacts of their grazing are magnified (Fisher & Goldney 1997). Livestock grazing in the riparian zone is known to have a negative impact on water quality, soils, aquatic and riparian wildlife as well as stream bank vegetation (Belsky, Matzke & Uselman 1999). Change in understorey structure and composition due to grazing is also known to influence bird species abundance and diversity. Heavily grazed areas have significantly different riparian bird community composition when compared with lightly grazed sites (Jansen & Robertson 2001*b*). Degradation of riparian areas cannot be reversed in a few years of protection (Belsky, Matzke & Uselman 1999).

The results of the present study indicate that it takes at least ten years to restore populations of Superb Fairy-wrens and Brown Treecreepers and overall bird community composition in areas of the riparian zone that have been fenced of from the effects of livestock. Average abundance of Superb Fairy-wrens ranged from 1.5 individuals at young (1-5yrs) sites to 5.5 individuals at old (10+yrs) sites. Similarly, an increasing trend was evident for the Brown Treecreeper with average abundance ranging from 0 at young sites to 1.5 at old sites. The condition of these riparian areas prior to fencing off had no significant effect upon the probability of occurrence of either indicator bird species.

The Superb Fairy-wren is a specialised ground foraging insectivore relying upon an understorey cover of logs and branches for nesting and foraging. The Brown Treecreeper is a specialised trunk foraging insectivore that also relies upon fallen timber (Walters, Ford & Cooper 1999). It is therefore not surprising that the plot-scale habitat variables fallen logs and fallen branches were significant factors in the presence of both indicator species in fenced off areas of the riparian zone. Disturbances such as grazing and clearing lead to the reduction or complete absence of these habitat features on which both bird species rely. As canopy forming trees develop in fenced off areas they contribute to significant layers of leaf litter and quantities of coarse woody debris (i.e. fallen logs and branches) (Fisher 2001; Spooner, Lunt & Robinson, in press) which are essential as habitat for grazing sensitive bird species such as the Superb Fairy-wren and the Brown Treecreeper (Jansen & Robertson 2001*b*).

The results from riparian habitats are similar to those from woodland habitats. Neave *et al*. (1996) indicated that as understorey complexity increased with increased canopy cover, so to did the abundance of the Superb Fairy-wren. Similarly, in Barrett's (2000) five year study of birds on farms, the diversity of ground foraging birds (e.g. Superb Fairy-wren) increased by 30% and bark foraging birds (e.g. Brown Treecreeper) increased by 70% for every 10 fallen trees per farm.

Grazing by livestock has had a negative impact on riparian bird communities through habitat removal and reductions in habitat quality (Jansen & Robertson 2001*b*), and this has been a major cause of decline of birds in southern Australia (Reid 1999). Bird community composition in my study revealed a response to the time since riparian areas were fenced off from livestock. Most of these differences in both seasonal surveys were due to changes in the relative proportions of birds that are either known to be 1) grazing and clearing tolerant, such as the Galah (*Cacatua roseicapillus*), Sulphur-crested cockatoo (*Cacatua galerita*) and Australian Magpie (*Gymnorhina tibicen),* and 2) grazing and clearing intolerant, such as the Superb Fairy Wren (Jansen & Robertson 2001*b*).

These responses were likely due to increasing habitat quality in the form of leaf litter layers and coarse woody debris as sites recovered from the effects of livestock. The results of my study on riparian habitats concur with the conclusions of a more general study of woodland birds where bird diversity at heavily grazed sites was found to be restored 15 years after the removal of stock (equivalent 10+ yrs site in my study) and reached a maximum diversity after 25 years (Barrett 2000).

6.2. Effects of the size of fenced-off area

Smaller areas of habitat support fewer species than large areas of habitat (MacArthur & Wilson 1967). In a designed experiment of fragment size on numbers of species of insects, Collinge (1998) found large plots to have a higher number of insect species than did medium plots, which in turn contained more species than small plots. Though smaller habitat patches may support a larger abundance of birds per unit area, large patches have a higher species diversity (Simberloff 1988).

Studies by Fahrig (1997) suggest that as patch size decreases to ≤80% of its original size, regional bird extinctions will steadily increase. Reducing any habitat to ≤10% of it former area will eventually result in the loss of 50% of species in that habitat (Possingham & Field 2001) For example, in the Mount Lofty Ranges of South Australia only 6.5% of the original habitat remains. This has resulted in the local extinction of 8 bird species with several other bird species present in critically small populations (Ford *et al.* 2001). Reduction in habitat and patch size especially affects those species with large home ranges (e.g. Square-tailed Kite) (Ford *et al.* 2001). As a consequence of decreasing patch size, most remnants may become too small or isolated to support viable populations of many birds (Robinson & Traill 1996).

Some bird species are more sensitive to the effects of habitat fragmentation and decrease in patch size than others (Barrett, Ford & Recher 1994). Jansen & Robertson (2001*b*) identified the Brown Treecreeper as being sensitive to the effects of clearing, whereas species such as the Sulphur-crested Cockatoo and Galah are known to be clearing tolerant. In the woodlands of Victoria, Loyn (1987) found bird species diversity to be greatest at medium sized (10-150ha) sites, with sites under 10ha supported by predominately clearing tolerant farmland birds such as the Noisy Miner (*Manorina melanocephala*).

Analysis of the indicator bird species data over all seasons in the present study revealed that the size of riparian sites was not a significant factor in the presence or absence of the Superb Fairy-wren, but for the Brown Treecreeper there was a significant effect of size in sites which had been fenced off for at least 10 years (in more recently fenced sites very few Brown Treecreepers were detected). Thus it appears that in term of size of fenced-off area the Brown Treecreeper is more sensitive to the effects of size than the Superb Fairy-wren.

Since size was not a significant factor in the presence or absence of the Superb Fairy-wren, it appears that this species is responding to changes in habitat quality rather than quantity (see 4.1), while the Brown Treecreeper is responding to both. This is supported by Barrett, Ford & Recher's (1994) study of woodland birds in various sized remnants of southern Australia where they concluded that in habitat fragments <6ha, habitat quality is at least as important as the size of the remnant for conserving bird species richness.

Though there have been many studies of bird community diversity in sites of different size (e.g. Loman & von Schantz 1991; Barrett, Ford & Recher 1994; Possingham & Field 2001) there has been little research into the differences between bird communities in sites of different size. Levels of grazing are known to affect bird community composition though size was not investigated (Fisher & Goldney 1997; Jansen & Robertson 2001*b*).

Woodland bird species form a specialist community that rely almost wholly on woodland regions for habitat, foraging, and breeding purposes. The loss of habitat to woodland bid communities by clearing, fragmentation and reduction in patch size has resulted in this community now having one of the highest concentrations of locally extinct and threatened bird species (Robinson & Traill 1996).

6.3. Management

Riparian habitats are centres for biodiversity and act as corridors to help foster the movement of fauna (e.g. Elmore 1992; Crome, Isaacs & Moore 1994; DLWC 2000; Jansen & Robertson 2001*b*). The benefits of fencing-off degraded riparian areas to exclude livestock are well documented (e.g. Barrett 2000; Robertson & Rowling 2000; Jansen & Robertson 2001*a*; Spooner, Lunt & Robinson, in press). Exclusion of livestock from riparian areas has resulted in greater tree regeneration and groundcover biomass than is present at unfenced sites (Robertson & Rowling 2000). Riparian areas in the Murray-Darling Basin of Southern Australia suffer higher impacts from grazing than adjacent non-riparian areas (Robertson 1997), with bird communities also known to be declining due to the effects of grazing in these areas (Reid 1999).

Riparian areas fenced to exclude livestock are managed in different ways. In my study, landholders managed each fenced-off riparian site differently. Methods of weed control management within sites included crash grazing (sheep, cattle or both), herbicide spot spraying, mechanical removal of weeds to no management at all. These different methods of weed management within fenced riparian sites had no significant effect on the presence or absence of either indicator bird species. From a habitat perspective, these results suggest that bird species responded to an increase in habitat complexity within sites and were not adversely affected by minor changes in habitat due to weed management techniques.

Quality of habitat in fenced-off riparian sites in the present study was an important factor in determining the presence of indicator bird species. Since numbers of fallen logs and branches as well as canopy cover were significant in the presence of the two indicator bird species, increasing the abundance of logs and branches in these habitats may be desirable. It may be feasible for landholders to increase habitat complexity by bringing coarse woody debris into these fenced-off riparian areas. Similarly, in remnant areas, canopy cover and leaf litter can be increased with the additional planting of canopy forming trees.

The size of fenced-off riparian areas was a significant factor in this study for one indicator species but not the other. Thus the question that now needs to be asked; is there a *critical* size for the fencing off of riparian habitats to which woodland birds will respond? Indicator bird species in the present study responded to fenced-off riparian areas as small as 1ha in size. It is possible that fenced areas even of this size are viable in maintaining populations of grazing-sensitive avifauna. Most farm fenced conservation sites are currently funded through schemes such as the *National Heritage Trust* (NHT) and government bodies such as the Department of Land and Water Conservation (DLWC). In order to ensure that funding given for the fencing of these areas is feasible in terms of return of woodland avifauna it appears that sites need to be at least 1ha in size, and larger for more sensitive species such as the Brown Treecreeper.

Fenced-off remnants and plantings of riparian vegetation provide vital habitat for avifauna. As habitat quality increases with the number of years since riparian areas were fenced-off, the probability of occurrence of grazing sensitive bird species like the Superb Fairy-wren and the Brown Treecreeper increased. Currently, fenced riparian areas are scattered on private lands across regions. Management of these fenced riparian areas should now aim at connecting these remnants across the landscape to form a continuous habitat with reduced exposure to intensive agricultural practices. As woodland bird species abundance and diversity steadily decreases in southern Australia, the continued fencing-off of riparian areas to exclude livestock is essential in helping to increase habitat quality and subsequently halt the decline of woodland bird species.

7. REFERENCE LIST

Backhouse, G. N. & Clark, T. W. 1995, Case studies and policy initiatives in endangered species recovery in Australia: introduction. *People and nature conservation: perspectives on private land use and endangered species recovery.* Editors A. Bennett, G. N. Backhouse & T. W. Clark. Surrey Beatty, Chipping Norton.

Barrett, G. 2000, *Birds on farms: Ecological management for agricultural sustainability* (online). www.nccnsw.org.au/member/cbn/projects/LifeLines6.4/NatVeg_Bir.html [Accessed 27 Sept. 2001].

Barrett, G. W., Ford, H. A. & Recher, H. F. 1994, Conservation of woodland birds in a fragmented rural landscape. *Pacific Conservation Biology,* **1**, pp.245-256.

Belsky, A. J., Matzke, A. & Uselman, S. 1999, Survey of livestock influences on stream and riparian ecosystems in the western United States. *Journal of Soil and Water Conservation,* **1**, pp.419-431.

Bureau of Meteorology. 2001, *Climate averages for Australian sites* (online). http://www.bom.gov.au/climate/averages/tables.html [Accessed 24 July 2001].

Clarke, K. R. & Warwick, R. M. 1994, *Change in marine communities: an approach to statistical analysis and interpretation*. Natural Environment Research Council, U.K.

Collinge, S. K. 1998, Spatial arrangement of habitat patches and corridors: clues from ecological field experiments. *Landscape and Urban Planning,* **42**, pp.157-168.

Crome, F., Isaacs, J. & Moore, L. 1994, The utility to birds and mammals of remnant riparian vegetation and associated windbreaks in the tropical Queensland uplands. *Pacific Conservation Biology,* **1**, pp.328-343.

DLWC. 2000, *Caring for our natural resources: Murrumbidgee region* (online). http://www/dlwc/nsw.gov.au/care/wetlands/activities/murrumbidgee/index.html [Accessed 24 July 2001].

Elmore, W. 1992, Riparian responses to grazing practices. *Watershed Management: balancing sustainability and environmental change.* Editor R. J. Naiman. Springer-Verlag, New York, pp.442-457.

Environmental Protection Authority (EPA). 1995, *Murrumbidgee River Catchment: Catchment Overview* (online). http://www.epa.nsw.gov.au/soe/95/9_4.htm#0_9_4_1_0_0_0_ [Accessed 16 Apr. 2001].

Fahrig, L. 1997, Relative effects of habitat loss and fragmentation on population extinction. *Journal of Wildlife Management,* **61**, pp.603-610.

Fisher, A. M. 2001, Avifauna changes along a *Eucalyptus* regeneration gradient. *Emu,* **101**, pp.25-31.

Fisher, A. M. & Goldney, D. C. 1997, Use by birds of riparian vegetation in an extensively fragmented landscape. *Pacific Conservation Biology,* **3**, pp.275-288.

Fleischner, T. L. 1994, Ecological costs of livestock grazing in western North America. *Conservation Biology,* **8**(3), pp.629-644.
Ford, H. A., Barrett, G. W., Saunders, D. A. & Recher, H. F. 2001, Why have birds in the woodlands of Southern Australia declined? *Biological Conservation,* **97**, pp.71-88.

Jansen, A. & Robertson, A. I. 2001*a*, Relationships between livestock management and the ecological condition of riparian habitats along an Australian floodplain river. *Journal of Applied Ecology,* **38**, pp.63-75.

Jansen, A. & Robertson, A. I. 2001*b*, Riparian bird communities in relation to land management practices in floodplain woodlands of south-eastern Australia. *Biological Conservation,* **100**, pp.173-185.

Kinross, C. M. 2000, *The ecology of bird communities in windbreaks and other avian habitats on farms*. Charles Sturt University, Bathurst. PhD Thesis.

Loman, J. & von Schantz, T. 1991, Birds in a farmland - more species in small than in large habitat islands. *Conservation Biology,* **5**, pp.176-188.

Loyn, R. H. 1987, Effects of patch area and habitat on bird abundances, species numbers and tree health in fragmented Victorian forests. *Nature conservation: The role of remnants of native vegetation.* Editors D. A. Saunders, G. W. Arnold, A. A. Burbidge & A. J. M. Hopkins, pp.65-77.

MacArthur, R. H. & Wilson, E. O. 1967, *The theory of island biogeography*. Princeton University Press, Princeton.

MacNally, R. C. 1997, Monitoring forest bird communities for impact assessment: the influence of sampling intensity and spatial scale. *Biological Conservation,* **82**, pp.355-367.

Morton, S. R., Short, J. & Barker, R. D. 1995, *Refugia for biological diversity in arid and semi-arid Australia*. CSIRO Division of Wildlife and Ecology, Canberra.

Neave, H. M., Cunningham, R. B., Norton, T. W. & Nix, H. A. 1996, Biological inventory for conservation evaluation III. Relationships between birds, vegetation and environmental attributes in southern Australia. *Forest Ecology and Management,* **85**, pp.197-218.

NPWS. 2000, *National Parks and Wildlife Service, New South Wales* (online). http://www.npws.gov.au [Accessed 16 Apr. 2001].

Possingham, H. P. & Field, S. A. 2001, *Regional bird extinctions and their* *implications for vegetation clearing policy* (online). http://homepages.picknowl.com.au/peters/Bird%20extinction.HTML [Accessed 7 Apr. 2001].

Recher, H. F. & Lim, L. 1990, A review of the current ideas of extinction, conservation and management of Australia's terrestrial vertebrate fauna. *Proceedings of the Ecological Society of Australia,* **16**, pp.287-301.

Reid, J. R. W. 1999, Threatened and declining birds in the New South Wales Sheep-Wheat Belt: Diagnosis, characteristics and management. *Consultancy report to NSW National Parks and Wildlife Service.* Canberra.

Robertson, A. I. 1997, Land-water linkages in floodplain river systems: the influence of domestic stock. *Frontiers in Ecology: Building the Links.* N. Klomp, I. Lunt & (eds). Elsevier Scientific, Oxford, pp. 207-218.

Robertson, A. I. & Rowling, R. W. 2000, Effects of livestock on riparian zone vegetation in an Australian dryland river. *Regulated Rivers: Research and Management,* **16** , pp.527-541.

Robinson, D. & Traill, B. J. 1996, *Conserving woodland birds in the wheat and sheep belts of southern Australia*. RAOU Conservation Statement No. 10. Royal Ornithologists Union, Melbourne.

Simberloff, D. 1988, The contribution of population and community biology to conservation science. *Annual Review of Ecology and Systematics,* **19**, pp.473-511.

Simpson, K. & Day, N. 1999, *Field guide to the birds of Australia*. Viking, Ringwood, Victoria.

Spooner, P., Lunt, I. & Robinson, W. In Press, Is fencing enough? The short-term effects of stock exclusion in remnant grassy woodlands in Southern Australia. *Ecological Management and Restoration*.

SPSS Inc. 1999, SPSS for Windows, SPSS Inc. Chicago, IL.

Walters, J. R., Ford, H. A. & Cooper, C. B. 1999, The ecological basis of sensitivity of brown treecreepers to habitat fragmentation: a preliminary assessment. *Biological Conservation,* **90**, pp.13-20.

Wilson, A. D. 1990, The effects of grazing on Australian ecosystems. *Proceedings of the Ecological Society of Australia,* **16**, pp.235-244.

8. APPENDICES

Appendix 1

Figure 1.1. One of the smallest (1ha) and youngest (1-5 years since fenced) sites at "Mustang Park".

Figure 1.2. One of the medium (2-4ha) sized and medium aged (5-10 years since fenced) sites at "Meribindinyah".

Figure 1.3. One of the largest (4+ha) and oldest (10+ years since fenced) sites at "Braeside".

Appendix 2

List of regional woodland bird species (excluding raptors and water birds) provided to volunteer bird observers. Bold indicates those species observed across all sites in winter and spring counts (All taxonomy follows Simpson & Day, 1999).

COMMON NAME	SCIENTIFIC NAME
Australian magpie	***Gymnorhina tibicen***
Australian raven	***Corvus coronoides***
Bar shouldered dove	***Geopelia humeralis***
Black eared cuckoo	***Chalcites osculans***
Black faced cuckoo shrike	***Coracina novaehollandiae***
Black-chinned honeyeater	***Melithreptus gularis***
Brown quaill	***Coturnix australis***
Brown songlark	***Cinclorhamphus cruralis***
Brown thornbill	***Acanthiza pusilla***
Brown treecreeper	***Climacteris picumnus***
Brown-headed honeyeater	***Melithreptus brerirostus***
Buff-rumped thornbill	***Acanthiza reguloides***
Clamroue reed warbler	***Acrocephalus stentoreus***
Cockatiel	***Leptolophus hollandicus***
Common blackbird	***Turdus meruld***
Common bronzewing	***Phaps chalcoptera***
Common starling	***Stumus vulgaris***
Crested pigeon	***Ocyphaps lophotes***
Crested shrike-tit	***Falcanculus frontatus***
Crimson rosella	***Platycerus elegans***
Diamond firetail	***Stagonopleura guttata***

Double-barred finch	*Taeniopygia bichenovii*
Dusky woodswallow	***Artamus cyanopterus***
Eastern rosella	***Platycercus eximius***
Eastern spinebill	***Acanthorhynchus tenuirostris***
Eastern-yellow robin	***Eopsaltria australis***
European goldfinch	***Carduelis carduelis***
Fairy martin	***Hirundo ariel***
Fan-tailed cuckoo	***Cacomantis flabelliformis***
Flame robin	***Petroica phoenicea***
Fuscous honeyeater	***Lichenostomus fuscus***
Galah	***Cacatua roseicapillus***
Golden headed cisticola	***Cisticola exilis***
Golden whistler	***Pachycephala pectoralis***
Grey butcherbird	*Cracticus torquatus*
Grey fantail	***Rhipidura fuliginosa***
Grey shrike-thrush	***Colluricincla harmonica***
Grey-crowned babbler	***Pomatostomus temporalis***
Hooded robin	***Melanodryas cucullata***
House sparrow	***Passer domesticus***
Jacky winter	***Microeca fascinans***
Kookaburra	***Dacela novaeguinea***
Leaden flycatcher	***Myiagra rubecula***
Little friarbird	***Philemnon citregularis***
Little lorikeet	***Glossopsitta pusilla***
Magpie-lark	***Grallina cyanoleuca***
Masked lapwing	***Vanellus miles***
Mistletoebird	***Dicaeum hirundinaceum***
New-Holland honeyeater	*Phylidonyris novaehollandiae*
Noisy friarbird	***Philemnon corniculatus***
Noisy miner	***Manorina melanocephala***
Peaceful dove	***Geopetia striata***
Pied butcherbird	***Cracticus nigrogularis***
Pied currawong	***Strepera graculina***
Rainbow bee eater	***Merops ornatus***
Red wattlebird	***Anthochaera caranculata***
Red-browed finch	***Neochmia temporalis***
Red-capped robin	*Petroica goodenovii*
Red-rumped parrot	***Psephotus haematonotus***
Restless flycatcher	***Myiagra inquieta***
Rufous songlark	***Cinclorhamphus mathewsi***
Rufous whistler	***Pachycephala rufiventris***
Sacred kingfisher	***Todiramphus sanctus***
Scarlet robin	***Petroica mulitcolor***
Silvereye	***Zosterops lateralis***
Southern whiteface	***Aphelocephala leucopsis***
Speckled warbler	***Chthonicola sagittata***

Spotted pardalote	***Pardalotus punctatus***
Striated pardalote	***Pardalotus striatus***
Striated thornbill	***Acanthiza lineata***
Sulphur-crested cockatoo	***Cacatua galerita***
Superb parrot	***Polytelis swainsonii***
Superb-fairy wren	***Malurus cyaneus***
Tree martin	***Hirundo nigricans***
Varied Sittella	*Daphoenositta chrysoptera*
Variegated-fairy wren	***Malurus lamberti***
Weebill	***Smicrornis brevirostris***
Welcome swallow	***Hirundo rustica***
Western gerygone	***Gerygone fusca***
White-breasted woodswallow	*Artamus leucorynchus*
White-browed babbler	*Pomatostomus superciliosus*
White-browed scrub wren	***Sericornis frontalis***
White-eared honeyeater	***Lichenostomus leucotis***
White-naped honeyeater	***Melithreptus lunatus***
White-plumed honeyeater	***Lichenostomus penicillatus***
White-throated gerygone	*Gerygone olivaceae*
White-throated treecreeper	***Cormobates leucophaeus***
White-winged chough	***Corcorax melanorhamphos***
Willie wagtail	***Rhipidura leucophrys***
Yellow faced honeyeater	***Lichenostos chrysops***
Yellow rosella	***Platycercus elegans flaveolus***
Yellow thornbill	***Acanthiza nana***
Yellow-rumped thornbill	***Acanthiza chrysorrhea***
Yellow-tufted honeyeater	*Lichenostomus melanops*

Appendix 3a

Values of the index of weed control and management techniques used within fenced riparian sites. Management techniques were assessed in March 2001.

1 = Mechanical. Weed removal by hand. Carried out on intermittent basis
2 = Grazing-cattle only. Occasional crash grazing to remove unwanted weeds and reduce fire risk.
3 = Grazing-sheep only. Occasional crash grazing to remove unwanted weeds and reduce fire risk.
4 = Grazing-cattle and sheep. Occasional crash grazing to remove unwanted weeds and reduce fire risk.
5 = Herbicides. Spot spraying to prevent invasions by unwanted noxious weeds.
6 = No management. Fenced areas are left with no weed control or management techniques employed.

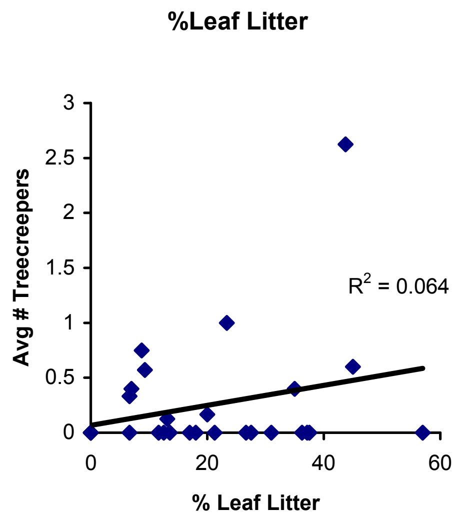
Appendix 3b

Values of the index of site condition prior to fencing. Prior condition was assessed in March 2001 for riparian habitat adjacent to each of the 27 sites.

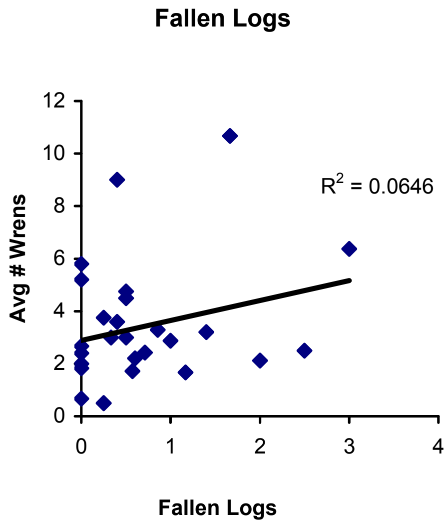
1 = no grazing or cropping with 100% coverage of understorey and continuous tree and canopy cover.
2 = some previous cropping and/or grazing, but no longer being practised. Almost 100% (not <95%) understorey cover with some bare patches.
3 = occasional crash grazing with strong understorey presence (not<80%) and little to no tree coverage (not>10%).
4 = rotational grazing and resting (50/50) with minimal understorey (<40%) and little to no tree coverage.
5 = continually cropped or grazed with no tree or canopy cover and heavily grazed with little (<10%) to no understorey presence.

Appendix 4(a-d)
Examples of scatter plots of habitat variables vs. indicator bird species carried out prior to logistic regression analysis

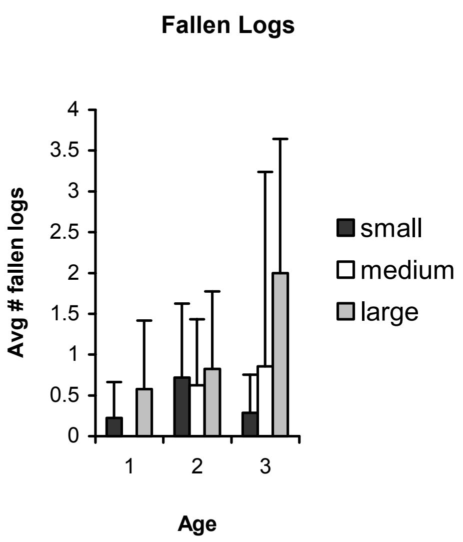
(a)



(b)



(c)



(d)