

CHAPTER 1

LITERATURE REVIEW

1.1. BACKGROUND

As anthropogenic changes are proceeding at an unprecedented rate worldwide, the conservation of habitat for birds is becoming increasingly important (Fuller, 1982; Karr, 1982; Lynch & Wigham 1984; McLellan *et al.*, 1986). Concern for the declining number of birds in remnant vegetation as a result of habitat loss and fragmentation has inspired numerous studies (Howe, 1984; Loyn, 1987; Saunders 1989; Newmark, 1990; Barrett *et al.*, 1994; Bennett & Ford, 1997). The composition of bird communities, as well as the number of species, are being affected by these two broad threats. The conservation of remnant habitats may be further complicated by ongoing domestic grazing practices. There has been very little work where the direct effects of grazing on forest and woodland bird assemblages have been examined. This is particularly because the effects of forest clearing, fragmentation and other types of degradation confound the effect of grazing. The effect of livestock grazing and forest clearing are difficult to disentangle because intact forests are rarely heavily grazed, and it is rare for cleared paddocks to be lightly grazed (Jansen *et al.*, 2001). This makes the impact of grazing on bird communities less easy to evaluate in agricultural regions around the world. The effects of grazing on bird communities are discussed in this chapter in the light of Australian studies. There is currently no information on the impact of grazing on birds in forests in Bhutan.

1.2. EFFECTS ON THE FOOD CHAIN IN AN ECOSYSTEM

There is growing evidence that grazing by livestock adversely affects the abundance and diversity of ground dwelling invertebrates (Abbott *et al.*, 1979; Abensperg-Traun, 1992; Abensperg-Traun *et al.*, 1996; Bromham *et al.*, 1999). This is likely to seriously disrupt the availability of food to those bird species dependent, either directly or indirectly on such invertebrates. Intensive and continuous grazing can impoverish the soil seed bank by uprooting and trampling native seedlings, thus preventing many native plants reaching maturity (Mawson & Long, 1995). Native plant species were found to survive better and are more diverse in ungrazed habitats than grazed habitats (McIntyre & Lavorel, 1994). This affects ground foraging birds, which are dependent on native plant seed. Mawson & Long (1995) observed that four species of parrots, which do not feed on the seeds of introduced plants, have declined in Western Australia due to grazing. Reid (1999) noted that 15 out of 20 declining bird species in the wheat-sheep belt of New South Wales were ground and/or low-shrub feeders and dwellers, and seed-eaters were well represented among them. Earlier studies by Recher & Lim (1990) and Saunders and Ingram (1995) reached a similar conclusion. The loss of shrubs and their replacement with annual grass and herbs may favour generalist granivores, but disadvantage specialists that depend on shrubs for food and shelter (Seddon *et al.*, 2001). Therefore grazing tends to reduce the diversity of granivorous birds even though there may be an increase in density of a few species.

1.3. EFFECTS ON HABITAT COMPLEXITY

Prolonged grazing by livestock is detrimental to birds because it reduces the quality and the complexity of the habitat. Grazing reduces biomass on the ground, in the shrub layer and potentially in the tree layer due to lack of regeneration. In the long term, it affects animals that depend on each trophic layer for food and/or shelter. The effect of intense prolonged grazing is severe. Livestock remove and damage understorey by browsing on shrubs and tree saplings as well as by trampling them (Barrett, 1995). Total shrub cover has been shown to favour the number and diversity of woodland bird species (e.g. Arnold & Weeldenberg, 1998; Saunders & de Rebeira, 1991; Arnold, 1988; Seddon *et al.*, 2001).

1.4. EFFECTS ON MICROHABITAT DIVERSITY

Live plants such as lichens, bryophytes, herbs and shrubs contribute structural complexity to plant communities. Additionally, it is thought that rocks, coarse debris, and fallen timber are also essential in providing surface and near-surface coarseness and microhabitat diversity in intact healthy habitats (Laven & MacNally, 1998; Reid, 1999). A recent study by Mac Nally *et al.* (2001) showed that some riparian birds are more abundant and the riparian bird community more diverse, in sites with an accumulation of coarse woody debris. In an intensively managed farmland, even with a good proportion of tree cover, these ground-layer textural elements disappear over time. This could have a considerable detrimental effect on the land and soil invertebrates (Reid, 1999) and consequently on the birds that are dependent on them. Coarse woody debris has been identified as an important component of habitat for two of the most severely declining species in the Australian wheat-sheep belt, namely

Hooded Robin *Melanodryas cucullata* and Brown Treecreeper *Climacteris picumnus* (Reid, 1999).

1.5. OTHER EFFECTS OF GRAZING

The grazing of livestock may also indirectly affect other bird species, including bark foragers and other insectivores. Bird species that feed on invertebrates located within the strips and coils of decorticating bark may be affected if these are browsed or rubbed off. Many invertebrates living in bark or on foliage also may have stages of their life cycle in the soil and litter at the base of trees. This means that alteration of ground microhabitats by grazing can adversely affect those species of bird that are not ground-foragers (Recher & Lim, 1990; Saunders & Curry, 1990).

It has been suggested that the effect of grazing by livestock is most pronounced in small woodland patches due to a variety of indirect effects (Barrett, 1995). For instance, eucalypt dieback in the New England Region of NSW, which is caused by excessive defoliation by leaf-eating insects, is probably the indirect result of intensified grazing practices (Lowman & Heatwole, 1992). Dieback is more severe in small, open heavily grazed patches than in larger forest patches with an intact understory (Loyn, 1987; Morgan, 1981). Dieback is associated with greatly reduced diversity and number of insectivorous or nectarivorous birds (Ford and Bell, 1981). A positive feedback loop may be set up, whereby birds that eat leaf-eating insects decline in grazed habitats (Grey *et al.*, 1998; Loyn, 1987) due to the reduced structural diversity of habitats and increased dieback (Ford & Bell, 1981; Barrett, 1995), and this, in turn, exacerbates the intensity of dieback caused by an increase in leaf-eating insects.

In south-eastern Australia high grazing pressure resulting in the removal of the understorey also contributes to an increased abundance of Noisy Miners *Manorina melanocephala*, especially in small woodland patches (Loyn, 1987; Dunkerley, 1989; Grey, 1995). A dominance of Noisy Miners in grazed habitats significantly reduces avian diversity and abundance (Barrett *et al.*, 1994; Grey *et al.*, 1998).

Thus, grazing inevitably brings about some modification of the habitat and intensive grazing may lead to a major change in habitat structure (Ford, 1985; Ford, 1989; Loyn, 1987, Barrett *et al.*, 1994; Arnold & Weeldenburg, 1998). Such changes in habitats lead to changes in bird community composition (MacArthur *et al.*, 1962; Stauffer & Best, 1980), and indeed a number of studies, worldwide, have shown that bird communities change in response to land management practices which alter habitat structure and food sources (Farley *et al.*, 1994; Dobkin *et al.*, 1998; Schieck *et al.*, 2000). Owing to their position in the higher trophic levels of most ecosystems and their sensitivity to environmental stresses, birds provide a reliable way of monitoring the quality and health of our environment (Reid *et al.*, 2000). Moreover, they are relatively easy to observe and are considered a good medium for conveying information about the conservation of biodiversity in fragmented woodland landscapes, where cropping and grazing predominate (Seddon *et al.*, 2001).

This thesis is divided into three parts, and consists of 10 chapters. Part one (Chapters 2-5) describes the case study on a woodland bird community in grazed and ungrazed study sites on the New England Tableland, Australia. Part two (Chapters 6-9) describes the case study on the bird community in grazed and ungrazed study sites in two forest types in Bhutan. Part three (Chapter 10) is a general discussion, which outlines the different impacts of grazing in the study sites in Australia and Bhutan.

CHAPTER 2

CASE STUDY I

2.1. INTRODUCTION

Grazing by livestock is recognized as one of the prime causes of the decline and loss of woodland birds throughout the agricultural regions of Australia (Recher and Lim, 1990; Saunders & Curry, 1990; Smith *et al.*, 1994; Arnold & Weeldenburg, 1998; Recher, 1999; Reid, 1999). Despite the prevalent recognition that grazing of woodland is likely to cause degradation, with adverse impacts on woodland birds, the relationships between bird communities and grazing management have attracted very little attention within Australia (Jansen and Robertson, 2001). The effect of livestock grazing is confounded by the conspicuous effect of clearing where the two occur together. Recent studies, however, suggest that livestock grazing has a separate effect from clearing on the composition of bird community (Ludwig *et al.*, 2000; Jansen and Robertson, 2001).

Virtually, no study, so far, has addressed the impact of grazing on birds in woodland on the northern tableland of NSW, although the possible effect of grazing has been mentioned (Ford & Bell, 1981; Barrett 1995). It appears that a good proportion of understorey vegetation of the woodland remnants on the Armidale plateau have been impaired by consistent sheep and cattle grazing since the early days of European settlement (Ford and Bell, 1981). Barrett's (1995) predictive model has shown that grazing and the resultant habitat characteristics could affect the distribution of birds in the woodland remnants on the Armidale plateau. Emphasis has been placed on the need to test such hypotheses to quantify the impact of grazing on the status of birds in these areas (Barrett, 1995; Ford *et al.*, 2001). Such emphasis is

heightened as the need for a conservation approach now extends beyond the frontier of nature reserves and into the fragments of off-reserve areas like agricultural land where an ecological disaster may be taking place insidiously (Barrett *et al.*, 1994; Barrett, 1995). Moreover, growing circumstantial evidence suggests the need for concern about the effect of grazing on a number of other woodland bird species, which have been recognized as declining (Loyd, 1987; Saunders and Curry, 1990; Ford *et al.*, 2001; Jansen and Robertson, 2001).

This study compared the woodland bird community in grazed and ungrazed areas in eucalypt woodland near Armidale on the New England Tablelands of NSW in an attempt to address the following questions:

1. Is there any significant difference in abundance of individual species between grazed and ungrazed habitats?
2. Is there any significant difference in seasonal variation in abundance of individual species between grazed and ungrazed habitats?
3. Is there any significant difference in composition and abundance of ecological guilds between grazed and ungrazed habitats?
4. Do the assemblages of birds differ between grazed and ungrazed plots?
5. How are the bird assemblages associated with habitat variables?

CHAPTER 3

METHODS

3.1. INTRODUCTION

The clearing of native vegetation in the New England Tablelands commenced with its early settlement by graziers in the 1830s (Barrett *et al.*, 1994). Early settlers found an open woodland with an abundance of grass and rapidly started using it to rear cattle and sheep (Ford, 1985). Only in the early 1900s did the extensive clearing of woodland stop (Davidson & Davidson, 1992). Only a small portion of the eucalypt woodland of New England remains in its original state (Ford, 1985).

In this chapter I describe the study sites for Case Study I, their location, climate and habitat description. This is followed by a description of the bird survey techniques, habitat measurements and data analysis.

3.2. LOCATION

The study areas chosen were within 20 km of UNE, Armidale (30°30'S, 151°40'E), NSW (Fig. 3.1). They included parts of the Newholme Property (including Dumaresq Dam and Mt. Duval) (Fig. 3.2 & 3.3), Imbota Nature Reserve (Fig. 3.4), and private land around the Imbota Nature Reserve (Fig. 3.5). Dumaresq Dam and the private land had only grazed plots and Imbota Nature Reserve had only ungrazed plots. Mt. Duval had both grazed and ungrazed plots.

property near Imbota Nature Reserve and 25 at Newholme of which 14 were at Dumaresq Dam and three on Mt. Duval. The 32 sampling points in ungrazed plots, included 21 at Imbota Nature Reserve, and 11 at Newholme including three on Mt. Duval. The sampling points within each plot were at least 200 m away from each other to avoid recording the same individuals at the neighbouring points. The 64 sampling points were all in areas that had trees with patchy shrubby understoreys. Open areas, where trees had been mostly cleared, were avoided. All sampling points were at least 200 m away from dams and at least 50 m from any edge with open country. Areas clearly dominated by Noisy Miners *Manorina melanocephala* were also avoided as this species is known to affect avian diversity and abundance by aggressive exclusion of other species (Grey et al., 1998; Major *et al.*, 2001). Of course, part of this affect is because miners often dominant in more open areas, where grazing pressure may be high. Since the sampling points were placed well away from water, water birds were not encountered; I recorded only woodland and forest species.

Imbota Nature Reserve has not been grazed by livestock for 2 years before the study started and was only lightly grazed for at least 20 years before that. The neighbouring property is grazed by horses, sheep and cattle. The ungrazed area at Newholme has had livestock excluded since 1986, whereas the grazed area has intensive sheep-grazing. All sites experienced grazing by native animals, such as Eastern Grey Kangaroos *Macropus giganteus* and Swamp Wallabies *Wallabia bicolor*, as well as feral herbivores European Rabbits *Oryctolagus cuniculus* and Brown Hares *Lepus capensis*.

3.3. CLIMATE

Armidale and the current study area, where the current study plots are located has a temperate climate with warm summers, cold winters and an average of 790 mm of rain annually with most of it (65%) occurring from October to March. Severe frosts are common during winter.

The average monthly maximum and minimum temperatures for Armidale from January 2000 to September 2001 are given in Fig. 3.6. Temperatures were generally close to normal, with the highest temperature of 35.1 °C on 15 January, 2000, and the lowest of -9.0 °C degrees was on 7 June 2001. The annual rainfall in 2000 was 658.8 mm, 132 mm lower than the average and was Armidale's driest year since 1992. Rainfall was below average in every month except March and November. The monthly values of rainfall for 2000 to September 2001 are presented in Fig. 3.7.

3.4. HABITAT DESCRIPTION

All the grazed and ungrazed plots were in eucalypt woodland with a scattered shrub layer such as the Fern-leaf Wattle *Acacia filicifolia*, Blackthorn *Bursaria spinosa*, Sifting Bush *Cassinia quinquefaria* and regenerating eucalypts. The most common types of woodland trees are New England Stringybark *Eucalyptus caliginosa*, occurring in the poorer rocky soils along ridges and hill-tops, Blakely's Red Gum *E. blakelyi* and Yellow Box *E. melliodora* association, limited to richer soils at lower altitudes.

3.5. BIRD SURVEY

Birds were surveyed by point counts in both grazed and ungrazed sites to record presence/absence and the number of individuals. Point counts can be imagined to be transects of zero length conducted at zero speed. They are conducted by searching for birds from that point within a standardized time and distance. The sampling points were marked permanently during the first visit, so that the following visits were made to the same points. Point counts have a number of advantages over line transects. Once the observer is at the point, he or she can concentrate solely on detecting, locating and identifying birds, without the need to traverse what may be difficult terrain. The observer can also take the easiest route into and away from the sampling point. Further, it is easier to place points randomly or systematically than it is to lay out transects in patchy habitat. Describing the vegetation structure associated with the point is also easier than for a line (Bibby *et al.*, 1992). The use of line transects in patchy habitats would be problematic as each line may traverse several habitat types, which may bias the habitat sampled.

The bird species were identified and recorded by either sight or call. Only those bird species calling within 50 m from the sampling points and only those seen within 100 m have been recorded. Birds around each sampling point were counted over a period of 10 minutes. Standardizing time in such a way avoids the problem of increased species diversity and abundance in some points resulting from increased search effort (see Watson *et al.*, 2000) and movement of birds into the area. One drawback of point counts is that birds may be disturbed or flushed by the observer approaching each point. In order to lessen the impact of such an effect, 5 minutes was taken after arriving at the sampling point to allow the birds to settle down and to give some time for the observer to get ready for the search.

Each sampling point was surveyed for birds four times from October 2000 to September 2001: in spring 2000 (October-November), summer 2001 (December), autumn 2001 (March-April) and winter 2001 (August-September). Each sampling point was, therefore, visited only once in each season. The bird counts were carried out in the morning from 7 am to 11 am in spring, autumn and winter. In summer, the census was done earlier: from 5.30 am to 10.30 am, because activity of birds may decline due to heat later in the day. The surveys were intentionally conducted in fine weather, with no rain or excessive wind, to remove any bias due to unpleasant weather.

The number of birds of each species seen within 50 m of each sampling point, or heard within 100 m, was recorded onto a data sheet. In order to avoid recording the same bird by call and sight, careful observation was made after hearing its call and it was recorded only when it was seen. Those birds that were hard to see were recorded only after confirming their call. The distance to birds recorded by their call is approximate. Simpson and Day (1993) was used to aid the bird identification and for scientific names.

3.6. HABITAT MEASUREMENT

In order to investigate relationships between bird assemblages and habitat characteristics, a number of habitat variables were measured at each site. Twelve habitat variables were measured at each of the 64 points in grazed and ungrazed habitats in the New England study area. The habitat variables included canopy height, extent of dieback, percentage of shrub cover, number of gums, number of boxes, number of stringybarks, number of shrub species, number of fallen logs (> 4m long and 0.20 cm dim), number of mistletoes, number of dead trees, proportion of grass

cover and number of droppings of domestic livestock (principally sheep). The habitat variables were measured within a 25 m radius of the sampling point for bird counts. The extent of eucalypt dieback and shrub cover was measured visually within each 25 m radius. The proportion of grass cover and frequency of droppings were recorded in 1m² quadrats along four opposite directions from the centre of the 25 m radius circle and the total of all 1m² quadrats within the 25 m was calculated for the final survey at each sampling point. Since there was little seasonal variation in habitat variables, these measurements were taken only once (during the winter).

3.7. DATA ANALYSIS

A list of the number of birds of each species recorded at all 64 points, (32 each in grazed and ungrazed habitat) from October 2000 to September 2001, was compiled (Appendices 1a & 1b). From data recorded for each plot (grazed/ungrazed) the following results were obtained: (1) total number of species recorded at each point in each plot, (2) total number of species present exclusively in either grazed or ungrazed plots, (3) percentage composition of each ecological guild in each plot.

Further, the following analyses were undertaken. A contingency table of the presence or absence of each bird species was constructed. The data were analysed using 'Chi square' to detect any apparent preference for grazed and ungrazed plots.

Basically, the data comprised repeated counts of the number of bird species in grazed and ungrazed plots over four seasons. Therefore, repeated-measures analysis of variance (ANOVA) was used to detect any relationships between plot (grazed/ungrazed) and/or season and bird species richness and abundance. The above analysis was applied to the overall total number of bird species recorded during the study period. Additionally, the birds were divided into three different ecological

guilds – canopy birds, shrub birds and ground birds, and this same analysis was conducted on these guilds. These guilds were derived on the basis of behaviour and foraging activity (Ford *et al.*, 1985; 1986). Homogeneity in the variances of the data sets was tested using Levene's test. In cases where heterogeneity was detected ($P < 0.05$), the necessary transformations were applied. All the statistics were done using MINITAB™ statistical software.

Canonical Correspondence Analysis (CCA) was used to illustrate the relationship between assemblages of bird species and their environment. CCA is a multivariate method that is designed to extract synthetic environmental gradients from ecological data. The gradients are the basis for briefly describing and visualizing the differential habitat preferences of species through an ordination diagram (ter Braak, 1986; ter Braak & Verdonschot, 1995). A set of community samples (e.g., bird counts) and associated environmental measurements (e.g., canopy height, grass cover, % of dieback, etc) typically yields an enormous amount of noisy data making it difficult to interpret. Multivariate methods provide a means to structure the data by separating systematic variation from noise (Gauch, 1982). The CCA takes into account the unimodal relationships between species and environmental variables. It is also suitable for incidence data (presence/absence) even if abundance is measured quantitatively (e.g., number of individual birds or biomass of each species present). The above reasons make canonical correspondence analysis suitable compared to other traditional linear-based multivariate methods (ter Braak, 1986; ter Braak & Verdonschot, 1995).

Forty-eight bird species were analysed from all the sampling points over four seasons ((32 + 32) x 4). Thus, the abundance table contains 48 x 256 non-negative values. The number of species per sampling point varied between 11 and 22. The

number of occurrences per species varied between 1 and 29 points. Some species occurred only a few times and could have been deleted without much influence on the analysis. The Canonical Correspondence Analysis (CCA) was performed on a matrix of 48 species and 256 sampling point visits and a secondary matrix of 18 environmental variables. This leads to an ordination diagram, in which points represent species and sampling points and vectors represent habitat variables, illustrating the position of bird species, sites and habitat variables along the major axes (ter Braak & Prentice, 1988). Canonical correspondence analysis was done using a package called CANOCO™ version 4.5 (ter Braak & Smilauer, 1998).

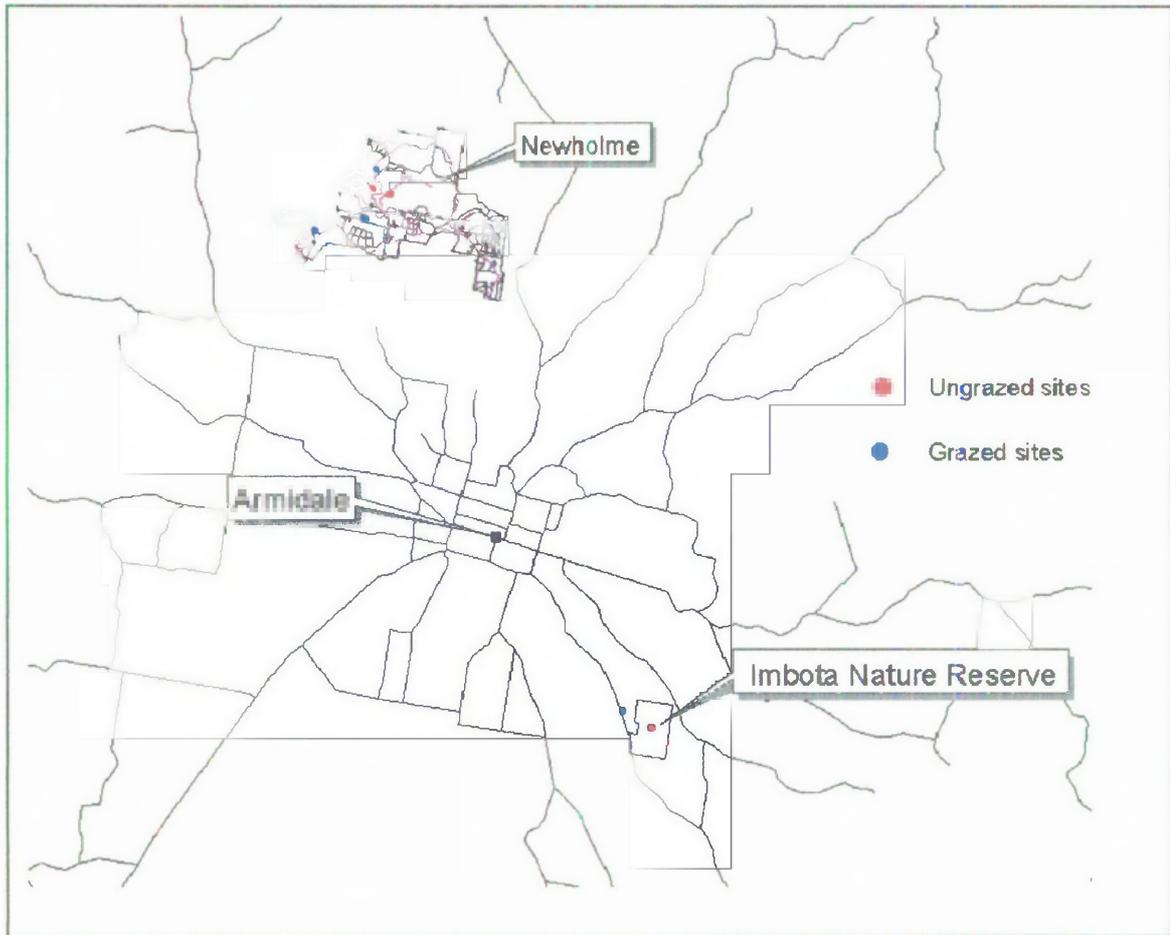


Fig. 3.1. Location map of study areas within 20 km of New England, Armidale. The clusters of sampling points lay around the dots in grazed (blue) and ungrazed (red) plots.

There were 5 plots, representing clusters of sampling points in the Newholme Property with three in grazed plots (Dumaresq Dam, Newholme and Mt. Duval) and two in ungrazed plots (Newholme and Mt. Duval). Another cluster of sampling points in Imbota Nature Reserve representing the largest and least modified woodland remnant near Armidale and on adjacent private property, which represents grazed plots as it had been grazed by sheep, horse and perhaps by cattle. In total there were seven study plots: four in grazed sites, and three in ungrazed sites.

A total of 64 sampling points were chosen: 32 in grazed plots and 32 in ungrazed plots. The sampling points in grazed plots included seven on private



Fig. 3.4. Ungrazed site in eucalypt woodland at Imbota Nature Reserve.



Fig. 3.5. Gazed site in eucalypt woodland at private property near Imbota Nature Reserve.



Fig. 3.2. Grazed site in eucalypt woodland at Newholme Property.



Fig. 3.3. Ungrazed site in eucalypt woodland at Newholme Property.



Fig. 3.6. Monthly maximum and minimum temperature (°C) for Armidale from September 2000 to September 2001.

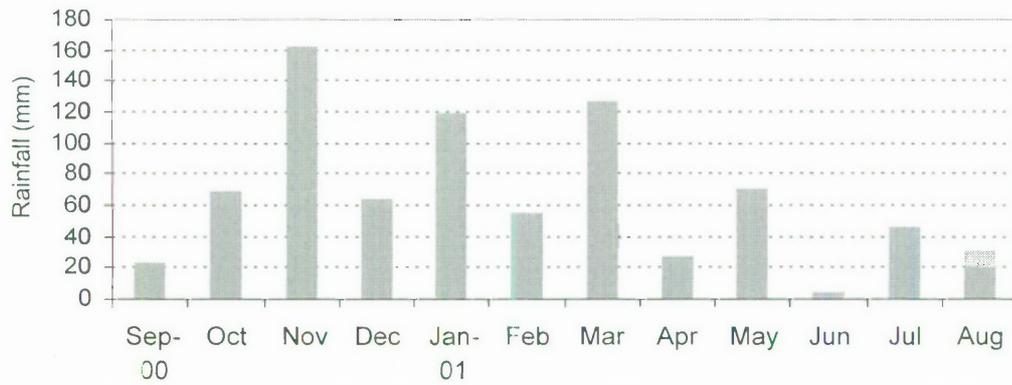


Fig. 3.7. Monthly rainfall (mm) for Armidale from September 2000 to September 2001.

CHAPTER 4

RESULTS

4.1. COMPOSITION OF BIRD ASSEMBLAGES

Fifty-one species of birds were recorded at the study plots, with several additional species such as Tawny Frogmouth, Brown Goshawk, Diamond Firetail, and Satin Flycatcher being encountered outside the sample points and census periods. Three species, Channel-billed Cuckoo, Jacky Winter and Fan-tailed Cuckoo, were detected only in one or two plots in only one season and consequently were excluded from further analysis. For subsequent analyses, a total of 910 birds representing 48* species were considered with 422 individuals from 45 species occurring in grazed, and a total of 488 individuals of 46 species in ungrazed plots (Appendices 1a & 1b). Crested Shrike-tits in all seasons, and Yellow-rumped Thornbills in autumn, were recorded exclusively in ungrazed plots and Australian Magpie-larks were recorded exclusively in grazed plots in spring and summer (Table 4.1).

Table 4.1: Bird species detected exclusively in either grazed or ungrazed plots in New England study area in one or more seasons. (+) mark indicates the presence of that species.

Species	Grazed plots				Ungrazed plots			
	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win
Australian Magpie-lark	+	+		-	-	-	-	-
Crested Shrike-tit	-	-		-	+	+	+	+
Yellow-rumped Thornbill	-	-		-	-	-	+	-

* Scientific names given in Appendix 2.

The species recorded in the study plots were divided into three different ecological guilds based on their behaviour and foraging activity (Ford *et al.*, 1985; 1986). The bird community was made up of 28 canopy foragers, 15 ground foragers and 4 shrub dwellers (Fig. 4.1).

Five species occurred significantly more often in ungrazed plots, and four species more in grazed plots (Table 4.2). Three of the birds found more in the grazed plots were large-bodied birds, and all of the species found more in the ungrazed plots were small insectivores that forage at various levels.

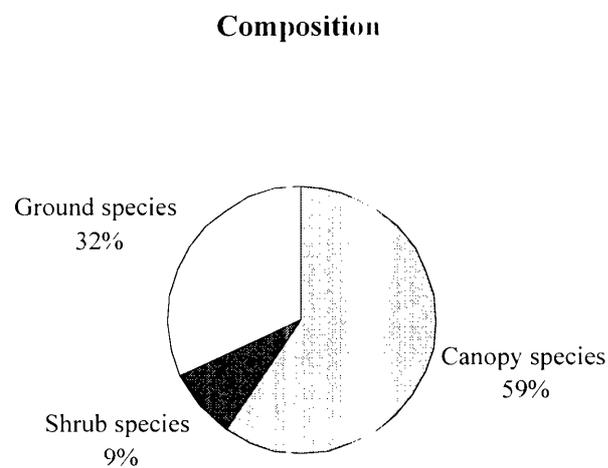


Fig. 4.1. Percentage composition of species of the three ecological guilds recorded at the New England study area.

Table 4.2. Number of sampling points containing each species that occurred significantly more often in grazed or ungrazed plots in New England study area.

Species		Number of sample points	
		Grazed	Ungrazed
Crimson Rosella	9.05**	28	17
Red Wattlebird	5.74**	26	17
Laughing Kookaburra	9.33**	25	13
Eastern Spinebill	4.27*	16	8
Buff-rumped Thornbill	5.74**	17	26
Striated Thornbill	6.34**	13	23
Leaden Flycatcher	4.65*	6	14
Golden Whistler	6.49**	4	13
Speckled Warbler	7.819**	2	11

* P < 0.05, ** P < 0.01, *** P < 0.001,

4.2. BIRD ASSEMBLAGE STRUCTURE ALONG HABITAT VARIABLES

Canonical Correspondence Analysis (CCA) was performed on a matrix of abundance of 48 bird species and 18 habitat variables using all counts, that is, four seasons by 64 plots. The result of CCA indicates that the two axes explained 4.8 % of variance in the species data and 35.4 % of species-habitat relation in the grazed plots and ungrazed plots (Table 4.3a). This indicates that bird species composition at the two plots is not well separated, though habitat is more clearly so.

Table 4.3: . a) Mean values for each of the habitat variables for grazed and ungrazed sites in New England, with p value for comparisons between grazed and ungrazed values. b) CCA performed on a matrix of abundance of 48 bird species and 12 habitat variables and four seasons, plus grazed/ungrazed, for the New England study area. c) Correlations between habitat variables and the first two axes of the CCA.

a) Habitat Variable	Grazed	Ungrazed	P value
Canopy Height	17.3	17.2	0.971
% Dieback	6.72	5.29	0.414
% Grass Cover	5	19.3	0.312
% Droppings	74.8	50.9	0.000*
% Shrub Cover	9.7	22.1	0.003*
No. of Gums	1.66	4.72	0.011
No. of Boxes	3.09	2.79	0.766
No. of Stringybarks	12.4	10.7	0.355
No. of Shrub Species	1.22	1.69	0.021
No. of Logs	4.41	3.14	0.138
No. of Mistletoes	4.25	2.38	0.147
No. of Dead Trees	1.75	1.76	0.987

* significant, using Bonferroni correction

b)	Axis 1	Axis 2
Eigenvalues	0.22	0.19
Species-habitat correlations	0.73	0.68
Cumulative % variance of species data	2.60	4.80
Cumulative % species-habitat relation	18.80	35.40

c)	Axis 1	Axis 2
Habitat variables		
Canopy height	-0.027	0.333
% Dieback	-0.055	0.040
% Grass cover	0.046	0.017
Number of droppings	-0.356	-0.329
% Shrub cover	-0.363	0.312
No. Gums	0.269	-0.167
No. Box	-0.022	0.139
No. Stingybarks	-0.084	0.144
No. Shrub species	-0.054	0.088
No. Fallen trees	-0.435	0.131
No. Mistletoes	-0.186	-0.036
No. Dead trees	-0.399	0.022
Grazed	-0.228	-0.434
Ungrazed	0.228	0.434
Spring	-0.064	0.199
Summer	-0.032	-0.366
Autumn	-0.043	-0.116
Winter	-0.043	-0.116

Two ordination diagrams were constructed to aid the visual interpretation of how sampling points (Fig. 4.2a) and bird species (Fig. 4.2b) were separated along the axes. The arrangement of the sampling point (represented by a small cross) in the ordination diagram (Fig. 4.2a) is defined by the presence of similar bird assemblages in relation to the habitat variables.

In the ordination diagrams (Fig. 4.2a), the sampling points were scattered almost uniformly and did not separate into discrete clusters. The length of each arrow corresponds to the importance of each habitat variable. Important habitat variables therefore tend to be represented by longer arrows than less important habitat variables (ter Braak, 1986). The correlation values of the habitat variables and the ordination axes are given in Table 4.3b. Among the habitat variables, only number of gums, number of droppings, canopy height, shrub cover, number of fallen logs and number of dead trees, grazed and ungrazed variables were more important than other habitat variables in determining the structure of bird assemblages (Fig. 4.2a). The number of droppings showed a close association with the grazed variable, whereas canopy height tends to show an inclination towards the ungrazed variable. Other variables did not appear to be associated strongly with either grazed or ungrazed variables (Fig. 4.2a).

White-winged Chough, Crested Shrike-tit, Golden Whistler, Little Lorikeet, Varied Sittella, Striated Thornbill and Yellow-rumped Thornbill fall towards the ungrazed end of the diagram (upper right hand corner of Fig. 4.2b). Varied Sittella is also strongly associated with canopy height. Species such as Sacred Kingfisher, Restless Flycatcher, Willie Wagtail, Noisy Miner, Australian Magpie and Australian Magpie-lark are towards the grazed end (bottom of Fig. 4.2b). Sacred Kingfisher, though, falls in the group because it is a summer visitor. Dusky Woodswallow, Fuscous Honeyeater, Eastern Rosella, Silvereye, Black-faced Cuckoo-Shrike, Rufous

Whistler and Olive-backed Oriole are associated with the number of gums. White-eared Honeyeater, Galah and Eastern Spinebill are associated with the number of dead trees, fallen logs, though perhaps number of mistletoes may be associated with the honeyeaters. White-browed Scrubwren and Superb Fairy-wren occur more towards the percentage of shrub cover (Fig. 4.2b). Other species occur more toward the centre in the ordination diagram (Fig. 4.2b), and therefore are not particularly associated either with grazed and ungrazed plots or with any of the other habitat variables.

1.0

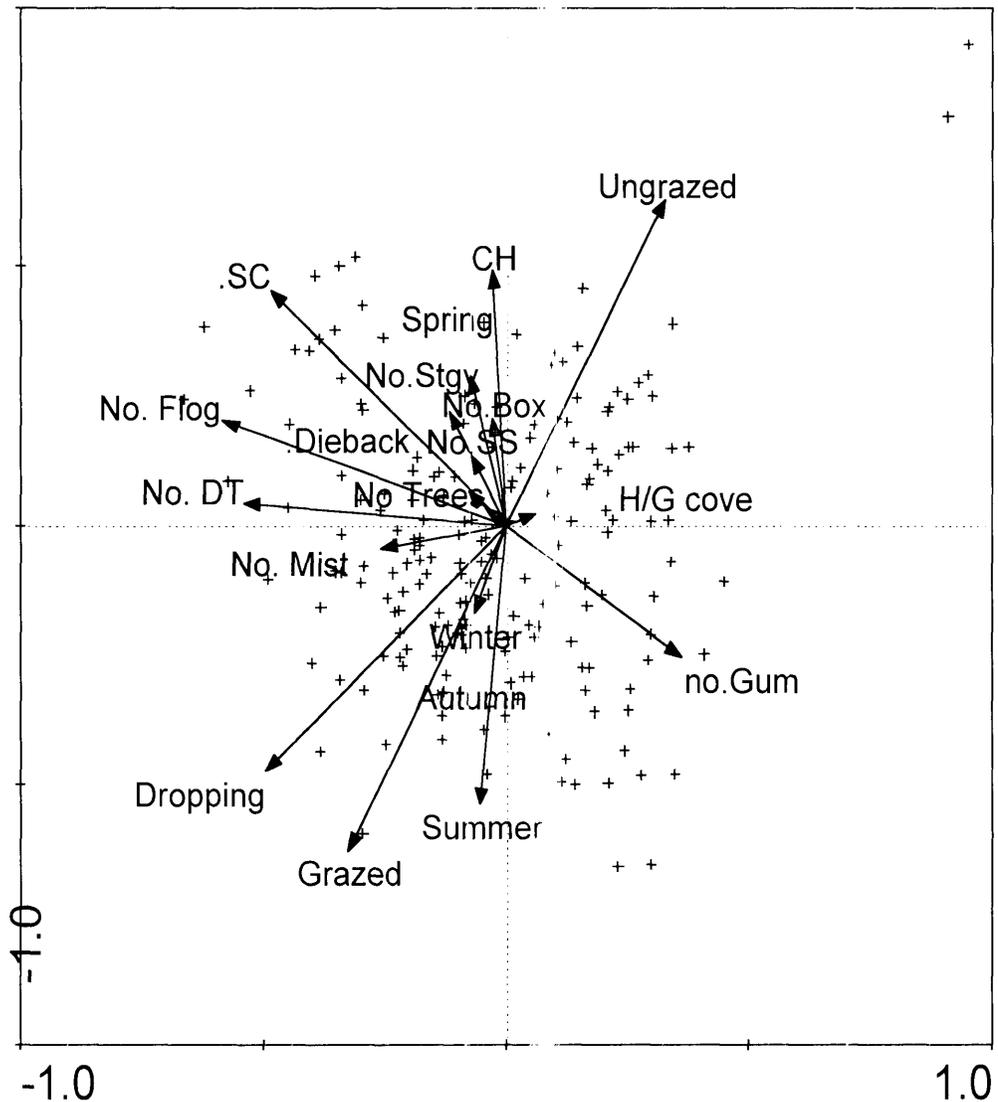


Fig. 4.2a. Canonical Correspondence Analysis (CCA) ordination diagram with 256 sampling points (+) and 18 habitat variables (arrows) in the New England study area; first axis is horizontal, second axis is vertical. Longer arrows exhibit a greater correlation with the ordination axes than habitat variables with short arrows. The composition birds defined the position of sampling point (+) with respect to the habitat variables. The habitat variables are: CH = canopy height, No. DT = number of dead trees, SC = shrub cover, No. Stgy = number of Stringybarks, No. Box = number of Box, H/G Cover = herb/grass cover, No. Mist = number of mistletoes, No. Flog = number of fallen logs, no. Gum = number of gums, No. Trees = number of trees (gums + box + stringybarks), Dropping = number of herbivore droppings, spring, summer, autumn, winter, grazed and ungrazed.

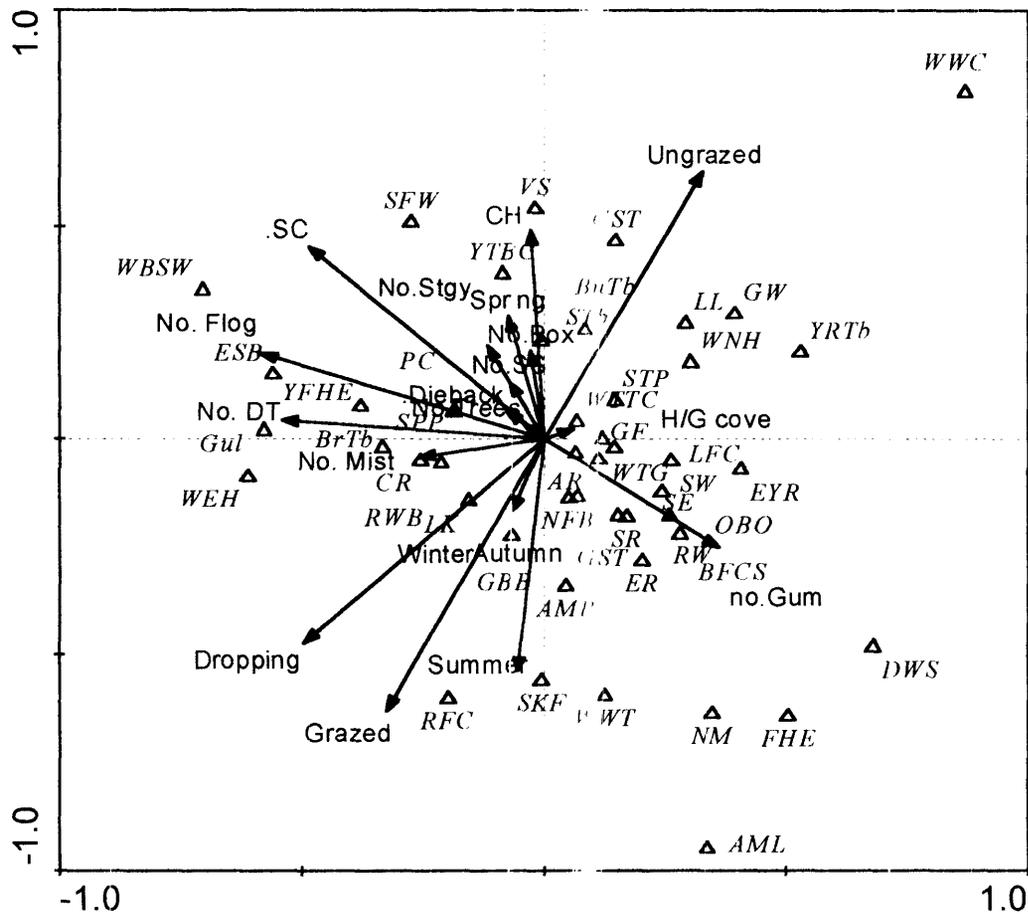


Fig. 4.2b. Canonical Correspondence Analysis (CCA) ordination diagram with 48 bird species (small triangle) and 18 habitat variables (arrows) in the New England study area; first axis is horizontal, second axis is vertical. The habitat variables are shown in Fig. 4.2a. The bird species shown are: AMP = Australian Magpie, AML = Australian Magpie-lark, AR = Australian Raven, BuTb = Buff-rumped Thornbill, BrTb = Brown Thornbill, BFCs = Black-faced Cuckoo Shrike, CR = Crimson Rosella, CST = Crested Shrike-tit, DWS = Dusky Woodswallow, ER = Eastern Rosella, ESB = Eastern Spinebill, EYR = Eastern Yellow Robin, FHE = Fuscous Honeyeater, GF = Grey Fantail, Gal = Galah, GBB = Grey Butcherbird, GST = Grey Shrike Thrush, GW = Golden Whistler, LK = Laughing Kookaburra, LL = Little Lorikeet, LFC = Leaden Flycatcher, NM = Noisy Miner, NFB = Noisy Friarbird, OBO = Olive-backed Oriole, PC = Pied Currawong, RW = Rufous Whistler, RFC = Restless flycatcher, RWB = Rufous Wattlebird, SKF = Sacred Kingfisher, SFW = Superb Fairy-wren, SE = Silvereye, STb = Striated Thornbill, SPP = Spotted Pardalote, SW = Speckle Warbler, SR = Scarlet Robin, STP = Striated Pardalote, VS = Varied Sittella, WTTC = White-throated Treecreeper, WBSW = White-browed Scrub-wren, WTG = White-throated Gerygone, WNH = White-naped Honeyeater, WWC = White-winged Cough, WEH = White-eared Honeyeater, WWT = Willie Wagtail, YFHE = Yellow-faced Honeyeater, YRTb = Yellow-rumped Thornbill, YTBC = Yellow-tailed Black Cockatoo.

4.3. SPECIES RICHNESS AND SEASONAL VARIATION

Prior to the repeated measures ANOVA, Levene's homogeneity tests were applied to detect the heterogeneity in variance and transformations were made where necessary as shown in the ANOVA tables (Table 4.4 to 4.7). Overall bird species richness did not differ significantly between grazed and ungrazed plots (Table 4.4). However, there was a significant effect of season on overall species richness. More species were recorded in spring and summer than in autumn and winter (Fig 4.3).

There was no season by plot (grazed/ungrazed) interaction on overall bird species (Table 4.4).

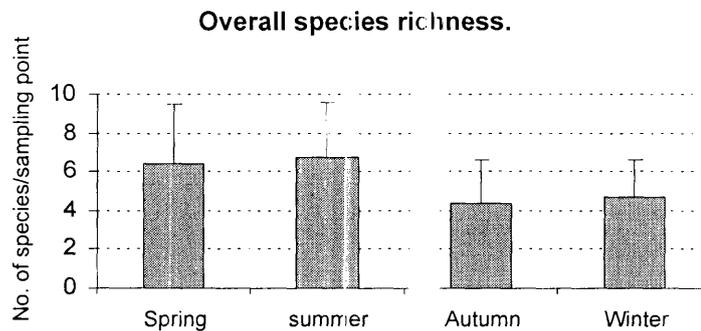


Fig. 4.3. Mean number of bird species per sampling point in New England study area in four seasons.

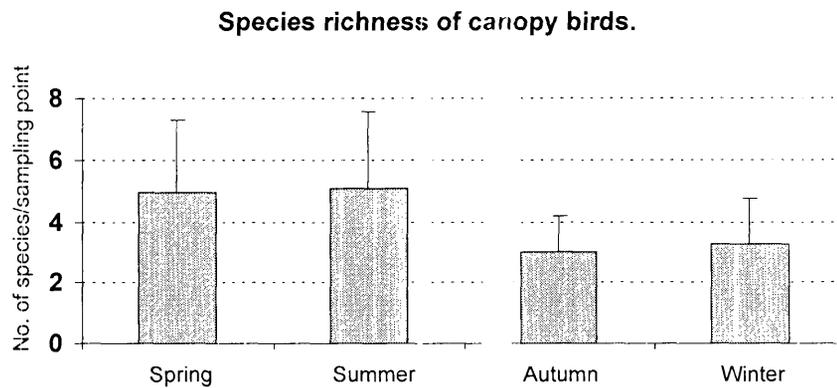


Fig. 4.4. Mean number of canopy bird species per sampling point in New England study area in four seasons.

The plot (grazed/ungrazed) did not have a significant effect on canopy, shrub or ground species richness. However, there was a significant effect of season on canopy bird species richness only (Table 4.5). This may be due to the fact that more canopy species are recorded with few individuals. The number of canopy bird species per sample point was again higher in spring and summer than autumn and in winter (Fig 4.4). Shrub and ground bird species did not vary significantly between the seasons (Table 4.6 and 4.7). There was no season by plot interactions for species richness in any of the three ecological guilds.

Table 4.4: The results of repeated-measures ANOVA for overall species richness and abundance in New England grazed and ungrazed plots. The results of Levene's homogeneity of variance test and subsequent data transformation are also given.

Source of variation	Species Richness				Abundance			
	Df	MS	F	P	Df	MS	F	P
Plot (P)	1	0.02	0.04	ns	1	9.38	0.19	ns
Error	62	0.42			62	49.31		
Season (S)	3	3.56	10.87	***	3	73.93	2.36	ns
P x S	3	0.15	0.46	ns	3	28.52	0.91	ns
Error	186	0.33			186	31.27		
Levene's Test	-		3.07*				1.72 ^{ns}	
Transformation	Square-root.							

* P < 0.05, ** P < 0.01, *** P < 0.001, ns P > 0.05.

Table 4.5: The results of repeated-measures ANOVA for canopy bird species richness and abundance in New England grazed and ungrazed plots. The results of Levene's homogeneity of variance test and subsequent data transformation are also given.

Source of variation	Species Richness				Abundance			
	df	MS	F	P	Df	MS	F	P
Plot (P)	1	0.02	0.05	ns	1	0.03	0.03	ns
Error	62	0.37			62	1.00		
Season (S)	3	4.79	15.56	***	3	3.37	4.77	**
P x S	3	0.14	0.45	ns	3	0.26	0.37	ns
Error	186	0.31			186	0.71		
Levene's Test	-		3.67*		-		2.14*	
Transformation	Square-root				Square-root			

* P < 0.05, ** P < 0.01, *** P < 0.001, ns P > 0.05.

Table 4.6: The results of repeated-measures ANOVA for shrub bird species richness and abundance in New England grazed and ungrazed plots. The results of Levene's homogeneity of variance test and subsequent data transformation are also given.

Source of variation	Species Richness				Abundance			
	df	MS	F	P	Df	MS	F	P
Plot (P)	1	0.00	0.01	ns	1	5.35	1.15	ns
Error	62	0.45			62	4.65		
Season (S)	3	0.42	2.06	ns	3	5.74	3.02	*
P x S	3	0.15	0.73	ns	3	3.70	1.95	ns
Error	186	0.20			186	1.90		
Levene's Test	-		0.92 ^{ns}		-		1.85 ^{ns}	
Transformation	-				-			

* P < 0.05, ** P < 0.01, *** P < 0.001, ns P > 0.05.

Table 4.7: The results of repeated-measures ANOVA for ground bird species richness and abundance in New England grazed and ungrazed plots. The results of Levene's homogeneity of variance test and subsequent data transformation are also given.

Source of variation	Species Richness				Abundance			
	df	MS	F	P	Df	MS	F	P
Plot (P)	1	0.18	0.64	ns	1	15.50	2.08	ns
Error	62	0.26			62	7.47		
Season (S)	3	0.04	0.16	ns	3	4.65	0.47	ns
P x S	3	0.45	1.90	ns	3	16.13	1.62	ns
Error	186	0.24			186	9.99		
Levene's Test					ns		1.35 ^{ns}	
Transformation	Root-root		67.7 ^{***}					

*P < 0.05, ** P < 0.01, *** P < 0.001, ns P > 0.05.

4.4. ABUNDANCE OF BIRDS AND SEASONAL VARIATION

There was no significant difference between grazed and ungrazed plots in the abundance of birds or between the different seasons (Table 4.4). There was also no significant interaction between the plots (grazed/ungrazed) and season. The mean overall bird abundance for each season is given in Fig. 4.5.

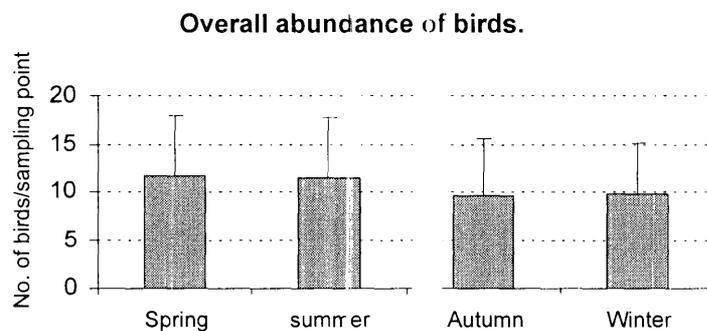


Fig. 4.5. Mean number of birds per sampling point in New England study area in four seasons.

There was no significant difference in abundance of the three ecological guilds - canopy, shrub and ground birds, between grazed and ungrazed plots (Table 4.5, 4.6, and 4.7). However, the abundance of canopy and shrub birds changed seasonally, with the former being significantly more common in spring and summer than winter and autumn, and the latter being least common in summer and most common in winter (Fig 4.6 and 4.7). The abundance of ground birds did not vary significantly among the seasons (Table 4.7). There was no significant season by plots (grazed/ungrazed) interactions on the abundance of any of the three ecological guilds.

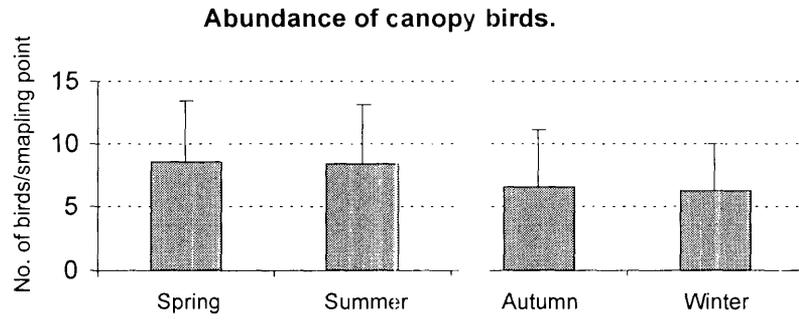


Fig. 4.6. Mean number of canopy birds per sampling point in New England study area in four seasons.

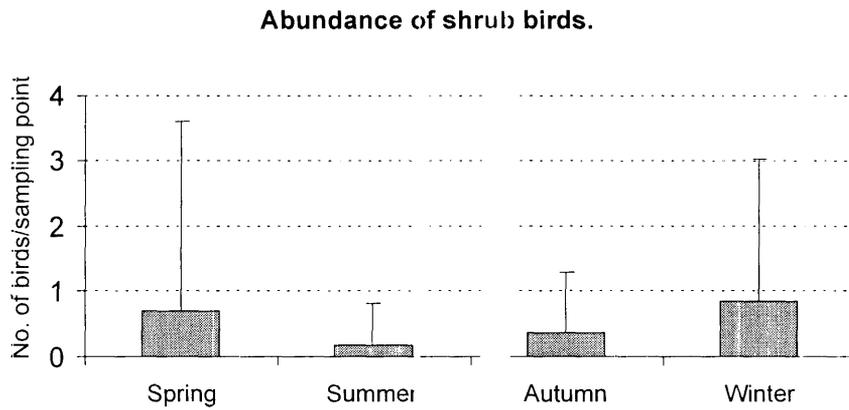


Fig. 4.7. Mean number of shrub birds per sampling point in New England study area in four seasons.

CHAPTER 5

DISCUSSION

5.1. COMPOSITION OF BIRD ASSEMBLAGES

The composition of bird assemblages in eucalypt woodlands in New England associated with grazed or ungrazed sites can be shown in three ways: 1) species recorded in grazed or ungrazed plots only, 2) species recorded significantly more often in grazed or ungrazed plots and 3) species lying towards grazed or ungrazed axes in Canonical Correspondence Analysis (CCA). The latter included several species identified by the first two methods

The study showed that each of the grazed and ungrazed sites had differing species composition, although the amount of variation accounted for by bird species was small (4.8 %). The Crested Shrike-tit and Yellow-rumped Thornbill occurred exclusively in the ungrazed sites. In addition to this, five species of small, common woodland birds (Speckled Warbler, Buff-rumped Thornbill, Golden Whistler, Leaden Flycatcher and Striated Thornbill) were found significantly more frequently in ungrazed sites. The ordination diagram also displayed an association of several others (White-winged Chough, Little Lorikeet and Varied Sittella) with ungrazed sites.

The Crested Shrike-tit and Speckled Warbler have experienced an overall decline in the Wheat-Sheep belt region of South-east Australia (Barrett *et al.*, 1994; Reid, 1999). All the Crested Shrike-tits and Speckled Warblers that I observed were at Imbota Nature Reserve (Appendix 1b), which is protected from livestock grazing. The former feeds on invertebrates taken from beneath ribbons of peeling bark, preferably on Yellow Box *E. melliodora* (Ford *et al.*, 1985; Emison *et al.*, 1987), which was abundant at Imbota. Speckled Warblers forage on the ground with litter and light herb/grass cover (Ford *et al.*, 1985). They also nest on or close to the ground.

Most of the other species associated with the ungrazed sites are dependent on healthy woodland with a dense grassy or shrubby understorey (Robinson, 1993; Barrett *et al.*, 1994; Robinson & Traill, 1996). All these species are either bark-foragers or foliage/aerial insectivorous (Blakers, *et al.*, 1984; Recher & Holmes, 1985; Ford *et al.*, 1985) with the exception of the nectarivorous Little Lorikeet and ground foraging White-winged Chough. There is a positive correlation between the density of foliage insectivores and foliage cover, between bark-foragers and the area of bark; and between ground-foragers and annual litter fall (Gilmore, 1985). Most of these microhabitats may be relatively more abundant in ungrazed sites than grazed sites. Apart from that, competition with other birds may push a species out of a habitat that it would otherwise have been able to occupy. Therefore the occurrence of the small insectivores such as Varied Sittella, Striated Thornbill and Yellow-rumped Thornbill in ungrazed sites may be due to the availability of intact understorey and the low abundance of Noisy Miners (Barrett, 1995). Noisy Miners are strongly associated with degraded woodland (Grey *et al.*, 1998) but occur in the ordination diagram opposite to dead trees and dieback (although the latter shows only very weak association with either axis). Catterall *et al.* (1991) suggested that small insectivorous birds were deterred from foraging at the edge of forest patches due to presence of large, aggressive species such as Noisy Miners. However, sites with abundant Noisy Miners were intentionally avoided in the current study.

It is also worth mentioning that several of these species, except for Leaden Flycatchers, take part in Mixed Species Flocks (MSF), the core of which is usually formed by species like Buff-rumped and Striated Thornbills, which Varied Sittellas and Golden Whistlers tend to follow (Sedgwick, 1949; Bell, 1980; 1985).

The presence of Yellow-rumped Thornbills only in ungrazed sites was contradictory to the findings of other studies. Arnold & Weeldenburg (1998) and Watson *et al.* (2000) found that Yellow-rumped Thornbills were more common in open, degraded habitats with little shrub cover. This discrepancy may be due to chance as the species was only recorded in one season (autumn) during my study.

Except for the Eastern Spinebill, a suite of open country species such as Noisy Miner, Australian Magpie, Australian Magpie-lark, Sacred Kingfisher, Restless Flycatcher, Willie Wagtail, Crimson Rosella, Red Wattlebird and Laughing Kookaburra were recorded either significantly more often or occurred highly associated with the grazed axis in the ordination diagram, in addition to exclusive records of the Australian Magpie-lark in the grazed sites. Similar trends were also observed by Ford and Bell (1980) in the Armidale area in sites affected to varying degrees by dieback. They attributed this to the loss of understorey cover, which resulted in greater exposure of the nests of small birds to predation and weather, as a probable reason for the lower abundance of small insectivorous birds.

Some of these species are large birds and feed most often in open ground, eating insects or other items, but they also perch and nest in trees (Blakers *et al.*, 1984; Catterall *et al.*, 1991). Moreover several of these species have benefited from fragmentation and degradation of woodland and are associated with the grazing of introduced livestock (Barrett *et al.*, 1994; Robinson & Traill, 1996). Jansen & Robertson (2001) also listed most of these species to be grazing tolerant in the floodplain woodlands of South-Eastern Australia and suggested that grazed areas may be more suitable than ungrazed areas for these species.

The occurrence of the Sacred Kingfisher with the rest of this group (i.e. towards the centre bottom in Fig. 4.2b) may be because it is a summer visitor rather

than being associated with grazed sites. Ford & Bell (1981) also recorded this species in summer in their study sites near Armidale, NSW. The occurrence of the Eastern Spinebill in grazed sites is less easy to explain, and in the ordination diagram it occurs perpendicular to the grazed-ungrazed axis. Fisher & Goldney (1997) did not record the species from grazed sites. It is possible that it is more linked to the abundance of mistletoes. Also the significantly greater occurrence of Crimson Rosella in grazed sites is inconsistent with Barrett *et al.*, (1994). Crimson Rosellas usually prefer woodland with intact understorey and have been frequently sighted in healthy woodlands (Barrett *et al.*, 1994; Barrett 1995). Again the ordination diagram does not indicate a close association with grazed sites, but possible links with mistletoes or dead trees. Two other studies also showed that the Laughing Kookaburra was more abundant in least grazed or ungrazed woodland (Fisher & Goldney 1997; Jansen & Robertson 2001). Probably their abundance in grazed plots may be linked to their greater abundance at Newholme near the Dumaresq Dam, which had more grazed sites.

A species dependency on the tree, shrub, ground layer, shrub layer, or canopy layer will determine which habitat is suitable for it flourish (Robinson, 1991; Garnett 1992; Mawson & Long, 1995). The ordination diagram displayed an association of White-browed Scrub-wren and Superb Fairy-wren with the percentage of shrub cover, which agrees with their preference for understorey. Dusky Woodswallow, Fuscous Honeyeater, Eastern Rosella and Black-faced Cuckoo-shrike were associated with the number of gums. These species are typically associated with open, grassy woodlands, where gums tend to predominate, rather than stringybarks (Barrett, 1995; Ford *et al.*, 1985). Many authors suggest that most birds prefer sites with dense understorey (Recher, 1969; Dobkin *et al.*, 1995; Watson *et al.*, 2000).

5.2. ABUNDANCE OF BIRDS AND SPECIES

The overall abundance of birds and individual species did not differ significantly between grazed and ungrazed sites. This could possibly be due to two reasons. Firstly, the grazed plots lay adjacent to ungrazed plots in both places, and the birds may have moved freely between the two types of plot. For example, the most heavily grazed plots were those on private land near Imbota and the grazed plots in Newholme, which lay adjacent to the ungrazed sites at Imbota Nature Reserve and Newholme respectively. The woodlands at Imbota Nature Reserve have remained undisturbed for a long time, and represent a close comparison to original woodlands. The habitat complexity could be still intact in these woodlands, which would provide suitable niches for different species to flourish and move.

Secondly, unlike other grazing related studies (Loyn, 1987; Bromham, *et al.*, 1999; Jansen, *et al.*, 2001; Watson, *et al.*, 2000), which examine more than two categories of habitats depending on the intensity of grazing, this study considered only grazed and ungrazed sites where the points in the grazed sites have been chosen carefully to be more comparable to ungrazed sites. Plots were chosen so that even the grazed sites had a fairly similar number of trees, amount of shrub understorey herbaceous layer as the ungrazed sites restricting the variation in other factors as far as possible. This is quite evident from the fact that the habitat variables did not show any significant difference in the grazed and ungrazed sites except for the herbivore droppings, which are undoubtedly associated with the grazed sites. Therefore, habitat variables measured did not show any distinctive difference between the grazed and ungrazed sites. Consequently, insignificant difference in bird species abundance is not surprising.

There was seasonal variation in the bird species. More species were recorded in summer and spring than autumn and winter. This was probably due to the arrival of summer visitors such as Sacred Kingfisher, Leaden Flycatcher and Olive-backed Oriole (Ford & Bell, 1981). The total number of species ranged from 35 in winter to 41 in summer. Most of these species are known to show marked seasonal variation (Ford *et al.*, 1985). There was no significant interaction between plot type (grazed/ungrazed) and season indicating less seasonal influence on the abundance of bird species between grazed and ungrazed sites. However, long-term observations are needed to trace out clearly the seasonal influence on the diversity and assemblage of birds in grazed and ungrazed sites.

5.3. CONCLUSION

Clearly, the diversity and abundance of bird species did not differ significantly between grazed and ungrazed sites, but the bird assemblages showed a distinct pattern. On grazed plots there was an occurrence of larger birds, which are mostly open-country species and known to benefit from anthropogenic changes. A collection of small insectivores in ungrazed sites suggests that these sites are probably used more often by these kinds of species. Moreover, two of the species (Crested Shrike-tit and Speckled Warbler) recorded in ungrazed sites are regarded as declining in agricultural land, which suggests that undisturbed sites provide a more diverse range of microhabitats that are essential for the survival of certain species. These species are likely to be affected by continued grazing and clearing of their habitat. Retention and management of understorey in woodland remnants has been advocated as essential for conservation of these species, both of which are declining in the pastoral areas of NSW (Reid, 1999; Seddon *et al.*, 2001).