Habitats of the Striated Grasswren *Amytornis striatus rowleyi* at Opalton, central western Queensland

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Summary. Habitat of the Striated Grasswren *Amytornis striatus rowleyi* (Rusty Grasswren *A. rowleyi*) was examined at 51 sites with spinifex *Triodia* spp. at Opalton in central western Queensland during 14 visits between May 2009 and October 2012. At both small (radius 30 m) and large (radius 100 m) spatial scales, Striated Grasswrens occupied mostly Normanton Box *Eucalyptus normantonensis* low open woodland on spinifex-covered flat or gently sloped terrain with sandy soil covered by brown or reddish-brown lateritic gravel. This habitat comprised 55–57% of all habitats used at both sampling scales. The Grasswrens occurred less frequently in other spinifex-covered low open woodland or low open forest sites dominated by Mountain Yapunyah *E. thozetiana,* Lancewood *Acacia shirleyi,* Mulga *A. aneura* or Gidgee *A. cambagei*. A sparse shrub layer of Witchetty Bush *A. kempeana* or cassia *Senna* spp. was present in ~50% of sites sampled at the larger scale. Six sites on low caprock mesas were characterised by a relatively high density of Witchetty Bush shrubs (maximum cover 15%) and a relatively low cover of spinifex (14.8%) under a sparse tree layer of Mountain Yapunyah or Lancewood. The overall average height of spinifex hummocks (excluding seeding stalks) was 37.5 cm, and the average cover of spinifex was 26.3%.

Introduction

The Striated Grasswren *Amytornis striatus* is a polytypic species comprising three subspecies: *A. s. whitei* in the Pilbara; *A. s. striatus* in the inland deserts, Murray–Mallee and central New South Wales; and *A. s. rowleyi* in the Forsyth Range system in central western Queensland (Schodde & Mason 1999). It is a small (~18 g) secretive passerine that spends most of its time on the ground and moves quickly for cover in spinifex hummocks when disturbed (Pringle 1982; Schodde 1982).

In western Queensland, Striated Grasswrens were first collected in 1967, ~32 km south of Opalton (Macdonald 1970). Some 32 years later, in 1999, this isolated western Queensland population was recognised as a subspecies (Schodde & Mason 1999) and named *A. s. rowleyi* after Ian Rowley. More recently, studies of mitochondrial DNA in Australian grasswrens suggest that *A. s. rowleyi* may be a true species (Christidis *et al.* 2010). Indeed at the time that this paper went to press, Christidis *et al.* (2013) explicitly elevated it to species status, giving it the name of Rusty Grasswren *A. rowleyi*. Most contemporary observations have been near Opalton and Lark Quarry Conservation Park (records from BirdLife Australia: see Barrett *et al.* 2003) but no published field-based studies on *A. s. rowleyi* are known.

Broadly, Striated Grasswrens live in spinifex *Triodia* spp. (Schodde 1982; Parker 2003) whether on sandplains, dunes or stony hills (Schodde 1982). *A. s. striatus* has been referred to as the sandplain subspecies (Brouwer & Garnett 1990), whereas *A. s. whitei* occurs in rocky hills in the Pilbara (Johnstone *et al.* 2013) and *A. s. rowleyi* occurs in stony breakaways in western Queensland (Schodde 1982). More recently, Schodde & Mason (1999) ascribed the habitat of *A. s. rowleyi* as spinifex on a mixture of sandplains and rocky hills, whereas Higgins *et al.* (2001) grouped *A. s. rowleyi* with *A. s. striatus* and stated that both these subspecies occupied spinifex grasslands with or without an overstorey of shrubs and mallee eucalypts on sandplains, dunes and swales. At Opalton, however, spinifex grows in patches, usually with an overstorey of shrubs or eucalypts, but not on sandplains or sand-dunes. Rather, the terrain with spinifex at Opalton is mostly level or gently sloping stony ground. The aim of the present study was to determine the habitats occupied by Striated Grasswrens at Opalton by sampling at two spatial scales, nominally 'small' (radius 30 m) and 'large' (radius 100 m).

Study area

The circular study area was centred on Opalton (23°15′S, 142°46′E), ~100 km south of Winton (Figure 1; see also AUSLIG 1: 250 000 Topographic NATMAP: Maneroo) in the Channel Country (Bioregion 5 in the Queensland Department of Environment and Heritage Protection's regional ecosystem framework). An arbitrary radius of 6 km was chosen after considering the observer's personal safety and a need to effectively search the site. The study area is characterised by a series of low ranges (maximum altitude ~270 m above sea-level), from which many incised gullies and small drainage lines terminate in Sandy Creek (altitude ~240 m asl) or other creeks outside the study area. The landscape consisted of a mosaic of vegetation types (herein 'habitats') and ecotonal areas. At altitudes >260 m asl, low caprock mesas were dominated by scattered Mountain Yapunyah (5–7 m tall) and a sparse shrub layer of acacias and cassias (scientific names are in Table 2). Scarps of mesas supported Lancewood (7–9 m tall) on stony lithosols, sometimes dense without any understorey of shrubs or grasses. The upper and lower slopes of mesas (and occasionally low hills) were gentle, dominated by Normanton Box low open woodland (4–6 m tall) and Gidgee low open woodland (5–7 m tall), respectively. Sandy Creek was lined with River Red Gums (10–15 m tall) and Mulga (6–8 m tall) south of the road crossing (Figure 1) and Coolabah *Eucalyptus coolabah* (8–12 m tall) north of the crossing, where it formed braided channels up to 0.8 km wide. Small pockets of Mulga low open woodland, sometimes with isolated small patches of spinifex, were scattered generally through the study area except for the northern sector, where large stands of pure Mulga (without spinifex) occurred on red soils. Spinifex covered about half of the area, mostly on the upper slopes and mesa areas. It was generally absent from the lower slopes, where Gidgee or Mulga low open woodland or cassia shrubland persisted, and also from the braided channels of Sandy Creek. Vegetation types in the Channel Country bioregion are described in detail elsewhere (Department of Environment and Heritage Protection 2013).

Because the area has been extensively mined for opal since 1888 (McKenzie 2000), numerous eroded miners' tracks and abandoned diggings are present. There has been no grazing by domestic livestock and there have been no major bushfires for at least 20 years (P. Gregory & A. Hubbard pers. comm. 2012). Most annual rainfall (75%) is tropical in origin, falling between November and March. The nearest weather station accredited by the Australian Bureau of Meteorology is Weona Station (No. 37104), 22 km north, where the long-term average annual rainfall, recorded continuously for 48 years, is 360 mm. The first

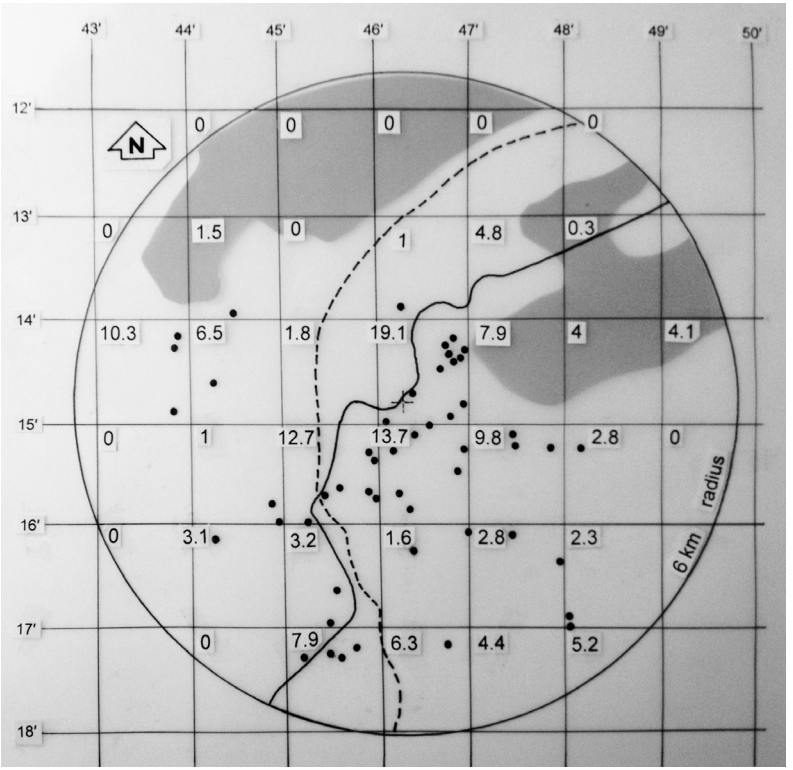

Figure 1. Circular study area (radius 6 km) and overlaid grid in minutes of latitude (south of 23°S) and longitude (east of 142°E). The value in the top left of a square is the cumulative searching effort (hours) in that 1-minute square. Closed circles (●) indicate sites where individuals or groups of Striated Grasswrens were seen (n = 51). The main road (unbroken line), Sandy Creek (dashed line) and large stands of pure Mulga without spinifex grass (shaded) are also shown.

two visits to Opalton were at the end of an 8-year drought (Queensland Government 2013) that was broken by heavy rains in summer 2009/2010. Above-average rainfall and good seasons prevailed until the completion of surveys in October 2012.

Methods

The study site was divided into a grid of 1-minute squares (Figure 1) and visited 14 times between May 2009 and October 2012. During these visits, ranging from 1 to 18 days (median duration 5.5 days), searches for Striated Grasswrens were undertaken for a total of 138.1 cumulative hours as follows: May 2009 (0.7 h), October 2009 (20.4 h), April 2010 (12.8 h), May 2010 (8.8 h), August 2010 (10.2 h), October 2010 (3.6 h), November 2010 (3.8 h), April 2011 (5.0 h), May 2011 (8.0 h), September 2011 (2.7 h), October 2011 (18.8 h), March 2012 (9.5 h), May 2012 (8.9 h) and September–October 2012 (24.9 h). Most 1-minute grid squares with spinifex were searched (Figure 1), but with variable effort depending on accessibility. Those searched included all spinifex-covered woodland and forest types (*sensu* Specht 1981) in the study area.

Sites where individual or groups of Striated Grasswrens were first seen were used as centre-points for sampling the habitat at a small scale (radius 30 m) and assessing its structural form in both small- and large-scale (radius 100 m) habitat plots. These particular scales were chosen after consideration of the Grasswren's approximate territory size and the tightly meshed mosaic of habitat types that existed at Opalton (*sensu* Jones 2001). Because the maximum territory size for *A. s. striatus* in the South Australian mallee was 5.2 ha (equivalent diameter 260 m: Karubian 2001), I attempted at first to find adjacent sites >260 m apart so as to sample habitat in different territories. After the fourth visit, however, I inadvertently began to see some Grasswrens at sites that were <260 m from the sites found previously. To increase the size of the overall pool of data, while recognising that the number of territories sampled may not increase, 11 sites <260 m apart ('b' and 'c' sites, Appendix 1; median separation 200 m) were analysed in addition to the 40 primary survey sites (i.e. the 'a' sites, Appendix 1) to provide a combined pool of 51 sites. The nearest-neighbour distances between the 40 'a' sites were 250–1650 m (median 570 m), suggesting that a minimum of 40 territories was sampled.

All searches were by a single observer, driving slowly or walking, without the use of call-playback. With adaptation of the methods of Black *et al.* (2006), Striated Grasswrens were detected by: (1) hearing contact calls, (2) hearing song, (3) hearing alarm calls, (4) flushing, (5) observing birds hopping or running along the ground and (6) observing birds perched low (0.5–2 m above ground) in trees or shrubs. Thirty-five individuals or groups (69%) were detected while the observer was walking, and the remaining 16 individuals or groups (31%) while driving. In all cases, presence was confirmed by sight as some of the vocalisations of the Striated Grasswren were similar to those of the Rufous-crowned Emu-wren *Stipiturus ruficeps*. Seven sites had to be revisited on subsequent days to confirm the presence of Grasswrens after initially hearing vocalisations.

Small-scale (radius 30 m) sampling of habitat features

From the centre of the plot, a tape measure and conspicuous markers were used to show the circumference of a circle of radius 30 m. The habitat features recorded inside the circle are given in Table 1. The average spinifex cover was calculated from a straight transect measurement from the centre. A surveyor's 100-link tape was laid over the hummocks, the coverage of which was individually measured and cumulatively added. Where spinifex cover was homogeneous, a single transect was used (19 sites). Otherwise, two or three transects were used (23 and 9 sites, respectively) and the site's overall weighted average cover calculated after visually estimating the relative proportions of each of the different areas. For example, if 60% of the area of the circle had 20% cover and the remaining 40% had 25% cover, the overall average cover of the site was 22%. The proportion of bare ground was also estimated for the overall average calculation. The height of spinifex assigned to each plot was determined by measurement of a typical hummock. Its height (excluding seed stalks) was measured with a graduated stick pushed to the ground through the hummock (accuracy ±2 cm). All trees and shrubs were identified and counted individually. The density of herbs and forbs was recorded as 'sparse', 'very sparse' or 'absent'.

Small-scale (radius 30 m) and large-scale (radius 100 m) sampling of habitat

Given that the study area comprised a mosaic of habitats, structural habitat assessments were made at both small and large spatial scales to provide data with greater overall robustness (*sensu* Orians & Wittenberger 1991; Chalfoun & Martin 2007). For large plots, the same centre-point was used as for small plots, and ~10 markers were erected to show points on the circumference of the 100-m-radius circle after stepping the radius from the centre. Habitat in both small and large plots was classified by structure according to Specht (1981), with tree, shrub and ground layers recorded independently. Where more than a

Table 1. Dominant habitat features of small (radius 30 m) circular habitat plots (n = 51) where Striated Grasswrens were seen at Opalton, central western Queensland, 2009–2012. Maximum dimensions of stones in gravel and larger rocks are given.

Feature	*No. sites present*	*% sites*
Flat terrain	29	57
Gentle slope	20	39
Sandy soil	51	100
Lateritic gravel (5–35 mm, median 15 mm)	49	96
Some larger rocks (150 mm maximum)	15	29
Colour of lateritic gravel		
Brown	23	45
Reddish-brown	14	27
Mottled brown	9	18
Other	5	10
Litter		
Absent or very sparse	12	24
Sparse	34	67
Medium density	5	10
Spinifex hummocks		
Small	17	33
Medium	33	65
Large	1	2
Hummocks >20 years post fire*	50	98
Site disturbed by miners' diggings	11	22
Distance from centre to nearest drainage line or gully		
<30 m	16	31
30–100 m	11	22
101–200 m	6	12
>200 m	18	35
Herbs or forbs		
Absent	34	67
Very sparse	8	16
Sparse	9	18
Termite mounds		
Absent	9	18
Present (1–39 mounds/site, median 8)	42	82
Altitude (asl)		
<260 m	45	88
>260 m (caprock mesa)	6	12

* One small site showed evidence of a small fire 5–7 years ago

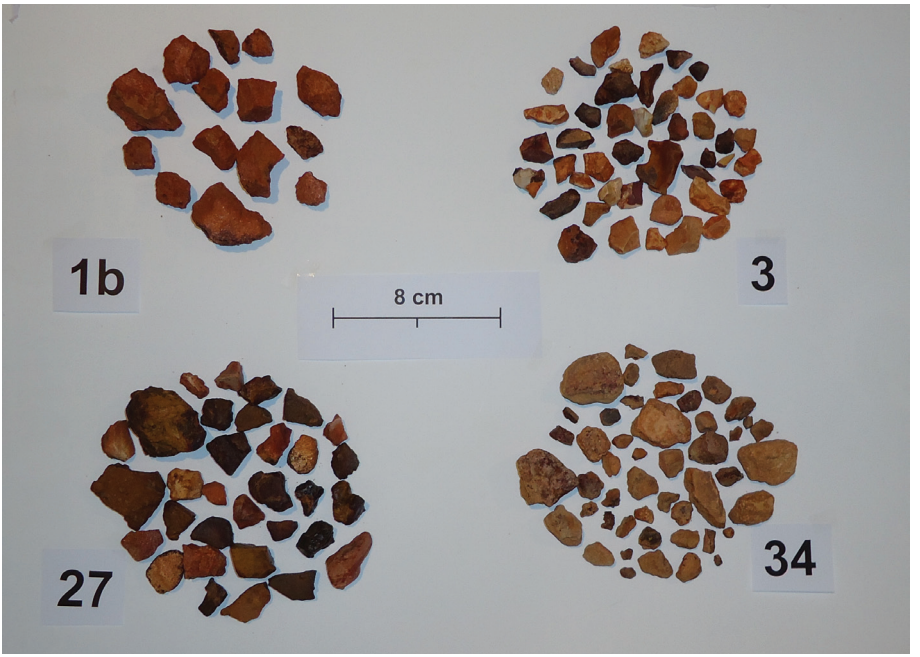

Figure 2. Samples of lateritic gravel from Striated Grasswren *A. s. rowleyi* sites 1b, 3, 27 and 34 at Opalton, Qld, showing variability in size and colour of gravel.

Figure 3. Typical habitat of the Striated Grasswren *A. s. rowleyi* at Opalton, Qld. Left: Site 13b—Normanton Box low open woodland with an average spinifex cover of 34%. Right: Site 22—mixed Normanton Box and Mulga low open woodland with a mixed open shrub layer of Witchetty Bush and cassia and an average spinifex cover of 13%. White flags (10 m apart) are located on the diameter of each circular sampling plot, 5 m each side of its centre. Photos: K.A. Wood

single habitat existed, the percentage of each type was assessed after walking through the circular area and recording the approximate boundaries of each type after careful inspection. Mixed habitats comprised two or more tree species, evenly distributed in the circular areas. Multiple habitats comprised two or more tree species clearly separated from each other. To quantify the relative contribution of each habitat type in mixed habitats, percentage values were assigned to those habitats as if they were multiple. For example, in mixed Normanton Box, Yapunyah and Mulga low open woodland, 33.3% contribution was arbitrarily assigned to each structural type.

Google Earth maps were overlaid with 1-minute grids to provide a reference for geographical and ecological information while in the field. A Garmin GPS60 Navigator (USA) was used to record co-ordinates, altitudes and some large distances.

Results

Small-scale (radius 30 m) sampling of habitat features

At a small spatial scale, Striated Grasswrens at Opalton occupied relatively flat spinifex sites with sandy soil and brown or reddish-brown lateritic gravel (Table 1, Figures 2–3). Some sites (29%) had larger rocks (up to 150 mm in maximum dimension) in addition to gravel (Table 1), but no sites where Grasswrens were recorded contained boulders or rocky outcrops. The dominant tree species was multi-stemmed Normanton Box (4–6 m tall), which occurred in 84% of sites (Table 2). Of 34 sites that included Normanton Box low open woodland (partly or entirely), Witchetty Bush (1–2.5 m tall) and/or cassia formed a shrub layer in 20 sites (~59%: Appendix 1). There was no shrub layer in the other 14 Normanton Box low open woodland sites. Witchetty Bush was the most common shrub overall (~70% overall: Table 2). It was most abundant on six mesa sites (sites 19, 37a, 37b, 37c, 38 and 39: Appendix 1) in association with Mountain Yapunyah and Lancewood low open woodland. These six mesa sites in combination accounted for 307 (41%) of the 750 Witchetty Bushes counted (Table 2). The maximum cover of Witchetty Bush (on mesa sites 37a, 37b and 37c) was 15%.

Gullies or drainage lines intersected 16 of the small (radius 30 m) habitat plots (Table 1), and were usually lined with Normanton Box (effectively multi-stemmed mallee trees <10 m high). Litter, mostly of dead Normanton Box (Front cover) and Witchetty Bush branches, formed a sparse layer at 34 (67%) sites (Table 1). Herbs and forbs were absent from 34 sites (67%), and formed a sparse or very sparse ephemeral layer at the remaining 17 sites (Table 1). Copper Burr *Sclerolaena minuta* was the most common forb. Termite mounds (Figure 4) occurred at 82% of sites (median 8 mounds/site where they occurred: Table 1) and were particularly notable on mesas. One mesa site (37c) had 39 termite mounds.

The average height of spinifex hummocks (excluding seed stalks) was 37.5 cm, with an average percentage cover of 26.3% (Table 3). At the six mesa sites, the average height of spinifex (37.5 cm) was similar to that at sites at lower altitude (37.4 cm) but the average percentage coverage at mesa sites (14.8%) was almost half the coverage elsewhere (27.8%: Table 3). Two species of spinifex were identified: Grey Spinifex *Triodia longiceps* (which was common), and Pin Cushion Spinifex *T. molesta* (which was uncommon).

Table 2. Mature trees and shrubs counted in small (radius 30 m) habitat sample plots (n = 51) where Striated Grasswrens were seen at Opalton, Qld, 2009–2013. Plants are listed in descending order of frequency within each stratum of vegetation.

Plant species	*Cumulative total*	*No. (and %) sites present*	*Mean (and range) per plot*
Trees (mostly >4 m tall)			
Normanton Box *Eucalyptus normantonensis*	582	43 (84)	13.5 (1–60)
Lancewood *Acacia shirleyi*	172	16 (31)	10.8 (1–30)
Mulga *Acacia aneura*	104	15 (29)	6.9 (1–25)
Mountain Yapunyah *Eucalyptus thozetiana*	48	14 (27)	3.4 (1–20)
Gidgee *Acacia cambagei*	31	6 (12)	5.2 (1–15)
Leopardwood *Flindersia maculosa*	21	5 (10)	4.2 (1–9)
Bastard Mulga *Acacia stowardii*	9	3 (6)	3.0 (1–5)
Bendee *Acacia catenulata*	3	2 (4)	1.5 (1–2)
Sandalwood *Santalum lanceolatum*	2	2 (4)	1
Beefwood *Grevillea striata*	1	1 (2)	1
River Red Gum *Eucalyptus camaldulensis*	1	1 (2)	1
Total	**974**		
Shrubs (mostly <1 m except Witchetty Bush, refer text)			
Witchetty Bush *Acacia kempeana*	750	29 (57)	25.9 (1–78)
Crinkled Cassia *Senna artemisioides helmsii*	72	6 (12)	12.0 (2–29)
Sticky Cassia *Senna glutinosa*	69	7 (14)	9.9 (3–21)
Silver Cassia *S. a. artemisioides*	43	4 (8)	10.8 (2–23)

Table 2 Shrubs (mostly <1 m except Witchetty Bush) continued

Plant species	*Cumulative total*	*No. (and %) sites present*	*Mean (and range) per plot*
Oval-leaf Cassia *S. a. oligophylla*	42	6 (12)	7.0 (1–20)
Silver-leaf Cassia *Senna phyllodinea*	33	6 (12)	5.5 (1–14)
Hopbush *Dodonaea lanceolata*	21	3 (6)	7.0 (1–11)
Cowle's Wattle *Acacia elachantha*	18	3 (6)	6.0 (1–10)
Dwarf Needlewood *Hakea collina*	7	4 (8)	1.8 (1–4)
Conkerberry *Carissa lanceolata*	6	2 (4)	3.0 (1–5)
Sandplain Wattle *Acacia bivenosa*	4	4 (8)	1
Emu Bush sp. *Eremophila alatisepala*	4	1 (2)	4
Honeysuckle *Capparis lasiantha*	3	1 (2)	3
Weeping Emu Bush *Eremophila longifolia*	2	2 (4)	1
Silky Wattle *Acacia acradenia*	2	2 (4)	1
Ruby Saltbush *Enchylaena tomentosa*	1	1 (2)	1
Bowman's Emu Bush *Eremophila bowmanii*	1	1 (2)	1
Total	**1078**		

Single habitats occurred at 37 small-scale sites and mixed habitats at the remaining 14 sites (Table 4, Appendix 1). Normanton Box dominated the tree stratum in 22 of the 37 single habitats (~60%). Other notable single habitats were Mountain Yapunyah low open woodland over Witchetty Bush (three sites) and Lancewood low open forest over Witchetty Bush (four sites: Appendix 1). Witchetty Bush (1–2.5 m tall) and/or cassia formed a shrub layer in 35 (~70%) small plots (Appendix 1). When the contribution of the various habitats was calculated, Normanton Box low open woodland was the most abundant habitat, representing 55.2% of all habitats in small plots (Table 5).

Table 3. Height (cm) and percentage vegetation cover (PVC) of spinifex *Triodia* spp. at all 51 sites (6 mesa sites and 45 non-mesa sites) where Striated Grasswrens were recorded at Opalton, Qld. Mean is given ± standard deviation.

	Height			*PVC*		
	Non-mesa	*Mesa*	*All sites*	*Non-mesa*	*Mesa*	*All sites*
Mean	37.4 ± 9.6	37.5 ± 5.2	37.5 ± 9.2	27.8 ± 9.1	14.8 ± 8.8	26.3 ± 9.9
Maximum	80	45	80	49	28	49
Minimum	20	30	20	8	2	2

Table 4. Number of single, mixed and multiple habitats at 51 sites where Striated Grasswrens were recorded at Opalton, Qld. Data are presented for small (radius 30 m) and large (radius 100 m) sample plots.

Habitat plot size	*Habitat category*			
	Single	*Mixed*	*Multiple, with two habitats*	*Multiple, with three habitats*
Small	37	14	Nil	Nil
Large	12	3	31	5

Table 5. Percentage contributions of different habitats at 51 sites where Striated Grasswrens were recorded at Opalton, Qld: data from small (radius 30 m) and large (radius 100 m) sample plots, listed in descending order of percentage in small plots.

Habitat	*Small*	*Large*
Normanton Box low open woodland	55.2	56.7
Lancewood low open forest	13.4	10.1
Mountain Yapunyah low open woodland	11.8	14.9
Mulga low open woodland	10.5	9.4
No tree layer (with shrubs)	3.9	1.3
Leopardwood low open woodland	2.6	0
Gidgee low open woodland	2.6	5.7
No tree or shrub layer	0	1.7
River Red Gum forest	0	0.2
Total	**100**	**100**

Large-scale (radius 100 m) sampling of habitat

In comparison with habitats determined at small plots, where there were 37 single habitats, only 12 large-scale plots had single habitats (Table 4, Appendix 1). Six of these were Normanton Box low open woodland without a shrub layer, three mesa sites had Mountain Yapunyah trees over Witchetty Bush (sites 19, 37a and 37c), two had Normanton Box over cassia, and one was Mountain Yapunyah low open

Figure 4. Female Striated Grasswren *A. s. rowleyi* standing on a compacted termite mound at Opalton, Qld, August 2009. Photo: Dean Portelli

woodland without a shrub layer. Thirty-six of the large plots had multiple habitats, whereas no small plots had multiple habitats (Table 4). Five large plots (4, 9, 21, 38 and 40) contained three different habitat types (Appendix 1).

Notwithstanding the diverse range of habitats recorded in the large plots, the mallee eucalypt Normanton Box was present in all but six sites (10, 19, 27b, 31, 37a and 37c). Three of these (sites 19, 37a and 37c) were on mesas where Mountain Yapunyah was the dominant tree species. When the contribution of the various habitats was calculated for the large plots, Normanton Box low open woodland was the most common habitat, representing 56.7% of all habitats (Table 5). Importantly, however, at both spatial scales of sampling, Striated Grasswrens were also present in other low open woodland or low open forest sites dominated by Mountain Yapunyah, Lancewood, Mulga and Gidgee. Cumulatively, these other four habitat types comprised 40.1% of all habitats present in large plots and 38.3% in small plots (Table 5). Witchetty Bush (1–2.5 m) and/or cassia formed a shrub layer in 25 large plots (~50%, Appendix 1)

Discussion

Although Normanton Box low open woodland over spinifex was the most common habitat occupied by Striated Grasswrens at Opalton (55.2–56.7% of all habitat types), four other types of low open woodland or forest over spinifex were also used, cumulatively comprising 38.3–40.1% of all habitat types (Table 5). These other low open woodland or low open forest habitats, which were dominated by Mountain Yapunyah, Lancewood, Mulga or Gidgee (Leopardwood was very low in abundance), were mostly in ecotonal areas adjacent to Normanton Box low open woodland. In the large plots, only 12 of the 51 sites (24%) were single habitats; the remaining 39 sites were either mixed or multiple habitats, showing that Striated Grasswrens at Opalton also occupied ecotones between Normanton Box low open woodland and other low open woodlands.

This study shows that the habitat used by the Striated Grasswren *A. s. rowleyi* at Opalton has both ecological similarities and differences between that of its sister subspecies *A. s. striatus* and *A. s. whitei* elsewhere in Australia (see Higgins *et al.*

2001). All three subspecies usually occur in spinifex with an overstorey of mallee eucalypts, but *A. s. striatus* favours sandplains, *A. s. whitei* favours stony hills, and *A. s. rowleyi* favoured gravel-covered flats and gentle slopes at Opalton. Indeed, an obvious dissimilarity in habitats of these subspecies is the substrate, which was brown or reddish-brown lateritic gravel on sandy soil at 49 of the 51 sites analysed. Ecological differences between the habitat favoured by *A. s. striatus* and *A. s. rowleyi*, in combination with the findings of Christidis *et al.* (2010) of a genetic mitochondrial DNA distance of >4% between these subspecies, further support taxonomic revision of *A. s. rowleyi* (see Christidis *et al.* 2013).

Lateritic gravel has not been mentioned previously as a specific component in the habitats of grasswrens (see Higgins *et al.* 2001). Presumably, it was either absent or considered not important. Yet small stones and pebbles were certainly present in some sites where Carpentarian Grasswrens *A. dorotheae* were found recently north of Mt Isa, Qld (photograph in Harrington *et al.* 2009). Carpentarian Grasswrens occupy spinifex-covered low open eucalypt woodland with a sparse layer of *Acacia* shrubs (Harris 1992; Harris & Stewart 2009), a habitat that resembles that of *A. s. rowleyi* at Opalton. Similarity of habitats and plumages of *A. s. rowleyi* at Opalton and Carpentarian Grasswrens near Mt Isa provide further evidence of the relatively close phylogenetic affinities of these two taxa in comparison with the grasswrens in other clades (see Christidis *et al.* 2010, 2013).

Unlike the craggy or dissected rocky sites preferred by some other grasswren species (e.g. Black *A. housei,* White-throated *A. woodwardi* and Dusky *A. purnelli* Grasswrens: Higgins *et al.* 2001), most sites used by Striated Grasswrens at Opalton were either flat (57%) or on a gentle slope (39%) (Table 1). Despite such flatness, 16 small plots (31%) were crossed by shallow drainage lines or gullies, and the centres of another 11 sites (22%) were <100 m away from drainage depressions (Table 1). Such drainage lines, often lined with Normanton Box and covered by spinifex, are a feature of the landscape at Opalton. Striated Grasswrens may exhibit a preference for these habitats, especially in drought, because spinifex growing there has greater access to soil moisture than elsewhere, providing a more reliable source of food and cover from predators. In 1972, three pairs of Striated Grasswrens were collected 7 km west of Fermoy (~25 km from Opalton) in spinifex associated with Normanton Box growing along small watercourses among low sandstone ridges (Ford & Parker 1974). The habitat of 10 sites in the present study was similar to the short habitat description at Fermoy.

Seemingly contrary to reports that Striated Grasswrens prefer 'tall' or 'dense spinifex' (Parker 1982; Schodde 1982; Blakers *et al.* 1984; Morcombe 2000), Striated Grasswrens at Opalton inhabited spinifex sites with an average grass height of 37.5 cm and an average vegetation cover of 26.3%. Although the range of both measurements is large (20–80 cm for height, 2–49% for cover), Short-tailed Grasswrens *A. merrotsyi* (previously subspecies *A. s. merrotsyi*) in the Flinders Ranges, South Australia, appear to occupy areas of spinifex with a similar height and density. Carpenter (1998) reported that spinifex in areas used by Short-tailed Grasswrens in the Flinders Ranges was usually <50 cm high, with only 64% of the ground covered with spinifex (30% bare ground or rocks, 6% shrubs). Finding Striated Grasswrens at Opalton in mesa areas where the spinifex cover was very

sparse (average 14.8%, n = 6: Table 3) was unexpected. Striated Grasswrens at Opalton often foraged on lateritic gravel between spinifex hummocks. The proportion of food taken there, compared with that taken inside the hummocks where the birds are unseen, is unknown, but undisturbed grasswrens might consume an appreciable quantity of food taken from lateritic gravel (see also Wood 2014). Low coverage of spinifex provides greater foraging opportunities on lateritic gravel than inside the hummocks but also imposes a greater risk of predation.

Although this study provides information about the foraging habitat of *A. s. rowleyi* at Opalton, the results should be treated with caution. Firstly, only the areas with spinifex were systematically searched and, although it has been widely accepted that Striated Grasswrens live in spinifex habitats, their occurrence in *Banksia* heath (Eckert 1982) and Broombush *Melaleuca uncinata* (Carpenter & Matthew 1986) in South Australia has been reported previously. Habitats without spinifex were not systematically searched in the present study, although many hours were spent walking and driving through such areas during the 14 visits to Opalton, and Striated Grasswrens were not encountered in areas devoid of spinifex. Secondly, occurrence of *A. s. rowleyi* on mesas may be under-represented. Mesas at Opalton were low and often poorly delineated, yet extensive in area, with isolated pockets of various spinifex-covered habitats. Mesa and non-mesa areas may not have been searched for durations of time that reflect their respective sizes. Thirdly, the habitat was investigated only in spring and autumn (except for one visit in August 2010), i.e. not in hot summer or cold winter months. Further studies at other sites throughout the geographic range of this taxon are needed to determine the preferred habitat elsewhere.

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Appendix 1. Habitats (tree stratum/shrub layer/ground-cover) in small (radius 30 m) and large (radius 100 m) habitat sample plots at 51 sites where Striated Grasswren were recorded at Opalton, central western Queensland. Tree stratum (includes emergents): G = Gidgee low open woodland, L = Lancewood low open forest, Lp = Leopardwood low open woodland, M = Mulga low open woodland, N = Normanton Box low open woodland, R = River Red Gum forest, Y = Mountain Yapunyah low open woodland. Shrub layer: A = Acacia open shrubland (other than Witchetty Bush), C = Cassia low open shrubland, H = Hopbush low open shrubland, W = Witchetty Bush shrubland. Ground-cover: S = Spinifex hummock grassland (sometimes with a very sparse cover of herbs or forbs). – = layer absent; / separates tree, shrub and ground layers; + signifies mixed habitats.

Site no.	*Small habitat plot*	*Large habitat plot*
1a	N/–/S	N/–/S
1b	–/W/– + –/C/S	N/W+C/S
2	N/–/S	N/–/S
3	N/–S	N/–/S (80%), –/–/– (20%)
4	N/–/S	N/–/S (80%), M/–/S (10%), R/–/– (10%)
5	N/C/S	N/C/S
6	N+Y/W/S	N+Y+L/W/S
7	N/A/S	N/A/S (60%), G/–/–(40%)
8a	N+M/C/S	N+M/W+C/S
8b	N+M+L/W/S	N+M/W/S (75%), L/–/S (25%)
9	M+Lp/W/S	G/–/S (50%), N/–/S (25%), –/–/– (25%)
10	L/W/S	L+M/W/S (75%), Y+L/W/S (25%)
11	N/–/S	N/–/S (70%), L/–/S (30%)
12	N/W/S	N/–/S (80%), L/–/S (20%)
13a	N/–/S	N/–/S (85%), G/–/– (15%)
13b	N/–/S	N/–/S
14	M/W/S	M/W/S (80%), N+M/W/S (20%)
15a	N/W/S	N+M/W/S (75%), L/–/S (25%)
15b	N+L/W+C/S	N+M/W/S (75%), L/–/S (25%)
16	N/W+A/S	N/–/S (75%), L/–/S (25%)

Appendix 1 continued

Site no.	*Small habitat plot*	*Large habitat plot*
17a	N/W/S	N/W/S (50%), L/–/S (50%)
17b	N/W/S	N/W/S (80%), L/–/S (20%)
18	N/C/S	N/–/S
19	–/W/S	Y/W/S
20a	N/W/S	N/–/S (85%), M+G/–/– (15%)
20b	N+L/C+H/S	N/–/S (80%), L/–/– (20%)
21	N+L/W/S	N+L/W/S (50%), Y/–/S (25%), L/–/S (25%)
22	N+M/W+C/S	N/W/S (80%), N+M/W/S (20%)
23	L/W/S	–/W/S (70%), N+L/–/S (30%)
24	N/C/S	N/–/S (60%), G/C/S (40%)
25	Y/C/S	N/–/S (50%), Y/–/S (50%)
26	N/C/S	N/–/S (60%), –/–/– (40%)
27a	N+Lp/–/S	N/–/S
27b	M/C/S	M/C/S (50%), G/–/S (50%)
28	N+Y/–/S	N/–/S (50%), Y/–/S (50%)
29	N/–/S	N/–/S
30	M/W/S	M/–/S (75%), N/W/S (25%)
31	Y/–/S	Y/–/S
32	N/–/S	N/–/S (90%), G/–/–(10%)
33	N/–/S	N/–/S (90%), L/–/– (10%)
34	L/C/S	N/–/S (80%), L/–/S (20%)
35a	G/C/S	N/C/S
35b	N+M/C/S	N/–/S (75%), M+G/C/S (25%)
36a	N/–/S	N/–/S (70%), G/–/S (30%)
36b	N+Lp+G/–/S	N/–/S (50%), G/–/S (50%)
37a	Y/W/S	Y/W/S
37b	L/W/S	Y+L/W/S (50%), N+M/W/S (50%)
37c	Y/W/S	Y/W/S
38	Y/W/S	Y/W/S (80%), L/W/S (10%), N/W/S (10%)
39	L/W/S	Y/W/S (75%), L/W/S (25%)
40	N/W/S	N/–/S (70%), L/–/S (20%), Y/–/S (10%)