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More than just Night Parrots: A baseline bird survey of Pullen Pullen Reserve, south-western Queensland

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Abstract. The birds of arid environments often exhibit nomadism, seasonal breeding and population fluctuations that respond to highly variable weather patterns. In this study we present data from a baseline bird survey in Bush Heritage Australia's Pullen Pullen Reserve in south-western Queensland. We conducted seasonal surveys (October–November 2018, May 2019) in 40 sites representing Spinifex (*Triodia* spp.) grasslands, a complex of Mitchell *Astrebla* spp./chenopod grasslands and Georgina Gidgee *Acacia georginae* riparian woodlands, using a standardised 2-ha census. A total of 85 species was recorded in the standardised sites, as well as an additional 16 species recorded opportunistically. Twenty-six species (31%), many of which were nomadic, were recorded from only one of the surveys. Bird abundance and species richness were highest in the post-wet-season survey (May 2018), and there was strong variation in the composition of the bird species between the three habitats surveyed. These data provide a baseline to continue monitoring and to understand the resident and more peripatetic elements of this arid bird community, which should be surveyed regularly to investigate the role of changing management and the long-term influence of global environmental change.

Introduction

The birds of arid environments exhibit adaptations to these habitats, including nomadism, breeding and population fluctuations that link to boom-and-bust weather and resource patterns (Dickman & Tischler 2010). Surveys of bird communities in Australian deserts have indicated that different functional groups of species, based on their foraging habit and diet, changed in relative dominance depending on the vegetation type (i.e. grasslands or woodlands) and spatial and temporal patterns in rainfall (Tischler *et al.* 2013). Bird abundance and richness in the arid zone can double or quadruple in wet versus dry years, because of the high degree of nomadism and immigration to some areas (Jordan *et al.* 2017); however, there is also a suite of common species that remain *in situ* and fluctuate very little over these cycles of heightened and depleted resources (Jordan *et al.* 2017).

The Channel Country in Queensland is typical of many arid regions of Australia, and forms part of the Lake Eyre Basin and includes iconic river systems such as the Diamantina River and Cooper Creek. Long-term surveys of the Diamantina National Park in 1994–2009 recorded 180 species from bird censuses over 15 visits, and other species recorded opportunistically—Plains-wanderer *Pedionomus torquatus*, Letter-winged Kite *Elanus scriptus* and Night Parrot *Pezoporus occidentalis*—have been reported in other sources (Ley *et al.* 2011). In 2013, Night Parrots were recorded on a property adjacent to Diamantina National Park (Murphy *et al.* 2017) and a section of the property was purchased by Bush Heritage Australia to manage as a conservation reserve. The region, also encompassing Astrebla Downs and Diamantina National Parks, is notable in Queensland for having a high number of threatened species, probably partly because of the lack of critical environmental threats such as the Red Fox *Vulpes vulpes* and European Rabbit *Oryctolagus cuniculus* (Murphy *et al.* 2018).

Bush Heritage Australia instigated research and monitoring of the Night Parrot, and initiated some additional baseline monitoring of the vertebrate fauna in order to provide data on condition and change in the fauna and landscape, especially in the light of changed management of the property (i.e. removal of cattle grazing). This paper reports the results of a baseline bird survey of Pullen Pullen Reserve and describes (i) the variation in species over the two seasons of sampling, (ii) the variation in the pattern of the bird community across the main habitat types sampled, and (iii) site and landscape-scale predictors of the species recorded over two surveys. These data, and future surveys, are an important first step in effective conservation and adaptive management for biodiversity in this arid environment and add to the significant conservation and research efforts focused on the Night Parrot at Pullen Pullen Reserve (Murphy *et al.* 2017, 2018; Iwaniuk *et al.* 2020; Leseberg *et al.* 2020a,b).

Methods

Study area

Bird surveys were conducted at Bush Heritage Australia's Pullen Pullen Reserve (–23.5, 141.5) located 200 km south-west of Winton, Queensland, and bordering Diamantina National Park (Figure 1). This region is arid in climate (annual rainfall ~250 mm), and the vegetation consists largely of Mitchell grass *Astrebla* spp. and chenopod

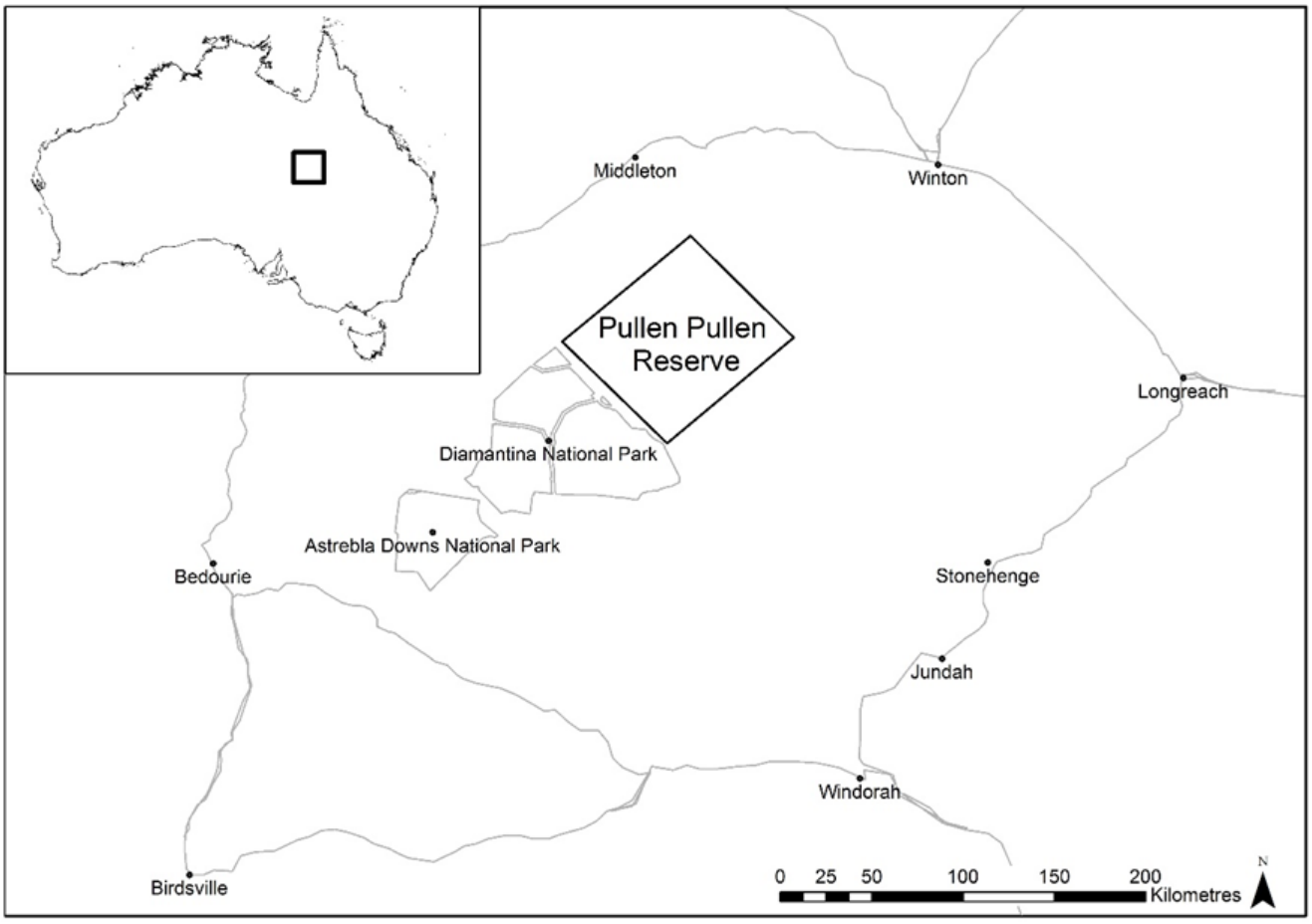

Figure 1. The location of Pullen Pullen Reserve and nearby protected areas in south-western Queensland. The exact boundary and location of the Reserve are not shown because of concerns about human disturbance on the Night Parrot.

grasslands, Spinifex *Triodia longiceps* grasslands, gibber plains, floodplains and ephemeral channels lined with Coolabah *Eucalyptus coolabah* and Georgina Gidgee *Acacia georginae*.

Sampling

The bird surveys were conducted over two periods: 31 October–13 November 2018 and 15–24 May 2019. Forty sites representing three main habitat types—Spinifex grasslands, a complex of Mitchell grass and chenopod grasslands (hereafter Mitchell/chenopod grasslands) and ephemeral predominantly Georgina Gidgee-lined channels (hereafter Gidgee riparian woodlands) (Appendix 1)—were established. The weather for each survey was contrasting. In the October–November period, it was extremely hot and windy (35–42°C daily maximum), and in May, cooler, and after a period of rain (28–31°C daily maximum). In the 2 years before the surveys in 2018–2019, the rainfall at Winton Airport was ~50% of the average in 2017 (185 mm) and average in 2018 (350 mm).

Diurnal bird surveys were undertaken in a plot 100 m x 200 m at each site and consisted of one experienced observer (authors ASK, SGK, PLK and volunteers Michael Mathieson, Dan Ferguson, Gina Barnett, Eric Vanderduys) conducting a diurnal 10-minute count recording all individual birds heard and seen within the plot. These counts occurred on six separate visits and at different times of the day over the course of 5 days. In general, counts were conducted during three visits in the early morning (<2 h after sunrise), and three visits in the period after. Birds flying over the plot and interacting with the habitat (e.g. hunting by raptors) and birds outside the plot in the same habitat were recorded but scored as zero. The broader fauna survey included nocturnal active searches (3 x 30 person-minute searches), largely focused on reptiles (Kearney *et al.* 2021); however, nocturnal birds were recorded and included in the site list. The survey effort for each plot is therefore six 10-minute surveys and three 30 person-minute nocturnal searches. Birds were also recorded opportunistically during travel between survey plots, or via other activities on the Reserve, and species recorded only in this manner (i.e. birds not also recorded in the plot-based census) were included in the final list.

For each plot and for each survey period, we were able to derive total bird species richness, and total bird abundance and the abundance of each species. Data on abundance are derived from the total number of birds seen and heard from standardised diurnal and nocturnal counts, rather than from the calculation of density; several studies have demonstrated that measures of relative abundance provide patterns of population trends equivalent to those derived from estimates of absolute abundance (Slade & Blair 2000; Hopkins & Kennedy 2004).

In each plot, the cover of the ground layer was recorded along a 100-m transect (star picket 0–100 m), halfway through the bird census plot. A 100-m tape was laid out along the central line of the quadrat and, using a laser pointer, the cover was recorded at 1-m intervals in the following categories: crust, disturbed (broken ground or water), rock, annual grass, perennial tussock grass, perennial hummock grass, annual herb/forb, shrub, perennial herb/forb, non-native herb/forb, non-native grass, non-native shrub, sedge and fern. The cover of the tree layer was also recorded along the 100-m tape, using a densiometer; the crown-cover distance for each plant species that intersects the 100-m tape represents the percentage cover.

Two landscape-scale environmental variables were derived via ArcMap 10.7.1 (ESRI 2019) for each plot: (i) a measure of total spinifex cover (Murphy & Murphy 2016) in a circular buffer of diameter 1 km around each plot, and (ii) a measure of total tree cover in a buffer of 1-km diameter around each plot (Queensland Department of Environment & Science 2018).

Analysis

The seasonal variation in total bird richness and abundance, abundance of bird species and ground cover functional groups recorded in the 2018 and 2019 surveys were examined using the Wilcoxon matched pairs test. Only bird species recorded in ≥5 plots over the combined two surveys were used.

We examined multivariate patterns in composition of the bird community, defined as the relative abundance of each bird species per site, using PRIMER/PERMANOVA v7.0.13 (Clarke & Gorley 2015). Firstly, we constructed a site by species table populated by abundance of each species, fourth root transformed the data and constructed a Bray–Curtis resemblance (similarity) matrix. We tested the strength of the *a priori* categorisation of the sites by habitat and season using PERMANOVA (Anderson *et al.* 2008), which 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 then undertook a constrained canonical analysis of principle coordinates (CAP) to find the strongest axes of variable correlation through a multivariate cloud to characterise and maximise *a priori* group differences (Anderson *et al.* 2008). Vector fitting uses Spearman rank correlations, and we used a cut-off $R = 0.4$.

Finally, we examined the variation in abundance of bird species recorded in response to site and landscape covariates. We derived two site variables (total ground cover excluding litter, and total woody vegetation cover) and two landscape variables (spinifex cover, and foliage projective cover in a 1-km buffer); however, total ground cover excluding litter was strongly positively correlated to the 1-km spinifex cover ($R = 0.49$) and total woody vegetation was strongly positively correlated to 1-km foliage projective cover ($R = 0.52$). Therefore, we decided to test only the landscape-scale variables, given the mobility of birds in our study environment, and we used generalised linear mixed (multi-level) models (Payne *et al.* 2010) to examine the relationship. Mixed models combine both fixed and random terms and estimate the variance within a group against the variance; in this case, we used habitat type and season as the random effects, and the landscape variables as the fixed effects. We fitted negative binomial regression models, which have the same mean structure as Poisson regression, but with a variance estimate that is a quadratic function of the mean (Ver Hoef & Boveng 2007). We fitted only additive models as we were interested only in size and direction of the main effects. Variance components are 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 4067 individual birds comprising 85 species was recorded via the standardised census across 40 sites sampled in October–November 2018 and May 2019 (Appendix 2). In the standardised surveys, corvids were grouped as *Corvus* spp., given uncertainty in splitting the three possible species during the time-constrained surveys. An additional 16 species were recorded opportunistically during our surveys: Australian Bustard *Ardeotis australis*, Straw-necked Ibis *Threskiornis spinicollis*, Australian White Ibis *T. moluccus*, Glossy Ibis *Plegadis falcinellus*, Bush Stone-curlew *Burhinus grallarius*, Black-fronted Dotterel *Elseyornis melanops*, Banded Lapwing *Vanellus tricolor*, Masked Lapwing *V. miles*, Inland Dotterel *Peltohyas australis*, Plains-wanderer *Pedionomus torquatus*, Eastern Barn Owl *Tyto delicatula*, Night Parrot *Pezoporus occidentalis*, Grey-headed Honeyeater *Ptilotula keartlandi*, Torresian Crow *Corvus orru*, Little Crow *C. bennetti* and Australian Raven *C. coronoides*. Three of the species recorded are of conservation significance under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999*: Plains-wanderer (Endangered), Grey Falcon *Falco hypoleucos* (Vulnerable) and Night Parrot (Endangered).

The most frequently recorded species over the 80 surveys were Budgerigar *Melopsittacus undulatus* ($n = 57$), Zebra Finch *Taeniopygia castanotis* ($n = 54$), Willie Wagtail *Rhipidura leucophrys* ($n = 47$), Diamond Dove *Geopelia cuneata* ($n = 41$), Singing Honeyeater *Gavicalis virescens* ($n = 36$), Rufous Whistler *Pachycephala rufiventris* ($n = 36$), Crested Bellbird *Oreoica gutturalis* ($n = 31$), Variegated Fairy-wren *Malurus lamberti* ($n = 25$), Black-faced Woodswallow *Artamus cinereus* ($n = 23$) and Spinifexbird *Poodytes carteri* ($n = 21$). Species richness was higher in all habitats in 2019 than in 2018, highest in the Gidgee riparian woodland sites in 2019, and lowest in the Mitchell grass/chenopod sites in 2018 (Figure 2a). Species abundance was highest in the Gidgee riparian woodland sites in 2018 and 2019, and lowest in the Spinifex grassland sites in 2018 and the Mitchell grass/chenopod sites in 2019 (Figure 2b).

Twenty-six of the 85 species (31%) recorded from the standardised surveys were recorded in only one of the surveys across the two seasons: Emu *Dromaius novaehollandiae*, Fork-tailed Swift *Apus pacificus*, Black Falcon *Falco subniger*, Mulga Parrot *Psephotellus varius,*

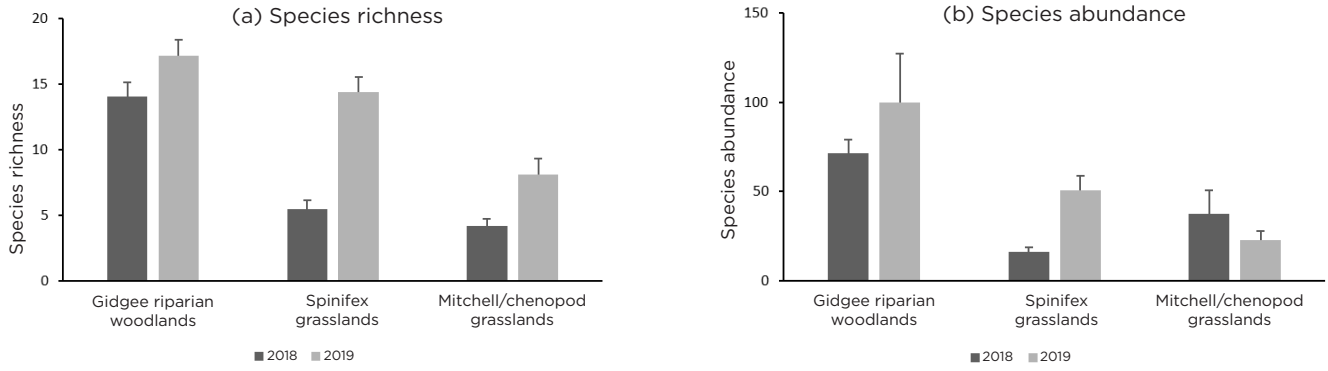

Figure 2. The means (and standard errors) of (a) total bird species richness and (b) bird species abundance across the three habitat types, for each survey period at Pullen Pullen Reserve, Queensland.

Splendid Fairy-wren *Malurus splendens*, Orange Chat *Epthianura aurifrons*, Gibberbird *Ashbyia lovensis*, Red-browed Pardalote *Pardalotus rubricatus*, Pied Honeyeater *Certhionyx variegatus*, Little Friarbird *Philemon citreogularis* (November 2018) and Flock Bronzewing *Phaps histrionica*, Black-shouldered Kite *Elanus axillaris*, Whistling Kite *Haliastur sphenurus*, Black Kite *Milvus migrans*, Collared Sparrowhawk *Accipiter cirrocephalus,* Galah *Eolophus roseicapilla*, Little Corella *Cacatua sanguinea*, Black-eared Cuckoo *Chalcites osculans*, Southern Boobook *Ninox boobook*, Spotted Bowerbird *Chlamydera maculata*, White-plumed Honeyeater *Ptilotula penicillata*, Yellow-throated Miner *Manorina flavigula*, Black Honeyeater *Sugomel nigrum,* Ground Cuckoo-shrike *Coracina maxima*, Pied Butcherbird *Cracticus nigrogularis* and Magpie-lark *Grallina cyanoleuca* (May 2019).

Overall bird abundance was highest in the 2019 surveys, as was bird species richness (Table 1). Nineteen species varied significantly in abundance between the 2018 and 2019 surveys. Eight were absent in 2018 (Pallid Cuckoo *Heteroscenes pallidus*, Cockatiel *Nymphicus hollandicus,* Red-tailed Black-Cockatoo *Calyptorhynchus banksii*, Rufous-crowed Emu-wren *Stipiturus ruficeps*, Masked Woodswallow *Artamus personatus*, White-browed Woodswallow *A. superciliosus*, Grey Fantail *Rhipidura albiscapa* and Rufous Songlark *Cincloramphus mathewsi*) and two were absent in the 2019 surveys (Rainbow Bee-eater *Merops ornatus* and Little Woodswallow *Artamus minor*) (Table 1). Only two species, present in both surveys, were recorded in higher abundances in 2018 (Little Button-quail *Turnix velox* and Horsfield's Bushlark *Mirafra javanica*), with the remainder more abundant in 2019 (Table 1).

Seven of the site-based habitat variables were significantly different between the October–November 2018 and May 2019 surveys; ground cover, annual grass, annual herbs and forbs, perennial grass cover and rock cover were higher in May 2019 after the summer rainfall, and crust and litter cover were higher in the initial October–November 2018 survey (Table 1).

The PERMANOVA results revealed that there was a significant difference in bird composition across habitat [df = 2, Pseudo-*F* = 9.6. P(perm) = 0.001], season [df = 1, Pseudo-*F* = 7.4. P(perm) = 0.001] and their interaction [df = 2, Pseudo-*F* = 2.8. P(perm) = 0.001]. The canonical analysis of principle coordinates indicated that there was strong separation in bird composition across the habitats and some bird species were correlated (*R* >0.4) with habitat groups, namely Spinifexbird with the Spinifex sites, Horsfield's Bushlark with the Mitchell grassland sites, and Variegated Fairy-wren, Varied Sittella *Daphoenositta chrysoptera*, Rufous Whistler and Grey Shrike-thrush *Colluricincla harmonica* with the Gidgee riparian sites. The Singing Honeyeater was correlated with a set of sites lying between the gradient between the Gidgee and Spinifex sites (Figure 3).

The abundance of 13 species indicated significant regression with the landscape variables. Three species (Rainbow Bee-eater, Spiny-cheeked Honeyeater *Acanthagenys rufogularis* and Rufous Whistler) were positively associated with foliage projective cover in a 1-km buffer, and four species (Crested Pigeon *Ocyphaps lophotes*, White-winged Triller *Lalage tricolor*, Black-faced Woodswallow and Painted Finch *Emblema pictum*) were negatively associated with the foliage projective

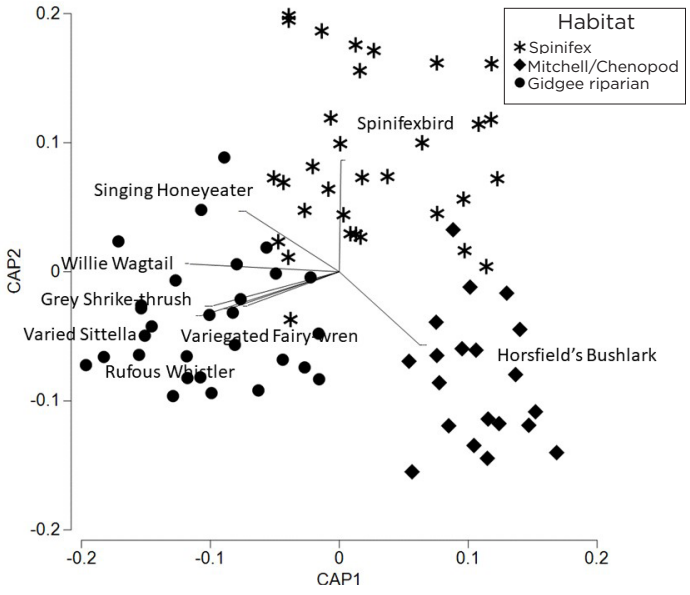

Figure 3. Spearman rank correlations (*R* >0.4) of bird species vectors overlain on constrained canonical analysis of principle ordination of bird composition for each habitat in the study sites at Pullen Pullen Reserve, Queensland. CAP1 and CAP2 refer to the axes for the canonical analysis of principle coordinates.

Table 1. Seasonal differences in the surveys in 2018 and 2019 at Pullen Pullen Reserve, Queensland, in the total bird abundance and species richness, individual bird species abundance, and ground cover of site habitat. Only species with significant variation are tabulated. Data are the mean (and standard error) across the 36 paired quadrat sites; *n* = number of surveys; *Z* = the Wilcoxon matched pairs test statistic. Highest values for each species are indicated in bold. Probability levels are **P* <0.05, ***P* <0.01 and ****P* <0.001. See Appendix 2 for scientific names of birds.

Species/functional group	n	*2018*	*2019*	Z^p
Birds				
Total bird abundance	80	40.83 (5.71)	**60.92 (11.05)**	2.48*
Total bird species richness	80	8.15 (0.84)	**13.77 (0.89)**	4.69***
Spinifex Pigeon	13	0.15 (0.08)	**1.00 (0.36)**	2.37*
Pallid Cuckoo	13	0 (0)	**0.65 (0.18)**	3.17**
Little Button-quail	11	**0.78 (0.23)**	0.08 (0.04)	2.75**
Rainbow Bee-eater	10	**0.68 (0.21)**	0 (0)	2.80**
Nankeen Kestrel	21	0.15 (0.06)	**0.78 (0.16)**	3.04**
Cockatiel	10	0 (0)	**0.25 (0.20)**	2.80**
Red-tailed Black-Cockatoo	9	0 (0)	**0.28 (0.09)**	2.66**
White-winged Fairy-wren	10	0.03 (0.03)	**1.23 (0.48)**	2.85**
Rufous-crowed Emu-wren	5	0 (0)	**0.33 (0.16)**	2.02*
Brown Honeyeater	7	0.03 (0.03)	**0.68 (0.26)**	2.36*
Crested Bellbird	28	0.20 (0.11)	**1.6 (0.29)**	3.81***
Rufous Whistler	22	1.08 (0.32)	**2.60 (0.60)**	3.47***
Australian Magpie	8	0.05 (0.05)	**0.33 (0.12)**	2.52*
Masked Woodswallow	14	0 (0)	**4.28 (1.70)**	3.29***
White-browed Woodswallow	6	0 (0)	**1.10 (0.49)**	2.20*
Little Woodswallow	9	**0.33 (0.11)**	0 (0)	2.66**
Grey Fantail	7	0 (0)	**0.58 (0.24)**	2.40*
Horsfield's Bushlark	7	**0.83 (0.35)**	0.03 (0.03)	2.35*
Rufous Songlark	8	0 (0)	**0.63 (0.36)**	2.52*
Habitat				
Ground cover (excluding litter) %	80	28.3 (3.07)	**34.35 (2.97)**	2.46*
Annual grass %	80	2.65 (0.50)	**5.95 (1.31)**	3.15**
Annual herbs and forbs %	80	2.32 (0.52)	**5.87 (0.85)**	4.65***
Crust %	80	**34.28 (3.19)**	25.82 (3.14)	3.77***
Litter %	80	**16.25 (3.01)**	9.25 (1.37)	2.51*
Perennial tussock grass %	80	2.62 (1.24)	**3.75 (1.44)**	1.92*
Rock %	80	19.55 (3.57)	**28.57 (3.71)**	3.71***

cover (Table 2). For the spinifex cover in the 1-km buffer, Hall's Babbler *Pomatostomus halli* and Spinifexbird were positively associated, and White-winged Fairy-wren *Malurus leucopterus* and Zebra Finch negatively associated. Two species (Nankeen Kestrel *Falco cenchroides* and Masked Woodswallow) were negatively associated with foliage projective cover and positively with spinifex cover (Table 2).

Discussion

This survey has provided a baseline of standardised surveys and data on the avifauna of the Pullen Pullen Reserve in south-western Queensland. In comparison with surveys in adjacent Diamantina National Park over 15 years (Ley *et al.* 2011), our short study over 7 months, documented >50% of the birds recorded in Ley *et al.*'s longer-term survey (Ley *et al.* 2011). Arid bird communities are composed of nomadic and immigrant species with a core of resident species. Our data indicated that this is potentially the case at Pullen Pullen; 31% of the species were recorded in only one of our surveys, and many of these species are migratory or nomadic (e.g. Fork-tailed Swift, Mulga Parrot, Pallid Cuckoo, Rainbow Bee-eater, woodswallows, Grey Fantail, Black Honeyeater, Pied Honeyeater). There is a group of species that are common and potentially resident (i.e. Diamond Dove, White-winged Fairy-wren, Singing Honeyeater, Rufous Whistler, Grey Shrike-thrush, Crested Bellbird, Willie Wagtail, Horsfield's Bushlark) but long-term monitoring will provide clearer information on the core bird community and the more ephemeral components. Some

Table 2. The results of the generalised linear mixed modelling for birds, testing for the effect of foliage projective cover (FPC) and spinifex cover (SC) in 1-km buffers around the study sites at Pullen Pullen Reserve, Queensland. Habitat within survey time is the random effect. The estimate (Est.) is the direction of the effect, the Wald statistic is an equivalent to the *F* statistic, and *P* is the significance level; SE = standard error. We tabulate all significant results where *P* is <0.05. See Appendix 2 for scientific names of birds.

	FPC (%)				*SC (%)*			
Species	*Est.*	*SE*	*Wald*	*P*	*Est.*	*SE*	*Wald*	*P*
Crested Pigeon	–0.366	0.153	5.70	0.019				
Rainbow Bee-eater	0.363	0.109	10.99	0.001				
Nankeen Kestrel	–0.481	0.157	9.34	0.003	0.058	0.027	4.49	0.037
White-winged Fairy-wren					–0.674	0.209	10.42	0.002
Spiny-cheeked Honeyeater	0.225	0.093	5.76	0.019				
Hall's Babbler					0.113	0.047	5.59	0.021
Rufous Whistler	0.225	0.071	9.94	0.002				
White-winged Triller	–0.203	0.117	3.00	0.088				
Masked Woodswallow	–0.906	0.182	24.64	<0.001	0.115	0.033	11.68	0.001
Black-faced Woodswallow	–0.455	0.202	5.07	0.027				
Spinifexbird					0.041	0.021	4.24	0.043
Painted Finch	–0.758	0.311	5.92	0.017				
Zebra Finch					–0.047	0.026	4.19	0.044

of the birds recorded opportunistically are aquatic species and there is a substantial influx of waterbirds and waders into the floodplains that bisect the south-western portion of the property after rainfall or flood pulses from the upper catchments of the Diamantina River (Ley *et al.* 2011).

The two surveys that were undertaken had very contrasting seasonal conditions. Although some of the variation recorded in the species is probably because of typical movement of species into and out of the arid zone on an annual basis, there was a lower abundance of some potentially resident species that were under-recorded because of the hot and windy conditions in October–November 2018 interfering with visual and aural observations (Nankeen Kestrel, White-winged Fairy-wren, Rufous-crowned Emu-wren and Crested Bellbird). Regardless of this, however, there was strong variation in abundance, richness and composition across the three habitats. The structurally more complex sites in the Gidgee riparian woodlands had more birds species, and of greater abundance, than the grasslands, a typical pattern of arid environments (Jordan *et al.* 2017), although bird species richness and abundance in the Spinifex and Mitchell grasslands increased substantially in the May 2019 surveys (Table 1). The compositional division was correlated to some key species that are more abundant in the different habitat surveyed, such as Spinifexbird in the hummock grasslands, Horsfield's Bushlark in tussock grasslands, and woodland birds (Rufous Whistler, Grey Shrike-thrush) in the Gidgee riparian woodlands. Vegetation structural diversity is a key predictor of bird composition in most Australia environments (Tassicker *et al.* 2006).

Very few species showed significant association with the landscape-scale predictors used in the regression, and this is in part because of the low abundance of many species and the short nature of the survey. However, there are some obvious patterns in the relationship between the amount of woodland or spinifex cover in the surrounding matrix, and the abundance of grassland (Crested Pigeon, Nankeen Kestrel, woodswallows and Painted Finch) and woodland birds (i.e. Spiny-cheeked Honeyeater, Rufous Whistler). The continuum between site and landscape changes in grass and tree cover is important to understand the context of species distribution (Price *et al.* 2009) as many birds forage in open areas and nest or shelter in adjacent trees. Our data have provided a preliminary snapshot of the occurrence and distribution of birds at Pullen Pullen Reserve. Given the mutable nature of arid environments and the significant influence of climate (Dickman & Tischler 2010), however, long-term and consistent monitoring should be embedded as a critical component of the management, in order to unravel the essential and peripheral components of the bird communities.

This paper describes the genesis of long-term monitoring in this new conservation reserve. Many monitoring programs fail because of lack of continuity and resourcing, the lack of review and adaptation of the monitoring to changing management questions, and institutional malaise (Lindenmayer & Likens 2010). Though our data are not in response to a specific research or management question, they represent the first step of any program: characterisation of the avifauna and the simple habitat relationships, which provides the baseline to propose questions for the next phase of the work. Future work should embrace an adaptive management and monitoring framework (Lindenmayer & Likens 2009) and consider the long-term response of the birds to cycles of extreme rainfall and drought, the benefits or any perverse outcomes of the removal of cattle, and the effects of fire exclusion in the spinifex environments (i.e. critical Night Parrot habitat) or the potential need to burn components of the Mitchell Grass Downs where grazing has now been removed. Given the spectre of rapid global environmental change, long-term monitoring is a critical aspect of understanding the variability in pattern of the wildlife over time, and of how to increase the resilience of this wildlife effectively into a future of more extreme weather events.

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Appendix 1. Location (decimal latitude and longitude), plot bearing and habitat of survey sites in Pullen Pullen Reserve, Queensland. Plot bearings are E = east, N = north, S = south and W = west, and represent the orientation of the 2-ha plot (i.e. E indicates that the centreline of the plot runs east etc.).

Site no.	*Latitude*	*Longitude*	*Plot bearing*	*Habitat*
1	–23.4683	141.5262	N	Mitchell/chenopod grasslands
2	–23.4653	141.5254	S	Mitchell/chenopod grasslands
3	–23.4898	141.5153	E	Gidgee riparian woodlands
4	–23.4991	141.5236	W	Mitchell/chenopod grasslands
5	–23.5053	141.5194	E	Gidgee riparian woodlands
6	–23.5127	141.5099	E	Gidgee riparian woodlands
7	–23.5084	141.5016	N	Gidgee riparian woodlands
8	–23.5115	141.4928	N	Spinifex grasslands
9	–23.5027	141.4940	N	Gidgee riparian woodlands
10	–23.5257	141.5118	S	Spinifex grasslands
11	–23.5426	141.5221	W	Mitchell/chenopod grasslands
12	–23.5762	141.4981	E	Spinifex grasslands
13	–23.5858	141.4877	S	Spinifex grasslands
14	–23.5899	141.4692	N	Spinifex grasslands
15	–23.5867	141.4646	N	Spinifex grasslands
16	–23.5840	141.4603	N	Gidgee riparian woodlands
17	–23.5755	141.4659	E	Spinifex grasslands
18	–23.5752	141.4599	E	Spinifex grasslands
19	–23.5738	141.4217	S	Gidgee riparian woodlands
20	–23.5864	141.4455	S	Gidgee riparian woodlands
21	–23.5276	141.5609	N	Mitchell/chenopod grasslands
22	–23.5234	141.5633	S	Mitchell/chenopod grasslands
23	–23.5140	141.5743	S	Mitchell/chenopod grasslands
24	–23.5107	141.5812	N	Mitchell/chenopod grasslands
25	–23.5008	141.5877	S	Mitchell/chenopod grasslands
26	–23.5020	141.5927	N	Mitchell/chenopod grasslands
27	–23.2213	141.7731	E	Spinifex grasslands
28	–23.2271	141.7766	N	Spinifex grasslands
29	–23.2355	141.7700	W	Gidgee riparian woodlands
30	–23.2479	141.7664	W	Spinifex grasslands
31	–23.2544	141.7661	W	Spinifex grasslands
32	–23.2560	141.7629	E	Spinifex grasslands
33	–23.2680	141.7577	S	Spinifex grasslands
34	–23.2783	141.7597	W	Gidgee riparian woodlands
35	–23.2869	141.7681	N	Spinifex grasslands
36	–23.2948	141.7741	W	Gidgee riparian woodlands
37	–23.3045	141.7824	N	Spinifex grasslands
38	–23.3051	141.7857	S	Gidgee riparian woodlands
39	–23.3067	141.7916	S	Gidgee riparian woodlands
40	–23.3153	141.7962	N	Gidgee riparian woodlands

Appendix 2. The mean abundance for each bird species recorded for the combined surveys by habitat type at Pullen Pullen Reserve, Queensland. Opportunistic records (*) are identified in a separate column, and these represent bird species not recorded in the survey plots but recorded only during travel between the plots or during other activities on the Reserve; *n* = number of surveys; names of bird families are shown in bold.

Species		*Opportunistic records*	*Habitat*		
Common name	*Scientific name*		*Mitchell/chenopod (n = 20)*	*Spinifex (n = 32)*	*Gidgee riparian (n = 28)*
Casuariidae					
Emu	*Dromaius novaehollandiae*		1.3	0.0	0.0
Columbidae					
Eastern Spinifex Pigeon	*Geophaps plumifera leucogaster*		1.1	0.0	2.5
Common Bronzewing	*Phaps chalcoptera*		1.2	0.0	0.0
Flock Bronzewing	*Phaps histrionica*		0.0	11.0	0.0
Crested Pigeon	*Ocyphaps lophotes*		1.8	2.0	1.5
Diamond Dove	*Geopelia cuneata*		5.1	1.5	3.8
Eurostopodidae					
Spotted Nightjar	*Eurostopodus argus*		1.0	0.0	1.0
Aegothelidae					
Australian Owlet-nightjar	*Aegotheles cristatus*		1.0	1.0	1.0
Apodidae					
Fork-tailed Swift	*Apus pacificus*		0.0	0.0	20.0
Cuculidae					
Horsfield's Bronze-Cuckoo	*Chalcites basalis*		1.0	1.0	1.0
Black-eared Cuckoo	*Chalcites osculans*		1.0	0.0	0.0
Pallid Cuckoo	*Heteroscenes pallidus*		1.1	1.0	1.0
Otididae					
Australian Bustard	*Ardeotis australis*	*			
Threskiornithidae					
Straw-necked Ibis	*Threskiornis spinicollis*	*			
Australian White Ibis	*Threskiornis moluccus*	*			
Glossy Ibis	*Plegadis falcinellus*	*			
Burhinidae					
Bush Stone-curlew	*Burhinus grallarius*	*			
Charadriidae					
Black-fronted Dotterel	*Elseyornis melanops*	*			
Banded Lapwing	*Vanellus tricolor*	*			
Masked Lapwing	*Vanellus miles*	*			
Inland Dotterel	*Peltohyas australis*	*			
Pedionomidae					
Plains-wanderer	*Pedionomus torquatus*	*			
Turnicidae					
Little Button-quail	*Turnix velox*		1.6	1.5	1.0
Tytonidae					
Eastern Barn Owl	*Tyto delicatula*	*			
Strigidae					
Southern Boobook	*Ninox boobook*		0.0	0.0	1.0

Appendix 2 continued

Species		*Opportunistic records*	*Habitat*		
Common name	*Scientific name*		*Mitchell/chenopod (n = 20)*	*Spinifex (n = 32)*	*Gidgee riparian (n = 28)*
Accipitridae					
Black-shouldered Kite	*Elanus axillaris*		1.0	0.0	0.8
Wedge-tailed Eagle	*Aquila audax*		1.0	1.0	1.2
Spotted Harrier	*Circus assimilis*		1.0	1.0	1.0
Collared Sparrowhawk	*Accipiter cirrocephalus*		1.0	0.0	0.0
Whistling Kite	*Haliastur sphenurus*		0.0	1.0	0.0
Black Kite	*Milvus migrans*		1.0	1.0	1.0
Meropidae					
Rainbow Bee-eater	*Merops ornatus*		1.7	0.0	2.0
Alcedinidae					
Red-backed Kingfisher	*Todiramphus pyrrhopygius*		1.0	0.0	1.0
Falconidae					
Nankeen Kestrel	*Falco cenchroides*		1.1	1.3	1.2
Brown Falcon	*Falco berigora*		1.0	1.0	1.5
Grey Falcon	*Falco hypoleucos*		1.0	0.0	1.0
Black Falcon	*Falco subniger*		0.0	1.0	0.0
Peregrine Falcon	*Falco peregrinus*		1.0	0.0	1.0
Cacatuidae					
Cockatiel	*Nymphicus hollandicus*		1.3	3.0	3.0
Red-tailed Black-Cockatoo	*Calyptorhynchus banksii*		1.0	1.0	1.0
Galah	*Eolophus roseicapilla*		0.0	2.0	1.5
Little Corella	*Cacatua sanguinea*		0.0	3.3	0.0
Psittaculidae					
Mulga Parrot	*Psephotellus varius*		4.0	0.0	0.0
Australian Ringneck	*Barnardius zonarius*		1.3	0.0	0.0
Night Parrot	*Pezoporus occidentalis*	*			
Bourke's Parrot	*Neopsephotus bourkii*		2.9	0.0	1.8
Budgerigar	*Melopsittacus undulatus*		4.4	5.6	2.1
Maluridae					
Variegated Fairy-wren	*Malurus lamberti*		2.8	0.0	1.9
Splendid Fairy-wren	*Malurus splendens*		2.0	0.0	0.0
White-winged Fairy-wren	*Malurus leucopterus*		3.0	2.9	3.0
Rufous-crowned Emu-wren	*Stipiturus ruficeps*		0.0	0.0	1.4
Ptilonorhynchidae					
Spotted Bowerbird	*Chlamydera maculata*		1.0	0.0	1.0
Meliphagidae					
Brown Honeyeater	*Lichmera indistincta*		1.0	0.0	1.0
Little Friarbird	*Philemon citreogularis*		1.5	0.0	0.0
Black Honeyeater	*Sugomel nigrum*		1.0	0.0	0.0
Pied Honeyeater	*Certhionyx variegatus*		2.0	0.0	0.0
Gibberbird	*Ashbyia lovensis*		1.0	0.0	0.0
Crimson Chat	*Epthianura tricolor*		2.3	0.0	0.0
Orange Chat	*Epthianura aurifrons*		1.0	1.0	0.0
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*		1.0	0.0	1.0
Singing Honeyeater	*Gavicalis virescens*		1.0	1.0	1.0

Appendix 2 continued

Species		*Opportunistic records*	*Habitat*		
Common name	*Scientific name*		*Mitchell/chenopod (n = 20)*	*Spinifex (n = 32)*	*Gidgee riparian (n = 28)*
Meliphagidae continued					
White-plumed Honeyeater	*Ptilotula penicillata*		2.0	0.0	0.0
Grey-headed Honeyeater	*Ptilotula keartlandi*	*	1.0	1.0	1.0
Yellow-throated Miner	*Manorina flavigula*		0.0	0.0	1.0
Pardalotidae					
Red-browed Pardalote	*Pardalotus rubricatus*		1.0	0.0	0.0
Acanthizidae					
Inland Thornbill	*Acanthiza apicalis*		2.1	0.0	0.0
Chestnut-rumped Thornbill	*Acanthiza uropygialis*		1.5	0.0	0.0
Pomatostomidae					
Hall's Babbler	*Pomatostomus halli*		3.2	0.0	1.0
Neosittidae					
Varied Sittella	*Daphoenositta chrysoptera*		2.3	0.0	0.0
Oreoicidae					
Crested Bellbird	*Oreoica gutturalis*		1.0	1.5	1.0
Cinclosomatidae					
Chestnut-breasted Quail-thrush	*Cinclosoma castaneothorax*		1.4	0.0	1.0
Pachycephalidae					
Rufous Whistler	*Pachycephala rufiventris*		1.4	1.0	1.0
Grey Shrike-thrush	*Colluricincla harmonica*		1.1	0.0	1.0
Campephagidae					
Ground Cuckoo-shrike	*Coracina maxima*		5.0	0.0	0.0
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*		1.0	0.0	0.0
White-winged Triller	*Lalage tricolor*		2.4	0.0	1.3
Artamidae					
Masked Woodswallow	*Artamus personatus*		6.0	0.0	2.2
White-browed Woodswallow	*Artamus superciliosus*		3.9	0.0	4.5
Black-faced Woodswallow	*Artamus cinereus*		3.6	1.3	3.1
Little Woodswallow	*Artamus minor*		1.2	0.0	1.0
Australian Magpie	*Gymnorhina tibicen*		1.0	1.0	1.1
Pied Butcherbird	*Cracticus nigrogularis*		1.0	0.0	0.0
Grey Butcherbird	*Cracticus torquatus*		1.0	0.0	1.0
Rhipiduridae					
Willie Wagtail	*Rhipidura leucophrys*		1.1	1.0	1.1
Grey Fantail	*Rhipidura albiscapa*		1.5	0.0	1.0
Monarchidae					
Magpie-lark	*Grallina cyanoleuca*		3.0	1.0	0.0
Corvidae					
Torresian Crow	*Corvus orru*	*			
Little Crow	*Corvus bennetti*	*			

Appendix 2 continued

Species		*Opportunistic records*	*Habitat*		
Common name	*Scientific name*		*Mitchell/chenopod (n = 20)*	*Spinifex (n = 32)*	*Gidgee riparian (n = 28)*
Corvidae continued					
Australian Raven	*Corvus coronoides*	*			
Crow/raven	*Corvus* sp.		1.0	1.3	1.0
Petroicidae					
Red-capped Robin	*Petroica goodenovii*		1.3	0.0	0.0
Jacky Winter	*Microeca fascinans*		1.0	0.0	0.0
Hooded Robin	*Melanodryas cucullata*		0.0	0.0	1.2
Alaudidae					
Horsfield's Bushlark	*Mirafra javanica*		0.0	1.5	0.0
Locustellidae					
Brown Songlark	*Cincloramphus cruralis*		1.0	1.0	1.5
Rufous Songlark	*Cincloramphus mathewsi*		2.3	1.0	1.0
Spinifexbird	*Poodytes carteri*		1.0	0.0	1.1
Dicaeidae					
Mistletoebird	*Dicaeum hirundinaceum*		1.2	0.0	1.0
Estrildidae					
Painted Finch	*Emblema pictum*		1.5	0.0	3.2
Zebra Finch	*Taeniopygia castanotis*		5.4	4.6	3.8
Motacillidae					
Australasian Pipit	*Anthus novaeseelandiae*		1.0	1.0	1.0