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Is Landscape Context Important for Riparian Conservation? Birds in Grassy Woodland

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Abstract

An important challenge for riparian management is to determine the extent to which landscape context influences the faunal assemblages of riparian habitats. We examined this challenge in the variegated landscapes of southeastern Queensland, Australia where riparian vegetation is surrounded by both extensive grazing and intensive cropping. We investigated whether riparian habitats adjacent to different landuses support similar bird assemblages. Three types of riparian habitat condition were sampled (uncleared ungrazed; uncleared grazed; cleared grazed) in four different land-use contexts (ungrazed woodland; grazed woodland; native pasture; crop) although only six of the 12 possible treatment combinations were available. Eighty percent of bird species responded significantly to changes in both riparian habitat condition and landscape context, while fewer than 50% of species were significantly influenced by landscape context alone. The influence of landscape con-text on the bird assemblage increased as the surrounding land use became more intensive (e.g., woodland to native pasture to crop). Riparian zones have been shown to have consistently high biodiversity values relative to their extent. These findings suggest it is not enough to conserve riparian habitats alone, conservation and restoration plans must also take into consideration landscape context, particularly when that context is intensively used land.

Keywords: riparian restoration; eucalypt woodland; livestock grazing; landscape matrix; noisy miner; stream management

1. Introduction

Vegetation structure, resource availability and habitat size have long been used to explain the diversity, distribution and abundance of bird species (Arrhenius, 1921, MacArthur and MacArthur, 1961 and Willson, 1974). The broader landscape in which a habitat is situated, here referred to as the landscape context, may play just as great a role in explaining avian diversity as local habitat characteristics (Wiens, 1989, Saunders et al., 1991, Pearson, 1993, McGarigal and McComb, 1995, Sisk et al., 1997, Mazerolle and Villard, 1999, Saab, 1999, Renjifo, 2001, Ricketts et al., 2001 and Heartsill-Scalley and Aide, 2003). With increasing emphasis placed on the conservation of riparian zones, and significant resources being allocated for their restoration, an understanding of the effect of the nearby landscape has critical management implications.

Riparian zones are being modified or lost at an alarming rate (Kauffman et al., 1997). These ecosystems provide habitat for a disproportionately large number of plant and animal species relative to their area (Catterall et al., 2001) as well as essential ecosystem functions (Kauffman et al., 1997 and Naiman and Decamps, 1997). The high edge to area ratio of riparian habitats makes them vulnerable to changes in the surrounding landscape. Riparian context is therefore likely to be an important consideration in any riparian management and restoration plan.

The provision of water, timber and rich soils has made riparian habitats valuable assets to grazing and agricultural enterprises. As a result riparian habitats have undergone widespread vegetation clearing and modification, stream bank erosion, silting up of streambeds, alteration of below-ground processes, non-native weed invasions, reduced water flows and reduced water quality (Kauffman and Krueger, 1984, Robertson, 1997, Jansen and Robertson, 2001 and Kauffman et al., 2004). In grassy eucalypt woodland landscapes of eastern Australia, domestic livestock, predominantly cattle and sheep spend a large amount of their time foraging and camping within the riparian zone.

Fencing of riparian zones to manage stock is widely advocated as a way to restore biodiversity and ecosystem function of riparian habitats, yet its high cost prohibits its widespread implementation (MacLeod, 2002). Furthermore, present restoration strategies occur in the absence of knowledge of the influence of landscape context. If the broader landscape is shaping the faunal assemblages within these habitats, does restoration of the riparian zone in isolation have limited value? In particular we might ask; how important is it to conserve more riparian habitat, or improve the context of already conserved riparian habitat? For researchers to answer these questions, we need to first understand the relative importance of landscape context.

This study examines the relative influence of landscape context and local riparian habitat condition in shaping the bird assemblages of grassy eucalypt woodland vegetation and specifically addresses the following hypotheses.

1. Riparian habitats with similar local habitat condition but with different landscape contexts are likely to contain different bird species assemblages due to the influences exerted by the surrounding landscape.
2. The influence of landscape context on bird species richness, abundance and composition is likely to be greater as the intensity of the surrounding land uses increases (Martin and Possingham, 2005), as a result of changes in habitat suitability (Ries and Sisk, 2004).
3. With increasing intensity of the use of the wider landscape, the riparian bird assemblage will become less rich, the abundance of 'edge specialist' bird species such as noisy miners, *Manorina melanocephala* (Piper and Catterall, 2003), members of the family Corvidae and Artamidae (Piper et al., 2002), exotic birds and native generalist foragers will increase as will overall mean bird body size (Wiens et al., 1985). Conversely the abundance of small-bodied woodland/forest species will decline.
4. Riparian habitats with different local habitat condition are likely to contain different bird species assemblages regardless of similar landscape contexts.

While several studies have examined the influence of landscape context on fauna of different habitat types (Lindenmayer et al., 1999, Mazerolle and Villard, 1999, Wolff et al., 2002, Brotons et al., 2003, Collinge et al., 2003 and Shriver et al., 2004) this is the first to examine the influence of landscape context specifically on birds of the riparian zone.

2. Methods

2.1. Study location

The study region is located in the Southeast Queensland Bioregion, Australia (Sattler and Williams, 1999). The sample area is bounded by 26–28°S and 151–153°E and covers an elevation range of 300–550 m. The climate is sub-tropical with most rain falling in summer, and frosts occurring between May and September. Annual rainfall is approximately 960 mm with a temperature averaging 17–28 °C in summer and 5–16 °C in winter. Temperatures drop below freezing across most of the study region in winter.

The native vegetation is grassy eucalypt woodland and forest. At the time of this study the landscape state was variegated, that is, native vegetation comprised the majority of the landscape matrix (McIntyre and Hobbs, 1999) with approximately 30% of the study region covered in woodland/forest, over 50% in modified native vegetation and less than 20% intensively used land. Modified native vegetation was altered to various degrees by tree clearing and livestock grazing (main land use in the region). Intensive land uses such as cropping and sown pastures were generally limited to pockets of fertile alluvial landforms. Lucerne (*Medicago sativa* L.), a low growing perennial legume, grown for livestock forage, was the dominant crop in the region. Key tree species within the riparian zones were *Eucalyptus tereticornis* and riveroak, *Casuarina cunninghamiana* and in adjacent woodland *Eucalyptus crebra* and *E. melanophloia* (Martin et al., 2000). Native grasses and forbs in the understorey provide some of the richest grasslands recorded globally (McIntyre and Martin, 2001). At the time of this study, native shrub density was low with the exotic, bird dispersed, *Lantana camara* the dominant shrub in terms of crown cover (Fig. 1).

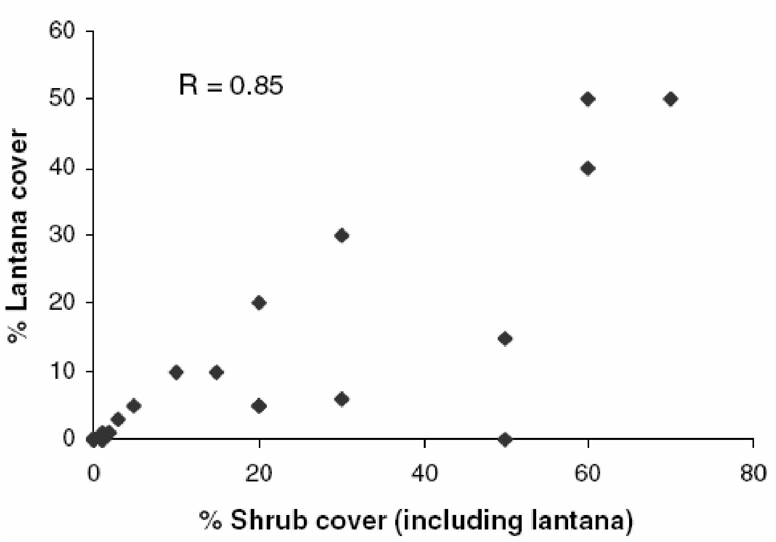

Fig. 1. Proportion of exotic shrub *Lantana camara* in the shrub understorey of grassy eucalypt woodland riparian habitats. Each point represents the average of 5 point count estimates, taken at random points in each of 48–2 ha sites, of the overall proportion of shrub cover of the site and of the proportion of *Lantana camara* cover of the site, where Pearson's correlation, $R = 0.85$.

2.2. Site selection

Two hectare (25 m by 800 m) riparian sites were located along third and fourth-order streams as determined by Australian Surveying and Land Information Group 1:250,000 drainage maps. In geographical terms, a stream of the first-order is a stream which does not have any other stream feeding into it. A stream of the second-order is one which is formed by the joining of two or more first-order streams. A third-order stream is one below the confluence of two or more second-order streams, and so forth. The landscape context treatment in which the riparian sites were situated had to be a minimum of 50 ha in extent and distributed more or less equally on either side of the riparian habitat (Fig. 2). Uncleared riparian strips (surrounded by either native pasture or crops) were on average 50 m in width including the stream bank and bed. Riparian sites were carefully chosen to have very similar vegetation structure and composition within the different contexts.

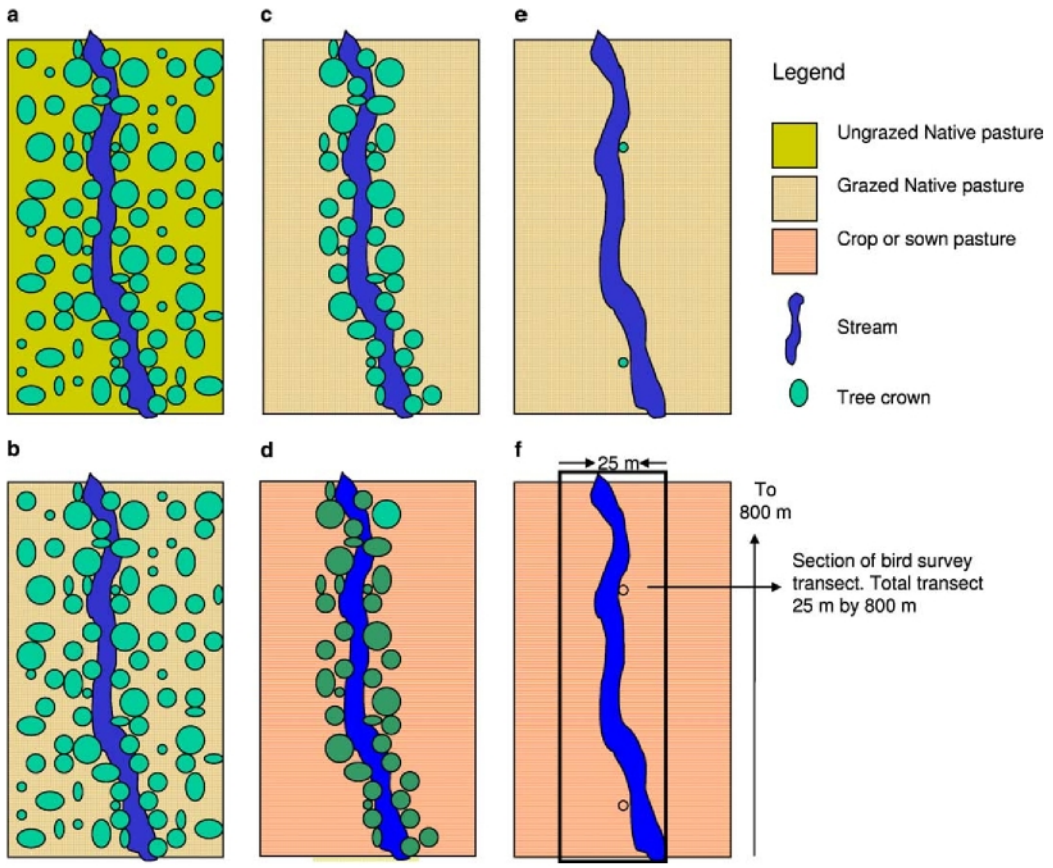

Fig. 2. Aerial representation of 50 by 100 m sections of the 25 by 800 m (2 ha) survey sites consisting of six riparian zones and their context (a) Ru-Wu; uncleared ungrazed riparian habitat surrounding by ungrazed grassy woodland (b) R-W; uncleared grazed riparian habitat surrounded by grazed grassy woodland (c) R-N; uncleared grazed riparian habitat surrounded by grazed native pasture (d) R-C; uncleared grazed riparian habitat surrounded by cropping (e) T-N; cleared grazed riparian habitat surrounded by native pasture (f) T-C; cleared grazed riparian habitat surrounded by cropping. Note the 2 ha transect was placed parallel to the riparian channel.

The vegetation structure and grazing history of a site was ascertained through discussions with landholders, and was checked for consistency with the assessed condition of the site using knowledge of vegetation dynamics and composition in the region (Martin et al., 2000, McIntyre and Martin, 2001, McIntyre and Martin, 2002, McIntyre et al., 2002 and McIntyre et al., 2003). For grazed sites, only sites with a history of moderate, selective grazing were included in this study.

2.3. Site descriptions

Our design matrix consisted of three riparian habitat types (uncleared ungrazed, uncleared grazed, and cleared grazed) each with one of four landscape contexts (ungrazed woodland, grazed woodland, native pasture, crop) (Table 1), however, only six of the possible 12 treatment combinations were available in the field making a complete factorial analysis impossible (Table 2). Instead, four analyses were conducted for the following sets of variables: individual species relative mean abundance, total species relative abundance, and total species richness. The first design examined the influence of landscape context (three levels: grazed woodland, native pasture, crop) on uncleared grazed riparian habitats (Design 1, Table 2). The second design examined the influence of landscape context (two levels: native pasture, crop) on cleared, grazed riparian habitats (Design 2, Table 2). The third design examined the influence of both landscape context (two levels: native pasture, crop) and riparian habitat condition (two levels: uncleared, cleared, Design 3, Table 2). The final design provided an indication of the influence of both riparian habitat condition (tree clearing and livestock grazing) and landscape context (tree clearing, livestock grazing and cropping) by comparing all six riparian treatments to one another, although due to the lack of a full factorial design we can only make inference about the relative importance of either landscape context or riparian habitat type (Design 4, Table 2).

Table 1.
Description of riparian habitats and landscape context

Code	Treatment description
	Riparian habitat
Ru	Uncleared riparian vegetation. Tree, shrub and native herbaceous layer present. Little or no livestock grazing (ungrazed)
R	Uncleared grazed riparian vegetation. Modified by moderate grazing. Majority of shrub layer absent due livestock grazing
T	Cleared (treeless) riparian vegetation, with mature trees and shrub layer removed. Maximum of two tree saplings present along survey transect. Moderately grazed
	Landscape context
Wu	Uncleared grassy eucalypt woodland/forest. Tree, shrub and native herbaceous layer present. Little or no livestock grazing
W	Uncleared grazed grassy eucalypt woodland/forest. Moderately grazed native herbaceous layer present b majority of shrub layer absent due to livestock grazing
N	Native pasture (cleared woodland). Moderately grazed native herbaceous layer, present. Trees cleared an shrub layer removed due to effects of livestock
C	Cropping. All native tree, shrub and herbaceous layers replaced by crops, especially lucerne (*Medicago sativa* L)

Eight replicates of each of the six combinations of riparian habitat and landscape context treatments were selected, giving a total of 48 sites. In the treatments that were uncleared, we selected sites of uniform tree density across all riparian and context treatments. Half of the riparian sites (both uncleared and cleared) contained permanent water with the remainder being ephemeral. Survey sites were stratified across an area of 1000 km^2 and the distance between sites was a minimum of 1 km.

Table 2.
Riparian habitats and context design matrix

Riparian habitat	Landscape context			
	Uncleared ungrazed woodland (Wu)	**Grazed woodland (W)**	**Native pasture (N)**	**Crops (C)**
Uncleared (Ru)	Ru-Wu[4]	–	–	–
Uncleared grazed (R)	–	R-W[1,4]	R-N[1,3,4]	R-C[1,3,4]
Cleared grazed (T)	–	–	T-N[2,3,4]	T-C[2,3,4]

Only six of the 12 possible combinations were available in the field and these are denoted as combinations of the codes in Table 1. Superscripts indicate treatments analysed in Designs 1, 2, 3 and 4 (see Table 3).

2.4. Bird sampling

Each of the 48 two hectare sites was searched by a single observer (T.G.M.) traversing the site in a single direction and recording the abundance of all bird species seen or heard during a 20 min interval, taking care to avoid double counting of birds (Barrett et al., 2003). For records based on calls, estimates of abundance were based on the number of birds calling. Surveys were repeated on two different days over each of three seasons (summer 2001/2002, winter 2002, summer 2002/2003), giving a total of 288 site visits. Sites ran parallel to the watercourse with birds being recorded on both sides. With the exception of aerial feeders (swifts, swallows and raptors), all birds flying 20 m or above the canopy were excluded. The total number of individuals recorded of each species was summed across the two visits in each season to give an index of the intensity of use of each site by each bird species, referred to as relative abundance. Comparison of relative abundance estimates are only valid if detection probabilities between sites are similar (MacKenzie et al., 2002). Due to the open structural nature of grassy eucalypt woodland and riparian habitat and the high number of records made by calls, we are confident that the detection probabilities of individual bird species did not vary across riparian habitats (Martin et al., 2005). Nomenclature follows Christidis and Boles (1994) as shown in Table 3.

Bird counts were made on fine mornings in summer (November–January) between 0445 and 0945 and in winter (June–July) between 0645 and 1145. During summer, surveys were not conducted when the temperature rose above 35 °C or during winter below −2 °C.

To avoid possible sampling biases, a restricted random visitation method was used, whereby the survey region was partitioned into six geographical regions and each region (and subsequent sites within each region) was visited randomly (Mac Nally and Horrocks, 2002).

3. Data analysis

3.1. Individual species, species richness and abundance response

Exploratory analysis using general linear models revealed that ‘season’ was not a significant explanatory variable in our analyses. We therefore pooled the data across seasons and examined the variation in individual bird species abundance, species richness and relative mean abundance using single factor (landscape context) and two factor (landscape context, riparian

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Table 3.

Summary of estimates of relative abundance $(\bar{x})$ and standard deviation (SD) from ANOVA results for four designs; Design 1, Wooded riparian (R-W, R-N, R-C), Design 2, Treeless riparian (T-N, T-C); Design 3, Riparian habitat by landscape context (R-N, R-C, T-N, T-C); Design 4, riparian habitat and context (all sites), where Freq = percent of visits in which a species occurred over *n* = 144 (6 treatments × 24 replicates) or if occurred in winter only (*n* = 48), summer only *n* = 96

Family species name	Freq	S	Abundance estimate	Uncleared grazed riparian			Cleared grazed riparian		Design number				
				Ru-Wu	R-W	R-N	R-C	T-N	T-C	1	2	3	4
Anatidae													
Australian Wood Duck	25.7	sw	$\bar{x}$	0.54	0.04	0.50	1.79	0.71b	2.92a	ns	*	C*	*
Chenonetta jubata			SD	2.11	0.20	1.35	5.27	1.40	4.78				
Pacific Black Duck	20.1	sw	$\bar{x}$	0.29	0.17	0.08	0.38	0.5b	1.25a	ns	*	H** C*	**
Anas superciliosa			SD	1.08	0.48	0.41	0.82	0.98	1.82				
Phalacrocoracidae													
Little Pied Cormorant	16.0	sw	$\bar{x}$	0.08b	0.04b	0.17b	0.13b	0.17b	0.54a	ns	ns	H*	**
Phalacrocorax melanoleucos			SD	0.28	0.20	0.38	0.45	0.48	0.66				
Ardeidae													
White-faced Heron	14.6	sw	$\bar{x}$	0.00b	0.00b	0.08b	0.17ab	0.25ab	0.46a	ns	ns	ns	**
Egretta novaehollandiae			SD			0.41	0.48	0.44	0.51				

Family species name	**Freq**	**S**	**Abundance estimate**	**Uncleared grazed riparian**			**Cleared grazed riparian**		**Design number**				
				Ru-Wu	**R-W**	**R-N**	**R-C**	**T-N**	**T-C**	**1**	**2**	**3**	**4**
Nankeen Night Heron	12.5	s	$\bar{x}$	0.24	0.08	0.58	0.26	0.00	0.26	ns	ns	ns	ns
Nycticorax caledonicus			SD	0.84	0.40	0.75	0.45		0.34				
Threskiornithidae													
Straw-necked bis	11	sw	$\bar{x}$	0.00	0.04	0.00	0.75	0.67	1.25	ns	ns	ns	ns
Threskiornis spinicollis			SD		0.20		2.05	1.66	3.26				
Rallidae													
Dusky Moorhen	11.8	sw	$\bar{x}$	0.00	0.00	0.13	0.42	0.29	0.54	ns	ns	ns	ns
Gallinula tenebrosa			SD			0.45	1.28	0.62	0.93				
Charadriidae													
Masked Lapwing	9.7	sw	$\bar{x}$	0.00b	0.00b	0.04ab	0.17ab	0.54ab	0.63a	ns	ns	H*	**
Vanellus miles			SD			0.20	0.56	1.28	1.21				
Columbidae													
Crested Pigeon	15.3	sw	$\bar{x}$	0.00	0.00b	0.21b	1.38a	0.04b	0.88a	**	***	C**	***
Ocyphaps lophotes			SD			0.59	2.00	0.20	1.42				
Cacatuidae													

Family species name	Freq	S	Abundance estimate	Uncleared grazed riparian			Cleared grazed riparian		Design number				
				Ru-Wu	**R-W**	**R-N**	**R-C**	**T-N**	**T-C**	**1**	**2**	**3**	**4**
Galah	49.3	sw	$\bar{x}$	0.58	0.41b	2.88ab	5.96a	1.46b	6.42a	**	**	C**	***
Cacatua roseica			SD	1.21	0.88	4.19	8.19	1.96	5.64				
Psittacidae													
Scaly-breasted Lorikeet	22.2	sw	$\bar{x}$	1.13ab	0.67ab	2.00a	1.42ab	0.42ab	0.00b	ns	ns	H**	*
Trichoglossus chlorolepidotus			SD	1.90	1.49	3.80	2.26	1.34					
Australian King-Parrot	12.5	sw	$\bar{x}$	0.33	0.17	0.58	0.46	0.00	0.00	ns	–	H**	ns
Alisterus scapularis			SD	0.82	0.48	1.38	0.88						
Pale-headed Rosella	39.6	sw	$\bar{x}$	0.08b	1.04b	2.42a	2.46a	0.42b	0.38b	ns	ns	H***	***
Platycercus adscitus			SD	0.41	0.95	2.69	2.57	0.65	0.97				
Red-rumped Parrot	14.6	sw	$\bar{x}$	0.00	0.08b	0.00b	1.54a	0.63	1.00	**	ns	C*	**
Psephotus haematonotus			SD		0.41		3.27	1.44	1.87				
Cuculidae													
Common Koel	5.6	sw	$\bar{x}$	0.04	0.08	0.08	0.08	0.00	0.08	ns	ns	ns	ns
Eudynamys scolopacea			SD	0.20	0.41	0.28	0.28		0.28				
Centropodidae													

Family species name	Freq	S	Abundance estimate	Uncleared grazed riparian			Cleared grazed riparian		Design number				
				Ru-Wu	R-W	R-N	R-C	T-N	T-C	1	2	3	4
Pheasant Coucal	12.5	sw	$\bar{x}$	0.00	0.13	0.42	0.08	0.33a	0.08b	ns	*	C*	*
Centropus phasianinus			SD		0.45	0.65	0.41	0.76	0.28				
Halcyonidae													
Azure Kingfisher	5.5	sw	$\bar{x}$	0.08	0.04	0.13	0.04	0.00	0.08	ns	ns	ns	ns
Alcedo azurea			SD	0.28	0.20	0.45	0.20		0.28				
Laughing Kookaburra	21.5	sw	$\bar{x}$	0.42	0.75	0.58	0.29	0.13	0.17	ns	ns	ns	ns
Dacelo novaeguineae			SD	0.88	1.26	1.01	0.55	0.33	0.82				
Sacred Kingfisher	42.7	s	$\bar{x}$	0.71bc	1.63abc	2.5ab	2.88a	0.04bc	0.04bc	ns	ns	H**	***
Todiramphus sanctus			SD	1.52	2.50	4.72	5.29	0.20	0.20				
Coraciidae													
Dollarbird	27.8	s	$\bar{x}$	0.5ab	0.88a	1.08a	0.63ab	0.08b	0.13b	ns	ns	H**	**
Eurystomus orientalis			SD	0.88	1.22	1.55	1.34	0.28	0.34				
Climacteridae													
White-throated Treecreeper	13.2	sw	$\bar{x}$	1.29a	0.17b	0.00b	0.00b	0.00b	0.00b	ns	ns	–	***
Cormobates leucophaeus			SD	1.27	0.48								

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Family species name	**Freq**	**S**	**Abundance estimate**	**Uncleared grazed riparian**			**Cleared grazed riparian**		**Design number**				
				Ru-Wu	**R-W**	**R-N**	**R-C**	**T-N**	**T-C**	**1**	**2**	**3**	**4**
Maluridae													
Superb Fairy-wren	58.3	sw	$\bar{x}$	4.67	5.96a	5.13a	0.88b	4.83	3.21	***	ns	C**	**
Malurus cyaneus			SD	5.47	5.05	4.31	2.01	4.51	3.34				
Variegated Fairy-wren	15.3	sw	$\bar{x}$	6.29	1.29a	0.00b	0.00b	0.00	0.00	*	–	–	***
Malurus lamberti			SD	5.53	2.94								
Red-backed Fairy-wren	77.1	sw	$\bar{x}$	5.88	10.25a	8.95a	3.88b	5.79a	2.92b	**	***	H* C***	***
Malurus melanocephalus			SD	4.59	6.35	6.17	3.58	3.59	2.73				
Pardalotidae													
Spotted Pardalote	13.9	sw	$\bar{x}$	6.29	0.58	0.00	0.25	0.00	0.00	ns	–	–	***
Pardalotus punctatus			SD	7.98	2.86		0.85						
Striated Pardalote	51.2	sw	$\bar{x}$	2.63ab	3.67a	1.88abc	2.33abc	0.38c	1.21bc	ns	ns	H*	**
Pardalotus striatus			SD	4.46	3.21	2.42	2.88	0.77	1.25				
White-browed Scrubwren	42.4	sw	$\bar{x}$	8.29	3.75ab	4.29a	2.21c	0.04	0.17	*	ns	H × C*	***
Sericornis frontalis			SD	5.27	4.33	4.37	0.45	0.20	0.64				
Speckled Warbler	10.4	sw	$\bar{x}$	1.13	1.00a	0.00b	0.00b	0.00	0.00	**	–	–	***

Family species name	**Freq**	**S**	**Abundance estimate**	**Uncleared grazed riparian**			**Cleared grazed riparian**		**Design number**				
				Ru-Wu	**R-W**	**R-N**	**R-C**	**T-N**	**T-C**	**1**	**2**	**3**	**4**
Chthonicola sagittata			SD	1.96	1.67								
Weebill	22.9	sw	$\bar{x}$	3.75	5.33a	1.33b	0.00b	0.00	0.00	***	–	–	***
Smicrornis brevirostris			SD	5.06	6.39	2.99							
White-throated Gerygone	30.6	sw	$\bar{x}$	2.21	1.71a	0.96ab	0.46b	0.00	0.04	**	ns	H***	***
Gerygone olivacea			SD	2.83	1.85	1.30	0.78		0.20				
Brown Thornbill	6.9	sw	$\bar{x}$	1.92a	0.58b	0.29b	0.00	0.00	0.00	ns	–	–	*
Acanthiza pusilla			SD	4.91	1.38	1.43							
Buff-rumped Thornbill	23.6	sw	$\bar{x}$	6.79	1.5a	1.46a	0.00b	0.00	0.00	*	–	–	***
Acanthiza reguloides			SD	6.41	2.28	2.36	0.00						
Yellow-rumped Thornbill	12.5	sw	$\bar{x}$	0.00	0.71	0.29	0.33	0.50	0.58	ns	ns	ns	ns
Acanthiza chrysorrhoa			SD		1.73	0.86	1.27	1.18	1.21				
Meliphagidae													
Striped Honeyeater	5.6	sw	$\bar{x}$	0.29	0.25	0.08	0.04	0.00	0.04	ns	ns	ns	ns
Plectorhyncha lanceolata			SD	1.23	0.74	0.41	0.20		0.20				
Noisy Friarbird	29.2	s	$\bar{x}$	5.5a	2.42ab	0.92b	0.26b	0.00b	0.04b	ns	ns	H*	***

Family species name	**Freq**	**S**	**Abundance estimate**	**Uncleared grazed riparian**			**Cleared grazed riparian**		**Design number**				
				Ru-Wu	**R-W**	**R-N**	**R-C**	**T-N**	**T-C**	**1**	**2**	**3**	**4**
Philemon corniculatus			SD	4.63	2.90	0.93	0.34		0.20				
Little Friarbird	26.0	s	$\bar{x}$	3.26a	2.66a	0.72ab	0.92ab	0.26b	0.16b	ns	ns	ns	*
Philemon citreogularis			SD	3.76	2.46	1.28	0.93	0.61	0.28				
Blue-faced Honeyeater	9.7	sw	$\bar{x}$	0.00	0.71	0.50	0.63	0.17	0.13	ns	ns	H**	ns
Entomyzon cyanotis			SD		2.27	1.22	1.10	0.56	0.61				
Noisy Miner	37.5	sw	$\bar{x}$	0.17	2.00b	5.75ab	9.08a	0.00	0.38	**	ns	H***	***
Manorina melanocephala			SD	0.48	3.22	6.51	6.54		1.64				
Lewin's Honeyeater	22.2	sw	$\bar{x}$	2.58a	0.92b	0.54b	0.38b	0.00b	0.08b	ns	ns	H**	***
Meliphaga lewinii			SD	3.36	1.52	1.25	0.71		0.41				
Yellow-faced Honeyeater	34.7	sw	$\bar{x}$	7.58	3.92a	3.00a	0.08b	0.00	0.00	**	–	H × C*	***
Lichenostomus chrysops			SD	6.62	3.63	6.37	0.41						
Fuscous Honeyeater	17.4	sw	$\bar{x}$	0.29	6.38a	0.17b	0.04b	0.00	0.00	***	–	ns	***
Lichenostomus fuscus			SD	0.81	7.11	0.56	0.20						
White-throated Honeyeater	15.3	sw	$\bar{x}$	2.46a	0.79b	0.79b	0.00b	0.00b	0.00b	ns	–	–	***
Melithreptus albogularis			SD	3.05	1.84	2.04							

Family species name	**Freq**	**S**	**Abundance estimate**	**Uncleared grazed riparian**			**Cleared grazed riparian**		**Design number**				
				Ru-Wu	**R-W**	**R-N**	**R-C**	**T-N**	**T-C**	**1**	**2**	**3**	**4**
Petroicidae													
Jacky Winter	8.3	sw	$\bar{x}$	0.04	0.67a	0.13b	0.00b	0.00	0.04	**	ns	ns	***
Microeca fascinans			SD	0.20	1.13	0.34			0.20				
Rose Robin	16.7	W	$\bar{x}$	0.75	0.75	0.16	0.00	0.00	0.00	ns	–	–	ns
Petroica rosea			SD	0.84	0.93	0.41							
Eastern Yellow Robin	8.3	Sw	$\bar{x}$	0.88a	0.42ab	0.08b	0.00	0.00	0.00	ns	–	–	**
Eopsaltria australis			SD	1.62	0.88	0.41							
Grey-crowned Babbler	10.4	Sw	$\bar{x}$	0.21	0.00b	0.75ab	1.92a	0.00	0.00	**	ns	H**	***
Pomatostomus temporalis			SD	1.02		2.09	3.20						
Cinclosomatidae													
Eastern Whipbird	14.6	sw	$\bar{x}$	1.00a	0.21b	0.04b	0.29b	0.00	0.00	ns	–	H*	***
Psophodes olivaceus			SD	1.14	0.59	0.20	0.69						
Neosittidae													
Varied Sittella	7.6	sw	$\bar{x}$	1.46	1.42a	0.13b	0.00c	0.00	0.00	**	–	–	**
Daphoenositta chrysoptera		SD	3.23	3.02	0.61								

Family species name	**Freq**	**S**	**Abundance estimate**	**Uncleared grazed riparian**			**Cleared grazed riparian**		**Design number**				
				Ru-Wu	**R-W**	**R-N**	**R-C**	**T-N**	**T-C**	**1**	**2**	**3**	**4**
Pachycephalidae													
Golden Whistler	39.6	w	$\bar{x}$	2.80	2.25ab	1.26a	0.12b	0.00	0.00	**	–	H*	***
Pachycephala pectoralis			SD	3.20	2.31	1.34	0.60						
Rufous Whistler	35.4	sw	$\bar{x}$	1.92	2.71a	0.67b	0.29b	0.00	0.25	***	ns	H*	***
Pachycephala rufiventris			SD	2.02	2.42	1.05	0.86		0.61				
Grey Shrike-thrush	6.9	sw	$\bar{x}$	0.04	0.50a	0.00b	0.17ab	0.00	0.00	*	–	–	*
Colluricincla harmonica			SD	0.20	0.98		0.64						
Dicruridae													
Restless Flycatcher	9.7	sw	$\bar{x}$	0.00b	0.33ab	0.63a	0.08b	0.13b	0.00b	ns	–	H* C*	*
Myiagra inquieta			SD		0.70	1.21	0.41	0.45					
Leaden Flycatcher	28.1	s	$\bar{x}$	1.67	0.79a	0.29ab	0.04b	0.00	0.00	*	–	H*	***
Myiagra rubecula			SD	1.55	1.38	0.75	0.20						
Magpie-lark	38.9	sw	$\bar{x}$	0.00	0.17c	1.13b	2.29a	0.58b	2.00a	***	***	C***	***
Grallina cyanoleuca			SD		0.48	1.68	1.68	1.28	1.29				
Grey Fantail	20.8	sw	$\bar{x}$	4.21a	1.17b	1.00b	0.33b	0.00b	0.00b	ns	–	H*	***

Family species name	**Freq**	**S**	**Abundance estimate**	**Uncleared grazed riparian**			**Cleared grazed riparian**		**Design number**				
				Ru-Wu	**R-W**	**R-N**	**R-C**	**T-N**	**T-C**	**1**	**2**	**3**	**4**
Rhipidura fuliginosa			SD	4.24	1.88	2.65	0.96						
Willie Wagtail	54.9	sw	$\bar{x}$	0.46c	2.25a	1.75ab	1.33abc	0.88bc	1.13bc	ns	ns	ns	***
Rhipidura leucophrys			SD	0.88	1.75	1.57	1.69	1.42	1.26				
Campephagidae													
Black-faced Cuckoo-shrike	24.3	sw	$\bar{x}$	0.46ab	0.88a	0.58ab	0.63ab	0.17ab	0.13b	ns	ns	H**	*
Coracina novaehollandiae			SD	0.98	1.15	0.93	1.10	0.61	0.61				
Oriolidae													
Olive-backed Oriole	21.5	sw	$\bar{x}$	0.75a	0.50ab	0.21ab	0.63ab	0.00b	0.04b	ns	ns	H**	**
Oriolus sagittatus			SD	1.33	0.78	0.51	1.06		0.20				
Artamidae													
Grey Butcherbird	6.3	sw	$\bar{x}$	0.00	0.00	0.42	0.46	0.00	0.00	ns	–	H**	ns
Cracticus torquatus			SD			0.97	1.28						
Pied Butcherbird	14.6	sw	$\bar{x}$	0.00b	0.17ab	0.46ab	0.71a	0.04ab	0.46ab	ns	ns	ns	*
Cracticus nigrogularis			SD		0.63	0.98	1.12	0.20	1.17				
Australian Magpie	51.4	sw	$\bar{x}$	0.46	1.04b	1.46b	3.83a	1.13	1.50	***	ns	H × C*	***

Family species name	Freq	S	Abundance estimate	Uncleared grazed riparian			Cleared grazed riparian			Design number			
				Ru-Wu	R-W	R-N	R-C	T-N	T-C	1	2	3	4
Gymnorhina tibicen			SD	1.41	1.42	1.50	3.12	1.57	1.53				
Pied Currawong	11.8	sw	$\bar{x}$	0.45	0.00	0.54	0.33	0.00	0.00	ns	–	H**	ns
Strepera graculina			SD	0.98		1.35	0.70						
Corvidae													
Torresian Crow	55.6	sw	$\bar{x}$	1.46	0.96b	1.42b	5.08a	0.58	2.54	**	ns	C**	**
Corvus orru			SD	2.21	1.20	1.56	8.25	1.38	2.72				
Corcoracidae													
Apostlebird	7.6	sw	$\bar{x}$	0.00	0.00b	0.46b	2.42a	0.00	0.00	**	–	H × C*	***
Struthidea cinerea			SD			1.61	4.13						
Motacillidae													
Richard’s Pipit	8.3	sw	$\bar{x}$	0.00	0.00	0.00	0.00	1.00a	0.29b	–	*	H × C*	***
Anthus navaeseelandiae			SD					1.44	0.81				
Passeridae													
Double-barred Finch	19.4	sw	$\bar{x}$	1.96	1.08	0.13	0.71	0.00b	1.00a	ns	**	C**	**
Taeniopygia bichenovii			SD	3.48	2.26	0.45	1.78		1.79				

Family species name	Freq	S	Abundance estimate	Uncleared grazed riparian			Cleared grazed riparian		Design number				
				Ru-Wu	R-W	R-N	R-C	T-N	T-C	1	2	3	4
Red-browed Finch	22.9	sw	$\bar{x}$	2.71	2.71a	0.67b	0.08b	0.08	0.08	**	ns	ns	***
Neochmia temporalis			SD	3.51	3.99	1.55	0.41	0.41	0.41				
Dicaeidae													
Mistletoebird	5.6	sw	$\bar{x}$	1.17	0.21	0.00	0.17	0.00	0.00	ns	–	–	ns
Dicaeum hirundinaceum			SD	3.48	0.83		0.56						
Hirundinidae													
Tree Martin	7.6	sw	$\bar{x}$	0.00	0.88	0.00	0.54	2.25	0.46	ns	ns	ns	ns
Hirundo nigricans			SD		3.53		2.45	6.63	1.56				
Sylviidae													
Clamorous Reed-Warbler	10.4	s	$\bar{x}$	0.00	0.00	0.00	0.04b	0.83a	1.44a	–	**	H***	***
Acrocephalus stentoreus			SD				0.20	1.55	2.08				
Golden-headed Cisticola	30.6	sw	$\bar{x}$	0.00b	0.08b	2.33a	0.21b	9.21a	1.71b	**	***	H × C**	***
Cisticola exilis			SD		0.41	4.41	0.72	8.16	2.56				
Silvereye	22.2	sw	$\bar{x}$	6.29	2.5a	1.08ab	0.21c	0.00	0.00	*	–	H*	***
Zosterops lateralis			SD	5.38	4.12	2.72	1.02						

Family species name	Freq	S	Abundance estimate	Uncleared grazed riparian			Cleared grazed riparian		Design number				
				Ru-Wu	**R-W**	**R-N**	**R-C**	**T-N**	**T-C**	**1**	**2**	**3**	**4**
Common Myna	6.9	sw	$\bar{x}$	0.00	0.00	0.00	0.08	0.00b	2.08a	–	*	H × C*	**
Acridotheres tristis			SD				0.41		4.70				

The season in which a bird occurred is shown (S = season, s = summer, w = winter). Letters indicate results of Tukey's HSD test. Estimates with the same subscript are not significantly different. Where either Design 1 or 2 were significant, letters are associated with these designs. Where neither Design 1 nor 2 were significant and Design 4 was significant, letters are associated with that design. In Design 3, an H indicates riparian habitat was significant, whereas a C indicates landscape context was significant and an interaction is denoted by H × C. The level of significance is shown by the asterisks as defined: *$P < 0.05$ **$P < 0.01$ ***$P < 0.0001$.

habitat condition) analysis of variance using the general linear model procedure within the SAS statistical package version 9.1 (SAS, 1989). Individual species were only analysed if they occurred in at least 6% of site visits (8 of 144 visits) across all three seasons combined. Pairwise differences between mean values were tested using Tukeys honestly significant different (HSD) comparisons (Zar, 1984).

3.2. Bird species assemblage response

Multivariate ordination analyses were used to compare bird species assemblages among the six treatments. Analyses were performed on abundance data pooled across the three seasons. Again, only species that occurred at 6% of sites were included in these analyses. Non-metric multi-dimensional scaling ordinations were performed using the PRIMER package (Clarke and Gorley, 2001) with the Bray-Curtis dissimilarity measure (Clarke, 1993). The position of sites on the ordination relative to other sites is based on the species compositional similarity of those sites, where sites with a similar bird species composition are close to one another in ordination space, whereas treatments with contrasting species composition are located further apart. Analysis of similarities (999 permutations) was used to test whether the variation in bird species composition between treatments was greater than the variation within treatments (Carr, 1996).

4. Results

4.1. Species relative abundance and richness response

A total of 146 species and 10,148 individuals were recorded across the six riparian context treatments over three seasons (summer 2001–02: 111 species, 3243 individuals; winter 2002: 102 species, 3291 individuals; summer 2002–03: 117 species, 3614 individuals). Amongst the six treatments significant differences in both species richness and relative mean abundance were recorded (Fig. 3). Patterns in both relative species richness and relative mean abundance were similar with progressive significant declines in estimates between three groups of treatments (Fig. 3); (1) ungrazed riparian surrounded by ungrazed woodland (Ru-Wu) and grazed riparian surrounded by grazed woodland (R-W); (2) grazed riparian surrounded by native pasture (R-N) and grazed riparian surrounded by crops (R-C); (3) cleared grazed riparian surrounded by native pasture (T-N); and (4) cleared grazed riparian surrounded by crops (T-C). The exception was a significant difference in species richness estimates between cleared grazed riparian habitats surrounded by native pasture (T-N) and those surrounded by crop (T-C; Fig. 3).

4.2. Individual species

Close to half (48%) of the species that were analysed individually showed a significant response to changes in landscape context (Table 3). For uncleared grazed riparian sites (R), different contexts had four sorts of effect (Design 1, Table 2). Nine species were significantly more abundant in riparian habitat surrounded by grazed woodland (R-W) or native pasture (R-N) than crop (R-C). These included superb fairy-wren, buff-rumped thornbill, grey shrike-thrush, and leaden flycatcher (Table 3). A further eight species were significantly more abundant in riparian habitat surrounded by grazed woodland (R-W) than either riparian habitat surrounded by native pasture (R-N) or crop (R-C) (e.g., variegated fairy-wren, speckled warbler, jacky winter, varied sitella). Seven species were significantly more abundant in riparian sites surrounded by crops (R-C) than by woodland (R-W) or native pasture (R-N) and included the crested pigeon, galah, magpie-lark, apostlebird and Australian magpie. The golden-headed cisticola was the only species most abundant in riparian habitat surrounded by native pasture (R-N).

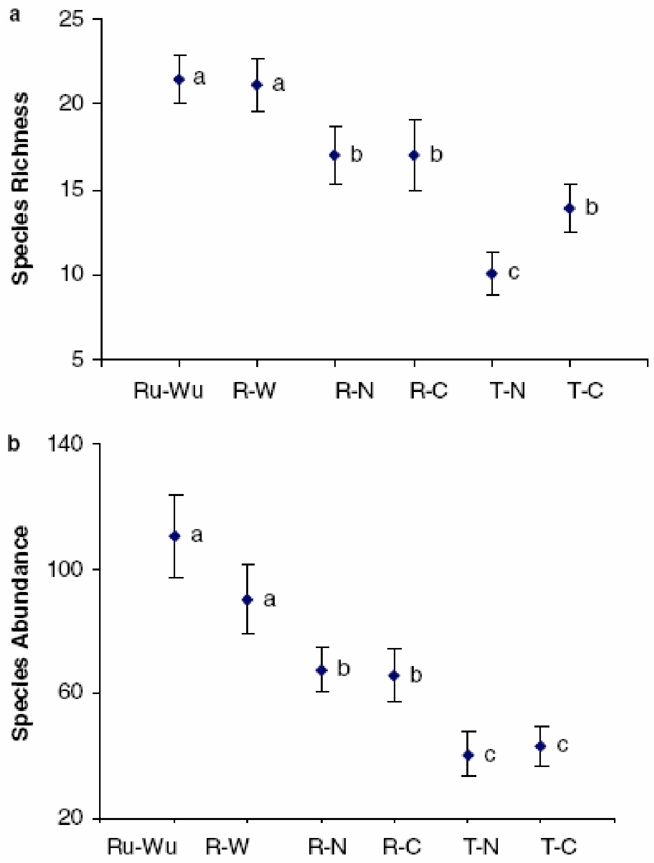

Fig. 3. Mean estimates from analysis of variance (general linear model procedure) of (a) relative species richness and (b) relative species abundance ± 1 standard error for the six riparian and context treatments across three seasons combined.

Comparison of landscape context effects on cleared grazed riparian sites (T) revealed two patterns (Design 2, Table 3). Six species were significantly more abundant in cleared grazed riparian sites surrounded by crops (T-C) and included the galah, common myna and crested pigeon whereas four species (pheasant coucal, red-backed fairy-wren, Richard's pipit and golden-headed cisticola) were most abundant in cleared riparian sites surrounded by native pasture (T-N).

The influence of riparian habitat condition (two levels: uncleared, cleared) and landscape context (two levels: native pasture, crop) revealed 45% of species showed a significant change in relative mean abundance in response to riparian habitat condition (e.g., pale-headed rosella, white-throated gerygone, clamorous reed-warbler) as compared to a 20% response to changes in landscape context (e.g., galah, magpie-lark, double-barred finch; Design 3, Table 3).

In the comparison of all six treatments we cannot attribute changes in bird species relative mean abundances to riparian habitat type or landscape context separately but rather look at the broad implications of grazing and tree clearing on birds using the riparian zone (Design 4, Table 3). In this analysis, 80% of species (58 species) exhibited a significant preference for one or more riparian habitats and context combinations. Fourteen species had significantly higher relative mean abundances in uncleared ungrazed riparian woodland surrounded by ungrazed woodland (Ru-Wu) compared with all other treatments and included the white-throated treecreeper, variegated fairy-wren and brown thornbill. A further 11 species were found to have statistically higher estimates of relative mean abundances in both uncleared ungrazed riparian habitats surrounded by ungrazed woodland (Ru-Wu) and grazed riparian surrounded by grazed woodland (R-W) than the two grazed uncleared riparian sites surrounded by native pasture (R-N) and crop (R-C) (e.g., speckled warbler, eastern yellow-robin, varied sittella, Table 3).

Five species preferred uncleared grazed riparian habitat adjacent to crops (R-C) (pheasant coucal, Australian magpie, torresian crow, red-rumped parrot and apostlebird). Relative mean abundances of two species (Australian wood duck, common myna) were highest in cleared riparian habitat surrounded by crop (T-C) and the relative mean abundance of an additional two species (crested pigeon, magpie-lark) were greatest in uncleared and cleared grazed riparian habitats adjacent to crop (R-C and T-C). Only two species (Richard's pipit, clamorous reed warbler) had significantly higher relative mean abundances in cleared riparian habitat compared with uncleared riparian habitat (Table 3).

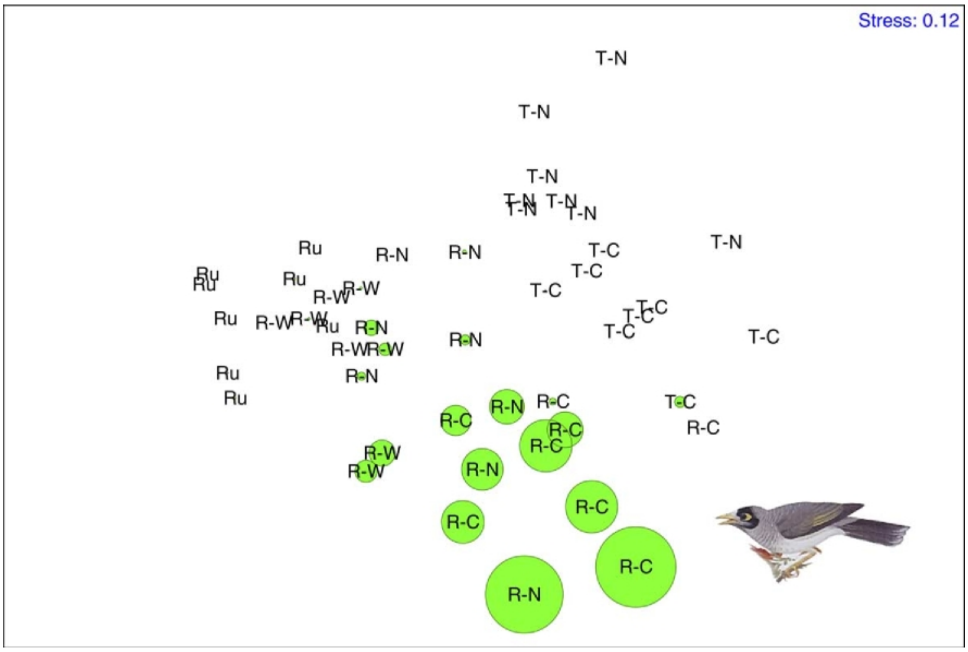

Fig. 4. Multidimensional scaling ordination (two dimensions) of bird species composition for all seasons combined showing similarity of species composition amongst the six riparian and context treatments based on Bray-Curtis dissimilarity measure, two-dimensional stress = 0.12, three-dimensional = 0.9. Bubbles depict the relative abundance of noisy miner *Manorina melanocephala* at each site. Ru is ungrazed uncleared riparian habitat surrounded by ungrazed woodland. All other treatments codes are defined in Fig. 2.

4.3. Bird species assemblage response

Ordination of all six treatments based on species composition of the sites was consistent with the general linear model results (Design 4) and revealed a clear separation between uncleared ungrazed riparian habitats surround by ungrazed woodland (Ru-Wu) and all other sites (Fig. 4). Amongst the uncleared grazed riparian sites (R), as the context became more intensive (woodland to native pasture to crop, Design 1) a change in the bird assemblage occurred between the three contexts. This pattern was potentially influenced by the high abundance of noisy miners at these sites, (Table 3) as depicted on the ordination in Fig. 4. This native honeyeater is known for its aggressive exclusion of other bird species from its territory (Piper and Catterall, 2003). Cleared riparian habitats (T-N and T-C) contained a distinctly different bird assemblage from uncleared riparian habitats (Ru-Wu, R-W, R-N, R-C). There were clear differences between the bird assemblages of cleared riparian habitats surrounded by native pasture (T-N) compared with crops (T-C) (Fig. 4). Analysis of similarities confirmed that all treatments were significantly different from one another (Table 4).

Table 4.

Results of one-way analysis of similarities pairwise tests between the riparian context treatments showing R-values and P values

Riparian treatment	Ru-Wu	R-W	R-N	R-C	T-N	T-C
Ru-Wu	–	0.48 (0.003)	0.61 (0.001)	0.97 (0.001)	0.98 (0.001)	0.99 (0.002)
R-W		–	0.32 (0.003)	0.90 (0.001)	0.95 (0.001)	0.99 (0.001)
R-N			–	0.28 (0.024)	0.63 (0.002)	0.70 (0.001)
R-C				–	0.91 (0.001)	0.61 (0.001)
T-N					–	0.49 (0.001)
T-C						–

All treatments are significantly ($P < 0.05$) different from one another. Treatments are defined in Table 2 and Fig. 2.

5. Discussion

5.1. Influence of landscape context

Riparian habitats in grassy eucalypt woodland support a rich and abundant bird assemblage which is significantly influenced by both the surrounding landuse and local habitat condition. Close to half of the bird species analysed in this study exhibited a significant change in relative mean abundance as a result of differences in the landscape context. However, an examination of the relative importance of landscape context compared with local habitat condition (Design 3) revealed that twice as many species responded significantly to changes in local habitat condition as a result of tree clearing, as opposed to changes in landscape context as a result of tree clearing and cropping (Design 3, Table 2).

Uncleared grazed riparian habitats surrounded by grazed woodland (R-W) contained a suite of bird species characterised as dependant on woodland/forest or bushland/shrubland (Catterall et al., 1997, Garnett and Crowley, 2000 and Loyn, 2002). As the landscape around a riparian area changed from woodland (R-W) to native pasture (R-N) several woodland species including the speckled warbler, variegated fairy-wren, varied sittella, jacky winter, fuscous honeyeater, weebill, rufous whistler, red-browed finch, disappeared or declined significantly.

In contrast, only a few species increased significantly in these sites and included the pale-headed rosella, crested pigeon, grey-crowned babbler and golden-headed cisticola. As the land use surrounding the uncleared grazed riparian habitat changed to crop (R-C) additional birds disappeared (e.g., weebill, brown thornbill, buff-rumped thornbill, white-throated honeyeater, jacky winter, varied sitella). Replacing these species was the presence or significant increase in relative mean abundances of the crested pigeon, galah, magpie-lark, Australia magpie, torresian crow, apostlebird, and perhaps most notably the noisy miner.

It is possible that the significant decline or disappearance of species in the transition from riparian sites surrounded by grazed woodland (R-W) to riparian sites surrounded by native pasture (R-N) is due, in part, to a reduction in suitable habitat size rather than a change in context per se. While these species may be dependant on riparian zones, none are restricted to riparian habitat and are found widely in adjacent grassy eucalypt woodland (Martin and McIntyre, unpublished data). If we consider only the species which did not occur in riparian sites surrounded by crops (R-C), previous studies of the impact of habitat loss and fragmentation suggest that the variegated fairy-wren, rufous whistler and red-browed finch are frequently found in small (1–2 ha) remnants (Bentley and Catterall, 1997 and Martin and Catterall, 2001), whereas according to Mac Nally and Bennett (1997) the speckled warbler and fuscous honeyeater are more likely to be negatively affected by habitat fragmentation effects.

5.2. Intensity of use of the landscape context

As hypothesised, the transition in uncleared grazed riparian sites with increasing intensification of their context (grazed woodland to native pasture to crop) was characterised by the loss or significant decline in small-bodied insectivores and nectarivores and the arrival or increase in relative mean abundance of large-bodied generalist ground foragers. Cleared riparian habitats surrounded by crops (T-C) were characterised by generalist ground foraging species; crested pigeon, Pacific black duck and exotic common myna, whereas those surrounded by native pasture (T-N), a less intensive surrounding landuse, were characterised by ‘grassland species’ (e.g., Richard’s pipit, golden-headed cisticola). In both uncleared and cleared riparian sites the resource availability of the context appears to influence the species composition of the riparian habitats. The context of a riparian habitat will provide birds with resources that are either additional, complementary or absent to those found within the riparian habitat (Ries and Sisk, 2004). Small-bodied, arboreal feeding, insectivores inhabiting an uncleared riparian site are likely to find additional resources in surrounding grazed woodland habitat whereas surrounding native pasture and crop habitat are likely to offer fewer such resources. Many ground foraging bird species which prefer cleared habitat, on the other hand, require trees to nest and roost making uncleared riparian sites surrounded by native pasture (R-N) or crops (R-C) desirable habitat (e.g., grey-crowned babbler, apostlebird).

The increased relative mean abundance of noisy miners at riparian sites surrounded by crops (R-C) is likely to influence the presence and relative abundance of other woodland birds, through its aggressive behaviour, particularly to birds with a smaller body size (<65 g) than the noisy miner (Piper and Catterall, 2003). The change in bird fauna recorded in riparian habitat surrounded by crops therefore, cannot be attributed directly to changes in context but indirectly by providing desirable habitat for the noisy miner. Further research is required to determine the relative contribution of grazing and context to noisy miner relative abundance. Although this work and other research suggests that as long as trees are present, both increasing grazing pressure and intensity of the use of the landscape context are positively associated with noisy miner abundance (Loyn, 1987, Catterall et al., 2002 and Martin et al., 2005), which has implications for the conservation of other woodland birds.

Elevated densities of large bodied species of the Corvidae (torresian crow), Artamidae (Australian magpie, pied and grey butcherbirds, and pied currawong) as well as high densities of the noisy miner have been recorded where Australian eucalypt woodland/forest abuts cleared land (Loyn, 1987, Catterall et al., 1991, Catterall et al., 1997 and Luck et al., 1999). Nest predation studies within this bioregion suggests that these species with the addition of the grey shrike-thrush are the major contributors to avian nest predation (Piper and Catterall, 2004). The density of the Australian magpie, torresian crow, and noisy miner were highest in uncleared grazed riparian sites surrounded by crop (R-C) and native pasture (R-N), however, the density of grey and pied butcherbirds and pied currawong did not vary with context, suggesting that densities of some key avian nest predators are not associated with these factors and that nest predation rates in riparian habitat may not vary greatly with different contexts in this study region.

5.3. Influence of riparian habitat condition

Landscape context was an important determinant of relative abundance of 48% of the bird species examined here, however, local habitat condition and landscape context had the most striking impact on riparian bird species influencing 80% of the bird assemblage. Examining the influence of riparian habitat condition as a result of tree clearing and landscape context separately revealed that twice as many species responded significantly to changes in habitat condition. Clearing riparian habitats of the tree layer results in a complete transformation of the bird assemblage from a species rich assemblage dominated by small-bodied insectivores and nectarivores to one dominated by a few large-bodied generalist foragers (Fig. 4, Table 3).

The introduction of grazing also has a substantial influence on riparian ecosystems (Kauffman and Krueger, 1984). Grazing reduces and often eliminates the native shrub layer and tall tussock forming grasses, resulting in a highly modified understorey structure (Schulz and Leininger, 1990 and McIntyre et al., 2003). The difference in vegetation structure between uncleared ungrazed riparian sites surrounded by ungrazed woodland (Ru-Wu) and grazed riparian sites surrounded by grazed woodland (R-W) is the substantial loss and alteration of the understorey vegetation. This alteration in habitat structure in turn changes the bird species foraging opportunities resulting in a substantial shift in the bird species assemblage (Martin and Possingham, 2005).

5.4. Riparian management and restoration implications

While it may be economically difficult for graziers and farmers to alter their land management practices around riparian habitats dramatically, results from this research can help target where conservation management and restoration resources could be best spent for the greatest gain in bird conservation.

Irrespective of landscape context, the clearing of trees and livestock grazing was the primary determinant of the bird species assemblage. Allowing trees to regenerate naturally or planting trees along cleared riparian habitat will result in a dramatic increase in bird species richness, relative abundance and change in composition. To allow such restoration, stock would have to be excluded from the riparian zone at least in the short to medium term to allow trees to establish and grow to a stage where they would no longer be vulnerable to damage. Given the choice of whether to restore a cleared riparian zone surrounded by native pasture (T-N) or by crops (T-C), this study suggests that the former may ultimately encourage a bird assemblage similar to uncleared grazed riparian habitat surrounded by native pasture (R-N; Fig. 4) which more closely resembles an intact riparian habitat (Ru-Wu).

Increasing riparian buffer widths have been suggested as one way of alleviating the impacts of surrounding landuses (Price and Lovett, 1999) and augmenting buffer widths in this study beyond the current 50 m could provide an alternative method of buffering against adjacent intensive land uses. We have found no published studies investigating the impact of different riparian buffer widths on Australian birds. Other research has reported wide buffer strips (e.g., 100 m) to be better than narrow ones (e.g., 20 m) for the conservation of woodland bird fauna (Stauffer and Best, 1980, Hannon et al., 2002 and Shirley, 2004).

Excluding stock from riparian habitats through fencing or other means is a widely regarded management strategy for riparian rehabilitation in rural landscapes. While we are unable to assess the effect of stock exclusion within different landscape contexts a comparison of uncleared ungrazed riparian sites surrounded by ungrazed woodland (Ru-Wu) and uncleared grazed riparian sites surrounded by grazed woodland (R-W) suggests that stock exclusion of the riparian zone benefits several woodland birds including white-throated treecreeper, brown thornbill, buff-rumped thornbill, variegated fairy-wren, white-browed scrubwren, Lewin's honeyeater, white-throated honeyeater, leaden flycatcher and eastern whipbird.

The benefits of stock exclusion for plant species richness, tree and shrub recruitment and grassland composition vary (Scougall et al., 1993, Petit et al., 1995, Prober and Thiele, 1995 and Spooner et al., 2002) and many factors including landscape context are likely to play a role in its success. Dramatic recoveries of vegetation and breeding birds have been observed in the south-western United States after four years of stock exclusion (Krueper et al., 2003), however, in Australia few studies document the impact of stock exclusion from riparian habitats on the bird assemblage.

What we are unable to demonstrate here is whether the recovery of vegetation through stock exclusion, would counteract the influence of landscape context. For example, could improved local habitat condition (e.g., increased understorey structure and diversity) along riparian habitats surrounded by cropping reduce the density of noisy miners in these riparian habitats? If it does not, then fencing may be an ineffective way to enhance the local bird assemblage and restoration of the surrounding context may be more beneficial.

6. Conclusion

Two additional processes threaten to intensify the land use around rural riparian zones. As demand for meat and livestock products continues to increase (Food and Agriculture Organization, 2002) so do the incentives to intensify grazing enterprises, compromising riparian habitats even further. Grazed landscapes close to major urban centres and coastal areas are under siege from another source of intensification; peri-urban development. Extensively managed grazing land is being transformed into small holding 'life-style blocks', a phenomenon reported globally (Greene and Stager, 2001).

This study suggests that riparian management and restoration to conserve woodland bird assemblages must consider both local habitat condition and landscape context. Without careful consideration of how to reduce the degradation of riparian habitat and the increasing level of intensive surrounding landuses, the decline in Australian woodland bird fauna (Garnett and Crowley, 2000) is predicted to continue.

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