

Determinants of bird assemblage composition in riparian vegetation on sugarcane farms in the Queensland Wet Tropics

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Abstract. Remnant habitat patches in agricultural landscapes can contribute substantially to wildlife conservation. Understanding the main habitat variables that influence wildlife is important if these remnants are to be appropriately managed. We investigated relationships between the bird assemblages and characteristics of remnant riparian forest at 27 sites among sugarcane fields in the Queensland Wet Tropics bioregion. Sites within the remnant riparian zone had distinctly different bird assemblages from those of the forest, but provided habitat for many forest and generalist species. Width of the riparian vegetation and distance from source forest were the most important factors in explaining the bird assemblages in these remnant ribbons of vegetation. Gradual changes in assemblage composition occurred with increasing distance from source forest, with species of rainforest and dense vegetation being replaced by species of more open habitats, although increasing distance was confounded by decreasing riparian width. Species richness increased with width of the riparian zone, with high richness at the wide sites due to a mixture of open-habitat species typical of narrower sites and rainforest species typical of sites within intact forest, as a result of the greater similarity in vegetation characteristics between wide sites and the forest proper. The results demonstrate the habitat value for birds of remnant riparian vegetation in an agricultural landscape, supporting edge and open vegetation species with even narrow widths, but requiring substantial width (>90 m) to support specialists of the closed forest, the dominant original vegetation of the area.

Additional keywords: agriculture, Australia, diversity, rainforest, riparian width.

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Introduction

Over the last 20 years or so there has been increasing research interest in the processes by which agriculture affects the ecology of birds (e.g. Ormerod and Watkinson 2000). Gaston *et al.* (2003) estimated that between a fifth and a quarter of bird numbers had been lost globally as a result of agriculture, while Green *et al.* (2005) showed that farming was the greatest extinction threat to birds. As only a small proportion of land is protected as nature reserves, conservation efforts need to address the biodiversity values of agricultural areas (Petit *et al.* 1999). There is a growing recognition of the importance of the diversity of ‘countryside’ elements to bird conservation (Ormerod and Watkinson 2000), and diversified agricultural systems may help buffer against extreme loss of diversity (Frishkoff *et al.* 2014). However, biodiversity is declining from land conversions of diverse, low-intensity agriculture to homogeneous, intensive production (Donald *et al.* 2001; Maron and Fitzsimons 2007).

Riparian zones (ribbons of streamside habitat) perform many important ecosystem functions. In agricultural landscapes, they may be left undeveloped because they are unsuitable for

cultivation or for their geomorphologic, water quality and ecological roles. They often support higher floral and faunal diversity than surrounding habitats (Bentley and Catterall 1997; Woinarski *et al.* 2000; Catterall *et al.* 2001), and make important contributions to in-stream habitats through the input of litter and large woody debris and provision of shade (Cummins 1993; Pusey and Arthington 2003). They are a key landscape element for avian diversity and their restoration can greatly benefit bird assemblages in agricultural areas (Johnson *et al.* 2007; Bennett *et al.* 2014). These zones can contribute to conservation of forest wildlife, in contrast to the surrounding agricultural land, which can be unfavourable to most forest species (Forman and Godron 1986; Catterall 1993), depending on landscape context. While many studies have focused on the role of such remnant vegetation, others have recognised that many species use diverse ‘countryside’ elements within farmland, and emphasise the benefits of landscape heterogeneity for conservation (Haslem and Bennett 2008). Thus, while riparian zones have been shown to have high biodiversity values, the influence of landscape context on bird assemblages increases as the surrounding land use becomes more intensive (e.g. woodland to pasture to crop)

(Martin *et al.* 2006). Remnant riparian ribbons can act both as patches of habitat in their own right and as corridors connecting larger patches. As they are often retained or restored to protect water quality and reduce erosion, there is potential for them to form part of larger networks of conservation reserves. In order to make improvements to the way riparian zones are managed, it is necessary to understand what factors might determine their value for wildlife.

Area of a patch is a major attribute that affects diversity (Forman 1995) and is determined in the riparian zone by the width and length of the vegetated strip. Since riparian zones are linear features, width may be of greater importance as it determines both the area of habitat available at any location along the stream, as well as the extent to which edge effects can permeate the strip. Edges attract species that may not occur in the forest proper (Moloney 2006), especially aggressive species such as miners and butcherbirds that can exclude smaller species (Major *et al.* 2001). Remnant attributes can therefore be more important than landscape attributes in determining the composition of bird communities.

In the Queensland Wet Tropics bioregion, in north-eastern Australia, many rainforest species can use remnants of forest as habitat and for dispersal (e.g. Isaacs 1994; Laurance and Laurance 1999), so riparian zones could play an important role in conservation in intensively farmed areas. This study was conducted in a lowland area of the Wet Tropics, where intensive sugarcane farming allows for little habitat diversity (Petit *et al.* 1999), and where riparian vegetation represents a large proportion of the remnant forest and could make a substantial contribution to off-reserve conservation. We aimed to identify factors that influence bird assemblages in riparian zones of sugarcane-growing areas by examining the relationships between the assemblages and characteristics of the riparian zone, including distance from the main contiguous forest and vegetation width. Such information is necessary for appropriate management of off-reserve habitats. The study comprised (1) a pilot survey to identify factors influencing bird assemblages in riparian forest, (2) an investigation of the effect of distance from remnant forest along a riparian corridor on the bird assemblage, and (3) an investigation of the effect of width of the riparian forest on the bird assemblage. The null hypotheses were that there would be no differences between the bird assemblages of riparian vegetation in sugarcane fields and in pristine forest, and that riparian width and distance from source forest would have no effect on assemblages.

Methods

Study area

The Queensland Wet Tropics bioregion contains the largest area of tropical rainforest in Australia and has great biological significance due to its high species diversity and endemism (Webb 1987; Goosem *et al.* 1999). However, some vegetation types, such as those on the coastal lowlands, have been extensively cleared and developed for agriculture and are not represented within the World Heritage Area (Mackey *et al.* 1989). In 1983, it was estimated that some 56.9% of rainforest in the lowland plains had been cleared (Winter *et al.* 1987), and that figure has increased over the past three decades: for example, ~66.5% of the study area is now under agriculture (Pitt *et al.* 2007).

The study was centred on the town of Tully (17°56'S, 145°56'E). Sugarcane production is the dominant land use in this area, although banana plantations and cattle grazing are also common (Webb 1966). The lowlands are bordered to the east by the Coral Sea and to the west by forested mountain ranges, most of which are protected by World Heritage status (Werren 1993). The climate is warm tropical, with a summer wet season (November to March) and a drier cooler season (April to October), although rainfall occurs in all months. The region is one of the wettest in Australia, with average annual rainfall of 4170 mm in Tully; mean minimum and maximum air temperatures range from 15.1–24.0°C in July to 22.7–31.3°C in December (data from the Australian Bureau of Meteorology).

The riparian vegetation of the study area comprises mainly streamside remnants with some regrowth of the original closed rainforest ('complex mesophyll vine forest': Webb 1959) that is mostly less than 100 years old. The length of intact rainforest edge in the study area was 31 km, the area of intact lowland forest (to 100 m elevation) was 10.1 km² (~39% of the study area), the total area of remnant riparian forest was 1.7 km² (~6.6% of the study area) and the total length of forested riparian ribbons was 53.2 km. The total edge length of riparian ribbons was nominally double this value, but functionally it was probably much less because of the large proportion of narrow (~20 m) ribbon length that might be considered a single 'edge'.

Study design and site selection

The study was undertaken during the early and mid dry season (April to August), 2003. Potential study sites were identified from topographic maps (1 : 50 000) of the study region (Mena Creek 8062-I, Tully 8062-II, Bilyana 8061-I). Approximately 100 ribbons of remnant riparian forest on sugarcane farms were classified according to several variables measured from these maps and from Google Earth[®]: they included maximum, minimum and mean width of the strip (width being the distance between the two vegetation edges, incorporating both banks and the stream); length of the strip; distance from large (>200 ha) blocks of remnant forest; connectivity (i.e. whether the strips formed part of a continuous corridor of vegetation that linked to these large forest blocks); and stream order. Only sites below 100 m altitude were considered and sites along major rivers were excluded, as the focus was on replicable lower-order streams.

For the pilot study, a preliminary analysis of frequency distributions of site characteristics across 58 sites (Appendix 1) allowed a replicated design for sites of different widths to be compared at constant length, and sites of different lengths to be compared at constant width (Table 1). Most sites were 'connected' (i.e. linked to the main forest), but a few 'unconnected' sites (isolated by 500–2750 m from the main forest by agricultural land: Appendix 1) were included to allow differences due to connectivity to be investigated. Three reference sites were located along streams within the main forest. Sites that had been modified recently or could not be accessed were excluded, and for some categories only two replicate sites were accessible (Table 1).

For the distance study, four streams that had at least 2 km of continuous riparian forest and that were connected to the main forest, were selected. For each stream, sites were selected at

Table 1. Sampling design for the pilot study

Sites include numbered replicate sites within each category of length and width of the riparian zone (S1–S20), plus three reference sites (C1–C3) and four unconnected sites (U1–U4), see text. Asterisks indicate sites that were originally selected but which became inaccessible

Width of forested riparian strip	Length of forested riparian strip			
	500–1000 m	1000–2000 m	>2500 m	~30 km
<40 m	S1, S2, S3, U1, U2, U*			
40–70 m	S4, S5, S6, U3, U4, U*	S10, S11, S*	S15, S16, S17	
>80 m	S7, S8, S9	S12, S13, S14	S18, S19, S20	
~200 m				C1, C2, C3

distances from the remnant forest of 50, 400, 800, 1600 and, for two streams only, 3200 m; four reference riparian sites in the main forest were also selected. For the width study, four sites were selected within width categories of <40 m, 50–70 m, and >80 m. To control for the effects of distance, these sites were situated at ~400 m from the main forest. The four reference sites in the main forest were also included.

Vegetation description

Rapid assessment of the main structural features of the vegetation followed Webb *et al.* (1976) and Walker and Hopkins (1990). The assessment was made along a 200-m length of vegetation at each site, in the same location where the bird surveys were conducted. Attributes recorded include estimates of canopy height, canopy cover, level of disturbance, abundance of weed species, and abundance of major life forms (Appendix 1). These features were chosen as they are related to differences in site quality (Webb 1959) and are readily observed without requiring precise measurement (Webb 1966), and because birds respond to habitat structure (MacNally 1990; Laurance *et al.* 1996). A four-point scale was used for recording most features (0, absent; 1, rare or inconspicuous; 2, occasional but conspicuous; 3, common), following Webb *et al.* (1976). Abundance of each species was estimated on a four-point scale, and the number of flowering/fruitlet species at the site were recorded. Total fruit/flower abundance for each site was measured by summing all species' abundance scores.

Bird surveys

For the pilot study, birds were surveyed during a single census at each site ($n = 27$) in April 2003. Surveys were conducted between dawn and 0900 hours, when birds are most active (Bibby *et al.* 1992). For the distance ($n = 22$) and width ($n = 16$) studies, birds were censused twice at each site. Morning (dawn to 0900 hours) and afternoon (1600 to 1800 hours) censuses were performed at least four days apart, in June 2003 for the distance study and July–August 2003 for the width study. Rainy and windy days, which reduce bird activity and detectability (Bibby *et al.* 1992), were avoided. Birds were identified to species and counted. Common names of birds used here follow Pizzey and Knight (1999); Latin names are given in Appendix 2.

Line transects in the interior of each site were not possible because of the dense vegetation and often rugged topography, so censuses used line transects (Eberhardt 1978) along the edge of the riparian vegetation with point counts (Recher 1988)

conducted within the riparian vegetation, about halfway between its edge and the stream. Five point counts were conducted at ~40-m intervals, perpendicular to the line transect. Each point count lasted 4 min, while 2 min was allowed to travel each 40-m interval, giving a total 28 min of search time for each census. A stopwatch was used so that all 28 min were spent actually searching for birds and did not include time spent walking into the strip for each point count or time spent identifying birds once spotted.

Analysis

Bird abundances for the width and distance studies were taken as the maximum number recorded for each species in the morning and afternoon censuses, to avoid double counting. Bird species were allocated to feeding, foraging-height and habitat guilds (Appendix 2). Feeding guilds were based on published diet descriptions, and allocated according to dominance in each species' diet (1, frugivore; 2, insectivore; 3, granivore; 4, nectarivore; 5, predator; 6, generalist). Foraging-height groups were based on field observations from the present study and published information (1, ground; 2, ground and vegetation <2 m; 3, vegetation >2 m but below canopy; 4, vegetation >2 m including canopy; 5, canopy and above; 6, all strata). Habitat groupings were allocated following Moloney (2006) (1, open habitats; 2, open forest habitats, not rainforest; 3, woodland and open forest; 4, variety of habitats, including rainforest; 5, rainforest and other closed vegetation; 6, rainforest obligates, or species dependent on rainforest plants).

Principal Component Analysis (PCA) (using PC-ORD[®]: McCune and Mefford 1999) was used to investigate relationships between vegetation and site characteristics. The correlation coefficient was used as the distance measure to standardise the various metrics. Non-metric multidimensional scaling (NMDS, in PC-ORD) of bird abundances (log-transformed) was used to ordinate sites. Correlation coefficients were calculated between the bird-derived NMDS axis scores and site characteristics, including the vegetation PCA axis scores, which acted as measures of vegetation complexity. Bird assemblages were compared between groups of sites using a multiple-response permutation procedure (MRPP, in PC-ORD), which tests for differences between *a priori* groups, and does not require assumptions such as multivariate normality and homogeneity of variances (McCune and Mefford 1999). Groups of sites compared for the pilot study included reference, connected and unconnected sites, and the different length and width categories.

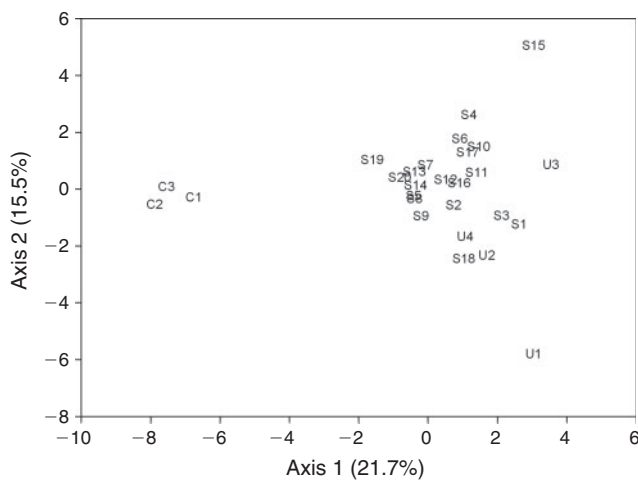


Fig. 1. PCA ordination of study sites by vegetation scores. Percentage variance explained by each axis is indicated. Symbols represent sites: S1–S20, sites connected to forest; U1–U4, unconnected sites; C1–C3, reference (within-forest) sites.

For the width and distance studies, species richness and total abundance were compared between groups of sites using one-way ANOVA or the Kruskal–Wallis K Samples Test, the non-parametric equivalent, if assumptions of normality or homogeneity of variances were not met (Francis 2001). Indicator species analysis (in PC-ORD) was used to identify species that characterised particular site groups, using the same distance or width categories. This method combines a species' abundance with its frequency of occurrence to identify indicator species (McCune and Mefford 1999).

Correlation coefficients were calculated between width or distance and vegetation scores, richness and abundance of the bird guilds, and the bird assemblage as a whole. Regression analysis was performed between riparian width and bird species richness and abundance measures, using non-linear models of best fit in the Sigmaplot[®] 12 package. SPSS[®] 10.0 for Windows was used for other univariate analyses.

Results

Pilot survey

Vegetation

The vegetation at the study sites was complex mesophyll vine forest (Webb 1959), although sclerophyllous species occurred at site S14 (*Acacia* spp. and *Melaleuca* sp.) and site S15 (*Acacia* spp.). PCA differentiated sites on Axis 1 largely on the basis of canopy characteristics and several forest plant groups, contrasting intact forest and disturbed sites (Fig. 1, Table 2). The width, length and area of sites strongly correlated with this axis. On Axis 2, greatest loadings were on various forest features, and there were no correlations with site dimensions apart from stream order (Table 2). MRPP analysis confirmed that reference sites were significantly different from both connected sites ($A = 0.110$, $P = 0.00025$) and unconnected sites ($A = 0.0253$, $P = 0.012$), but unconnected and connected sites did not differ significantly in their vegetation ($A = -0.0081$, $P = 0.652$).

Table 2. Correlations (Pearson's r) between axes of PCA ordination of sites in vegetation space with vegetation and environmental variables, sorted by Axis 1 value for r , indicating main drivers of the PCA

Values of P are not given as it was these variables that were used to derive the patterns

	Axis 1 ($r^2 = 0.22$)	Axis 2 ($r^2 = 0.15$)
Vegetation variables		
Canopy height	−0.843	−0.205
Canopy cover	−0.797	−0.084
Epiphytes	−0.636	−0.431
Palms	−0.523	0.088
Aroids	−0.366	−0.041
Pandans	−0.359	−0.191
Vines	−0.273	−0.217
Gingers	−0.228	−0.695
Tree ferns	0.043	−0.859
Ferns	0.065	−0.667
Fallen logs	0.255	−0.067
Cordylines	0.258	−0.079
Weeds	0.354	−0.572
Poisoning	0.403	−0.408
Logging	0.514	0.246
Disturbance score	0.545	−0.158
Erosion	0.587	−0.393
Site dimension and disposition variables		
Area	−0.528	−0.047
Width	−0.500	0.025
Length	−0.463	0.003
Stream order	−0.414	0.010
Gaps	0.043	0.144
Distance from forest (direct)	0.203	0.288
Distance from forest (corridor)	0.358	0.071

Birds

Forty-three bird species were recorded from the 27 sites (Appendix 2), with 7–16 species per sample. NMDS ordination of sites in species' space showed separation between reference sites and most other sites on Axis 1 (Fig. 2), which correlated positively with width and negatively with distance from the forest and PCA Axis 1 (Table 3). It appears that these relationships were driven by the contrast between the reference sites and the rest as there was no significant relationship between Axis 1 and width when reference sites were removed ($r = 0.118$, $P = 0.582$). Birds correlating positively with this axis were the chowchilla and spectacled monarch, both closed-forest specialists (Habitat Guilds 5 and 6). Birds correlating negatively with this axis were characteristic of mixed forest or more open country (Habitat Guilds 2 and 4). Axis 2 correlated negatively with stream order and vegetation PCA Axis 2 and positively with fruit abundance; birds correlating positively with this axis included the fruit eaters (Feeding Guild 1), yellow oriole, figbird and mistletoebird. MRPP analysis identified significant differences between reference sites and unconnected sites ($A = 0.2482$, $P = 0.0396$), between reference and other sites ($A = 0.0812$, $P = 0.0099$), and between unconnected and other sites ($A = 0.0599$, $P = 0.0268$).

MRPP analysis of the three width classes ('narrow', <40 m; 'mid', 40–70 m; 'wide', >80 m) showed significant

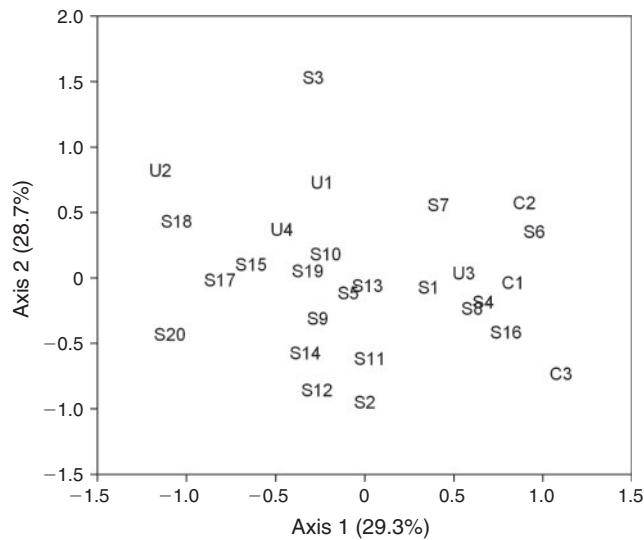


Fig. 2. NMDS ordination of study sites by bird abundances (three-axis solution, stress=0.15). Percentage variance explained by each axis is indicated. Symbols are as in Fig. 1.

differences in bird assemblages ($A = 0.030$, $P = 0.0281$), but with the only significant pairwise difference between narrow and mid classes ($A = 0.0363$, $P = 0.0298$). Distance, area and length of the riparian strip were correlated with Axis 1 of the ordination (Table 3), although these relationships were again driven by the reference sites as the correlations were not significant when these sites were removed. The ordination generated using vegetation scores showed a similar pattern. Of the individual vegetation features measured, only the abundances of fruiting species were significantly correlated with axes of the ordination of sites based on the bird assemblage (Table 3).

Distance study

Forty-nine bird species were recorded from the 21 sites sampled for this study, with 8–17 species per sample. Kruskal–Wallis tests found no significant difference in species richness ($\chi^2 = 6.425$, $P = 0.267$) or total abundance ($\chi^2 = 6.287$, $P = 0.279$) between groups of sites in the different distance categories. However, MRPP showed differences in assemblage composition among all distance categories ($A = 0.237$, $P = 0.0015$). The results of comparisons between pairs of groups using MRPP showed a gradual change in bird assemblages with distance from forest (Table 4). Each distance category had similar bird assemblages to the two next distances in both directions, but was significantly different from sites further away (except the 50-m and 1600-m sites, which were similar). The PCA indicated that distance was negatively correlated with characteristics of intact forest such as canopy height and cover, and positively with disturbance features (Table 2), so it is difficult to ascribe differences in bird assemblages to distance *per se*.

Some species showed clear patterns with distance (Table 5). For example, the pale yellow robin was the only species present at reference sites but not in the riparian remnants, and

Table 3. Correlations (Pearson's r) between axes of NMDS ordination of sites in bird species space with environmental variables and abundance of selected bird species

P = significance value (only values of $P < 0.05$ are given). Values of P are not given for birds as it was the bird data that were used to derive the patterns; in this case r shows the main drivers of the NMDS. Scientific names are given in Appendix 2

	Axis 1 ($r^2 = 0.293$)		Axis 2 ($r^2 = 0.287$)	
	r	P	r	P
Site variables				
Distance from forest	−0.583	0.001	−0.081	–
Length of strip	0.426	0.027	−0.012	–
Riparian width	0.527	0.005	−0.002	–
Area of strip	0.547	0.003	0.031	–
Stream order	0.044	–	−0.403	0.037
Vegetation variables				
PCA Vegetation axis 1	−0.410	0.027	0.289	–
Fruit abundance	−0.018	–	0.386	0.047
Weed abundance	0.007	–	0.286	–
PCA Vegetation axis 2	0.093	–	−0.355	0.050
Flower abundance	0.154	–	0.281	–
No. of flowering species	0.209	–	0.176	–
Canopy cover	0.320	–	0.186	–
Birds				
Yellow oriole	−0.789	–	0.305	–
Rainbow lorikeet	−0.732	–	−0.034	–
Willie wagtail	−0.584	–	0.185	–
Figbird	−0.414	–	0.437	–
Bar-shouldered dove	−0.409	–	−0.036	–
Black butcherbird	−0.147	–	0.445	–
Macleay's honeyeater	−0.076	–	0.433	–
Mistletoebird	−0.036	–	0.479	–
White-breasted woodswallow	0.035	–	0.432	–
Brown cuckoo-dove	0.062	–	−0.441	–
Little shrike-thrush	0.074	–	−0.441	–
Grey whistler	0.197	–	−0.67	–
Spectacled monarch	0.546	–	−0.214	–
Chowchilla	0.652	–	−0.087	–

Table 4. Probability values (P) of MRPP comparisons of the bird assemblages between sites at increasing distances from source forest (0 m)

Values shown in italics indicate distance pairs that had significantly different bird assemblages ($P < 0.05$)

	Distance from source				
	50 m	400 m	800 m	1600 m	3200 m
0 m	0.070	0.140	<i>0.005</i>	<i>0.008</i>	<i>0.008</i>
50 m	–	0.753	0.194	0.603	<i>0.024</i>
400 m		–	0.475	0.248	<i>0.018</i>
800 m			–	0.841	0.053
1600 m				–	0.186
3200 m					–

many species were found only at sites close to source forest (e.g. chowchilla, eastern whipbird, spotted catbird). Others, such as the willie wagtail and jacky winter, were found only at more distant sites. Indicator species analysis identified these two

Table 5. Occurrence (×) of selected bird species across sites at increasing distances from main forest
Scientific names are given in Appendix 2

	Distance from forest (m)					
	0 (reference)	50	400	800	1600	3200
Pale yellow robin	×					
Chowchilla	×	×				
Spotted catbird	×	×	×			
Wompoo fruit-dove	×	×	×	×		
Eastern whipbird	×	×	×	×		
Grey whistler	×	×	×	×	×	
Spectacled monarch	×	×	×	×	×	
Varied triller	×	×	×	×	×	×
Graceful honeyeater	×	×	×	×	×	×
Little shrike thrush	×	×	×	×	×	×
Silvereye	×	×	×	×	×	×
Yellow-spotted honeyeater	×	×	×	×	×	×
Rufous fantail	×	×	×	×	×	×
Yellow oriole		×	×	×	×	×
Bar-shouldered dove		×	×	×	×	×
Spangled drongo		×	×	×	×	×
Yellow-bellied sunbird		×	×	×	×	×
Willie wagtail			×	×	×	×
Jacky winter				×	×	×

species as significant indicators of the furthest (3200 m) sites ($P=0.014$ and $P=0.007$), while the eastern whipbird was indicative of 50-m sites ($P=0.042$). Many species occurred at all distances and at reference sites (e.g. rufous fantail, yellow-spotted honeyeater) (Table 5). Others, like the yellow-bellied sunbird, were absent from reference sites but were found across all distances in the remnant strips.

Neither species richness nor total abundance at each site were correlated with distance ($r=-0.057$, $P=0.807$, and $r=0.012$, $P=0.960$, respectively), but distance effects were evident in some guilds: abundances of species in Habitat Guilds 1, 2 and 3 (more open habitats) increased significantly with distance from forest ($r=0.516$, $P=0.017$, $r=0.794$, $P<0.001$, and $r=0.451$, $P=0.040$, respectively); the abundance of Guild 4 species (habitat generalists) showed no correlation with distance ($r=-0.060$, $P=0.797$); and the abundance of Habitat Guilds 5 and 6 (forest species) decreased with distance ($r=-0.603$, $P=0.005$, and $r=-0.492$, $P=0.023$). Thus, as distance from source forest increased, rainforest species decreased in abundance, while birds of more open habitats became more abundant (Fig. 3).

Width study

Forty-seven bird species were recorded across the 16 sites in this study, with between 8 and 19 species per sample. MRPP showed a significant difference among groups (reference, narrow, mid and wide) based on their bird assemblages ($A=0.245$, $P=0.0007$). However, comparisons between pairs of groups showed that while reference sites were different from all other groups (narrow: $A=0.292$, $P=0.0077$; mid: $A=0.301$, $P=0.0076$; wide: $A=0.185$, $P=0.0084$), bird assemblages at narrow, mid and wide sites were not significantly different.

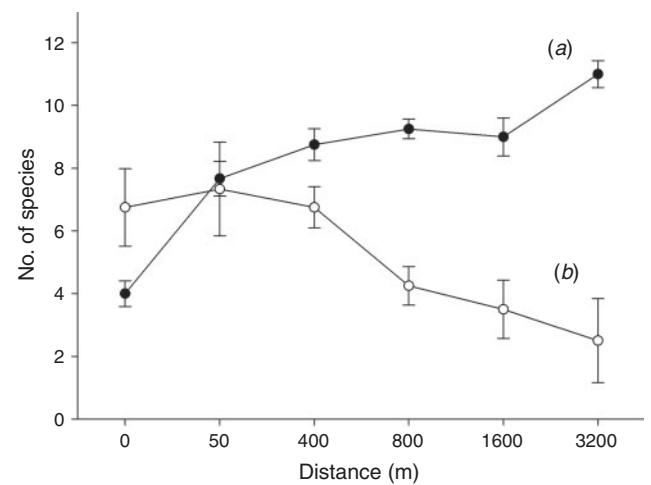


Fig. 3. Number of species ($\pm$ s.e.) of birds in (a) Habitat Guilds 1–4 combined, and (b) Habitat Guilds 5 and 6 combined, at riparian sites at different distances from forest. Distance 0 represents riparian sites within forest. Guilds are defined in the text.

Species richness differed significantly between the four categories of sites (references, <40 , 40 – 70 m, and >80 m widths) (one-way ANOVA: $F_{3,12}=16.337$, $P<0.001$). Tukey HSD *post hoc* analysis showed that reference and narrow (<40 m) groups did not differ from each other ($P=0.879$), as both had relatively low richness, while mid (40 – 70 m) and wide (>80 m) classes, with higher species richness, also did not differ ($P=0.943$).

Increasing width led to an initial increase then decline in the number of species in Habitat Guilds 1–4; there was a concomitant rise in the number of species in Guilds 5 and 6 (Fig. 4), which differed significantly between width categories (ANOVA: $F_{3,12}=8.709$, $P=0.002$). Species richness of Habitat Guilds 5 and 6 showed a significant linear relationship with riparian width in the remnant strips (excluding reference sites) ($r=0.893$, $P<0.001$). Species richness of birds in Habitat Guild 5 showed positive relationships with width ($r=0.652$, $P=0.022$), as did richness of Habitat Guild 6 species ($r=0.680$, $P=0.015$). Width itself correlated positively with characteristics of intact forest such as canopy height and cover and negatively with disturbance measures (Table 2). Other habitat guilds showed no significant relationship with width. Of the feeding and foraging stratum guilds, only insectivore richness correlated significantly with width ($r=0.720$, $P=0.008$).

Indicator Species Analysis identified the pied monarch as a significant indicator of sites in the wide (>80 m) category ($P=0.029$, Indicator value = 75). Although no other species were significant indicators, some did show identifiable patterns across the different classes of sites (Table 6). For example, the yellow-spotted honeyeater and the black butcherbird were found even at the narrowest sites, the eastern whipbird and the orange-footed scrubfowl occurred only at sites of 50 m or wider, the pied monarch was not found at sites less than 82 m wide, and the pale yellow robin and the white-eared monarch were found only at reference sites.

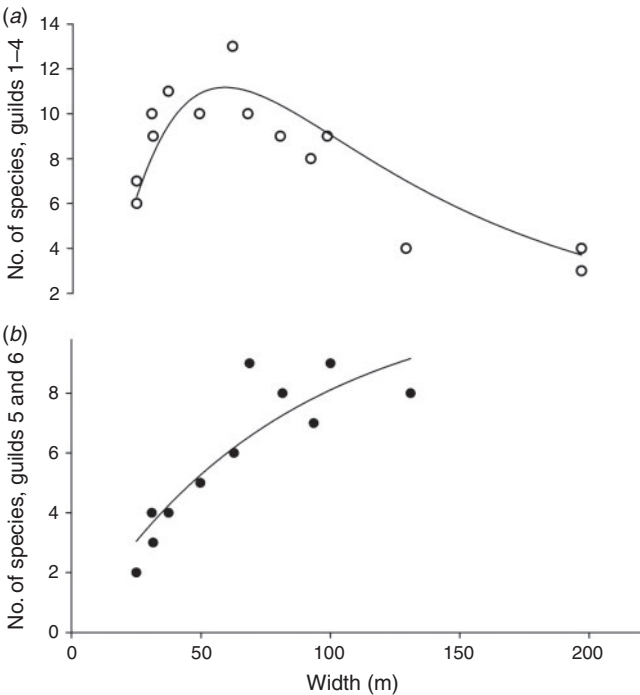


Fig. 4. Regressions of species richness per sample of birds with width of remnant riparian vegetation: birds from (a) Habitat Guilds 1–4 combined (following log-normal model) and (b) Habitat Guilds 5 and 6 combined (following exponential to maximum model). For (a) $F_{2,12}=47.72$, $r^2=0.874$, $P<0.0001$; for (b) $F_{1,13}=50.72$, $r^2=0.835$, $P<0.0001$. Width ‘200’ represents riparian sites in intact forest. Guilds are defined in text and Appendix 2.

Table 6. Range of riparian widths at which selected species from Habitat Guilds 5 and 6 (inhabiting rainforest or other thick vegetation) were recorded
Maximum width of sites was 125 m. Scientific names are given in Appendix 2

Species	Width of riparian zone (m)	
	Minimum	Maximum
Yellow-spotted honeyeater	25	125
Black butcherbird	25	125
Wompoo fruit dove	31	125
Spectacled monarch	32	125
Grey whistler	38	125
Orange-footed scrubfowl	50	125
Eastern whipbird	50	125
Chowchilla	50	125
Pied monarch	82	125
Spotted catbird	82	125
Pale yellow robin	Reference sites only	
White-eared monarch	Reference sites only	

Discussion

Remnant riparian forest sites provided habitat for forest and generalist bird species, but had distinctly different assemblages from those of the reference sites in the intact forest.

Bird assemblages in the remnant sites were influenced by width of the ribbon of forest and distance from the main forest. Assemblage composition changed progressively with distance, as birds of closed forest were replaced by species of more open habitats, although increasing distance was confounded by decreasing riparian width. Species richness was highest at the widest sites because of the presence of both closed-forest specialists and open-habitat or edge species. These contrasts were associated with differences in the vegetation, such as taller trees, greater canopy cover and fewer weeds at main forest (reference) sites. We note that this study was undertaken in the dry season; several further species would be expected to occur in the wet season (e.g. cuckoos) but, depending on their habitat preferences, would be expected to reflect the patterns described here.

While the vegetation was generally similar at connected and unconnected sites, vegetation changes may not yet be detectable as most remnants are much less than 100 years old. Some vegetation measures were related to width or distance – for example, canopy height and cover increased with width of the riparian zone. Weediness increased in narrower zones, probably because the large proportion of edge made them susceptible to disturbance and invasion (Panetta and Hopkins 1991), and because the decrease in canopy cover allowed more light through to the forest floor. Proliferation of edge habitat, facilitating intrusion by edge specialists, can deleteriously affect species that are reliant on large areas of forest (Moloney 2006).

Species diversity is typically lower in isolated patches than in patches connected by vegetation corridors (Harker *et al.* 1993), but no difference was found between the bird assemblages in unconnected and connected riparian sites in this study, even though a few specialist species did not appear in the unconnected sites. Their absence was probably masked in the analysis by the predominance of generalist species in the assemblages. Moloney (2006) made a similar observation for birds in remnant forest patches 50 km north of our study area, which he ascribed to the regular disturbance of the coastal forest by tropical cyclones.

Stream order may be important in determining wildlife assemblages in the riparian zone (Lock and Naiman 1998), and showed a negative relationship to the bird assemblages in this study, probably because stream order increased with distance from the main forest. We found that width of the riparian zone and distance from the main forest were the most important variables in explaining the bird assemblages. Distance from the main forest did not affect species richness or total abundance of birds, but did influence species composition, with forest species replaced by open-habitat species as distance from source forest increased. Species found at all distances were habitat generalists, such as the silvereye, which is known to use small and large habitat remnants (Evans *et al.* 1997), while species that occurred only close to or within intact forest were rainforest obligates or species that preferred dense vegetation; those recorded only at distant sites were non-rainforest species (Moloney 2006).

Increasing distance from source forest was unavoidably confounded by decreasing width of vegetation along the streams, making it difficult to separate the effects of distance from those of width. For example, distance and width both correlated strongly with Axes 1 and 2 of the PCA of sites by vegetation scores. However, bird species richness clearly increased with riparian width, as has been found elsewhere

(e.g. Croonquist and Brooks 1993; Spackman and Hughes 1995). Narrow sites had few rainforest specialists, most species being of more open habitats, probably because most of the area of small remnants is edge habitat (Evans *et al.* 1997). This effect is likely to be exacerbated in narrow riparian strips which, because of their linear nature, have a large edge : area ratio.

Nevertheless, reference sites had lower richness than all but the narrowest riparian ribbons, because they lacked edge or open-habitat species. Similarly, Laurance *et al.* (1996) found that both habitat-generalist and non-rainforest species used regrowth, but rarely entered rainforest. The higher richness at wider remnant sites was due to the presence of rainforest species, typical of reference sites, and non-rainforest species found in narrower strips, as reported elsewhere (e.g. Fisher and Goldney 1997). There was an increase in rainforest species richness with riparian width, although overall species composition did not differ significantly between width classes, again because of the masking effect of the larger number of generalist species. Insectivores were the only feeding guild that showed any significant correlation with width, with both their richness and abundance increasing in wider riparian zones.

Changes in assemblages correlated with vegetation characteristics associated with changing width and distance, and were driven by the distribution patterns of individual species. Thus, forest specialist species were found only at wide sites close to source forest; some edge species were found only at more distant sites; and many generalist species occurred at all distances and at reference sites. These patterns clearly relate to traits and needs of individual species. Similarly, Teillard *et al.* (2014) found that the abundance of specialists was strongly correlated with habitat extent and negatively correlated with habitat heterogeneity whereas generalists were more abundant in landscapes with a higher proportion of arable land and high heterogeneity; and Major *et al.* (1999, 2001), like us, found that small insectivores were more likely to be found in large forest remnants because aggressive birds excluded the smaller species from smaller remnants. Viewing landscapes as a species-specific gradient of states of remaining habitat and condition is important in conservation management (Lindenmayer *et al.* 2003) and understanding species-specific responses to vegetation cover is important for predicting the effects of vegetation restoration (Cunningham *et al.* 2014). Targeting richness alone may miss the individual responses of species, thereby leading to inappropriate management action (Miller and Cale 2000).

Our results suggest some conservation value of remnant riparian vegetation in Wet Tropics agricultural landscapes, in agreement with studies elsewhere (e.g. eastern USA: Keller *et al.* 1993; Brazil: Lees and Peres 2008; northern Queensland: Isaacs 1994; New South Wales: Fisher and Goldney 1997). Only two species (the pale yellow robin and the white-eared monarch) recorded at reference sites were not also found at remnant riparian sites. However, we did not investigate birds' survivorship or reproduction within sites, or passage through them, which are necessary to fully understand how to successfully restore fragmented environments (Marzluff and Ewing 2001). It is possible that riparian habitats are merely population sinks for specialist forest species, which would not persist without immigrants from source patches. However, while the riparian ribbons provided only about a tenth of the area of lowland forest in the

study area, they provided a greater length of forest edge, which is substantial habitat for native edge and generalist species, no doubt boosting their population sizes in the region, and probably not acting as sinks for them.

The demonstrated influence of width of riparian vegetation, and probably its distance from intact source forest, provide a guide for restoration efforts. The wider the riparian strip, the more effective it is likely to be in reducing edge effects and sustaining characteristics of intact closed forest, which in combination can sustain closed forest biota, providing both habitat and linkages between larger patches (Tucker 2000). In agricultural landscapes there is a need for compromise, such that an optimal width will provide wildlife habitat while minimising the loss of productive land. This study indicated an optimal width of more than 90 m, but even at that width some forest species were not recorded. Comparable conclusions have been drawn from studies elsewhere – for example, recommended widths of riparian forests include 100 m in the eastern USA (Keller *et al.* 1993), at least 40–45 m in the western USA (Hagar 1999; Pearson and Manuwal 2001), more than 100 m on Vancouver Island (Shirley *et al.* 2005), and 90–140 m in Brazil (Bueno *et al.* 2012).

The problem of separating the effects of distance from source forest from those of riparian width could only be solved by examining wide riparian zones further from the source. In the region studied here, this would have been possible only by including sites along higher-order streams, which may have inherent differences in their vegetation or bird assemblages. If distant sites are unable to support forest-interior birds that are sensitive to habitat fragmentation, restoration efforts may best be focussed on extending existing forest blocks or riparian strips close to these blocks. It is probable, though, that at least some species will use wide riparian zones even if they are not close to large areas of source forest. Therefore, restoration of sufficiently wide riparian zones could help to restore connectivity across the landscape, while also providing a reservoir of rainforest bird diversity. Although it is not possible to determine from this study whether such corridors will assist movement of wildlife (Gregory and Beier 2014), movement of many species through riparian strips has been demonstrated for nearby upland sites on the Atherton Tablelands (Isaacs 1994), and it is clear that they will at least provide important habitat. Even smaller habitat patches and linkages between them have value for many open-vegetation species, so conservation efforts in these areas, focusing on forested riparian strips as an integral part of a larger network of conservation reserves, should be beneficial (Petit *et al.* 1999). Our conclusion for land management is that in the intensive farming landscape of sugarcane production, forest bird conservation can be greatly enhanced by long, preferably inter-connecting, corridors of remnant or restored riparian forest of at least 90 m width, enhanced by active weed management.

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Appendix 1. Location and biophysical characteristics of study sites

Studies were: g, general survey; d, distance; w, width. Unless otherwise indicated, values are scores representing abundance or extent of condition (from 0 = not evident, to 3 = common). Flowering and fruiting species were scored as number of species, while weed, fruit and flower abundance were measured by totalling abundance scores for each species. Fruit species were classified as 'fleshy', 'dry' or 'fleshy/dry' according to published information. 'Fleshy/dry' species were given half the value of 'fleshy' species when abundances were calculated. An asterisk indicates reference sites that were located within intact blocks of forest, so were given notional width, length and area values

Site	Study	Map reference	Mean width of strip (m)	Length of strip (m)	Area of strip (ha)	Distance from source forest (m)	Stream order	Canopy height (m)	Average canopy cover (%)	Weed abundance	Total disturbance	Palms	Vines	Epiphytes	Gingers	Pandanus	Tree-ferns	Cordylines	Aroids	Ferns	Fallen logs	Fruiting species	Fruit abundance	Fleshy fruited species	Fleshy fruit abundance**	Flowering species	Flower abundance
C1	g,d,w	CA860235	200*	3000*	600*	0	4	25	80	0	1	3	3	3	3	3	3	2	1	2	2	1	2	0	0	2	2
C2	g,d,w	CA854183	200*	3000*	600*	0	2	25	82	0	1	3	3	3	3	3	1	1	2	3	2	0	0	0	0	1	2
C3	g,w	CA892320	200*	3000*	600*	0	4	28	84	4	1	3	3	3	3	3	3	2	2	3	2	2	2	2	2	3	3
C4	d	CA897136	200*	3000*	600*	0	1	25	80	1	0	2	3	3	3	3	3	2	2	2	2	3	3	3	2.5	2	3
C5	d,w	CA852226	200*	3000*	600*	0	2	25	74	0	1	1	3	3	3	3	3	2	2	2	2	2	4	0	0	1	1
S1	g	CA803403	36	600	2.2	434	1	18	82	7	2	2	3	1	1	1	1	2	1	2	1	3	5	3	4.5	2	2
S1w	w	CA803403	32	625	2.0	400	1	18	82	8	2	1	3	1	1	1	1	2	1	2	1	6	8	4	5.5	2	2
S2	g	CA959186	38	625	2.3	250	1	24	80	6	1	3	3	3	1	3	1	2	1	2	1	6	7	4	4	7	8
S3	g	CA869102	25	750	1.9	250	1	22	78	4	1	3	3	2	2	2	2	3	1	2	2	2	4	1	1	2	2
S3w	w	CA869102	25	750	1.9	400	1	20	70	5	1	2	3	2	2	2	2	3	1	2	2	3	5	3	4.5	0	0
S4	g	CA923237	61	972	5.9	437	3	20	72	4	2	3	3	3	3	3	1	3	1	2	3	5	9	3	5.5	5	7
S5	g	CA932234	69	500	3.4	250	2	25	76	6	0	3	3	3	3	3	2	2	2	2	2	4	6	3	3.5	5	9
S5a	d	CA936231	213	500	10.6	50	2	25	78	3	0	3	3	3	2	2	2	2	2	2	2	5	8	4	5	3	4
S5b	d	CA936227	44	500	2.2	400	2	22	76	7	0	3	3	3	2	3	2	2	2	2	2	5	7	3	5	5	6
S5c	d	CA935223	44	500	2.2	800	2	22	66	11	1	2	3	3	2	2	2	2	2	2	2	9	14	4	8	6	8
S5d	d	CA930215	19	500	0.9	1600	3	20	66	5	2	2	3	3	3	1	2	1	1	2	2	5	9	3	3.5	1	1
S5e	d	CA919207	19	500	0.9	3200	4	15	64	7	2	1	3	2	3	3	2	2	2	2	2	3	6	2	3.5	4	6
S5w	w	CA932234	50	500	3.7	400	2	25	76	6	1	2	3	3	3	3	2	2	2	2	2	4	4	3	2	1	1
S6	g	CA844393	67	610	4.1	366	2	22	74	8	2	3	3	3	3	1	2	2	2	2	2	7	8	4	5	4	6
S6w	w	CA844393	63	610	4.6	400	2	22	74	8	2	2	3	3	3	1	2	2	2	2	2	3	5	1	1	2	2

S7	CA891237	81	610	4.9	365	3	22	84	6	2	3	3	3	3	3	3	2	—	—	2	2	8	20	4	7.5	3	6	
	CA891237	82	610	5.7	400	3	22	80	7	2	2	3	3	3	3	3	2	—	—	2	2	5	5	3	2	3	4	
S8	CA888235	97	729	7.1	365	1	22	84	4	1	3	3	2	2	2	2	3	—	—	—	2	11	17	8	9.5	10	13	
	CA888235	94	730	8.5	400	2	22	84	4	1	3	3	2	2	2	2	3	—	—	—	2	3	4	3	3.5	2	2	
S9	CA864387	91	610	5.6	610	1	24	78	4	0	3	3	3	3	2	2	—	—	—	—	2	4	5	3	2	6	7	
	CA893083	31	900	2.8	2750	1	20	76	4	0	1	3	2	—	—	—	—	—	—	—	1	3	6	2	0	0	7	
U1	CA866189	63	1250	7.8	550	4	15	60	8	1	2	3	3	—	—	—	2	—	—	3	2	6	8	5	6	5	8	
	CA953090	38	750	2.8	500	1	22	70	6	1	3	2	2	—	—	—	—	3	—	—	2	4	6	2	1.5	1	2	
U2	CA866189	31	1250	7.8	400	4	15	60	8	2	2	3	3	—	—	—	2	—	—	3	2	2	4	2	4	3	4	
	CA806405	42	529	2.2	844	1	18	66	11	3	1	3	2	3	—	—	3	3	—	3	2	11	13	9	11	3	5	
S11	CA923342	49	1215	5.9	486	3	18	74	5	1	3	3	2	—	—	—	2	—	—	—	2	6	12	3	5	4	7	7
	CA876214	56	750	4.2	1000	2	24	76	8	1	3	3	2	—	—	—	—	—	—	—	2	5	9	4	7	5	7	
U4	CA798170	98	2200	21.6	980	4	20	76	6	1	3	3	2	—	—	—	—	—	—	—	1	2	4	0	0	2	3	
	CA806173	100	2200	22.0	400	4	22	72	7	1	—	3	2	—	—	—	—	—	—	—	2	6	8	1	2	4	6	
S12b	CA804169	56	2200	12.3	800	4	22	82	1	1	1	3	3	—	—	—	—	—	—	2	2	3	5	1	0.5	1	1	
	CA798170	25	2200	5.5	1600	4	20	66	11	2	2	3	3	—	—	—	—	—	—	—	2	1	3	1	3	4	7	
S12d	CA806173	100	1750	31.7	400	4	22	68	7	1	—	3	2	—	—	—	—	—	—	1	2	3	5	1	1	1	1	
	CA865384	116	1220	14.1	732	4	15	74	5	1	3	3	1	2	—	—	—	—	—	—	2	11	15	9	10.5	7	10	
S13	CA865384	131	1220	18.0	400	4	22	74	6	1	2	3	1	2	—	—	—	—	—	—	2	6	9	5	7	2	3	
	CA768180	146	2196	32.1	976	3	16	64	2	1	—	1	1	—	—	—	—	—	—	3	2	2	3	1	1	4	5	
S14	CA815022	42	7500	31.6	723	4	15	60	3	4	3	3	1	—	—	—	—	—	—	—	3	5	7	3	3	6	7	
	CA876224	68	4720	32.0	354	2	22	72	8	1	3	3	2	—	—	—	—	—	—	—	2	10	12	6	5	9	13	
S16a	CA876229	138	4720	64.9	50	2	25	80	3	1	3	3	3	2	—	—	—	—	—	2	2	8	11	4	6	3	4	
	CA876224	50	4720	23.4	400	2	22	72	6	1	3	3	2	2	—	—	—	—	—	—	2	8	9	5	4	3	3	
S16b	CA876224	50	4720	23.4	400	2	22	72	6	1	3	3	2	—	—	—	—	—	—	—	2	8	9	5	4	3	3	
	CA876221	44	4720	20.5	800	3	22	66	8	2	2	3	3	2	—	—	—	—	—	—	3	8	13	5	6	6	8	
S16c	CA876221	44	4720	20.5	800	3	22	66	8	2	2	3	3	2	—	—	—	—	—	—	3	8	13	5	6	6	8	
	CA879216	38	4720	17.7	1600	3	20	70	9	0	3	3	3	1	1	1	1	1	—	—	2	6	10	4	8	6	8	
S16d	CA891206	16	4720	7.7	3200	3	20	74	3	1	3	3	3	—	—	—	—	—	—	—	2	3	6	1	3	1	1	
	CA876224	50	4720	50.0	400	2	22	72	6	1	3	3	2	—	—	—	—	—	—	—	2	7	8	4	3.5	2	2	
S17	CA886183	69	12500	85.6	875	5	20	68	6	3	2	3	2	—	—	—	—	—	—	2	2	4	4	1	4	7	7	
	CA863076	81	4379	35.3	2551	1	20	78	4	2	3	3	2	2	—	—	2	—	—	—	1	5	9	2	4	2	2	
S18	CA870200	94	20000	187.5	1000	5	25	76	5	3	3	3	3	3	3	3	—	—	—	2	2	3	4	3	2.5	5	7	
	CA942118	92	3660	33.5	732	4	22	74	0	2	3	3	3	—	—	—	—	—	—	—	2	3	4	1	1	2	3	
S20	CA895134	75	3660	27.5	50	1	22	78	6	1	2	3	3	—	—	—	—	—	—	—	2	8	14	3	4	5	6	
	CA894131	69	3660	25.2	400	2	22	76	4	1	2	3	2	—	—	—	—	—	—	—	2	3	4	1	1	3	6	
S21b	CA893129	38	3660	13.7	800	2	20	76	5	1	3	3	3	2	—	—	—	—	—	—	2	9	13	7	9	4	6	
	CA891111	31	3660	11.3	2600	4	20	64	5	3	3	3	3	—	—	—	—	—	—	—	2	3	4	3	2.5	3	3	
S21d	CA894131	69	3200	24.0	400	2	22	76	4	1	2	3	2	—	—	—	—	—	—	—	2	4	4	1	1	2	2	
	CA959186	38	600	2.3	400	1	24	80	8	1	2	3	3	1	3	—	—	—	—	—	3	4	1	1	1	1	1	

Appendix 2. Bird species recorded and their assignment to guilds

‘+’ indicates species recorded in each set of samples. Habitat guilds: 1, open habitats; 2, variety of open forested habitats, but not rainforest; 3, woodland and open forest; 4, variety of habitats, including rainforest; 5, rainforest and other closed vegetation, e.g. gallery forest; 6, rainforest obligates, or species dependent on rainforest plants. Feeding guilds: 1, frugivores; 2, insectivores; 3, granivores; 4, nectarivores; 5, predators; 6, generalists. Foraging strata: 1, ground; 2, ground and vegetation below 2 m; 3, vegetation >2 m but below canopy; 4, vegetation >2 m including canopy; 5, canopy (top third of vegetation); 5+, above canopy; 6, use all strata

Common name	Scientific name	Sample type			Guild assignment		
		Pilot	Distance	Width	Habitat	Feeding	Stratum
Australian brush turkey	<i>Alectura lathami</i>	+	+	+	5	6	1
Barred cuckoo-shrike	<i>Coracina lineata</i>	+		+	6	1	4
Bar-shouldered dove	<i>Geopelia humeralis</i>	+	+	+	2	3	1
Black butcherbird	<i>Cracticus quoyi</i>	+	+	+	5	5	6
Black-shouldered kite	<i>Elanus axillaris</i>		+		1	5	5
Brown cuckoo-dove	<i>Macropygia amboinensis</i>	+	+	+	5	1	4
Chowchilla	<i>Orthonyx spaldingii</i>	+	+	+	6	2	1
Cicadabird	<i>Coracina tenuirostris</i>			+	4	2	5
Crimson finch	<i>Neochmia phaeton</i>		+	+	1	3	2
Double-eyed fig parrot	<i>Cyclopsitta diophthalma</i>	+			5	1	4
Dusky honeyeater	<i>Myzomela obscura</i>	+	+		4	4	6
Eastern whipbird	<i>Psophodes olivaceus</i>	+	+	+	5	2	2
Emerald dove	<i>Chalcophaps indica</i>		+		5	1	1
Fairy gerygone	<i>Gerygone palpebrosa</i>	+	+	+	5	2	6
Fairy martin	<i>Hirundo ariel</i>		+	+	1	2	5+
Figbird	<i>Sphecotheres viridis</i>	+	+	+	4	1	5
Forest kingfisher	<i>Todiramphus macleayii</i>	+	+		2	2	5
Golden whistler	<i>Pachycephala pectoralis</i>	+	+		5	6	5
Gould's bronze cuckoo	<i>Chrysococcyx russatus</i>		+	+	4	2	3
Graceful honeyeater	<i>Meliphaga gracilis</i>	+	+	+	4	4	6
Grey goshawk	<i>Accipiter novaehollandiae</i>			+	5	5	6
Grey whistler	<i>Pachycephala simplex</i>	+	+	+	6	2	6
Helmeted friarbird	<i>Philemon buceroides</i>			+	4	6	5
Jacky winter	<i>Microeca fascians</i>		+	+	2	2	6
Laughing kookaburra	<i>Dacelo novaeguineae</i>	+	+	+	4	5	1
Leaden flycatcher	<i>Myiagra rubecula</i>		+		3	2	4
Lemon-bellied flycatcher	<i>Microeca flavigaster</i>	+			2	2	3
Little shrike-thrush	<i>Colluricincla megarrhyncha</i>	+	+	+	4	2	6
Macleay's honeyeater	<i>Xanthotis macleayana</i>	+	+	+	6	4	6
Magpie lark	<i>Grallina cyanoleuca</i>	+	+		1	6	1
Metallic starling	<i>Aplonis metallica</i>	+			5	1	5
Mistletoebird	<i>Dicaeum hirundinaceum</i>	+	+	+	4	1	3
Northern fantail	<i>Rhipidura rufiventris</i>	+	+	+	3	2	4
Nutmeg mannikin	<i>Lonchura punctulata</i>			+	1	3	2
Orange-footed scrubfowl	<i>Megapodius reinwardt</i>	+	+	+	5	6	1
Pale yellow robin	<i>Tregellasia capito</i>	+	+	+	6	2	6
Pied monarch	<i>Arses kaupi</i>		+	+	6	2	6
Rainbow bee-eater	<i>Merops ornatus</i>	+	+	+	1	2	5+
Rainbow lorikeet	<i>Trichoglossus haematodus</i>	+	+		4	4	5
Red-backed fairy wren	<i>Malurus melanocephalus</i>			+	1	2	2
Rose-crowned fruit dove	<i>Ptilinopus regina</i>		+	+	5	1	4
Rufous fantail	<i>Rhipidura rufifrons</i>	+	+	+	4	2	6
Satin flycatcher	<i>Myiagra cyanoleuca</i>			+	3	2	4
Shining bronze-cuckoo	<i>Chrysococcyx lucidus</i>		+		5	2	4
Shining flycatcher	<i>Myiagra alecto</i>	+	+	+	5	2	3
Silvereye	<i>Zosterops lateralis</i>	+	+	+	4	6	6
Spangled drongo	<i>Dicrurus bracteatus</i>	+	+	+	4	5	4
Spectacled monarch	<i>Monarcha trivirgatus</i>	+	+	+	5	2	3
Spotted catbird	<i>Ailuroedus melanotis</i>	+	+	+	6	1	4
Sulphur-crested cockatoo	<i>Cacatua galerita</i>	+	+	+	4	3	5
Superb fruit-dove	<i>Ptilinopus superbus</i>	+	+	+	6	1	5
Varied triller	<i>Lalage leucomela</i>	+	+	+	4	6	5

(Continued)

Appendix 2. (Continued)

Common name	Scientific name	Sample type			Guild assignment		
		Pilot	Distance	Width	Habitat	Feeding	Stratum
White-breasted woodswallow	<i>Artamus leucorhynchus</i>	+			1	2	5+
White-eared monarch	<i>Monarcha leucotis</i>			+	5	2	5
White-winged triller	<i>Lalage sueurii</i>		+	+	3	6	5
Willie wagtail	<i>Rhipidura leucophrys</i>	+	+	+	2	2	2
Wompoo fruit-dove	<i>Ptilinopus magnificus</i>	+	+	+	6	1	5
Yellow honeyeater	<i>Lichenostomus flavus</i>	+			3	4	6
Yellow oriole	<i>Oriolus flavocinctus</i>	+	+	+	4	1	5
Yellow-bellied sunbird	<i>Nectarinia jugularis</i>	+	+	+	4	4	6
Yellow-breasted boatbill	<i>Machaerirhynchus flaviventer</i>		+		6	2	6
Yellow-spotted honeyeater	<i>Meliphaga notata</i>	+	+	+	5	4	6