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Birds respond to woodland type, soil and mesic gradients in heterogeneous woodlands at Dryandra

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Abstract. The vast clearance of forest and woodland for agriculture with the removal of more than 93% of the native vegetation has decimated the fauna of what is now known as the Western Australian wheatbelt. This clearing has been particularly severe on wandoo woodlands through the wheatbelt. In order to quantify the usefulness of what has been left, three native woodland types were surveyed for avian abundance and diversity, in a large heterogeneous remnant of old-growth woodland, at Dryandra. Birds were counted at 70 points along seven transects, through three woodland types: powderbark wandoo (*Eucalyptus accedens*), wandoo (*E. wandoo*) and a brown mallet (*E. astringens*) plantation. Greater abundance and species richness were detected in *E. wandoo* woodland, although this is thought to be related to the more mesic and productive low-lying contours of the landscape on which it is situated.

Keywords: forest, homogenisation, fragmentation, adaptive management, land-use change, biodiversity, ecology, disturbance.

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Introduction

The worldwide reduction and modification of forest and woodland habitats for agriculture has resulted in the dramatic decline of bird numbers (Bregman *et al*. 2014; Betts *et al*. 2017). Even in large reserves bird declines are forecast to continue through a reduction of food resources under climate change (Mac Nally *et al*. 2009). In Australia, temperate eucalypt woodlands were once widespread in what are now vast agricultural expanses (Prober *et al*. 2002; Bradshaw 2012). This vast removal of the woodland landscape has not occurred uniformly, either spatially or temporally, with woodlands on more productive soils being preferentially cleared first and most frequently (Hobbs and Saunders 1991; Mac Nally *et al*. 2000; Watson 2011). One area that has fared worse than most is the south-west of Western Australia, in which 14 million ha (an area larger than England) was cleared of 93% of its woodland vegetation (Kitchener *et al*. 1982; Hobbs and Hopkins 1990; Saunders and Ingram 1995). Moreover, its vegetation associations on better quality farming soils were cleared preferentially, with an estimated 97% loss of these more productive woodlands (Saunders 1989; Hobbs and Saunders 1991; Hobbs 1993). Within this recurring pattern, most of the surviving remnants were situated on less productive soils considered unsuitable for agriculture (Kitchener *et al*. 1982; Saunders and Curry 1990; Saunders and Ingram 1995).

In such a diminished environment it is important to understand how the remaining vegetation is used by the birds (e.g. Kitchener *et al*. 1982; Mac Nally *et al*. 2000; Miller and Cale 2000; Antos and Bennett 2005). This use of the environment by birds is particularly important for adaptive management strategies focussed on revegetation and management of the remaining stands, because learning about a system is an integral part of adaptive management (Prober and Smith 2009). A significant problem in understanding how the birds might use the remaining vegetation associations or woodland types is that the surviving remnants are typically small and isolated, and consequently homogeneous in terms of woodland type (Prober and Smith 2009). Such remnants are clearly unrepresentative of the vast expanses of heterogeneous woodlands present before widespread clearing took place. Yet, at Dryandra, landscape heterogeneity has been preserved with various vegetation associations still represented and still holding ecologically functional communities of flora and fauna – including the birds (Friend *et al*. 1995; DEC 2011; Fulton 2013). The juxtaposition of these woodland communities, in large contiguous remnants, allows us to test the null hypothesis that different woodland types harbour the same avian assemblages, when considered across the year (the alternative being that they do not). To test this assumption, we conducted point-transect surveys through three dominant woodland communities at Dryandra: *Eucalyptus wandoo* woodland, powderbark wandoo (*E. accedens*) woodland and a brown mallet (*E. astringens*) plantation. We aimed to assess how birds might use the woodland types and which ones were most frequented.

Methods

Study site

Dryandra Woodland (Dryandra) is located ~160 km south-east of Perth (32°48′S, 117°0′E) on the western side of the Western Australian wheatbelt (Fig. 1). Dryandra comprises a series of large woodland fragments, which are separated by agricultural land and scattered over an east–west distance of ~35 km (Friend *et al*. 1995; DEC 2011).

Landscape context and management

Dryandra is unlike other temperate woodland remnants in Australia due to several factors, including its overall size (27 000 ha), which embraces large areas of undisturbed old-growth woodland (Friend *et al*. 1995; DEC 2011) and its location on the central western side of the Western Australian wheatbelt where up to 97% of the original native vegetation has been removed (Saunders and Curry 1990; Saunders and Ingram 1995). Dryandra holds an almost intact avifauna with species in ecologically functional numbers, including many species lost from remnants of the central wheatbelt (Fulton 2013). It also harbours rare marsupials that have become extinct in the surrounding wheatbelt and some that have been reintroduced (DEC 2011; Fulton 2017). The natural presence of fluoroacetate (natural poison) bearing plants, particularly sandplain poison (*Gastrolobium microcarpum*) has had a major influence on allowing native species to persist at Dryandra (Short *et al*. 2005). Since the 1980s the control of the fox (*Vulpes vulpes*) using 1080 (fluoroacetate) baiting has enabled the recovery of marsupials, birds, and reptiles, which were adversely affected by fox predation (Burbidge *et al*. 1996; Friend and Beecham 2004; Possingham *et al*. 2004), although subsequent predation by cats (*Felis catus*) is now known to have reduced the numbers of some of these endemic animals (Marlow *et al*. 2015). Dryandra has been a focal point of research since the 1980s with baseline data accumulated across a wide diversity of biota (Friend *et al*. 1995; DEC 2011). Its ongoing management as a National Park suggests that this will continue.

Vegetation associations and mesic gradient

In general, Dryandra's woodlands are characterised by powderbark wandoo (*E. accedens*), jarrah (*E. marginata*) and brown mallet (*E. astringens*) on the mid and upper slopes, with *E. wandoo*, jam wattle (*Acacia acuminata*), and, less commonly, marri (*E. calophylla*), on the lower slopes and valleys; collectively, these associations are known as wandoo woodlands (Fig. 2*a–c*). Powderbark wandoo and *E. wandoo* woodland make up ~50% of the total area (McArthur *et al.*

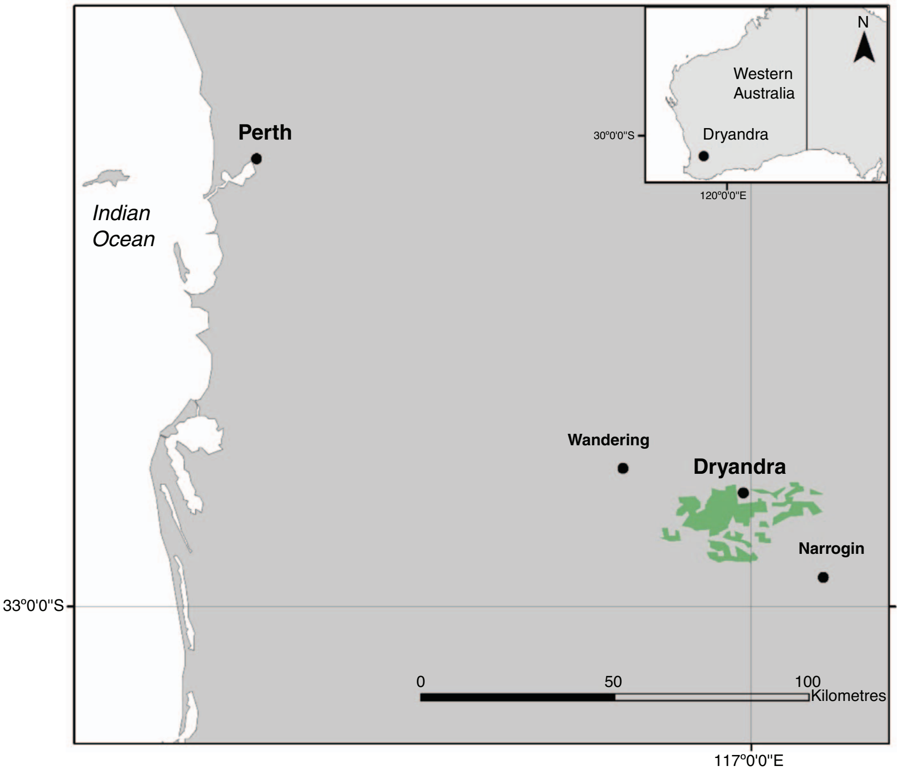

Fig. 1. Dryandra in relation to Perth and south-western Australia.

Fig. 2. The three woodland types surveyed at Dryandra: (*a*) *E. wandoo* woodland; (*b*) powderbark wandoo woodland; (*c*) brown mallet plantation. Note the different tree habits and ground vegetation associated with the varying mesic and productivity qualities of the soils, with *E. wandoo* being the most mesic.

1977; Coates 1993). At Dryandra, the lower levels of the landscape collect the most water and nutrients and thus have the richest and most mesic soils (DEC 2011). The slope or gradient is very gentle, ranging from 1:300 to 1:500 (McArthur *et al*. 1977). The *E. wandoo* woodland sites surveyed in this study were both found on the most productive and mesic soils in association with jam wattle and the Biberkine valley floor soils (DEC 2011). These low-lying contours can be viewed as almost indiscernible drainage lines on gentle gradients, which are more mesic than the surrounding valley floor and ridges. The vegetation communities follow this gentle gradient upslope, with *E. wandoo* situated in the lowest contours, which then grades up to powderbark wandoo and then brown mallet as the soil changes, becoming more lateric and carrying fewer nutrients. In this study the brown mallet plantation surveyed was situated on more nutrient rich Biberkine soils marginally above the *E. wandoo* woodland on a similar gradient to that of the *E. wandoo* and powderbark wandoo gradient at Marri Road.

Point-transect method

The point-transect method was chosen as a hybrid combining points and targeted transect lines. It was considered the best method to count both quickly and thoroughly; quickly to avoid double counting vagile species and thoroughly to capture the full abundance and species richness. Using equally spaced point counts allowed equal sampling within each woodland type. In total, 23 surveys were performed from 29 September 2003 to 5 December 2004, at two sites within Dryandra. Two surveys were performed each month, at each site, except April when only one survey was conducted. Each of the 23 surveys included seven transects, each having 10 points along its length, giving 70 points in total per survey. Four transects were performed at Marri Road (32°46′35.9″S, 116°55′34.1″E) and three at Gura Road (32°45′27.2″S, 116°57′16.1″E) (approximate centres given). All transects ran through two vegetation types with five point counts positioned in each vegetation type and with both sites having an unsealed management track at the centre separating the vegetation types. Birds using these management tracks as a resource (for example, puddles of water) are not reported here nor was the road area included in this survey. Marri Road separated powerbark wandoo and *E. wandoo* woodland while Gura Road separated the brown mallet plantation and *E. wandoo* woodland. The lowest points of the field sites were found at the edges of the two *E. wandoo* woodland field sites.

Transect lines were spaced 100 m apart and the points along transects were spaced 50 m apart. A circular area of 25 m radius was searched around each point. Point counts were undertaken quickly, lasting ~3–5 min, the duration dependant on how many birds needed to be counted. Quick point counts were used to minimise double-counting birds that were moving through the landscape or moving backwards and forwards between points (following Howe *et al*. 1995). Transects were walked in a castellated pattern, starting in either powderbark woodland or the brown mallet plantation and moving towards the low-lying area. At the completion of a transect the next was walked in the opposite direction. At these times careful attention was given to avoid double-counting birds. Birds were identified by sight and not by their calls, although any bird calling would attract attention and thus be seen and recorded. Birds simply flying over were not recorded. To be recorded a bird needed to be perched, foraging or in some way interacting within the bounds of the point being monitored.

Detectability was greatly enhanced by knowing many individual birds and their territories from other research on these sites and with the sites visited at least every 2–3 days, during the breeding seasons, for three years, before and during this study (Fulton 2005, 2006*a*, 2006*b*, 2006*c*, 2006*d*, 2006*e*, 2010, 2017; Fulton and Rose 2007). Nonetheless, cryptic birds such as bush stone-curlew (*Burhinus grallarius*) and tawny frogmouth (*Podargus strigoides*) in addition to nocturnal hollow roosting owls were not fully detected. This study did not use distance sampling techniques, because these methods were little known at the time.

Statistical analyses

Pearson's product-moment correlation coefficient was used to correlate bird abundance and species richness, with the distances from the 10 points along each transect to the lowest landscape contours. One-tailed tests were used because of the expectation that abundance and species richness would both increase as counts moved towards the lowest contours. One-way analysis of variance tests were used to compare the abundances and species richness of the four field sites, encompassing the three woodland types. Both total abundance and species richness, for the 23 bimonthly surveys, were used in this analysis. The Games–Howell procedure was chosen for *post hoc* tests because unequal variances were assumed with the three woodland types hypothesised to have different populations.

Results

Overall 2397 birds, of 52 species, were detected from 23 surveys at Dryandra (Table 1).

Abundance between woodland types

A one-way ANOVA detected a significant difference in abundances between *E. wandoo* woodland at both Marri Road and Gura Road against powderbark wandoo woodland and the brown mallet plantation respectively ($F_{3,88} = 18.73$, $P < 0.01$). *Post hoc* analyses, using the Games–Howell procedure (assuming unequal variances), did not find a significant difference between the two *E. wandoo* woodlands at Marri Road and Gura Road (mean difference = 4.13, s.e. = 5.71, $P = 0.89$); whereas significant differences were found between Marri Road *E. wandoo* and Marri Road powderbark wandoo (mean difference = 26.87, s.e. = 3.65, $P < 0.01$) and between Gura Road *E. wandoo* and Gura Road brown mallet plantation (mean difference = 17.69, s.e. = 5.38, $P < 0.02$). Additionally, a significant difference was found between the brown mallet plantation (at Gura Road) and powderbark wandoo woodland (at Marri Road) (mean difference = 13.30, s.e. = 3.11, $P < 0.01$).

Species richness between woodland types

A one-way ANOVA detected a significant difference in species richness between *E. wandoo* woodland, brown mallet plantation and powderbark wandoo woodland bird populations ($F_{3,88} = 17.815$, $P < 0.01$). *Post hoc* analyses, using the Games–Howell procedure (assuming unequal variances), did not find a significant difference between the two *E. wandoo* woodlands at Marri Road and Gura Road (mean difference = 2.04, s.e. = 1.44, $P = 0.50$); whereas significant differences were found between Marri Road *E. wandoo* and Marri Road powderbark wandoo (mean difference = 5.26, s.e. = 0.92, $P < 0.001$), and between Gura Road *E. wandoo* and Gura Road brown mallet plantation (mean difference = 5.69, s.e. = 1.12, $P < 0.01$). Contrasting with the significant difference reported for abundance, a significant difference was not found for species richness, between the brown mallet plantation and powderbark wandoo woodland (mean difference = 1.70, s.e. = 0.65, $P = 0.08$).

Association of bird numbers with the lowest contours

Bird numbers increased with proximity to the lowest contours in the landscape (Table 2). Using one-tailed tests, abundance and species richness were very strongly correlated: at Marri Road, through powderbark wandoo and *E. wandoo* woodland: abundance ($r = 0.947$, $P < 0.01$, $n = 10$) and species richness ($r = 0.751$, $P < 0.01$, $n = 10$); and at Gura Road, through the brown mallet plantation and *E. wandoo* woodland they were strongly correlated: abundance ($r = 0.597$, $P < 0.05$, $n = 10$) and species richness ($r = 0.688$, $P < 0.05$, $n = 10$).

Discussion

E. wandoo woodland has the greatest abundance and diversity of avifauna

The null hypothesis that all three woodland types carried the same abundance and diversity of birds is rejected, with *E. wandoo* woodlands having a significantly greater abundance and diversity than the other two woodland types (powderbark wandoo and the brown mallet plantation). This result is more compelling given it was recorded in spatially juxtaposed habitats as opposed to isolated remnants. A statistically significant gradient of avian abundance was also detected related to a mesic and productivity gradient. The notion of greater productivity is supported by invertebrate studies, which have reported greater invertebrate abundance and species richness in *E. wandoo* woodlands (Majer 1985; Majer *et al*. 2003). More precisely, these studies reported that *E. wandoo* woodland had more invertebrates than powderbark wandoo woodland (Majer *et al*. 2003) and that ground and litter invertebrate counts were higher at sites with greater moisture, with soil moisture greatest in the low-lying areas (Majer 1985). Contrasting with the differences detected between woodland types, the two spatially disjunct *E. wandoo* woodland habitats did not exhibit significant differences for either abundance or diversity in their avian populations. The lack of difference between the two *E. wandoo* woodlands supports the greater carrying capacity of these woodlands compared with the other two woodlands investigated.

The mesic gradient evident along the transects

The trends of increasing abundance and diversity along transects were strongly correlated with proximity to the lowest contour, i.e. the numbers of birds and bird species increased as the lowest contours were approached, regardless of woodland type. A mesic, and thus productivity, gradient is known from casual observations and invertebrate studies at the site. Its existence is further supported by the hydrogeological characteristics of the landscape (Salama and Bartle 1995). The region is geologically among the oldest on Earth with low

Table 1. Species abundance and incidence by site and woodland type

E. wan., *Eucalyptus wandoo* woodland; pwdbk, powderbark wandoo woodland; mallet, brown mallet plantation

Species	Marri Road		Gura Road		Total
	E. wan.	pwdbk	*E. wan.*	mallet	
Australian shelduck (*Tadorna tadornoides*)			2		2
Common bronzewing (*Phaps chalcoptera*)	10		5	4	19
Fan-tailed cuckoo (*Cacomantis flabelliformis*)	6		2	1	9
Painted button-quail (*Turnix varius*)	23	6	6	1	36
Square-tailed kite (*Lophoictinia isura*)		2	2		4
Wedge-tailed eagle (*Aquila audax*)	1		2		3
Brown goshawk (*Accipiter fasciatus*)			1		1
Southern boobook (*Ninox boobook*)	1		7		8
Rainbow bee-eater (*Merops ornatus*)	8		9	7	24
Sacred kingfisher (*Todiramphus sanctus*)	5		1		6
Laughing kookaburra (*Dacelo novaeguineae*)		4	1	10	15
Regent parrot (*Polytelis anthopeplus*)	2				2
Red-capped parrot (*Purpureicephalus spurius*)	15		5		20
Western rosella (*Platycercus icterotis*)	18		17	6	41
Australian ringneck (*Barnardius zonarius*)	111	29	81	31	252
Elegant parrot (*Neophema elegans*)	16		2		18
Purple-crowned lorikeet (*Glossopsitta porphyrocephala*)			4	7	11
Rufous treecreeper (*Climacteris rufus*)	74	32	48	18	172
Blue-breasted fairy-wren (*Malurus pulcherrimus*)	36	5	31	9	81
Brown honeyeater (*Lichmera indistincta*)		1			1
White-eared honeyeater (*Nesoptilotis leucotis*)			1		1
Brown-headed honeyeater (*Melithreptus brevirostris*)		2	1		3
White-naped honeyeater (*Melithreptus lunatus*)		2	1	3	6
Tawny-crowned honeyeater (*Glyciphila melanops*)	3		1		4
Red wattlebird (*Anthochaera carunculata*)	2		34	80	116
Singing honeyeater (*Gavicalis virescens*)		1			1
Yellow-plumed honeyeater (*Ptilotula ornata*)	213	73	216	185	687
Spotted pardalote (*Pardalotus punctatus*)		1			1
Striated pardalote (*Pardalotus striatus*)	14	24	23	6	67
Western gerygone (*Gerygone fusca*)		7		1	8
Weebill (*Smicrornis brevirostris*)		3			3
White-browed scrubwren (*Sericornis frontalis*)	3	1	5	1	10
Yellow-rumped thornbill (*Acanthiza chrysorrhoa*)			5		5
Inland thornbill (*Acanthiza apicalis*)		2	1		3
Chestnut-rumped thornbill (*Acanthiza uropygialis*)			2		2
Western thornbill (*Acanthiza inornata*)		2			2
White-browed babbler (*Pomatostomus superciliosus*)	19		84	9	112
Black-faced cuckoo-shrike (*Coracina novaehollandiae*)	11	1	20	6	38
Rufous whistler (*Pachycephala rufiventris*)	5		23	7	35
Golden whistler (*Pachycephala pectoralis*)		12	3		15
Grey shrike-thrush (*Colluricincla harmonica*)	37	10	32	5	84
Crested shrike-tit (*Falcunculus frontatus*)	4	1	1		6
Grey currawong (*Strepera versicolor*)		1	1		2
Australian magpie (*Gymnorhina tibicen*)			13	1	14
Dusky woodswallow (*Artamus cyanopterus*)	76		97	56	229
Willie wagtail (*Rhipidura leucophrys*)	26	1	40	3	70
Grey fantail (*Rhipidura fuliginosa*)		2	1		3
Australian raven (*Corvus coronoides*)	4	2	11	7	24
Scarlet robin (*Petroica multicolor*)		1			1
Western yellow robin (*Eopsaltria griseogularis*)	17	15	8	5	45
Fairy martin (*Petrochelidon ariel*)		1			1
Tree martin (*Petrochelidon nigricans*)	33	2	27	12	74
Total	793	246	877	481	2397

hydraulic gradients and an elevated watertable associated with the extensive removal of deep-rooted perennial trees (Hobbs 1993; Hatton *et al*. 2003). At the lowest contours on valley floors, precipitation supports areas of more mesic vegetation, that are able to switch from utilising rainfall in the wet season to groundwater during the dry season (Hatton *et al*. 2003).

Table 2. Transects and point counts

Bird abundance and species richness summaries are given for the 23 surveys conducted over 12 months for the two sites, Marri Road and Gura Road. Point distances are in metres from 450 m to the lowest landscape contour at each site marked with the zero (0). Point count positions are given by these measurements

Distance	Woodland	Marri Road		Woodland	Gura Road	
		Abundance	Species richness		Abundance	Species richness
450	Powderbark	35	12	Brown mallet	113	16
400	(*E. accedens*)	39	15	(*E. astringens*)	79	13
350		34	15		74	10
300		67	10		95	15
250		71	10		120	15
	Means	49	12	Means	96	14
200	*E. wandoo*	113	14	*E. wandoo*	255	29
150		162	20		124	16
100		171	23		134	20
50		141	19		134	22
0		206	23		230	27
	Means	159	20	Means	175	23

Thus, the presence of a mesic and productivity gradient underlies the vegetation associations and the avifaunal gradients identified in this study.

Mallet versus powderbark wandoo

Surprisingly, the plantation of brown mallet had a greater abundance of birds than the powderbark wandoo woodland, although their diversities were similar. Several *ad hoc* reasons may explain this unexpected similarity: soil quality, an overall greater avian diversity at the Gura Road site, brown mallet being a native tree and its simultaneous flowering during the study. Despite being in plantations, brown mallet is native to Dryandra and, as such, it presents a natural food source to the woodland community (Paton 1988; Fulton 2013) – 8316 ha, or 30% of Dryandra, has been planted out in brown mallet (Friend *et al*. 1995; Fulton 2013). During the study the brown mallet plantation at Gura Road flowered profusely and attracted many red wattlebirds (*Anthochaera carunculata*) and yellow-plumed honeyeaters (*Ptilotula ornata*), which increased the abundance of birds sharply without adding significantly to the species richness. The brown mallet plantation was planted on the more productive Biberkine soil at the Gura Road site whereas brown mallet would typically be found further upslope on poorer soils, at Dryandra. Despite the various explanations it is noteworthy that this planation attracted as many birds as it did.

Conclusion

The heterogeneous woodlands at Dryandra provided an opportunity to test faunal responses not available in smaller more homogeneous remnants. The woodland types were associated with soils and mesic gradients and did not have equal carrying capacities with regard to the avifauna. *E. wandoo* woodlands around the lowest landscape contours carried the greatest abundance and diversity of birds and bird species, highlighting their importance for woodland birds. However, other woodland types were used by birds and we suggest that conservation and management consider not just retaining heterogeneity in the landscape, but also to put the vegetation associations on the appropriate soils.

Conflicts of interest

The authors declare no conflicts of interest.

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