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Birds on the edge: Spatial and temporal patterns in the bird community recorded at a conservation reserve on a bioregion woodland–grassland boundary in central Queensland

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Abstract. Monitoring the changes in occurrence and abundance of wildlife communities over time is important for more effective and targeted management and understanding long-term changes due to local and global environmental influences. In this study, we report on the first systematic bird survey carried out on Edgbaston Reserve, a protected area on the boundary of tropical and semi-arid bioregions in north-central Queensland. We systematically sampled the bird fauna at 24 sites over five surveys between 2018 and 2020, using a combination of 2-ha area searches and timed nocturnal censuses. We examined variation in composition and species abundance across the surveys using multivariate, regression and non-parametric analyses. A total of 6201 bird records comprising 123 species was collected. Forty-six species exhibited significant variation in abundance across the six sampled habitat types (Ironbark, Gidgee and Escarpment woodlands, Springs, Spinifex grasslands and Mitchell Grass Downs). Species composition also varied significantly across habitats and surveys, and there were clear differences in the Spinifex and Mitchell grass bird communities compared with those in the woodlands. Twenty species were recorded in only one of the five surveys, and 17 species were recorded in significantly higher abundance in some survey years, associated with an influx of granivores and nomadic and migratory species. The location of the property on the boundary of woodlands and more arid grasslands that contain springs, and the contrasting mix of eastern- and western-distributed birds, suggests that the continued monitoring of the avifauna provides an important opportunity to investigate long-term trends, linked to environmental change and annual management, to assist the preservation of this important bird community situated on the edge of two bioregions.

Introduction

Monitoring the changes in occurrence and abundance of wildlife communities over time is a core activity for conservation (Robinson *et al*. 2018). Such data are critical in illuminating the effect of local management, the need for changes in management over time and the influence of broader environmental factors such as climate and weather that will have a significant effect on annual management decisions, including fire management (Lindenmayer *et al*. 2022a). Birds can be important indicators of environmental change (Scheele *et al*. 2019) and significant fluctuations have been reported as a consequence of severe rainfall deficits or surpluses (Connell *et al*. 2022). Conversely, birds seem to be more resilient than mammals to ecological changes (Woinarski *et al*. 2012), though this is dependent on the context and threat (Lindenmayer *et al*. 2020).

Landscapes on the boundary of different bioregions or vegetation communities can contain a fauna that represents an intermingling or transition of the broader biota of each (Smith *et al.* 2018). Often these locations can have an elevated diversity of species (Altamirano *et al.* 2020) or a fluctuating pattern of wildlife dependent on changing environmental conditions of each region (Caddy-Retalic *et al.* 2020). From a conservation perspective, maintaining connectivity across contrasting bioregions could strategically assist climate-driven range shifts in species over time (Littlefield *et al.* 2019). Similarly, locations with natural assets such as permanent springs can act as oases in environments that may suffer significant drought, and are important refuges for many taxa and communities (Cartwright *et al.* 2020). Fauna dependent on these resources can disintegrate if the springs vanish (Iknayan & Beissinger 2018).

In this study, we report on the first systematic bird survey carried out on Edgbaston Reserve, a protected area on the boundary of tropical and semi-arid bioregions, that contains the most diverse Great Artesian Basin spring complex in Australia (Rossini *et al.* 2018). The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin is a threatened ecological community (Australian Government 1999) and exhibits incredibly high endemism, including of fish, invertebrates and plants (e.g. Fahey *et al.* 2019). The avifauna of this important Reserve is also significant for several threatened and biogeographically limited species (Kern & Kutt 2021), though the patterns across the different vegetation types, and over time, have not been described. In this study we used data collected over multiple years and systematic surveys to examine the variation in bird community composition, species richness and abundance across the habitat types and years of survey, and the environmental factors that best predict the abundance of bird species at a site. Information about the distribution, abundance and environmental pattern in vertebrate fauna is important, not only for refining and targeting future survey effort but also

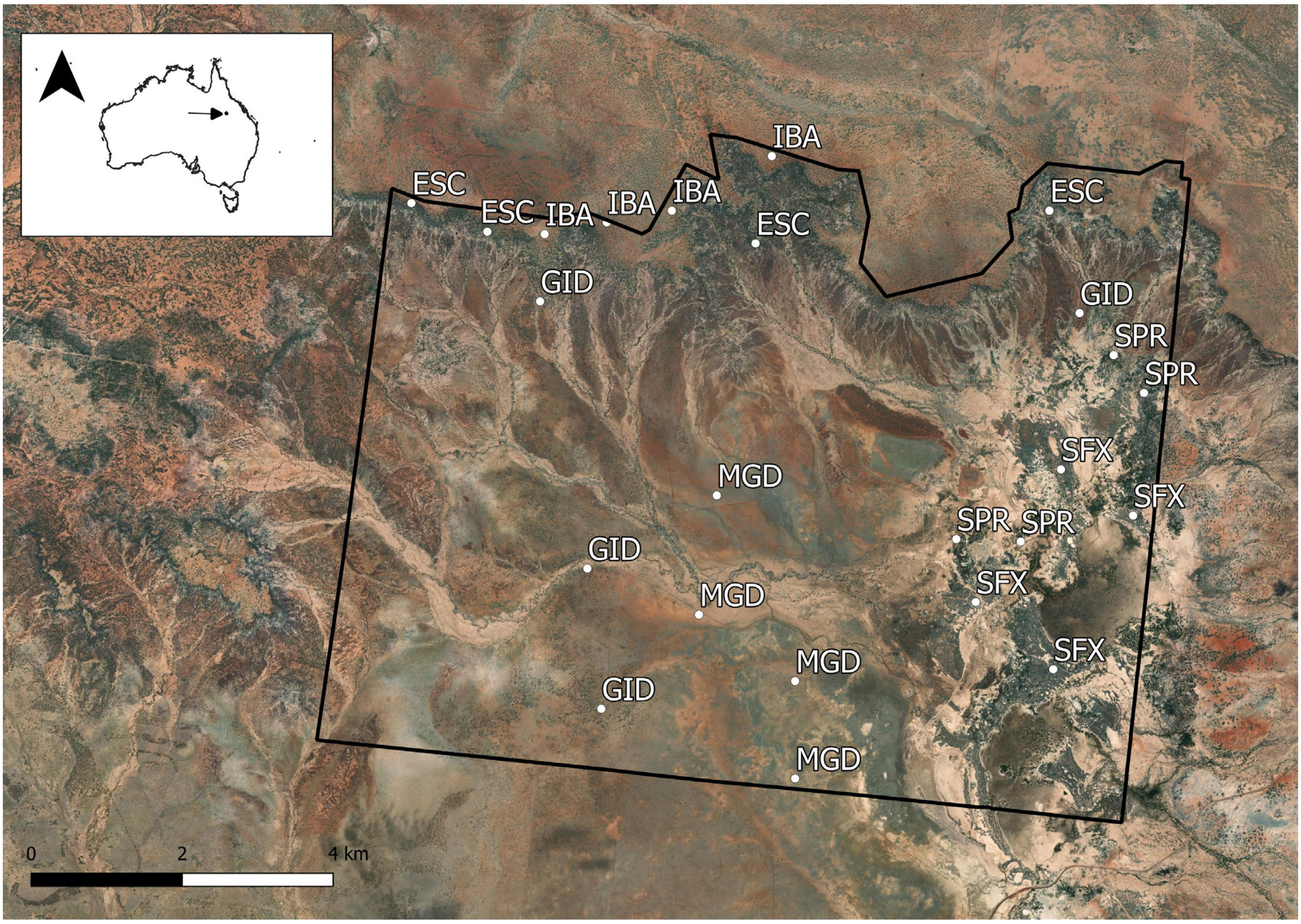

Figure 1. Satellite image of Edgbaston Reserve, Queensland, indicating the location of the survey sites. ESC = Escarpment, IBA = Ironbark, GID = Gidgee, MGD = Mitchell grass downs, SFX = Spinifex and SPR = Springs. Image source: Fugin *et al.* (2019)

for understanding, at least correlatively, the link between changes in ecosystems caused by management and the fauna that is resident in those ecosystems.

Method

Edgbaston Reserve (size 8074 ha, location –22.7309, 145.4147) is a conservation reserve owned and managed by Bush Heritage Australia and is located 160 km north-east of Longreach, in central-western Queensland (Figure 1). Edgbaston lies at the headwater of the Pelican Creek catchment and on the eastern boundary of the Mitchell Grass Downs bioregion that adjoins the western boundary of the Desert Uplands bioregion and western fall of the Great Dividing Range. This region is semi-arid in climate (450 mm rainfall per annum), and the vegetation consists largely of grasslands (dominated by Mitchell grass *Astrebla* and spinifex *Triodia* species), open woodlands (dominated by *Acacia*, *Eucalyptus* or *Melaleuca* species) and vegetated swamps and claypans associated with the artesian spring complex and the ephemeral Lake Mueller.

Records of vertebrate fauna on the Reserve were collected from systematic surveys conducted between March 2018 and October 2020 across six major vegetation communities: Mitchell *Astrebla* spp. grassland (Mitchell grass), Spinifex *Triodia* spp. grasslands (Spinifex), Gidgee *Acacia* spp. woodlands (Gidgee), White's Ironbark *Eucalyptus whitei* woodlands (Ironbark), escarpment Yapunyah *E. thozetiana* woodlands (Escarpment) and spring woodland complexes (Springs).

The fauna surveys were conducted over five 2-week periods in October 2018, March and October 2019, and March and October 2020. The pattern of monthly rainfall (recorded from Aramac, 40 km south of Edgbaston) across the survey period indicated typically drier conditions before the October surveys and wetter conditions before the March surveys, though seasonal conditions showed rainfall above average from October 2019 (Figure 2). In total, 24 sites (Appendix 1) were established in the six main habitat types listed above, with four permanently marked sites (100 m x 200 m) in each. This study reports on only the bird data; the methods and results for the other vertebrate fauna collected in this study will be reported separately (unpubl. data).

Bird surveys were undertaken in a 2-ha area and consisted of six 10-minute counts during which all individual birds seen and heard were recorded. The six counts were conducted over the course of 5 days, with three in the early morning (<2 h after sunrise) and three after this (from 2 h after sunrise to sunset). The broader fauna survey included nocturnal active searches (two searches of 30 person-minutes), largely focused on reptiles (Kearney *et al.* 2020); however, nocturnal birds were recorded and included in

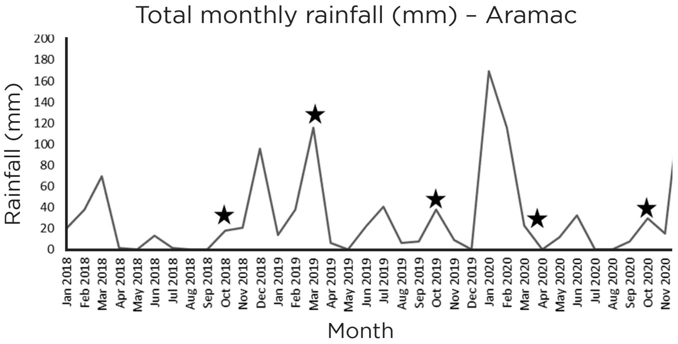

Figure 2. Monthly rainfall at Aramac across the period of the fauna surveys at Edgbaston Reserve, with each of the five survey months highlighted by stars.

the site data analysed in the present study, as the effort was consistent. The total effort for each plot is therefore six 10-minute surveys and two 30 person-minute nocturnal searches.

In the standardised surveys, corvids were grouped as corvid spp., given the uncertainty in identifying the three potential species (Torresian Crow *Corvus orru*, Little Crow *C. bennetti* and Australian Raven *C. coronoides*) within survey time constraints. The taxonomy in this paper follows BirdLife Australia (2019).

In each plot the cover of the ground layer was recorded along a 100-m transect (star pickets at 0 and 100 m). A 100-m tape was laid out along the central line of the quadrat and, using a laser pointer, the cover at 1-m intervals was recorded in the following categories: crust, disturbed (broken ground or water), rock, annual grass, perennial grass – tussock, perennial grass – hummock (*Triodia* sp.), annual herb/forb, shrub, perennial herb/forb, non-native herb/forb, non-native grass, non-native shrub, sedge, and fern. The percentage cover of the tree canopy was measured using a densiometer. The vertical projection of the canopy for each tree along the 100-m tape (as above) was recorded (e.g. if the canopy of a tree projected from the 20-m mark to the 30-m mark, the measurement was recorded as 10 m, and therefore 10% cover). The total for the 100 m is the total canopy cover, or the canopy cover for each tree species.

Analysis

For each survey, and for each of the 24 sites, we were able to derive total species richness and abundance of birds, functional groups of interest (i.e. granivores, nectarivores and insectivores), and abundance of each species. Abundance data were derived from total number of bird species recorded during the diurnal and nocturnal site surveys, rather than any calculation of absolute density. Previous studies have demonstrated that measures of relative abundance provide patterns of population trends proportional to those derived from estimates of absolute abundance (Slade & Blair 2000; Hopkins & Kennedy 2004).

We investigated the patterns in the bird community composition across each survey and habitat type and the interaction by using PERMANOVA v7.0.13 (Anderson *et al.* 2008). PERMANOVA is a distance-based, non-parametric, multivariate analysis of variance that calculates a pseudo *F*-statistic and associated *P*-value by means of permutations, rather than relying on normal-theory tables (Anderson 2001). We constructed a site by species abundance array, fourth root transformed the data and then created a Bray–Curtis resemblance (similarity) matrix. We examined the pattern in the data using a simple PERMANOVA design for the two factors and their interaction. We also undertook a constrained canonical analysis of principle coordinates for species composition across habitat types (using all survey data combined) in order to find the strongest axes of species correlation through the multivariate cloud that best characterise *a priori* habitat group differences (Anderson *et al.* 2008). We fitted species as vectors to the multivariate ordination via Spearman rank correlations, and we truncated the vectors to those with a correlation >0.6.

We examined the variation in total richness and abundance for all bird species and three functional groups, and abundance of all species across the six habitat types (using all survey data combined). We tested for significant differences using a Kruskal–Wallis non-parametric one-way analysis of variance (StatSoft Inc. 2022). We graphically presented the patterns in mean abundance (and standard error) for all bird species and for all insectivores, nectarivores and granivores per habitat across each survey. We also assessed the variation in abundance across the five surveys, testing for any significant differences between the observed and expected frequencies via a *Chi*-square test for goodness of fit (StatSoft Inc. 2022).

Finally, we examined the variation in abundance of species in response to site and landscape covariates for the entire survey data (120 samples). Variation in abundance was tested only for those species recorded in >20 sites over the five surveys. After examining the correlation between the site variables and consideration of the factors that typically predict bird pattern, we chose two site variables (tussock grass cover and spinifex cover) and one landscape variable (foliage projective cover in a 1-km buffer around the site) for the analysis. The foliage projective cover measure was derived using ArcMap 10.7.1 (ESRI 2019) from the State-wide Landcover and Trees Study tree cover data (Queensland Department of Environment & Science 2018). We used generalised linear mixed (multi-level) models in Genstat 18 (Payne *et al.* 2010), which combine both fixed and random terms and estimate the variance within a group against the variance; in this case, we used the survey as the random effect. We fitted negative binomial regression models and fitted only additive models of all three variables, as we were interested only in size and direction of the main effects. Variance components were estimated using maximum likelihood for the fixed effects and dispersion components, and approximate empirical Bayes estimates of the random effects and significance of the fixed effect were assessed via the Wald statistic (Payne *et al.* 2010).

Results

A total of 6201 birds records comprising 123 species was documented on Edgbaston Reserve from the standardised census conducted at 24 sites and sampled five times from March 2018 to October 2020. Although corvids were grouped as corvid spp. during systematic surveys, Torresian Crow, Little Crow and Australian Raven are all known to occur on the Reserve. Two of the taxa recorded are listed as having conservation significance: Southern Squatter Pigeon *Geophaps scripta scripta* (Vulnerable) and Painted Honeyeater *Grantiella picta* (Vulnerable) (Australian Government 2023).

The 20 most frequently recorded species during all surveys combined (*n* = 120) were corvid spp. (75% of the 120 samples across five surveys), Galah *Eolophus roseicapilla* (71%), Singing Honeyeater *Gavicalis virescens* (60%), Pied Butcherbird *Cracticus nigrogularis* (59%), Australian Magpie *Gymnorhina tibicen* (59%), Mistletoebird *Dicaeum hirundinaceum* (58%), Rufous Whistler *Pachycephala rufiventris* (54%), Little Friarbird *Philemon citreogularis* (53%), Black-faced Cuckoo-shrike *Coracina novaehollandiae* (48%), Weebill *Smicrornis brevirostris* (44%), Willie Wagtail *Rhipidura leucophrys* (43%), Crested Pigeon *Ocyphaps lophotes* (40%), Grey Shrike-thrush *Colluricincla harmonica* (39%), Brown Honeyeater *Lichmera indistincta* (38%), Cockatiel *Nymphicus hollandicus* (34%), Zebra Finch *Taeniopygia castanotis* (32%), Horsfield's Bronze-Cuckoo *Chalcites basalis* (25%), Striated Pardalote *Pardalotus striatus* (25%), Yellow-throated Miner *Manorina flavigula* (25%) and Noisy Friarbird *Philemon corniculatus* (25%).

Twenty species were recorded during only one of the five seasonal surveys (and sometimes multiple times during that survey). These were: Southern Squatter Pigeon, Fan-tailed Cuckoo *Cacomantis flabelliformis*, Brush Cuckoo *C. variolosus*, Royal Spoonbill *Platalea regia*, Intermediate Egret *Ardea intermedia*, White-faced Heron *Egretta novaehollandiae*, Australian Pelican *Pelecanus conspicillatus*, Australian Pratincole *Stiltia isabella*, Black-breasted Buzzard *Hamirostra melanosternon*, Square-tailed Kite *Lophoictinia isura*, Red-tailed Black-Cockatoo *Calyptorhynchus banksii*, White-browed Treecreeper *Climacteris affinis*, Blue-faced Honeyeater *Entomyzon cyanotis*, Painted Honeyeater, Pied Honeyeater *Certhionyx variegatus*, White-throated Gerygone *Gerygone olivacea*, Western Gerygone *G. fusca*, Ground Cuckoo-shrike *Coracina maxima*, White-breasted Woodswallow *Artamus leucorynchus* and Red-capped Robin *Petroica goodenovii*.

With respect to variation across habitat, there were significant differences in richness and abundance for all bird species, insectivores, nectarivores and granivores, except for granivore richness (Appendix 2). Mean bird abundance and species richness were highest in the Springs, with the Gidgee, Escarpment and Ironbark woodlands clustered with largely similar values below Springs (Appendix 2). For the functional groups (insectivores and nectarivores), the pattern was similar (highest or higher in Springs). Although granivores were most abundant in the Mitchell grass, their species richness was not very different across the habitat types (Appendix 2). Forty-six bird species exhibited significant variation in abundance across the habitat types, 37% of the total number of species recorded (Appendix 2). Of these, 16 were most abundant in the Springs habitat (e.g. Common Bronzewing *Phaps chalcoptera*, Pheasant Coucal *Centropus phasianinus*, Horsfield's Bronze-Cuckoo, Spotted Bowerbird *Chlamydera maculata*, Variegated Fairy-wren *Malurus lamberti*, Brown Honeyeater and Weebill) and, in comparison, only a single species was most abundant in the Spinifex habitat (Spinifexbird *Poodytes carteri*) (Appendix 2). In the Mitchell grass, species typical of treeless vegetation were more abundant (e.g. Emu *Dromaius novaehollandiae*, Flock Bronzewing *Phaps histrionica*, Nankeen Kestrel *Falco cenchroides*, White-winged Fairy-wren *Malurus leucopterus* and Horsfield's Bushlark *Mirafra javanica*), and in the woodland communities a range of woodland bird species was recorded more abundantly (e.g. White-throated Nightjar *Eurostopodus mystacalis* and Striated Pardalote in the Escarpments; Varied Sittella *Daphoenositta chrysoptera*, Crested Bellbird *Oreoica gutturalis*, Jacky Winter *Microeca fascinans* and Hooded Robin *Melanodryas cucullata* in the Gidgee; and Southern Boobook *Ninox boobook*, Red-winged Parrot *Aprosmictus erythropterus*, Black-faced Cuckoo-shrike and Pied Butcherbird in the Ironbark) (Appendix 2).

The variation across the surveys for each habitat indicated very few clear patterns (Figure 3). The most notable was the very consistent species richness in each habitat across surveys, more variation in abundance in each survey with different peaks in different habitats (i.e. compare Gidgee, Ironbark and Springs) and the low abundance and species richness in the treeless habitats (Mitchell grass and Spinifex). The peaks in abundances in different habitat types were in particular surveys, specifically in the Gidgee in March 2020 (linked to high insectivore and granivore abundance), in the Escarpment in October 2020 (linked to high insectivore abundance), in the Ironbark in March 2020 (linked to high granivore abundance) and in the Springs in October 2018 (linked to high nectarivore abundance) (Figure 3).

The *Chi*-square test of goodness of fit for abundance across surveys provided more insight to variation from survey to survey, though only granivores as a group (species richness and abundance) and 17 species were recorded in significantly higher numbers than expected in some survey years (Table 1). Granivores were most abundant in the March 2020 surveys (including Flock Bronzewing, Diamond Dove *Geopelia cuneata*, Budgerigar *Melopsittacus undulatus*), as were White-browed Woodswallows. Some species were recorded in higher numbers in the first two surveys: six species (including Emu, Little Friarbird and Little Woodswallow *Artamus superciliosus*) in October 2018, and five species (including Cockatiel, Galah and Grey Fantail *Rhipidura albiscapa*) in March 2019. In the October 2019 and 2020 surveys, only a single species in each was recorded in higher abundance (Mistletoebird and Yellow-rumped Thornbill *Acanthiza chrysorrhoa*, respectively: Table 1).

The PERMANOVA results indicated that there was a significant difference in species composition across habitat [df = 5, Pseudo *F* = 14.8, *P*(perm) = 0.001], survey number [df = 4, Pseudo *F* = 3.93, *P*(perm) = 0.001] and to a lesser degree the interaction [df = 20, Pseudo *F* = 1.16, *P*(perm) = 0.033]. The canonical analysis of principle coordinates indicated that there was strong separation in species composition across the habitats and Budgerigar, Australian Magpie, Pied Butcherbird, Black-faced Cuckoo-shrike, Rufous Whistler, Little Friarbird, Grey Shrike-thrush and Mistletoebird were strongly correlated with the cluster of woodland sites (Escarpment, Gidgee, Ironbark). Flock Bronzewing, Brown Songlark *Cincloramphus cruralis*, Horsfield's Bushlark and Australian Pipit *Anthus novaeseelandiae* were

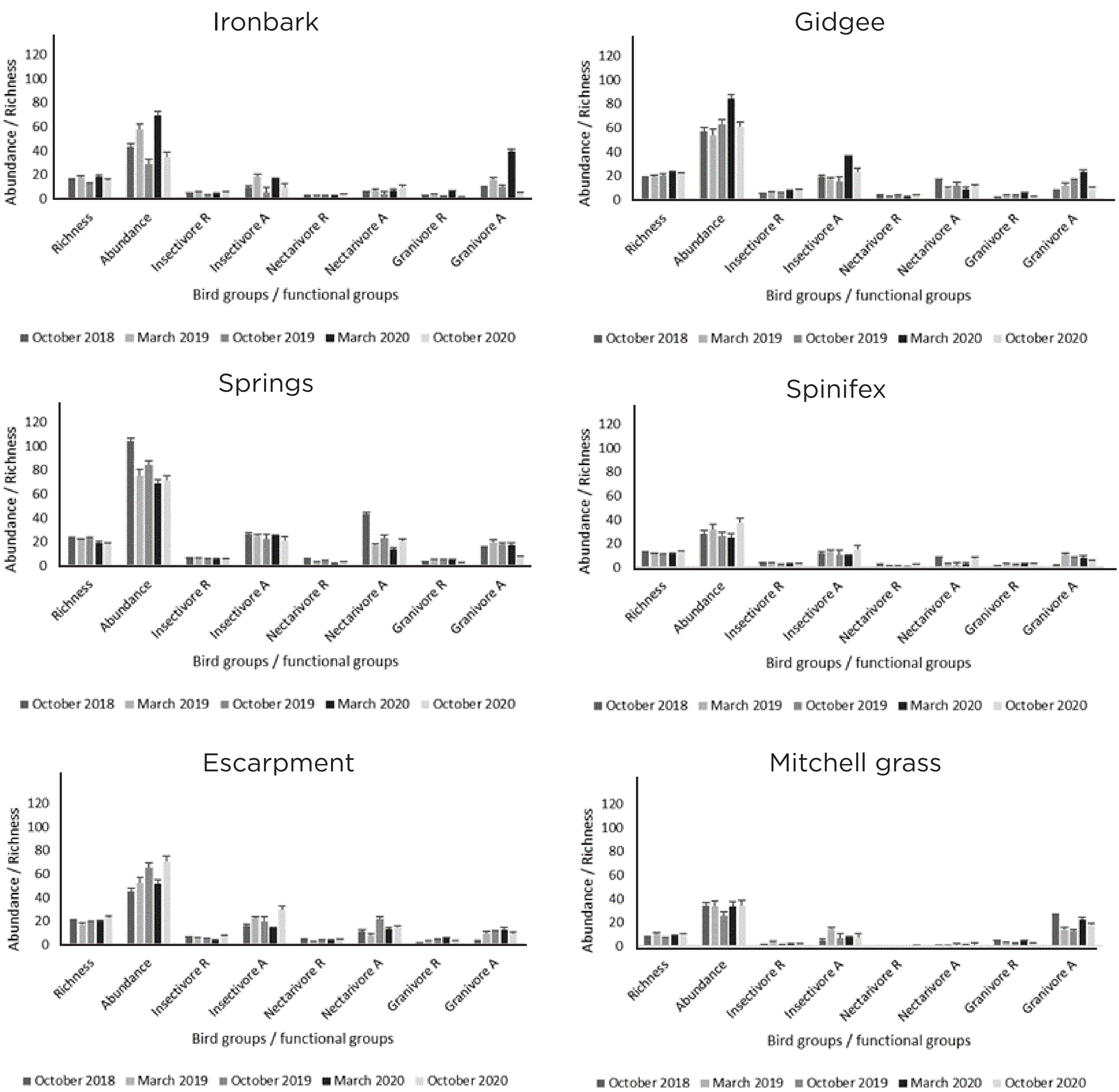

Figure 3. The mean and standard error in species richness (R) and abundance (A) for all bird species and for insectivores, nectarivores and granivores for each survey across each habitat type at Edgbaston Reserve.

correlated with treeless habitat, Mitchell grass and Spinifex (Figure 4).

Higher bird abundance had a negative association with higher spinifex cover, and granivore richness and abundance were similarly negatively associated with higher foliage projective cover and higher spinifex cover (granivore abundance only) (Table 2). Twenty bird species returned a significant model for the three environmental variables, and there was mainly a single significant parameter (Table 2). An association with the foliage projective cover was the most common effect (10 positive and three negative associations), and these were mostly woodland birds (e.g. Little and Noisy Friarbirds, Striated Pardalote, Weebill, Rufous Whistler and Grey Shrike-thrush). The strongest negative effect of foliage projective cover was for White-winged Fairy-wren, followed by Emu and Crested Bellbird (Table 2). There was a positive relationship between abundance for Southern Boobook and Spinifexbird and increasing spinifex cover, and a negative relationship with this variable for Willie Wagtail and Zebra Finch. For the six species where a significant relationship was identified with tussock grass cover, all were negative (Australian Bustard *Ardeotis australis*, Yellow-throated Miner, Rufous Whistler, Crested Bellbird, Pied Butcherbird and Willie Wagtail) (Table 2).

Discussion

Our study identified a bird community that was dominated by woodland bird species commonly recorded throughout eastern Australia (Fraser *et al.* 2019), although with additional species strongly associated with grasslands,

Table 1. The mean ± standard error (SE) for functional groups and bird species across the five surveys at Edgbaston Reserve, Queensland, that indicated a significant difference based on a *Chi*-square test of goodness of fit between the observed and expected values. The highest mean is shown in bold.

Functional group or species	*Oct. 2018 Mean ± SE*	*Mar. 2019 Mean ± SE*	*Oct. 2019 Mean ± SE*	*Mar. 2020 Mean ± SE*	*Oct. 2020 Mean ± SE*	*X^2*	*P*
Functional group							
Granivore richness	2.6 ± 0.3	3.6 ± 0.4	3.3 ± 0.3	**4.9 ± 0.3**	2.5 ± 0.3	26.7	<0.001
Granivore abundance	10.5 ± 3.1	13.7 ± 1.9	12.6 ± 1.8	**20.4 ± 2.9**	9.1 ± 1.5	16.7	0.002
Species							
Emu *Dromaius novaehollandiae*	**0.6 ± 0.2**	0.5 ± 0.2	0.1 ± 0.1	0.5 ± 0.3	0.2 ± 0.1	12.2	0.016
Flock Bronzewing *Phaps histrionica*	–	–	–	**0.9 ± 0.4**	–	16.5	0.002
Diamond Dove *Geopelia cuneata*	0.3 ± 0.2	0.3 ± 0.2	1.2 ± 0.8	**2.3 ± 0.9**	0.10.1	15.2	0.004
Fork-tailed Swift *Apus pacificus*	–	**0.6 ± 0.3**	0.4 ± 0.4	–	–	12.5	0.014
Rainbow Bee-eater *Merops ornatus*	0.3 ± 0.2	**0.6 ± 0.3**	–	**0.6 ± 0.3**	–	9.9	0.042
Cockatiel *Nymphicus hollandicus*	0.4 ± 0.4	**3.8 ± 1.1**	1.5 ± 0.7	3.6 ± 0.9	0.1 ± 0.1	41.6	<0.001
Galah *Eolophus roseicapilla*	1.5 ± 0.3	**4.4 ± 0.8**	4.2 ± 0.9	2.7 ± 0.8	3.6 ± 1.1	12.0	0.017
Budgerigar *Melopsittacus undulatus*	–	1.1 ± 0.5	–	**5.4 ± 1.8**	–	50.5	<0.001
Little Friarbird *Philemon citreogularis*	**5.3 ± 1.6**	1.0 ± 0.3	3.0 ± 1.1	1.4 ± 0.5	2.6 ± 0.7	9.1	0.050
Yellow-throated Miner *Manorina flavigula*	**1.1 ± 0.6**	0.3 ± 0.1	0.4 ± 0.2	–	0.8 ± 0.3	9.8	0.044
Yellow-rumped Thornbill *Acanthiza chrysorrhoa*	0.1 ± 0.1	0.2 ± 0.2	0.1 ± 0.1	0.4 ± 0.3	**1.0 ± 0.4**	14.1	0.007
White-winged Triller *Lalage tricolor*	**0.7 ±0.3**	–	0.5 ± 0.4	0.6 ± 0.4	0.1 ± 0.1	11.4	0.023
Pied Butcherbird *Cracticus nigrogularis*	**2.3 ± 0.4**	2.1 ± 0.4	1.3 ± 0.3	0.6 ± 0.2	0.9 ± 0.3	23.2	<0.001
White-browed Woodswallow *Artamus superciliosus*	–	0.8 ± 0.4	–	**2.4 ± 1.3**	–	16.4	0.003
Little Woodswallow *Artamus minor*	**1.1 ± 0.4**	–	–	–	0.3 ± 0.2	17.4	0.002
Grey Fantail *Rhipidura albiscapa*	–	**0.4 ± 0.2**	–	–	–	25.3	<0.001
Mistletoebird *Dicaeum hirundinaceum*	1.2 ± 0.3	1.0 ± 0.3	**2.6 ± 0.6**	1.1 ± 0.3	3.2 ±0.6	10.7	0.030

and a cohort of peripatetic species that appears when rainfall facilitates pulses of breeding and movement (Gibson *et al.* 2022). The Springs habitat, consisting of small pockets of shelter and resources in the surrounding treeless environments, has a concomitantly higher diversity and a somewhat idiosyncratic bird community. The Ironbark, Gidgee and Escarpment habitats, which are the most archetypal vegetation for diverse avifauna in eastern Australia, contain a group of species with a high degree of overlap (i.e. many species found in each) and are very different from the grassland communities. Though our surveys are not necessarily long-term, being designed initially for discovery rather than a management focus (Lindenmayer *et al.* 2022b), they nevertheless create a

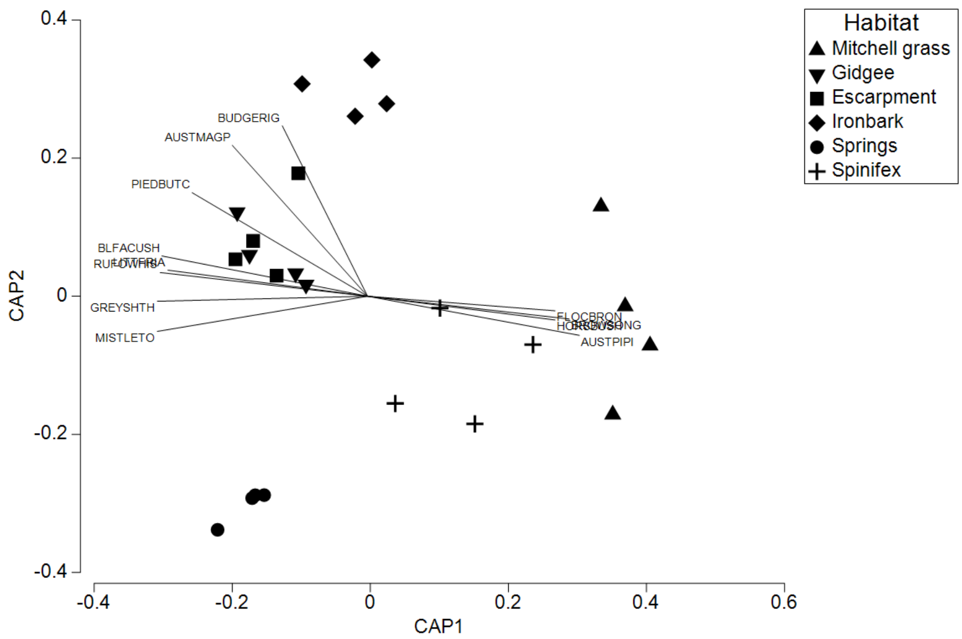

Figure 4. Spearman rank correlations (R >0.6) of bird species vectors overlain on the constrained canonical analysis of principle ordination of avian fauna composition for each habitat. BUDGERIG = Budgerigar, AUSTMAGP = Australian Magpie, PIEDBUTC = Pied Butcherbird, BLFACUSH = Black-faced Cuckoo-shrike, RUFOWHIS = Rufous Whistler, LITTFRIA = Little Friarbird, GREYSHTH = Grey Shrike-thrush and MISTLETO = Mistletoebird. The indistinguishable names in a cluster correlated with the Mitchell grass and Spinifex habitats are FLOCBRON = Flock Bronzewing, BROWSONG = Brown Songlark, HORSBUSH = Horsfield's Bushlark and AUSTPIPI = Australian Pipit. Please note that the labels BROWSONG and HORSBUSH and RUFOWHIS and LITTFRIA are overlapping and obscure each other.

strong foundation for continued sampling and refinement to provide more focused monitoring that explores dynamics of bird communities in response to management, restoration and climate change (Gardner *et al.* 2022).

The composition of the bird community was different between habitat types and changed from survey to survey, though this was largely because of strong separation in species from the woodland and grassland habitats, and to a lesser degree variation in abundance of species shared across habitats (i.e. woodland types). The composition and relative dominance of woodland birds in a community is a function of both habitat complexity and habitat preferences (Kutt & Martin 2010; Kutt & Vanderduys 2017). In our study we found a suite of ubiquitous and common species that characterised the woodland habitats, and typical grassland species, though the Springs habitat supported a curious amalgam. There were a few strong and well-established habitat associations, such as Spinifexbird and Spinifex, Horsfield's Bushlark and Mitchell grass, and Hooded Robin and Gidgee woodlands (Kutt *et al.* 2021a). The relative abundance of species in each habitat further reflected this treed–treeless dichotomy, though the Springs (which are in Spinifex grasslands but are often surrounded by some trees) create foci for a range of species, including high abundance of insectivores, granivores and nectarivores, and groups such as honeyeaters, cuckoos and doves. These oases of permanent water are significant for supporting species in periods of rainfall deficits (Cartwright *et al.* 2020); however, this property is in a landscape matrix where artificial water sources are common because of cattle and sheep grazing. The significance of these springs may be less for birds, compared with pre-pastoral times, though it is clear that large rainfall events still promote an increase in bird abundance and an influx of arid species.

The seasonality in bird abundance and species richness changes most often because of regional or continental migration, the phenology of flowering and fruiting plants, and resource pulses or deficits driven by long-term weather patterns (Mac Nally 1995; Hawkins *et al.* 2018; Pascoe *et al.* 2021). In arid environments where extreme rainfall and temperature oscillations occur, bird communities can vary markedly in abundance (Jordan *et al.* 2017). In our study, a suite of species peaked in abundance in some surveys or simply spiked in significant numbers in some surveys and were absent in others. Again, all were characteristic of either arid-zone species known to expand their ranges in response to resource pulses (i.e. Flock Bronzewing, Budgerigar) or winter or summer migrants (i.e. Rainbow Bee-eater *Merops ornatus*, Grey Fantail). Some species that occurred in each survey showed some local patterns of increase and decrease (e.g. Emu, Galah, Yellow-rumped Thornbill and Pied Butcherbird), and this may be because of local changes in breeding or distribution of food resources (Poulin *et al.* 1993). The simple conclusion for continuation of monitoring on this conservation reserve is that regular surveys that may in the future focus more on management responses need to also consider seasonal variation in each habitat. This will ensure that no spurious conclusions are drawn regarding a response to management that has a climate origin or vice versa.

Despite the relatively large number (123) of species recorded, very few patterns (<20%) in abundance of species could be effectively explained by site-based

Table 2. The results of the generalised linear mixed modelling for functional groups and bird species (recorded at >12 sites at Edgbaston Reserve), testing for the effect of foliage projective cover (FPC) in 1-km buffer around the site, and spinifex and tussock grass cover in each site for each survey. Survey is the random effect. The estimate (Est) and standard error (SE) are the direction of the effect, the Wald statistic is an equivalent to the *F* statistic and *P* is the significance level. Only species with a significant *P* value (<0.05) are tabulated.

Functional group or species	*FPC 1 km (%)*				*Spinifex cover (%)*				*Tussock grass cover (%)*			
	Est	*SE*	*Wald*	*P*	*Est*	*SE*	*Wald*	*P*	*Est*	*SE*	*Wald*	*P*
Functional group												
All birds abundance					–0.7	0.3	5.8	0.018				
Granivore richness	–0.6	0.3	5.9	0.016								
Granivore abundance	–1.1	0.4	7.4	0.008	–1.1	0.5	5.1	0.026				
Species												
Emu *Dromaius novaehollandiae*	–5.4	2.1	6.5	0.012								
Peaceful Dove *Geopelia placida*	3.2	0.8	14.6	<0.001								
Australian Bustard *Ardeotis australis*									–2.6	0.8	9.6	0.003
Southern Boobook *Ninox boobook*					2.1	0.9	4.9	0.028				
White-winged Fairy-wren *Malurus leucopterus*	–20.8	6.1	11.6	<0.001								
Brown Honeyeater *Lichmera indistincta*	3.2	0.7	20.2	<0.001								
Little Friarbird *Philemon citreogularis*	2.7	0.7	17.5	<0.001								
Noisy Friarbird *Philemon corniculatus*	2.3	0.9	6.0	0.016								
Yellow-throated Miner *Manorina flavigula*									–4.3	1.9	5.1	0.026
Striated Pardalote *Pardalotus striatus*	3.6	0.7	26.6	<0.001								
Weebill *Smicrornis brevirostris*	2.6	0.7	16.7	<0.001								
Crested Bellbird *Oreoica gutturalis*	–4.4	1.8	5.7	0.019					–7.8	2.5	9.8	0.002
Rufous Whistler *Pachycephala rufiventris*	0.5	0.1	20.5	<0.001					–2.9	1.1	7.2	0.008
Grey Shrike-thrush *Colluricincla harmonica*	2.4	0.5	18.8	<0.001								
Black-faced Cuckoo-shrike *Coracina novaehollandiae*	1.3	0.6	5.85	0.017								
Pied Butcherbird *Cracticus nigrogularis*									–3.2	0.9	12.6	<0.001
Willie Wagtail *Rhipidura leucophrys*					–2.7	1.2	5.2	0.025	–2.9	1.3	4.3	0.040
Spinifexbird *Poodytes carteri*					12.1	1.8	41.2	<0.001				
Mistletoebird *Dicaeum hirundinaceum*	1.8	0.5	16.0	<0.001								
Zebra Finch *Taeniopygia castanotis*					–4.0	1.5	7.0	0.009				

parameters. The environmental determinants of bird populations are generally a function of both the resources *in situ* where a species is recorded and the wider influence of the surrounding landscape matrix (Price *et al.* 2013). We investigated the effect of the dominant ground cover and foliage projective cover and, for the species for which a predictable response was identified over the combined surveys, mostly this was simply a reflection of the broad habitat preferences. Examples include negative tussock cover estimates for a few woodland birds with a high abundance in Gidgee habitat, which has a large component of bare ground; a positive or negative estimate for spinifex cover indicated strong ecological relationships (i.e. Spinifexbird) or abundance in woodland communities without spinifex in the ground cover (i.e. Ironbark and Southern Boobook); and simply the predictable relationship of woodland birds with higher surrounding tree cover. These relationships are explicable and well established for the region (Kutt *et al.* 2012a,b). Regardless, this suggests that future monitoring should be more selective in covariate choice, and perhaps examine mechanistic and functional responses tied more closely to management outcomes, rather than correlative patterns (Gosper *et al.* 2019).

There were a few notable records, such as a breeding pair of Painted Honeyeaters, and uncommon range vagrants (i.e. Fan-tailed Cuckoo, Square-tailed Kite, White-browed Treecreeper and Pied Honeyeater), and these have been discussed more thoroughly in a companion publication (Kern & Kutt 2021).

Our study provided a thorough systematic set of monitoring data for a significant conservation reserve, using established methods recommended for fauna surveys in Queensland (Eyre *et al.* 2018). Two main conclusions can be drawn from this baseline work. Firstly, these surveys provide a strong foundation for continuation or refinement of monitoring of management on this conservation reserve, an aspiration for many protected area managers but which is often not conducted or is conducted poorly (Kutt *et al.* 2021b). Secondly, given the location of the study on the boundary of extensive tropical woodlands (the Desert Uplands) and extensive Mitchell Grass Downs, the property offers an excellent opportunity for monitoring of fauna to investigate patterns of long-term environmental change, especially given the potential refuge free from pastoral management that the springs provide in periods of extreme rainfall deficit.

Although the importance of monitoring that is required for successful programs is frequently reiterated (Lindenmayer *et al.* 2022b), too often monitoring can peter out, lose focus, or become rote without review or renewal (e.g. Kutt *et al.* 2022). Though our study did not examine the link between the monitoring data and management, Edgbaston Reserve was purchased for conservation purposes >10 years before our surveys; apart from a simple inventory at purchase, no systematic or annual surveys of the terrestrial vertebrate fauna has been undertaken to either examine or inform land management. Our data provide a foundation for this next step to occur. Furthermore, aspirations to create national standards and monitoring at a continental scale (Guerin *et al.* 2020) can ignore the value of long-term small-scale programs that can reveal significant local trends and change over time (Prowse *et al.* 2021).

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Appendix 1. The location and habitat type of the sites surveyed at Edgbaston Reserve, Queensland.

Site	*Latitude (decimal)*	*Longitude (decimal)*	*Habitat*
EDGB01	–22.7326	145.3880	Mitchell grass
EDGB02	–22.7413	145.3713	Gidgee
EDGB03	–22.7580	145.3731	Gidgee
EDGB04	–22.7663	145.3981	Mitchell grass
EDGB05	–22.7547	145.3981	Mitchell grass
EDGB06	–22.7468	145.3857	Mitchell grass
EDGB07	–22.7095	145.3652	Gidgee
EDGB08	–22.7012	145.3584	Escarpment
EDGB09	–22.6978	145.3486	Escarpment
EDGB10	–22.7015	145.3658	Ironbark
EDGB11	–22.7001	145.3738	Ironbark
EDGB12	–22.6987	145.3822	Ironbark
EDGB13	–22.6922	145.3951	Ironbark
EDGB14	–22.7026	145.3930	Escarpment
EDGB15	–22.7109	145.4348	Gidgee
EDGB16	–22.6987	145.4309	Escarpment
EDGB17	–22.7159	145.4392	Springs
EDGB18	–22.7350	145.4417	Spinifex
EDGB19	–22.7295	145.4324	Spinifex
EDGB20	–22.7381	145.4272	Springs
EDGB21	–22.7378	145.4189	Springs
EDGB22	–22.7453	145.4214	Spinifex
EDGB23	–22.7533	145.4314	Spinifex
EDGB24	–22.7204	145.4431	Springs

Appendix 2. The mean ± standard error (SE) of abundance for functional groups and bird species in each habitat type at Edgbaston Reserve, Queensland. The *P* value indicates where there is a significant difference in the surveys, tested via the Kruskal–Wallis non-parametric analysis of variance. Where *P* is ≤0.05 the highest mean is shown in bold.

Functional group or species	*Escarpment*	*Gidgee*	*Ironbark*	*Mitchell grass*	*Spinifex*	*Springs*	*H*	*P*
	Mean ± SE	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*		
Functional group								
All birds richness	8.8 ± 0.3	9.1 ± 0.5	8.0 ±0.4	4.7 ± 0.4	6.5 ± 0.7	**9.4 ± 0.4**	17.1	0.004
All birds abundance	57.1 ± 4.0	63.9 ± 3.0	46.8 ± 4.3	32.2 ± 4.7	29.6 ± 3.7	**80.6 ± 12.2**	18.2	0.003
Insectivore richness	5.7 ± 1.6	6.6 ± 1.3	4.6 ± 0.9	2.0 ± 0.1	3.3 ± 0.9	**5.9 ± 3.4**	50.0	0.001
Insectivore abundance	20.2 ± 2.5	22.2 ± 3.7	11.8 ± 1.5	8.1 ± 1.8	12.2 ± 1.0	**24.1 ± 2.1**	35.4	0.001
Nectarivore richness	**3.9 ± 0.5**	3.6 ± 0.6	2.8 ± 0.4	0.2 ± 0.4	1.8 ± 0.3	3.8 ± 0.4	65.2	0.001
Nectarivore abundance	13.7 ± 1.4	11.6 ± 2.0	6.5 ± 3.0	0.2 ± 2.8	4.4 ± 1.4	**23.7 ± 2.7**	73.9	0.001
Granivore richness	3.5 ± 0.4	3.6 ± 0.3	3.2 ± 0.4	3.3 ± 0.3	2.7 ± 0.3	4.2 ± 0.4		
Granivore abundance	9.1 ± 0.2	13.8 ± 0.3	15.9 ± 0.2	18.7 ± 0.1	6.7 ± 0.3	**15.5 ± 0.4**	16.2	0.006
Species								
Emu *Dromaius novaehollandiae*	0.5 ± 0.5	1.8 ± 1.8	0.5 ± 0.3	**4.5 ± 0.9**	2.3 ± 0.5	1.5 ± 0.6	10.7	0.050
Brown Quail *Synoicus ypsilophorus*	–	–	–	0.3 ± 0.3	0.3 ± 0.3	–		
Pacific Black Duck *Anas superciliosa*	–	–	–	–	1.0 ± 0.7	–		
Southern Squatter Pigeon *Geophaps scripta scripta*	–	0.3 ± 0.3	–	–	–	–		
Common Bronzewing *Phaps chalcoptera*	0.8 ± 0.3	–	1.0 ± 0.6	–	–	**1.3 ± 0.6**	11.3	0.045
Flock Bronzewing *Phaps histrionica*	–	–	–	**5.5 ± 0.6**	–	–	22.8	0.004
Crested Pigeon *Ocyphaps lophotes*	2.3 ± 0.6	9.5 ± 3.4	3.8 ± 1.4	3.3 ± 2.6	2.5 ± 0.6	8.8 ± 2.9		
Diamond Dove *Geopelia cuneata*	1.5 ± 0.9	6.0 ± 2.3	0.3 ± 0.3	0.3 ± 0.3	5.5 ± 4.2	**11.5 ± 5.5**	12.5	0.029
Peaceful Dove *Geopelia striata*	2.5 ± 1.3	1.0 ± 0.7	0.3 ± 0.3	–	0.3 ± 0.3	**7.8 ± 1.4**	14.8	0.012
Tawny Frogmouth *Podargus strigoides*	0.5 ± 0.3	0.5 ± 0.5	0.3 ± 0.3	0.0	–	–		

Appendix 2 continued

Functional group or species	*Escarpment* *Mean ± SE*	*Gidgee* *Mean ± SE*	*Ironbark* *Mean ± SE*	*Mitchell grass* *Mean ± SE*	*Spinifex* *Mean ± SE*	*Springs* *Mean ± SE*	*H*	*P*
Spotted Nightjar *Eurostopodus argus*	**3.0 ± 1.2**	1.3 ± 0.8	3.0 ± 1.8	0.3 ± 0.3	0.3 ± 0.3	–	11.2	0.047
White-throated Nightjar *Eurostopodus mystacalis*	–	0.3 ± 0.3	–	0.3 ± 0.3	–	–		
Australian Owlet-nightjar *Aegotheles cristatus*	0.8 ± 0.5	1.0 ± 0.4	**1.0 ± 0.4**	–	–	0.3 ± 0.3		
Fork-tailed Swift *Apus pacificus*	0.3 ± 0.3	0.8 ± 0.8	2.5 ± 1.5	2.5 ± 2.5	–	–		
Pheasant Coucal *Centropus phasianinus*	0.3 ± 0.3	–	–	–	–	**1.3 ± 0.6**	12.9	0.025
Channel-billed Cuckoo *Scythrops novaehollandiae*	–	0.3 ± 0.3	–	–	0.3 ± 0.3	1.0 ± 0.4		
Horsfield's Bronze-Cuckoo *Chalcites basalis*	0.3 ± 0.3	4.0 ± 1.6	0.5 ± 0.3	1.0 ± 0.6	3.3 ± 0.9	**8.5 ± 4.8**	11.1	0.050
Fan-tailed Cuckoo *Cacomantis flabelliformis*	–	–	–	–	–	0.8 ± 0.8		
Brush Cuckoo *Cacomantis variolosus*	–	–	–	–	–	0.8 ± 0.8		
Pallid Cuckoo *Heteroscenes pallidus*	–	2.5 ± 1.0	0.5 ± 0.5	–	–	0.8 ± 0.5		
Brolga *Antigone rubicunda*	0.3 ± 0.3	0.5 ± 0.3	–	1.5 ± 0.5	1.5 ± 0.6	**2.8 ± 1.1**	13.8	0.016
Australian Bustard *Ardeotis australis*	–	0.8 ± 0.8	–	1.8 ± 1.0	1.3 ± 0.8	1.0 ± 0.6		
Royal Spoonbill *Platalea regia*	–	–	–	–	0.5 ± 0.5	–		
Intermediate Egret *Ardea intermedia*	–	–	–	–	0.3 ± 0.3	–		
White-faced Heron *Egretta novaehollandiae*	–	–	–	–	–	0.5 ± 0.5		

Appendix 2 continued

Functional group or species	Escarpment	Gidgee	Ironbark	Mitchell grass	Spinifex	Springs	*H*	*P*
	Mean ± SE	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*		
Australian Pelican *Pelecanus conspicillatus*	–	–	–	–	0.3 ± 0.3	–		
Masked Lapwing *Vanellus miles*	–	–	–	–	1.3 ± 1.3	–		
Painted Button-quail *Turnix varius*	0.5 ± 0.5	–	0.3 ± 0.3	–	–	–		
Red-chested Button-quail *Turnix pyrrhothorax*	–	–	–	1.3 ± 0.8	0.3 ± 0.3	–		
Little Button-quail *Turnix velox*	–	–	0.5 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	–		
Australian Pratincole *Stiltia isabella*	–	–	–	0.3 ± 0.3	–	–		
Southern Boobook *Ninox boobook*	1.0 ± 0.4	0.8 ± 0.5	**3.0 ± 0.8**	–	1.3 ± 0.5	2.0 ± 0.7	11.9	0.035
Black-shouldered Kite *Elanus axillaris*	–	0.3 ± 0.3	0.3 ± 0.3	–	–	–		
Black-breasted Buzzard *Hamirostra melanosternon*	–	–	–	0.3 ± 0.3	–	–		
Square-tailed Kite *Lophoictinia isura*	–	–	–	0.3 ± 0.3	–	–		
Wedge-tailed Eagle *Aquila audax*	–	1.3 ± 0.6	–	1.0 ± 0.7	0.8 ± 0.5	1.3 ± 0.5		
Spotted Harrier *Circus assimilis*	–	–	–	0.5 ± 0.3	–	–		
Brown Goshawk *Accipiter fasciatus*	0.3 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	–	0.3 ± 0.3	0.3 ± 0.3		
Collared Sparrowhawk *Accipiter cirrocephalus*	–	0.3 ± 0.3	0.3 ± 0.3	–	–	–		
Whistling Kite *Haliastur sphenurus*	–	–	–	0.5 ± 0.5	0.3 ± 0.3	0.3 ± 0.3		

Appendix 2 continued

Functional group or species	*Escarpment*	*Gidgee*	*Ironbark*	*Mitchell grass*	*Spinifex*	*Springs*	*H*	*P*
	Mean ± SE	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*		
Black Kite *Milvus migrans*	–	1.5 ± 0.6	–	0.5 ± 0.5	0.5 ± 0.3	0.3 ± 0.3		
Rainbow Bee-eater *Merops ornatus*	1.5 ± 0.9	2.5 ± 1.6	–	–	0.5 ± 0.3	**4.5 ± 0.6**	14.3	0.014
Oriental Dollarbird *Eurystomus orientalis*	0.5 ± 0.5	0.3 ± 0.3	–	–	0.3 ± 0.3	–		
Sacred Kingfisher *Todiramphus sanctus*	0.8 ± 0.5	–	–	–	–	0.8 ± 0.5		
Red-backed Kingfisher *Todiramphus pyrrhopygius*	1.3 ± 0.8	2.0 ± 1.2	0.3 ± 0.3	–	–	0.5 ± 0.5		
Laughing Kookaburra *Dacelo novaeguineae*	0.3 ± 0.3	–	0.8 ± 0.3	–	0.3 ± 0.3	–		
Nankeen Kestrel *Falco cenchroides*	–	–	0.5 ± 0.5	**4.8 ± 0.9**	0.3 ± 0.3	0.8 ± 0.8	15.5	0.008
Brown Falcon *Falco berigora*	0.3 ± 0.3	–	**1.0 ± 0.4**	**1.0 ± 0.3**	0.3 ± 0.3	–	13.6	0.018
Cockatiel *Nymphicus hollandicus*	2.3 ± 1.0	12.8 ± 4.6	15.8 ± 3.7	12.0 ± 2.5	6.3 ± 2.6	7.8 ± 5.8		
Red-tailed Black-Cockatoo *Calyptorhynchus banksii*	–	–	–	–	–	1.0 ± 1.0		
Galah *Eolophus roseicapilla*	20.5 ± 4.4	11.5 ± 1.3	26.8 ± 4.1	16.3 ± 6.0	8.5 ± 2.9	15.3 ± 3.4		
Sulphur-crested Cockatoo *Cacatua galerita*	0.3 ± 0.3	–	–	–	0.5 ± 0.5	0.3 ± 0.3		
Pale-headed Rosella *Platycercus adscitus*	4.8 ± 1.9	1.3 ± 0.8	0.8 ± 0.5	–	0.8 ± 0.5			
Australian Ringneck *Barnardius zonarius*	2.0 ± 0.8	5.5 ± 5.5	1.8 ± 1.1	–	0.3 ± 0.3	–		
Rainbow Lorikeet *Trichoglossus moluccanus*	0.3 ± 0.3	0.5 ± 0.5	0.3 ± 0.3	–	–	–		

Appendix 2 continued

Functional group or species	Escarpment	Gidgee	Ironbark	Mitchell grass	Spinifex	Springs	*H*	*P*
	Mean ± SE	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*		
Budgerigar *Melopsittacus undulatus*	5.3 ± 2.0	6.0 ± 1.8	**23.0 ± 5.0**	0.5 ± 0.5	3.3 ± 2.1	1.3 ± 0.8	15.3	0.009
Red-winged Parrot *Aprosmictus erythropterus*	2.5 ± 1.3	2.8 ± 1.5	**4.5 ± 1.3**	0.3 ± 0.3	–	1.5 ± 1.0	11.1	0.050
Spotted Bowerbird *Chlamydera maculata*	1.3 ±0.3	1.5 ±1.2	0.8 ±0.8	–	–	**3.8 ± 1.7**	11.2	0.048
White-browed Treecreeper *Climacteris affinis*	–	0.3 ± 0.3	–	–	–	–		
Brown Treecreeper *Climacteris picumnus*	0.3 ± 0.3	4.5 ± 4.5	0.3 ± 0.3	–	–	–		
Variegated Fairy-wren *Malurus lamberti*	0.3 ± 0.3	1.0 ±0.7	1.8 ± 1.0	0.3 ± 0.3	0.5 ± 0.3	**25.3 ± 12.5**	11.5	0.042
Red-backed Fairy-wren *Malurus melanocephalus*	–	–	1.8 ± 1.8	–	–	–		
White-winged Fairy-wren *Malurus leucopterus*	–	–	–	**21.5 ± 13.8**	4.0 ± 1.5	1.3 ±1.3	13.1	0.022
Brown Honeyeater *Lichmera indistincta*	5.5 ± 3.4	8.8 ± 6.0	1.5 ± 0.9	–	5.3 ± 3.1	**37.0 ± 8.2**	13.9	0.016
Blue-faced Honeyeater *Entomyzon cyanotis*	–	–	–	–	–	0.3 ±0.3		
White-eared Honeyeater *Nesoptilotis leucotis*	0.3 ±0.3	0.8 ± 0.8	0.0-	–	–	–		
Striped Honeyeater *Plectorhyncha lanceolata*	10.5 ± 5.3	5.0 ± 3.1	1.8 ±1.4	–	0.3 ± 0.3	1.5 ± 1.2		
Painted Honeyeater *Grantiella picta*	–	1.5 ± 1.5	–	–	–	–		
Little Friarbird *Philemon citreogularis*	**28.5 ± 6.6**	14.8 ± 6.1	10.5 ± 3.1	–	6.3 ± 3.5	20.0 ± 7.2	14.0	0.016
Noisy Friarbird *Philemon corniculatus*	**7.5 ± 2.3**	4.0 ± 1.5	6.3 ± 4.7	–	0.3 ± 0.3	4.3 ± 1.9	13.2	0.022

Appendix 2 continued

Functional group or species	*Escarpment*	*Gidgee*	*Ironbark*	*Mitchell grass*	*Spinifex*	*Springs*	*H*	*P*
	Mean ± SE	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*		
Black Honeyeater *Sugomel nigrum*	–	–	–	–	–	1.8 ± 1.2		
Pied Honeyeater *Certhionyx variegatus*	–	–	–	–	–	1.3 ±1.3		
Rufous-throated Honeyeater *Conopophila rufogularis*	0.3 ± 0.3	–	–	–	–	**7.5 ± 2.5**	13.4	0.019
Spiny-cheeked Honeyeater *Acanthagenys rufogularis*	3.8 ± 2.1	1.5 ± 1.2	–	–	–	**4.5 ± 1.2**	18.2	0.003
Singing Honeyeater *Gavicalis virescens*	8.5 ± 4.7	12.8 ±3.9	6.3 ± 3.0	0.8 ± 0.3	9.0 ±1.9	36.3 ± 21.0		
White-plumed Honeyeater *Ptilotula penicillata*	1.3 ± 1.3	1.3 ± 0.5	1.0 ± 1.0	–	0.5 ± 0.5	3.3 ± 2.3		
Yellow-throated Miner *Manorina flavigula*	2.3 ± 0.8	**7.3 ± 6.3 ±**	5.0 ± 1.4	–	0.5 ± 0.3	1.0 ± 0.6	13.8	0.017
Red-browed Pardalote *Pardalotus rubricatus*	1.5 ±0.9	0.5 ± 0.5	0.3 ± 0.3	–	0.3 ± 0.3	0.3 ± 0.3		
Striated Pardalote *Pardalotus striatus*	**9.0 ± 2.7**	0.3 ± 0.3	5.5 ± 1.3	–	2.0 ± 1.7	6.8 ± 3.4	14.1	0.015
White-throated Gerygone *Gerygone olivacea*	–	–	–	–	–	0.3 ± 0.3		
Western Gerygone *Gerygone fusca*	–	–	0.3 ± 0.3	–	–	–		
Weebill *Smicrornis brevirostris*	31.5 ± 4.3	3.3 ± 2.6	16.0 ± 4.1	–	0.5 ± 0.5	**33.0 ± 9.1**	18.7	0.002
Yellow-rumped Thornbill *Acanthiza chrysorrhoa*	**4.8 ± 1.3**	4.0 ± 2.3	1.5 ± 1.2	–	–	1.0 ± 0.6	12.7	0.027
Inland Thornbill *Acanthiza apicalis*	3.5 ± 2.6	–	–	–	–	–		
Chestnut-rumped Thornbill *Acanthiza uropygialis*	1.3 ± 1.3	–	1.5 ± 1.5	–		–		

Appendix 2 continued

Functional group or species	*Escarpment*	*Gidgee*	*Ironbark*	*Mitchell grass*	*Spinifex*	*Springs*	*H*	*P*
	Mean ± SE	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*		
Grey-crowned Babbler *Pomatostomus temporalis*	–	2.8 ± 2.4	0.3 ± 0.3	–		–		
Varied Sittella *Daphoenositta chrysoptera*	1.8 ± 1.2	**11.5 ± 7.2**	1.3 ± 1.3	–	–	–	14.4	0.013
Olive-backed Oriole *Oriolus sagittatus*	0.5 ± 0.3	–	0. ± 30.3	–	–	0.8 ± 0.5		
Crested Bellbird *Oreoica gutturalis*	0.3 ± 0.3	**8.5 ± 3.1**	2.5 ± 0.9	0.5 ± 0.5	–	–	17.8	0.003
Rufous Whistler *Pachycephala rufiventris*	**20.5 ± 4.1**	8.3 ± 3.3	2.2 ± 0.5	–	0.5 ± 0.3	13.3 ± 3.3	18.8	0.002
Grey Shrike-thrush *Colluricincla harmonica*	7.0 ± 1.4	4.5 ±0.9	2.3 ± 0.8	–	0.5 ± 0.3	**10.0 ± 2.3**	20.5	0.001
Ground Cuckoo-shrike *Coracina maxima*	–	–	–	–	1.5 ± 1.5	–		
Black-faced Cuckoo-shrike *Coracina novaehollandiae*	4.5 ± 1.2	5.5 ± 0.9	**8.3 ± 0.5**	–	2.0 ± 0.9	6.3 ± 0.3	18.5	0.002
White-winged Triller *Lalage tricolor*	0.3 ± 0.3	5.8 ± 2.7	0.5 ± 0.3	–	–	5.5 ± 2.8	15.5	0.009
Australian Magpie *Gymnorhina tibicen*	10.3 ± 1.4	7.8 ± 1.2	**10.8 ± 1.7**	2.0 ± 0.7	3.3 ± 0.8	3.5 ± 0.6	18.9	0.002
Pied Butcherbird *Cracticus nigrogularis*	9.8 ± 1.1	9.8 ± 1.8	**14.5 ± 1.9**	0.5 ± 0.3	2.0 ± 1.1	6.8 ± 1.3	18.3	0.003
Grey Butcherbird *Cracticus torquatus*	6.5 ± 3.2	0.5 ± 0.3	1.0 ± 0.7	–	0.3 ± 0.3	0.3 ± 0.3		
Masked Woodswallow *Artamus personatus*	–	–	2.5 ± 2.5	–	–	1.5 ± 1.5		
White-browed Woodswallow *Artamus superciliosus*	2.3 ± 1.3	**15.3 ± 5.3**	0.3 ± 0.3	–	–	1.3 ± 0.9	11.2	0.047
Dusky Woodswallow *Artamus cinereus*	–	2.5 ± 2.5	–	–	0.3 ± 0.3	–		
Black-faced Woodswallow *Artamus cyanopterus*	0.3 ± 0.3	2.3 ± 1.3	–	–	–	1.0 ± 1.0		
Little Woodswallow *Artamus minor*	2.8 ± 2.8	1.8 ± 1.8	2.0 ± 0.8	–	–	2.3 ± 1.7		

Appendix 2 continued

Functional group or species	*Escarpment*	*Gidgee*	*Ironbark*	*Mitchell grass*	*Spinifex*	*Springs*	*H*	*P*
	Mean ± SE	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*		
White-breasted Woodswallow *Artamus leucorynchus*	–	–	0.3 ± 0.3	–	–	–		
Willie Wagtail *Rhipidura leucophrys*	5.5 ± 2.4	**13.5 ± 4.8**	1.5 ± 0.6	0.8 ± 0.5	2.8 ±1.1	12.3 ± 5.2	12.1	0.033
Grey Fantail *Rhipidura albiscapa*	1.0 ± 0.7	0.3 ±0.3	0.3 ± 0.3	0.0 ± -	–	0.8 ± 0.5		
Leaden Flycatcher *Myiagra rubecula*	2.8 ± 1.9	–	–	–	–	1.8 ± 1.0		
Restless Flycatcher *Myiagra inquieta*	0.8 ± 0.8	0.3 ± 0.3	0.3 0.3	–	–	–		
Magpie-lark *Grallina cyanoleuca*	0.5 ± 0.3	**4.8 ± 1.9**	–	0.5 ± 0.5	2.5 ± 1.0	0.8 ± 0.3	12.3	0.031
Crow/raven *Corvus* sp.	10.0 ± 1.4	10.3 ±2.8	7.8 ± 1.5	7.5 ± 2.6	7.3 ±0.8	12.0 ± 3.1		
White-winged Chough *Corcorax melanorhamphos*	4.5 ± 3.0	–	2.8 ±2.8	–	–	1.8 ± 1.8		
Apostlebird *Struthidea cinerea*	5.0 ± 4.3	9.0 ±4.0	7.8 ± 5.9	–	0.3 ± 0.3	3.3 ± 2.9		
Red-capped Robin *Petroica goodenovii*	–	–	0.3 ± 0.3	–	–	–		
Jacky Winter *Microeca fascinans*	–	**9.5 ± 4.9**	–	–	–	0.5 ± 0.5	13.4	0.019
Hooded Robin *Melanodryas cucullata*	–	**3.5 ± 1.3**	–	–	–	–	16.4	0.006
Horsfield's Bushlark *Mirafra javanica*	–	–	–	**30.0 ± 8.7**	–	–	22.8	0.001
Australian Reed-Warbler *Acrocephalus australis*	–	–	–	0.5 ± 0.5	–	–		
Brown Songlark *Cincloramphus cruralis*	–	–	–	**9.8 ± 1.0**	0.3 ± 0.3	–	19.8	0.001

Appendix 2 continued

Functional group or species	*Escarpment*	*Gidgee*	*Ironbark*	*Mitchell grass*	*Spinifex*	*Springs*	*H*	*P*
	Mean ± SE	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*	*Mean ± SE*		
Rufous Songlark *Cincloramphus mathewsi*	–	–	1.3 ± 1.3	2.8 ± 2.1	1.5 ± 0.9	–		
Spinifexbird *Poodytes carteri*	–	–	–	–	**40.3 ± 5.2**	–	22.8	0.001
Mistletoebird *Dicaeum hirundinaceum*	10.0 ± 3.1	17.3 ± 3.1	2.5 ± 0.6	–	3.8 ± 1.9	**21.0 ± 2.4**	19.1	0.002
Zebra Finch *Taeniopygia castanotis*	0.5 ± 0.5	12.3 ± 4.9	0.8 ± 0.5	19.0 ± 7.3	3.3 ± 1.2	16.3 ± 12.6		
Double-barred Finch *Taeniopygia bichenovii*	–	–	–	–	–	**4.0 ± 2.1**	16.4	0.006
Australasian Pipit *Anthus novaeseelandiae*	–	–	–	**4.3 ± 0.6**	2.3 ± 1.6	–	19.2	0.002