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A survey of outlying populations of the Grey Grasswren *Amytornis barbatus*

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Two subspecies of the Grey Grasswren occupy terminal swamps of separate inland rivers, *Amytornis barbatus barbatus* on the Bulloo River and *A. b. diamantina* in Goyder Lagoon on the Diamantina. There have been sporadic reports from three other discrete areas; the Eyre Creek, Diamantina River and Cooper Creek floodplains. In a survey of those outlying populations, Grey Grasswrens were sparsely and unevenly distributed, being found at eleven localities (including one within 20 kilometres of Goyder Lagoon) but undetected at 16 where they had been observed previously, in some cases over several years. All five populations appear to be isolated from one another by distances of between 50 and 150 kilometres over which suitable habitat appears to be absent. Grasswrens from Eyre Creek belong to the same subspecies as those in Goyder Lagoon where Eyre Creek terminates, suggesting that in relatively recent times those two populations at least have been in reproductive contact, but the subspecific status of the other two outlying populations remains unknown. Our findings indicate that the outlying populations are small and that one or more might be declining towards local extinction. On the other hand we infer that Grey Grasswrens may be more able to disperse during exceptional seasonal conditions than is widely assumed to apply to grasswren species. Factors that might explain why the outlying populations are small and/or declining are discussed.

INTRODUCTION

The Grey Grasswren *Amytornis barbatus* (Maluridae) occupies the floodplains of several inland river systems in Australia's arid zone. Preferred habitats include Lignum *Muehlenbeckia florulenta* shrublands of varying density, lining channels and waterholes and on swamp flats, as well as more open shrublands of Old-man Saltbush *Atriplex nummularia* ssp. *nummularia* and mixed shrub species, towards the floodplain periphery (Black *et al*. 2012). The species was first reported in 1921 on the Bulloo floodplain south of the Queensland/ New South Wales border (Chenery 1922; MacGillivray 1923; McAllan 2000), but identified as distinct and described only in 1967 (Favaloro and McEvey 1968). That population is presently known only from the terminal swamps of the Bulloo on both sides of the State border and although that population was considered to have declined substantially (Hardy 2002, 2010), this is disputed (I. McAllan pers. comm.). It is listed as vulnerable in Queensland under the *Nature Conservation Act 1992* and nationally under the *Environment Protection and Biodiversity Conservation Act 1999*, and as endangered under the *New South Wales Threatened Species Conservation Act 1995* and in the *Action Plan for Australian Birds 2010* (Garnett *et al.* 2011). A second population found in Goyder Lagoon, South Australia in 1975 (Cox 1976) and later described as a separate subspecies *A. b. diamantina* (Schodde and Christidis 1987), is listed as rare in the schedules of the *South Australian National Parks and Wildlife Act 1972* and its habitat is identified as a Conservation Priority in the *SA Arid Lands Draft Biodiversity Strategy (Department for Environment and Heritage 2008*). That population is now believed to be relatively secure and its status is listed as 'least concern' by Garnett *et al.* (2011), following a targeted survey of Goyder Lagoon and the Warburton Creek floodplain immediately downstream (Black *et al*. 2009b). Those two well documented populations occupy the core distributions of their respective subspecies and will be considered here as the central populations.

Further Grey Grasswren records in Queensland include those of Schodde (1982), who provided unconfirmed reports from Lake Cudappan, which lies between catchments of the Diamantina River and Cooper Creek, and from Farrars Creek which enters the Diamantina River floodplain from the east. Joseph (1982) found Grey Grasswrens between Lake Machattie and Lake Koolivoo on the Georgina River/Eyre Creek floodplain between Birdsville and Bedourie and Jaensch and McFarland (2002) added a record from that vicinity and others from floodplain and channels at the southern edge of the Diamantina between Birdsville and Betoota. At Embarka Swamp, South Australia on the main branch of Cooper Creek west of Innamincka, May (1982) saw Grey Grasswrens twice in 1982 and again about a year later (Ian May, pers. comm.), but they were not seen subsequently (Reid 2000), and it later was inferred that a small satellite population might have become established briefly but had declined to local extinction (Black *et al.* 2009b, 2012). Grey Grasswrens were later identified in the Cooper Creek channels of south-west Queensland to the east and south of Ballera Gas Centre (Carpenter 2002). Several reports have followed from the Cooper Crossing south-east of Ballera Gas Centre and from Noccundra Waterhole on the Wilson River farther east (Birdlife Australia per A Silcocks, BirdingAus website).

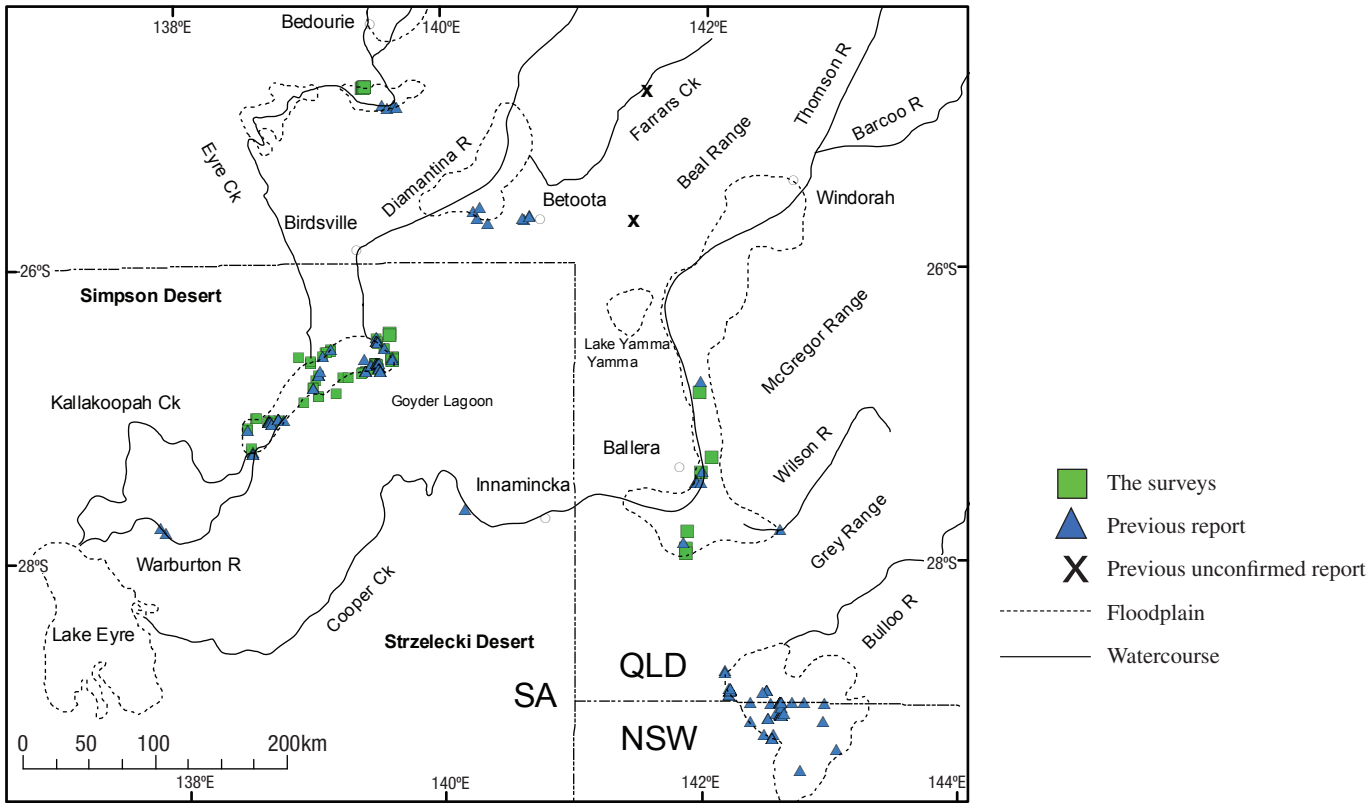

Figure 1. *Earlier records of the Grey Grasswren and those from the 2009 and present surveys; unconfirmed reports are indicated as X.*

The above records of Grey Grasswrens from within or between the floodplains of the Eyre Creek, Diamantina River and Cooper Creek systems, outside the known distribution of the central populations, will be referred to here as the outlying populations. We undertook to survey these outlying populations in 2012 and 2013 to gain an understanding of their size and potential connectivity with one another and with the central populations. We sought to determine whether the outlying populations are geographically separate from either the Bulloo (*A. b. barbatus*) or Goyder Lagoon (*A. b. diamantina*) populations and therefore possibly of distinct genetic and/or taxonomic identity. A further consideration was the size of outlying populations, which could inform an assessment of their conservation status. We also sought to document broad habitat characteristics and sources of disturbance among outlying populations along with micro-habitat structure at sites where Grey Grasswrens were present.

METHODS

We collated previous records of outlying populations of the Grey Grasswren, including specimens in the Queensland Museum and the National Wildlife Collection of CSIRO, Canberra, BirdLife Australia bird atlas data and published and unpublished records of the authors and others. The 18 localities of records are shown in Figure 1 and are summarised below:

Eyre Creek

1. 25 August, 13 October 1982, Cuttaburra Crossing on the Bedourie to Birdsville road 18 km south of Glengyle Homestead ~ 24º 55' S, 139º 39' E (Joseph 1982).
2. 13 October 1982, 9 km W of 1 above, south of Lake Koolivoo ~ 24º 56' S, 139º 33' E (Joseph 1982).
3. 24-25 October 1988 17 km south of Glengyle Homestead, ~ 24º 54.5' S, 139º 39' E (ANWC B41784-8, 41792)
4. 19 April 2001, Eyre Creek floodplain, north of Lake Koolivoo ~ 24º 53.6' S, 139º 35.7' E (Jaensch and McFarland 2002, RJ personal record).
5. 25 April 2009, south-east of Lake Koolivoo ~ 24º 56.3' S, 139º 36.0' E (G Dutson pers. comm. to RJ)

Diamantina River (all are from Jaensch and McFarland 2002)

1. 14 April 1984, Pelican Waterhole, Browns Creek, QM O22665, ~ 25º 41.5' S, 140º 36.5' E.
2. 20 April 1984, 'a channel' east of above, QM O22670, ~ 25º 41' S, 140º 40' E.
3. 20 April 1984, 'plain and channels' to the east of Thundapurty Waterhole, Diamantina Shire Survey ~ 25º 37.5' S, 140º 17.5' E.
4. 12 January 2001, 5 km south-east of Thundapurty Waterhole on the southern Diamantina floodplain, 25º 41' 36" S, 140º 16' 16" E.
5. 15 January 2001, periphery of Diamantina floodplain east of above, 25º 43' 42" S, 140º 20' 42" E.
6. 10 May 2002, near Thundapurty Waterhole, 25º 38' 51" S, 140º 14' 23" E.

Cooper Creek/Wilson River

1. 14 December 2001, 60 km S of Ballera Gas Centre, 27º 55' 00" S, 141º 50' 20" E (Carpenter 2002).
2. 14 December 2001, 17 km E of Ballera Gas Centre, 27º 25' 40" S, 141º 59' 00" E (Carpenter 2002).
3. 26 September 2005 and 21 May 2010, Cooper Crossing, 27º 30' S, 141º 56' E (Bill Moorhead, BirdingAus website).
4. 24 August 2006, Cooper Crossing, 27º 29' 58" S, 141º 58' 29" E (BirdLife Australia data).
5. 19 June 2007, Cooper Crossing, 27º 30' 05" S, 141º 56' 36" E (C Billingham, Birds Queensland).
6. 20 June 2009, Noccundra Waterhole, Wilson River, 27º 49' S, 142º 36' E (M Brasher, BirdingAus website).
7. 1990s, Buncheeda Swamp, ~ 26º 50' S, 141º 58' E (G Campbell, pers. comm. to GC).

Five field-survey trips were undertaken, the fifth with three, otherwise four observers, as follows:

1. 16-24 April 2012: the Eyre Creek floodplain between the towns of Bedourie and Birdsville and west to below the junction of Eyre Creek and the Mulligan River.
2. 12-21 August 2012: the Diamantina channels and floodplain east of Birdsville.

   Both of these surveys also included searches for sites of suitable habitat between the outlying populations and Goyder Lagoon itself.
3. 2-7 November 2012: the Cooper Creek and Wilson River floodplains to the south of and east of Ballera Gas Centre;
4. 19-26 May 2013: northern Cooper Creek floodplain from Ballera Gas Centre north to Windorah, including Lake Yamma Yamma; also Lake Cudappan and the southern edge of the Diamantina floodplain east of Birdsville.
5. 9-14 September 2013: Cooper Creek floodplain north-east, east and south of Ballera Gas Centre.

Localities of previous reliable records were visited to determine whether grasswrens were still present and searches were made in nearby areas, concentrating on those identified by local information, maps and aerial and satellite imagery as most likely to contain habitat suitable for the species. In the fourth trip from 19–26 May 2013 covering the northern Cooper floodplain we knew of only two Grey Grasswren records: the unconfirmed (and unlisted) report from Lake Cudappan, shown as X on the map, Figure 1 (Schodde 1982), and an imprecisely located landholder report from Buncheeda Swamp in the 1990s (Cooper 7 above). Searches were therefore directed at the most extensive areas of Lignum swamp as judged from examining maps and satellite imagery. In the third and fourth trips, personal knowledge (RJ) from previous aerial surveys of these floodplains also informed identification of target areas for searching. Where grasswrens were detected, a 200 metres vegetation transect was undertaken, using a range pole to measure cover at every two metres along the transect, recording shrub height in 25 centimetres categories. Methods used were those employed in the Goyder Lagoon/Warburton Creek study (Black *et al.* 2009b, 2012). The localities where grasswrens were detected and where negative searches commenced were recorded using a hand-held GPS unit.

RESULTS

Grey Grasswrens were found in the 2012–13 survey in 18 sites among the outlying populations at ten localities and in two sites at one locality north-east of Goyder Lagoon, where sites within 500 metres were deemed to be at the same locality. Of the 11 localities, only one was known from a precisely located earlier record and three were in Buncheeda Swamp, known only from a non-localised report. There were two in the Eyre Creek floodplain (Figures 2, 6) and eight in the floodplain of Cooper Creek, (Figures 3, 8), including Buncheeda Swamp. Apart from the locality upstream of Goyder Lagoon (Figures 4, 9) there were none on the Diamantina floodplain (Figures 5, 7). The searches that resulted in 20 survey records are described below and details of the 20 sites and eleven localities are listed in Appendix 1.

Eyre Creek floodplain

All previous records for this system have been alongside the Birdsville to Bedourie Road in Lignum where Eyre Creek crosses the road from east to west (known as Cuttaburra Crossing) on swampy floodplain (Joseph 1982; J. Young 1994 pers. comm. to AB; A. Silcocks (Birdlife Australia) 2001 pers. comm. to AB), and up to nine kilometres west on the southern shore of Lake Koolivoo and immediately to its north (Joseph 1982; Jaensch and McFarland 2002; A. Silcocks (BirdLife Australia) 2009 pers. comm. to AB; RJ personal records). These areas were examined thoroughly in April 2012, on the south side extending west to the limit of tall Lignum around Lake Koolivoo and east into Lignum restricted to the south-west aspect of Lake Machattie. The wetlands had undergone a moderate flood, with water persisting in most minor channels, and the Lignum had lush green foliage. We could not detect Grey Grasswrens at these localities at the time or during a subsequent search in August 2012.

Grey Grasswrens were found at a new locality on the Eyre Creek floodplain on 20 April 2012 approximately 20 kilometres north-west of Lake Koolivoo in healthy but sparsely foliaged Lignum in a dry area in the north-western corner of the floodplain (Figure 2). Three birds were heard and grasswrens were detected in the same area during the second survey on 18 August 2012**;** others were recorded at another site nearby and at three further sites up to two kilometres to the west and north-west on 19 August. The first survey was extended to the west (downstream) on the northern side of Eyre Creek to its junction with the Mulligan River and onto the southern side of Eyre Creek to include other wetlands around Kauri and Muncoonie Waterholes, co-incident with and then ahead of the advancing flood. We examined accessible areas of suitable floodplain habitat, chiefly Lignum, but also small areas of Old-man Saltbush, but no grasswren was located. From the Mulligan junction, Eyre Creek runs south through the Simpson Desert dunefield for about 150 kilometres to its entry into Goyder Lagoon and consists of a channel and multiple swale floodways containing little or no suitable Lignum habitat.

Figure 2. *Habitat at Eyre Creek site E1a, (shown ✱ on map Figure 6) Lignum with ephemeral Senecio, 18 August 2012.* (Photograph by R. Pedler)

Figure 3. *Habitat near Cooper Creek sites C4a-f, (shown ✱ on map Figure 8) Lignum with Nutheads, Spike Rush and Queensland Bluebush, 6 November 2012.* (Photograph by G. Carpenter)

Figure 4. *Habitat north of Goyder Lagoon near sites G1a, b (shown ✱ on map Figure 9) Lignum and Old-man Saltbush with Flock Bronzewings* Phaps histrionica *23 May 2011.* (Photograph by R. Pedler)

Figure 5. *East of Thundapurty Waterhole, site of January 2001 record (Diamantina 4, shown ✱ on map Figure 7) Lignum with Spike Rush and ephemeral Senecio, 15 August 2012.* (Photograph by R. Pedler)

Diamantina floodplain

The six previous records in the Diamantina channels and floodplain (Jaensch and McFarland 2002) are from a restricted area between Thundapurty Waterhole and a little beyond Pelican Waterhole on Browns Creek approximately 45 kilometres to the east A moderate flood followed by local rains two months earlier had dried and receded by mid-August 2012, allowing access to all sites. One site at the edge of Thundapurty Waterhole was in tall and dense Lignum; searches were made there and in similar vegetation for over two kilometres to the east and west. The sites of two other previous records approximately six and 18 kilometres to the east were in habitat as described by Jaensch and McFarland (2002): one near the edge of continuous floodplain vegetation (Figure 5) in tall (and fresh) Lignum over dense spike rush *Eleocharis plana*, the other in sparse Lignum lacking vigour in an isolated locality within the broader floodplain. The site of the Diamantina Shire survey record was not defined precisely, but an area of dense Lignum within the reported five-minute block was examined. Later David McFarland (pers. comm., 19 October 2012) reviewed original data and advised that the record had more likely come from Lignum in a major channel to the south, very close to Thundapurty Waterhole. The two sites of museum specimens from Browns Creek were also given only as five-minute blocks containing habitats of sparse low shrubs including chenopods, sparse low tussock grass and wooded channels. No significant areas of Lignum or Swamp Cane Grass *Eragrostis australasica* were found anywhere near those record sites but several small areas of low Cottonbush *Maireana aphylla* shrubland were present, perhaps the chenopods described.

No grasswrens were recorded at any of these Diamantina sites or at places containing what appeared to be suitable Lignum shrublands up to 15 kilometres west, 20 kilometres north and 25 kilometres north-east of Thundapurty Waterhole. Searches were also negative in mixed Lignum and other shrubs towards the northern limit of the Diamantina floodplain where crossed by the Betoota to Bedourie road and in Lignum in the downstream floodplain farther west to within approximately 10 kilometres of Birdsville. Two further searches on 25 May 2013 in two areas of large Lignum to the west of Thundapurty Waterhole also yielded no grasswrens.

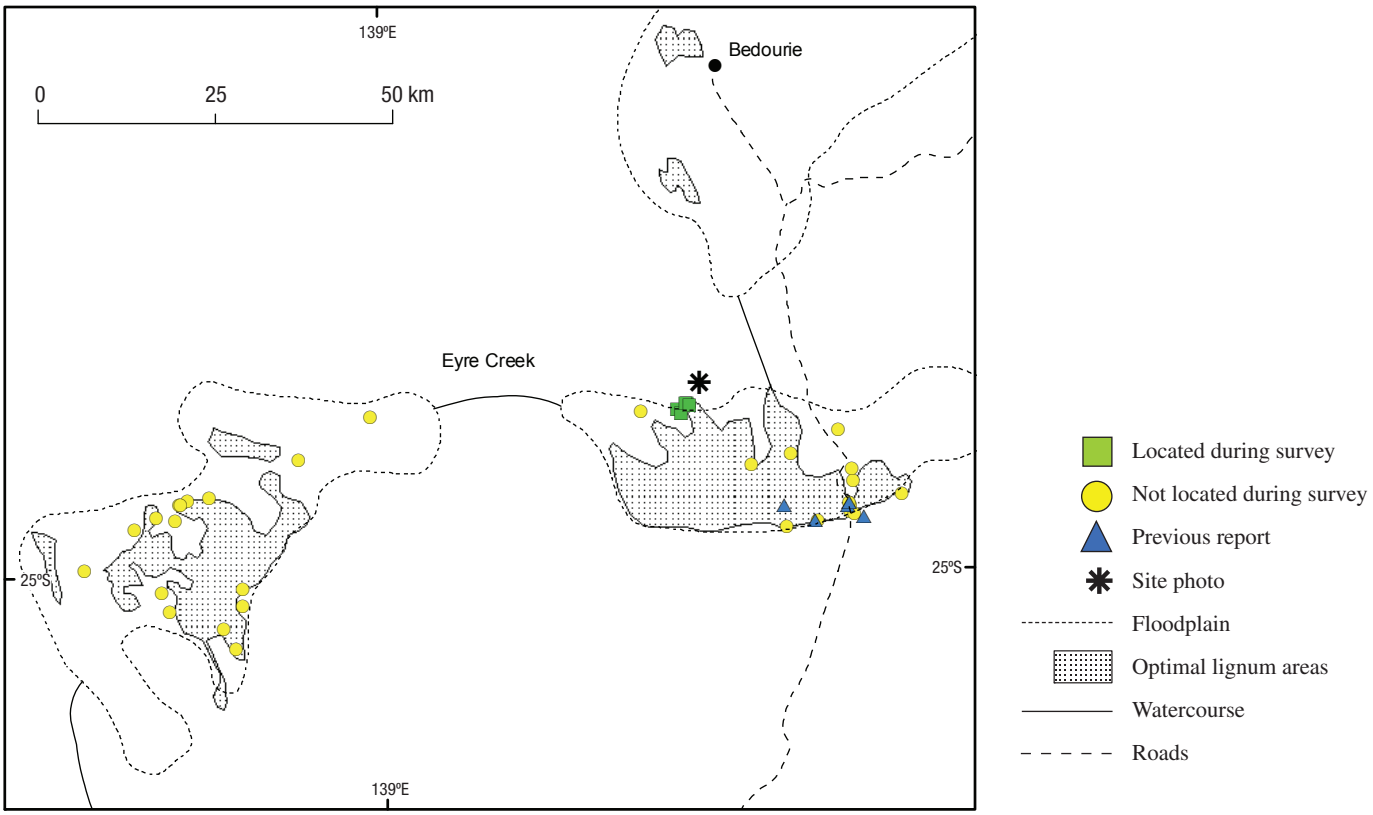

Figure 6. *Map of the Eyre Creek floodplain, showing its approximate limits, optimal areas of Lignum habitat, as identified from satellite imaging, previous Grey Grasswren records, survey records and negative search sites.*

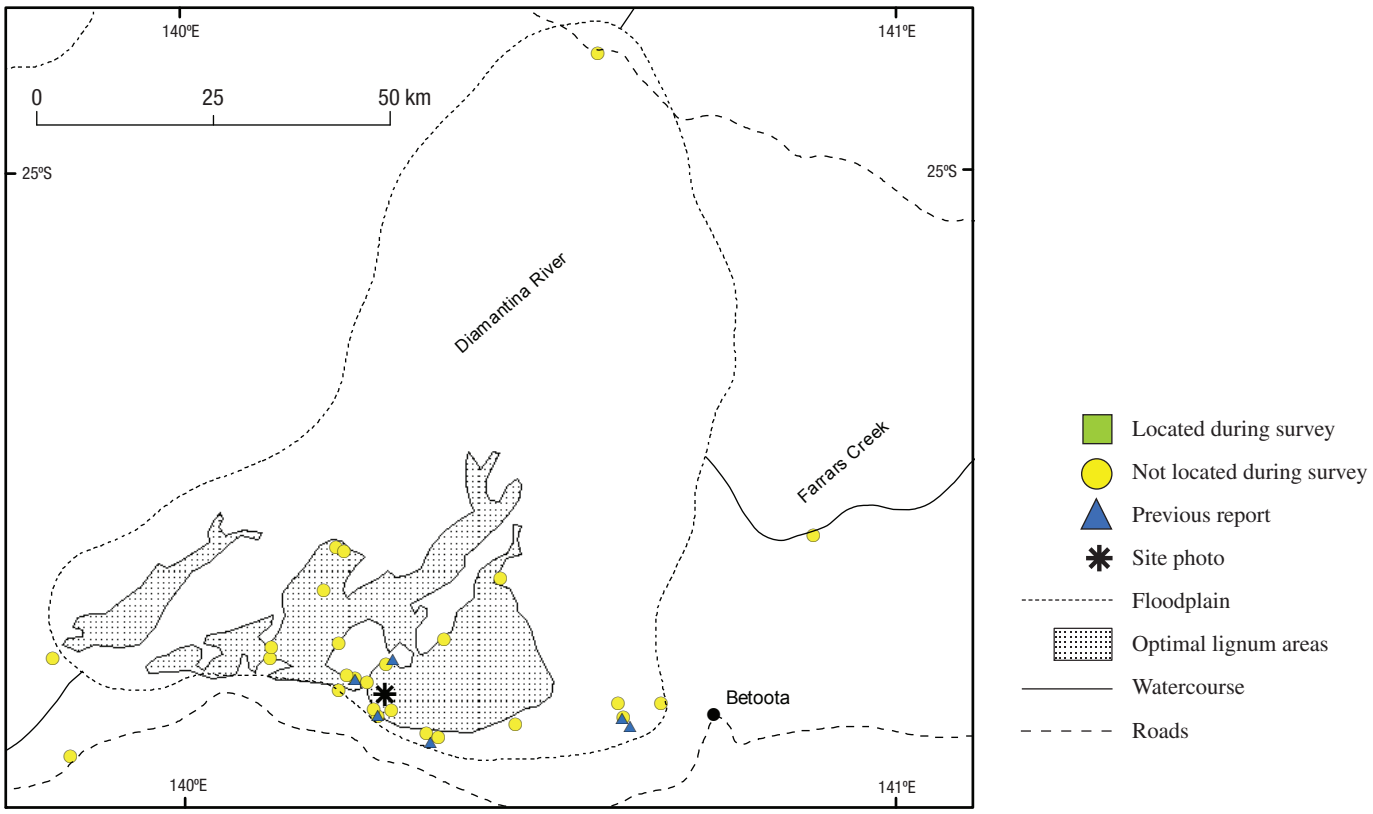

Figure 7. *Map of the Diamantina River channels and floodplain, showing its approximate limits, optimal areas of Lignum habitat, as identified from satellite imaging, previous Grey Grasswren records, survey records and negative search sites.*

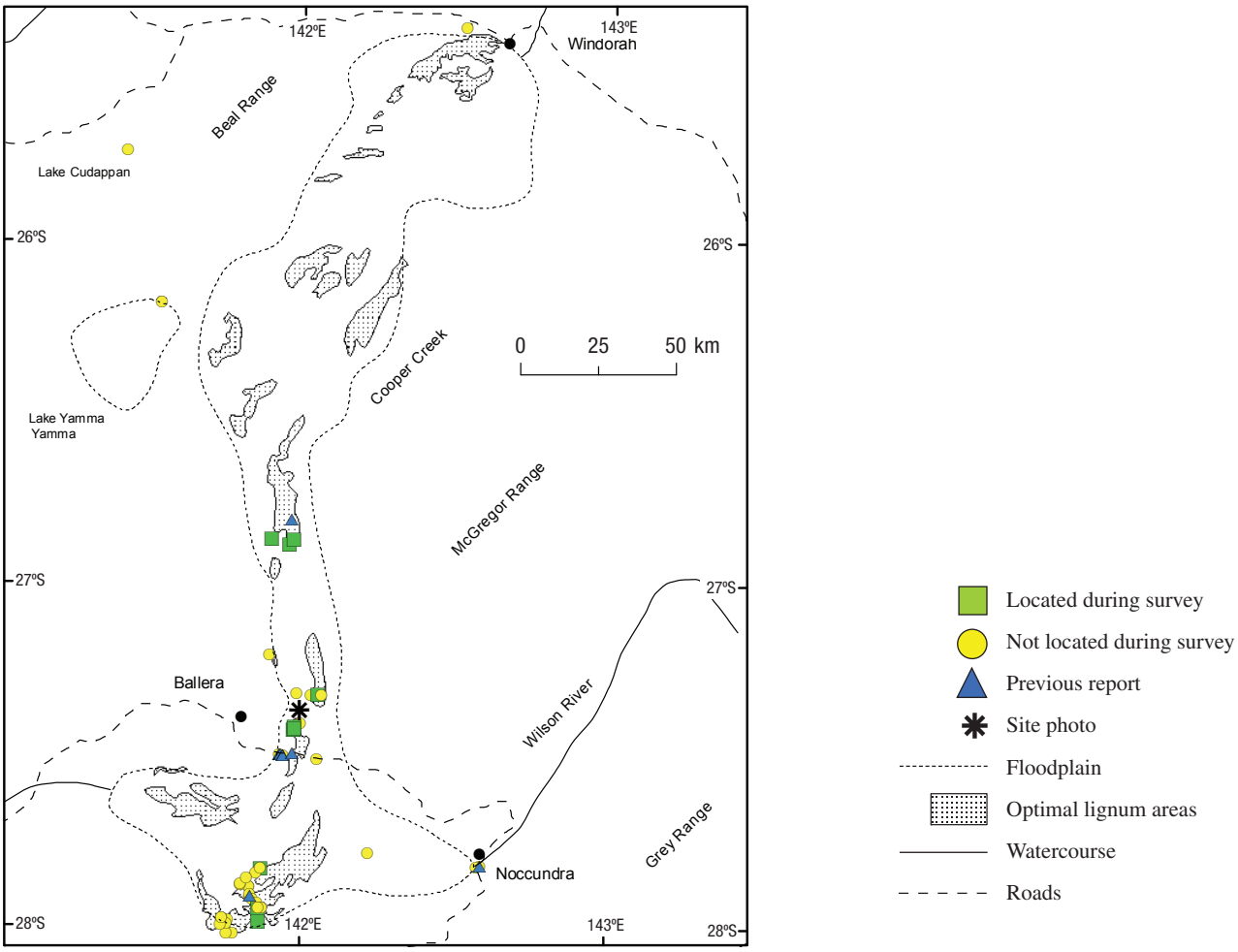

Figure 8. *Map of the Cooper Creek channels and floodplain, showing its approximate limits, optimal areas of Lignum habitat, as identified from satellite imaging, previous Grey Grasswren records, survey records and negative search sites.*

Cooper Creek and Wilson River floodplains

Grey Grasswrens have been reported on one or more occasions since 2009 at Noccundra Waterhole on the Wilson River approximately 50 kilometres to the east of the main Cooper channels. In November 2012 we examined the habitats surrounding the waterhole and farther downstream and then sought suitable areas west of Noccundra and south of Jackson, where the Wilson River and Cooper Creek floodplains merge; we examined one potential site but found no evidence of Grey Grasswrens. In November 2012 we also searched unsuccessfully for grasswrens at and near sites of several observations made between 2005 and 2010, up to 12 kilometres apart, where the Innamincka to Thargomindah road ("The Adventure Way") crosses many channels on the Cooper Creek floodplain. Next we investigated the area towards the southernmost bend of the Cooper floodplain where Grey Grasswrens were found in 2001, south of Little Tooley Wooley Waterhole (Carpenter 2002). We found no Grey Grasswrens at the 2001 site but recorded them at three nearby localities within 15 kilometres of each other near the southerly limit of the Cooper Creek floodplain on 4–5 November 2012. Despite the presence of ample Lignum habitat no grasswrens were detected during visits to sites farther south and west (to the area around Yetally Waterhole), but several observations were made of Yellow Chats and Tawny Grassbirds, neither documented previously from the southern Cooper floodplain (Jaensch *et al.* 2013). On 6 November 2012, we searched Carpenter's (2002) second locality from 2001, east of Ballera Gas Centre, and found grasswrens at four sites within 800 metres of each other (Figure 3).

For the fourth survey we lacked accurate localities for the two records known to us north of the last named site; those from Lake Cudappan and Buncheeda Swamp. We therefore identified the following areas from satellite imagery: six small or moderate sized areas of Lignum swamp north-east of Ballera Gas Centre; the extensive Buncheeda Swamp about 60 kilometres farther to the north-east; Lignum channels on the northern fringe of Lake Yamma Yamma; Candue Swamp farther upstream to the north-east; and 12 Mile Swamp near Windorah. We first investigated the area immediately north of the 6 November 2012 Grey Grasswren site-cluster but no grasswren was detected there. Three more of the six small areas of Lignum swamp were surveyed on 21 May 2013; grasswrens were heard about 12 kilometres north-east of the last 2012 locality but not seen, probably because rain had begun to set in, resulting in 15 to 25 millimetres falling over the whole of the planned survey area. An extended examination near the eastern margin of Buncheeda Swamp on 23 May 2013 was unsuccessful, other than the possible detection of contact calls,

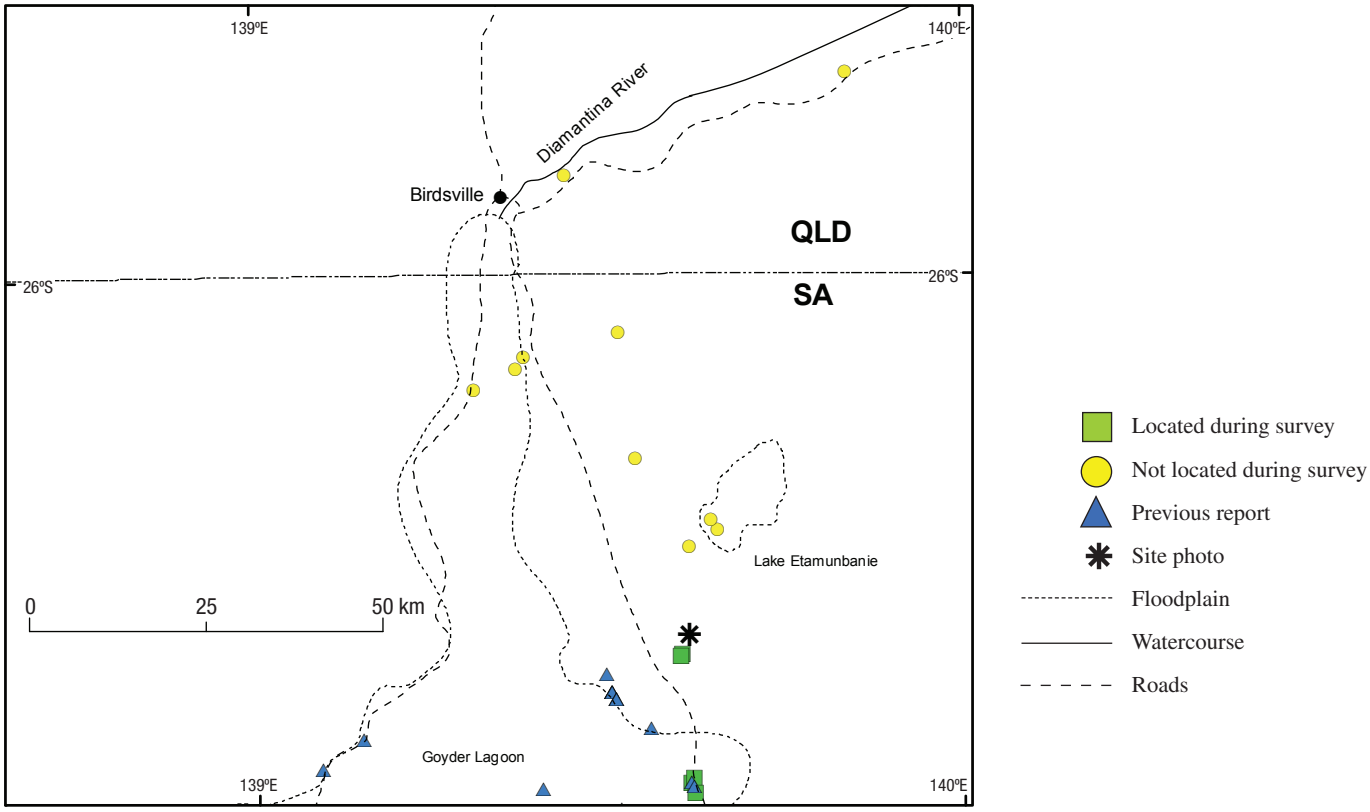

Figure 9. *Map of the southern Diamantina floodplain and northern Goyder Lagoon, showing its approximate limits, previous Grey Grasswren records, survey records and negative search sites.*

but at a channel near its southern extent (C6) at least three Grey Grasswrens were observed. No grasswren was detected at Lake Yamma Yamma or 12 Mile Swamp. Candue Swamp was inaccessible owing to extensive inundation of access tracks. We visited Lake Cudappan on 25 May 2013, but the apparently limited potential habitat for grasswrens, canegrass, scattered River Cooba (Belalie) *Acacia stenophylla* and sparse Lignum, had been severely burnt during extensive lightning fires of the previous summer.

On 11 September 2013 grasswrens were sought unsuccessfully at the site of the 23 May Buncheeda Swamp record (C6) but were seen and heard briefly to the north-west of that site near the northern end of Widindra Waterhole. On 12 September 2013 two grasswrens were located in Buncheeda Swamp where possible calls had been heard in May 2013. Searches on 13 September 2013 near the four closely located sites east of Ballera Gas Centre (C4a – C4d) revealed grasswrens in two places within the same general locality. A search near Tooley Wooley Waterhole which had almost dried out completely (Site C1) was negative.

Diamantina floodplain upstream from Goyder Lagoon

Grey Grasswrens were seen at two sites about eight kilometres north-east of Moongara Crossing on the Birdsville Track (26º 29' S) on 13 August 2012 in a mixed low shrubland of Lignum and Old-man Saltbush (Figure 4). This constituted a modest extension of known range north-east of Goyder Lagoon by about 20 kilometres but grasswrens were not detected in similar shrublands north to approximately 26º 21' S, west of Lake Etamunbanie. Channels associated with the Diamantina overflow (Gumborie Creek) farther north, to Cudary Yard approximately 26º 04' S, contained little if any suitable habitat. Areas of Lignum north of Goyder Lagoon, on the west of the main channel of the Diamantina, south to approximately 26º 14' S, and on the east, south to approximately 26º 08' S, were examined during the first and second survey trips but grasswrens were not found (Figure 9).

In summary, including two sites at a locality north-east of Goyder Lagoon, we detected Grey Grasswrens at 20 sites within eleven localities, two localities on Eyre Creek west of Lake Koolivooo, three on Cooper Creek at the southern end of Buncheeda Swamp, two on Cooper Creek east of Ballera Gas Centre, and three on the southern bend of Cooper Creek. We did not find Grey Grasswrens at previous localities on Eyre Creek near Lake Koolivoo, (reported between 1982 and 2009), at Noccundra Waterhole, (reported in 2009), at the Cooper Crossing southeast of Ballera (reports from 2005 to 2010) or in any part of the Diamantina floodplain (records in 1984 and 2001–2002), apart from immediately upstream of Goyder Lagoon (Figures 1, 6-9). Thus, of 36 sites at which Grey Grasswrens of the outlying populations have been recorded, 18 before and 18 during this study, only one pre-2012 site was found to be occupied during the survey, corresponding with the six 2012 sites C4a-C4f. In addition, when sites C1 (November 2012) and C6 (May 2013) were re-examined in September 2013 no grasswrens were found.

Table 1

Cover (per cent) at Grey Grasswren sites.

Cover type (heights in cm)	Goyder survey mean ± s. d.	E1a	E2b	E2c	C1	C2	C3	C4a	C6	This survey mean ± s. d.
Bare	34.5 ± 18.2	32	23	38	54	17	30	16	28	29.7 ± 12.3
Litter and non-shrub	34.5 ± 21.0	5	19	9	12	36	7	41	3	16.5 ± 14.4
Lignum <25	1	0	2	0	0	0	0	0	0	0.3
Lignum 26-50	1.4	4	4	4	0	0	0	0	0	1.5
Lignum 51-75	4.4	1	2	1	3	0	1	2	1	1.6
Lignum 76-100	7.1	3	2	3	8	2	1	4	4	3.4
Lignum 101-125	6.5	10	13	10	8	10	5	3	14	9.1
Lignum 126-150	4.8	8	9	8	7	8	15	16	13	10.5
Lignum 151-175	2.8	4	5	4	7	14	18	11	21	10.5
Lignum 176-200	3	10	2	10	1	12	17	2	14	8.5
Lignum >200	1.5	11	9	11	0	0	6	0	0	4.6
Lignum total	32.5 ± 16.2	63	48	51	34	46	63	36	67	51.0 ± 12.5
Other shrub cover with above		14	10	2	0	1	0	5	2	

Habitats

Habitats were documented in transects at eight grasswren sites, three on Eyre Creek (E1a, E2b, E2c) and five on Cooper Creek (C1-C4a, C6) floodplains. Their cover characteristics are shown in the Table and compared with the cover at Grey Grasswren sites from the Goyder/Warburton survey (Black *et al.* 2012). Note that, in the latter, each 25 centimetres height category represents the total of all shrubs in that category.

Cover characteristics of sites of the outlying populations of Grey Grasswren fall within the range of those found earlier in and downstream of Goyder Lagoon. Total Lignum cover varied from 34 percent to 67 percent and total shrub cover from 34 percent to 77 percent, compared with up to 76 percent in the earlier study, (Black *et al.* 2012) and the majority of sites reported here show comparatively high total and tall Lignum cover (Table 1). Cover other than Lignum at most Cooper Creek sites was dominated by dense, fresh or senescent Nutheads *Epaltes cunninghamii* (chiefly 50–100 cm in height), which was not present in any recordable quantity in the Goyder Lagoon study. Queensland Bluebush *Chenopodium auricomum* provided five percent cover at C4 and one percent at C9 and *Senecio* spp provided 10 percent cover at E4 and two percent at E5. Emergent River Cooba (Belalie) (1%) was present at C6; only at E1a did Old-man Saltbush contribute (14%) to the shrubland structure. In neither study did we devise any practical method of comparing grasswren-presence and grasswren-absence site characteristics as employed in surveys of Western and Thick-billed Grasswrens (Black *et al* 2009a, 2011). Some examples of habitats encountered during this survey are shown in Figures 2–5.

DISCUSSION

Population distribution, density and size

Compared with the 2009 survey, in which Grey Grasswrens were found at 54 localities in the Goyder Lagoon/Warburton Creek area over about eight days, they were detected at ten localities over about 24 days of searching among the outlying populations of Eyre Creek, Diamantina River and Cooper Creek during the current survey. Also in contrast to the Goyder Lagoon survey where 16 of 20 previous records were confirmed (Black *et al*. 2012), the current survey of outlying populations found grasswrens at only two localities (including Buncheeda Swamp) of 18 former record localities. Our survey of the Cooper Channel Country covered only a small proportion of the area of potential habitat, but those of the Eyre Creek and Diamantina floodplains achieved substantial coverage, and all three concentrated on habitat likely to be most suitable for Grey Grasswrens (Figures 2–5). Furthermore, two clusters of closely associated sites accounted for eleven of the 18 sites. We conclude therefore, that Grey Grasswrens are distributed very sparsely and unevenly in this vast area. Yet there are earlier and reliable reports from all three systems that we were unable to confirm. This suggests that one outlying population on the Diamantina River may no longer be extant and that the other two have declined significantly since they were first documented between the 1980s and 2000s, e.g. through repeated small-scale local site-extinctions. While the above comparisons of density do not necessarily indicate total abundance, our results nevertheless show that the three outlying populations of Grey Grasswren comprise relatively tiny numbers of birds in each of the river systems and collectively.

Significant gaps lacking suitable habitat separate the outlying populations from each other and from central populations. About 150 kilometres separate the Eyre Creek floodplain and Goyder Lagoon; between the Diamantina floodplain and the latter the gap is narrower with marginal habitat reducing it to about 50 kilometres. About 70 kilometres separate the Eyre Creek and Diamantina floodplains with only minimal potentially suitable habitat in low-lying drainage lines surrounding Bilpa Morea Claypan. The distance separating the Diamantina and Cooper floodplains is around 150 kilometres, but with the earlier unconfirmed record from Lake Cudappan situated enigmatically between the two. The distance between Noccundra and the terminal Bulloo is over 150 kilometres, with the Grey Range separating the Wilson (Lake Eyre Basin) and Bulloo catchments.

We find therefore that the Eyre Creek, upriver Diamantina and Cooper – Wilson populations are not currently in continuity with the larger central population in Goyder Lagoon. Yet Eyre Creek and Goyder Lagoon individuals are of the same subspecies and appear to belong to a single genetic pool (Christidis *et al.* 2010). The genetic identity of upriver Diamantina and Cooper Creek individuals is not yet determined and, in view of our findings, this question is of some moment. Birds from the Diamantina are (or were) relatively close geographically to those on Eyre Creek and the two river systems are hydrologically connected via Goyder Lagoon well upriver of the xeric and saline Lake Eyre environments. This suggests that they too might belong to the subspecies *A. b diamantina* but the same inference is not derived so readily for grasswrens in the Cooper Creek floodplain, with only the intervening historical but unconfirmed record at Lake Cudappan, a site now apparently unsuitable. The Cooper Creek population is certainly small and apparently isolated; its recent possible decline would provide additional evidence that it is threatened, and if genetically distinct it is a threatened subspecies. If, on the other hand, future analysis shows that it too belongs to the subspecies *A. b. diamantina*, the geographic separation of all three outlying populations from Goyder Lagoon and from one another would suggest that Grey Grasswrens are capable of substantial dispersal, perhaps at times during temporary breakdown of what are otherwise hostile barriers.

Grasswrens are widely considered to have poor dispersal ability (Higgins *et al.* 2001; Christidis *et al.* 2010) a factor considered relevant to their generally less secure conservation status in comparison with fairy-wrens (Skroblin and Murphy 2013). Their short rounded wings and wing to body mass relationship are however similar to those of fairy-wrens but neither group is thought to be capable of flying long distances (Rowley and Russell 1997). Schodde (1982) regarded the flight of grasswrens as weaker than fairy-wrens and showed that their sternum and its keel are shallower, suggesting a relative reduction in bulk of their pectoral muscles. Moreover grasswrens show pronounced taxonomic diversity and short range endemism, typical of poorly dispersing organisms (Schodde 1982; Austin *et al.* 2013).

While there is little direct evidence of how far grasswrens are able to disperse, among populations of the Striated Grasswren *Amytornis striatus* occupying vast tracts of Porcupine Grass *Triodia* spp. that are subject to periodic fires, birds may be absent from sites where they were recorded some years previously, yet found in the near vicinity (LP pers. obs.). Perhaps therefore grasswrens, or at least some grasswren species, may show more mobility than is generally assumed. A substantial level of mobility under particular circumstances, perhaps even as a common strategy for survival among Grey Grasswrens, might be inferred from the non-concordance of pre-2012 and recent survey records. The finding that they have apparently deserted places where they were observed over several or many years suggests that they do not show, in the outlying populations, the site (or at least locality) fidelity that characterises some grasswren species (Black *et al.* 2009a, 2011) or Grey Grasswrens in Goyder Lagoon (Black *et al.* 2012). Perhaps lesser locality fidelity in the Grey Grasswren is influenced by regimes of periodic habitat inundation, a stressor not experienced by other grasswren species. It should also be understood that regimes of inundation will differ year to year between river systems, as well as longitudinally within a given system and unpredictably even on one individual floodplain.

A comparison with the central Goyder Lagoon population

What explains the differences between Goyder Lagoon, where Grey Grasswrens have been found to be plentiful and faithful to locality, and the other inhabited areas of floodplain, where they appear to be unpredictably scattered and scarce? We believe the difference to be real and not a chance finding of the separate surveys; we list a number of possible explanations and further exploration of some of them is considered in the paragraphs below:

- A relative lack of refuges for grasswrens in the wetlands of outlying populations at times of flood and deep inundation, including the comparative rarity of Old-man Saltbush shrublands.
- Differences in the water regimes between Goyder Lagoon and the wetlands occupied by the outlying populations; also hypothetically, a recent change towards more extreme flooding intensity which might be having greater impact on upriver than downriver reaches and their associated floodplains.
- The greater floodplain area of Goyder Lagoon (~3,000 km²) with more extensive Lignum, Swamp Canegrass and fringing Old-man Saltbush shrubland, compared with the narrower upriver Diamantina and Eyre Creek floodplains and restricted areas of habitat on the wider Cooper floodplain.
- Comparatively greater destruction of habitat in the outlying populations by cattle grazing, feral animals and by fire; also potentially greater predation of the outlying populations by native and introduced carnivores;
- Unrecognised differences in the growth stage or other aspects of Lignum between areas inhabited by the central and outlying populations and the relationship of those differing ages and/or forms of Lignum to the habitat requirements of Grey Grasswrens;

Dispersal and refuges

It is possible that the extreme flood events of 1973–1977, similar to those of 2009–2012, were associated with major dispersal of Grey Grasswrens and the establishment of small satellite populations. The mechanism might involve displacement of grasswrens by flooding into habitats invigorated by repeated seasons of exceptional local rainfall that were capable of supporting them (perhaps over several years) during transit across usually inhospitable areas to other floodplain habitats. Such an explanation was offered for the presence of grasswrens for a brief period in the 1980s at Embarka Swamp, Cooper Creek, South Australia (May 1982, Black *et al.* 2009b, 2012). Floods certainly cause Grey Grasswrens to abandon long held territory. A major flood of the Bulloo River in 2000 displaced a dense population (47 individuals trapped in four days in 1991) from a Lignum site, apparently occupied continuously for the previous 16 years (Hardy 2002). Supportive evidence of

flood-related displacement was provided by Black *et al.* (2012), including an observation of Grey Grasswrens occupying Sandhill Canegrass *Zygochloa paradoxa* hummock grassland on dunes at Koonchera within Goyder Lagoon when flooded in the mid-1980s (R. Kernot pers. comm. to GC). Large floods can also result in temporary defoliation of the Lignum, as observed in Eyre Creek in April 2009 and on other occasions (RJ personal observation) and could thus inhibit or delay the return of Grey Grasswrens to previously occupied sites.

Grey Grasswrens of the Goyder-Warburton population are known to occupy densely vegetated Lignum swamps and Lignum-lined channels, as well as much more open Lignum and other vegetation such as Old-man Saltbush and mixed species shrublands in more peripheral parts of the floodplain beyond the major Lignum swamps (Black *et al.* 2012). This led us to postulate the role of shrublands of varying composition at the periphery of the floodplain acting as refuges during times of grasswren displacement because of flood. We found Grey Grasswrens of the outlying Cooper Creek population only in dense and flood-invigorated Lignum but on Eyre Creek they were in sparsely foliaged Lignum on a more peripheral part of the floodplain. In the former case our observations were made following moderate or only minor flooding but in the latter at the time of a moderate flood. Old-man Saltbush shrublands are uncommon in the upriver reaches of the Channel Country compared with the Goyder-Warburton floodplain and were rarely encountered during these surveys. It is therefore plausible that a relative lack of flood-time refuge sites inhibits the maintenance of larger numbers in the outlying populations. It is also noteworthy that two early specimen records from near Browns Creek were certainly peripheral on the eastern Diamantina floodplain, at least 10 kilometres beyond major channels and extensive Lignum shrublands. Furthermore the (atypical) habitat described from the five-minute blocks from which those specimens were taken was of "sparse low shrubs including chenopods, sparse low tussock grass and wooded channels" (cited by Jaensch and McFarland 2002). At our visit on 17 August 2012 we could see no likely Grey Grasswren habitat and suspected a serious error of recorded locality. The only "wooded" channels (i.e. with trees or presumably Lignum) were near Pelican Waterhole and some smaller waterholes associated with Browns Creek. The surrounding area, including the stated record-localities did, however correspond with the given description and included tussock grasses, very low shrublands of samphire and *Sclerolaena* spp and small areas of Cottonbush *Maireana aphylla* low shrubland. A further Diamantina observation had been made beyond the continuous floodplain habitat and consisted only of "sparse isolated Lignum shrubs lacking vigour"; another, while consisting of Lignum, at the edge of the floodplain, was considered "not as dense as (some), about 30–10 m apart", and, somewhat atypically, had a continuous understorey of dense Spike Rush *Eleocharis plana* (Jaensch and McFarland 2002, see also Figure 5), both records being at a time when the Lignum was inundated and the water level was rising. One possible interpretation of these observations (in 1984 and 2001) is that the grasswrens were forced into atypical habitats and localities following displacement from preferred habitat by its continuing inundation.

Flow regimes

While there are similarities between the vegetation of Goyder Lagoon and the floodplains of Eyre Creek, Diamantina River and Cooper Creek, differences in river flow regimes into and through these systems might be responsible for greater instability in the maintenance of habitat suitable for Grey Grasswrens in the outlying populations. Personal observation by some pastoral managers is that the water that enters Goyder Lagoon will stay there, flowing on through the Warburton Creek when inundated but occupying the lagoon for some time thereafter whereas, in upriver floodplains of the outlying populations, floodwaters are more likely to pass rapidly downstream. Flows in upper and middle reaches, particularly in the Diamantina which has no river-connected lakes to absorb floodwater, are sometimes relatively fast and deep, submerging and defoliating lignum and/or reducing the availability of potential grasswren habitat for several weeks or months in such years (RJ personal observation, with examination of satellite imagery and flood data). David Roshier (pers. comm.) observes that Goyder Lagoon is the largest of the Lignum swamps and has regular inflows and that these facts are likely to be of significance. Depth of inundation will also be pertinent and it is possible that this is less variable and less extreme in Goyder Lagoon than at other localities occupied by outlying populations but there is a paucity of information on hydrological conditions in all these systems. Justin Costelloe (pers. comm.) has identified the following potentially relevant factors for which good data are unavailable; the frequency and mean temporal duration of flows through a given reach, flow velocity, mean duration of periods without flow, the persistence of water after inflow has ceased, and the area of inundated preferred habitat and the depth of water around it. Such hydrological variables are almost certainly pertinent to the question of why the outlying populations of Grey Grasswren are sparsely distributed and may occupy different parts of the floodplain on a transient basis.

Habitat disturbance: fire and grazing

Grey Grasswrens of all populations occur entirely within properties whose principal land use is the grazing of cattle. Their habitat may be damaged if the grazing and trampling of cattle (and/or feral pigs) is excessive (Hardy 2010). While Lignum is relatively resilient to such activity, potential refuge habitats such as Old-man Saltbush and Swamp Canegrass may be more severely impacted (LP personal observations). The burning of Lignum is used as a management tool in parts of the Channel Country for opening up areas to encourage grass growth and enhance stock management (Jaensch 2009), and the practice was actively promoted in Queensland in comparatively recent times (Pressland *et al.* 1989). We found old burnt Lignum stumps at several localities, including Lake Cudappan and saw no Lignum on the western side of Lake Yamma Yamma where much existed up to 1974 (LP personal observation). These observations indicate that intermittent loss of Lignum is a real phenomenon and might apply more to habitats of the three outlying populations than to those at Goyder Lagoon. There is potential for localised grasswren populations to be eliminated by fire and, where this has been extensive or repeated over prolonged periods, larger populations could be lost, particularly where denser refuge areas of Lignum

are burnt. Habitat disturbance certainly occurs as a result of land use for cattle grazing, including the use of fire, and it is possible that this could affect grasswrens at a local level or even result in broader population declines. However it is less likely that it has occurred on a sufficient scale to account for the very different population densities and total populations in Goyder Lagoon compared with those in the three outlying floodplains under discussion.

Seasonal differences

The two surveys were conducted several years apart. In October 2009 local conditions were favourable following a good autumn flood through Goyder Lagoon which reached Lake Eyre. Through April, August and November 2012 local conditions were again favourable but with increasing desiccation over time since major floods in 2010 and 2011, although ephemeral growth in Goyder Lagoon in 2009 appeared to have persisted more strongly than it did in the outlying wetlands in 2012. By May and September 2013 local conditions were at their worst, following a summer with extreme temperatures and only minor to moderate autumn flooding. It was observed on those trips that birds of all species generally were in very low numbers and it is the experience of all authors and corroborated by others, including local observers, that this situation prevailed through much of arid eastern Australia in 2013, suggesting that substantial mortality might have occurred from heat stress on days of extreme temperature during the previous summer. We cannot therefore discount the possibility that some decline may have occurred also in the Goyder Lagoon populations since it was surveyed in 2009.

Conservation and management

Decline in already small populations of a species over a short period is a serious concern for conservation managers, as reflected in criteria A, B and C for the application of IUCN Red List categories at a regional level (IUCN 2003). Our findings suggest decline in the Eyre and Diamantina populations, the latter possibly to local extinction; they also show that all three outlying populations are small and, if considered in isolation, are thereby threatened on that basis alone. The Eyre and Diamantina populations probably contain fewer than 250 adult birds and could be considered endangered purely under criterion D (IUCN 2003); likewise the Cooper population, with probably fewer than 1000 adult birds would be vulnerable. Threatening processes for the species were identified by McAllan and Cooper (1995) and Hardy (2002, 2010) as habitat degradation from grazing pressures of stock and rabbits and from disturbance by the rooting of feral pigs. Additional threats or potential threats suggested by Black *et al.* (2012) were deliberately lit fire, increasing fire intensity or frequency resulting from climate change, and change to the frequency of inundation as a result of climate change and/or potential future regulation or over-exploitation of water resources of the catchments. Garnett *et al.* (2011) listed threats to the Bulloo population as cattle grazing, especially in dry years, drought, habitat degradation by rabbits and pigs, fire, predation, water extraction and invasive weeds. In addition potential threats might arise from the provision of new stock watering points or in association with oil, coal and gas exploration and extraction, including oil and chemical spills and disruption of water flows.

Of the threats listed above, some such as fire and the browsing by cattle will have a direct impact by temporarily or permanently reducing available habitat for the species. Others, such as drought, climate change and increased water exploitation, might impact less directly but are potentially even more significant threats in the longer term. Upstream river regulation and/or harvest may be the greatest potential threat for grasswrens downstream because Lignum is a wetland-associated plant and the sparse local rainfall is generally insufficient for the viability of Lignum shrublands in the deep-cracking floodplain clay in these arid zone communities, periodic river flooding being essential. Hardy (2002) provided evidence of "ringbarking" of Lignum by rabbits and habitat degradation by pigs in the Bulloo catchment but whether such damaging activity constitutes a seriously deleterious process among the populations discussed here is uncertain. Disruption of hydrological parameters as a result of oil, gas and coal exploration is more hypothetical as a threat. The impacts of predation and weed invasion on Grey Grasswrens have not been studied but it seems unlikely that they will have acted differentially on the conservation of outlying compared with central populations unless through unidentified habitat differences.

Our findings suggest decline and/or dispersal with the threat of local extinction of one or more of the outlying populations, despite and perhaps partly because of a series of major flood events since 2009. If, as it presently appears, they are effectively isolated from the substantial Goyder Lagoon population several questions arise. Is their separation more apparent than real? If so, under what circumstances might the populations merge? Has their potential for reproductive contact declined and, if so, what are the reasons and can they be addressed and reversed? It is possible that DNA analysis of museum specimens might provide evidence of prolonged reproductive isolation perhaps approaching that separating the two known subspecies. This seems very unlikely however, since Eyre Creek specimens have been shown to be genetically close to and perhaps indistinguishable from those in Goyder Lagoon (Christidis *et al*. 2010), suggesting a single panmictic population of *A. barbatus diamantina*. It is possible that the extreme flood events of 1973–1977, similar to those experienced from 2009–2012, were associated with major dispersal of Grey Grasswrens and the establishment of small satellite populations. If that is so we might anticipate the future detection of Grey Grasswrens in places where we have not found them recently, such as on the Diamantina floodplain in Queensland or at Embarka Swamp on the main branch of Cooper Creek in South Australia. Alternatively, major flood events might be responsible for losses within small isolated populations. Whatever the real explanation for such fluctuating fortunes in the outlying populations of Grey Grasswrens, observations over several decades and through diverse conditions may be needed before their potential to recover or be self-sustaining in the longer term, or their suspected high mobility, can be judged. Determining the genetic relationships between all populations will have significant implications for the species' conservation and for clarification of its infra-specific taxonomy.

These outlying populations appear to be both sparser and smaller in total than the Goyder-Warburton population and, if dependent on that central population as a source, the critical

significance of the latter for the conservation of the species is highlighted. While we found Grey Grasswrens relatively readily at 54 localities in the Goyder-Warburton floodplain (Black *et al.* 2012) we did not provide an estimate of its total adult population. While we have regarded it as secure, if containing fewer than 1000 adult birds it too would qualify as vulnerable under criterion D (IUCN 2003). The other central population, nominate *A. b. barbatus* has been reported to be in decline in New South Wales (Hardy 2010) and was considered endangered by Garnett *et al.* (2011), but a more detailed examination of its total distribution, including much potential Lignum habitat in Queensland is needed in order to further evaluate its conservation status.

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Appendix 1

Sites where Grey Grasswrens were detected during the survey.

Eyre Creek

E1a. 20 April 2012, one bird was seen and at least two were heard; 18 August 2012 ~ 20 km north-west of Lake Koolivoo, 24º 47' 26" S, 139º 25' 39" E. One or more were seen or heard at the same site on 18 August 2012.

E1b. 19 August 2012, probably three birds were seen ~ 300 m north-west of E1a, 24º 47' 20" S, 139º 25' 20" E.

E2a. 19 August 2012, one or more birds were seen ~ 1.5 km west of E1a, 24º 47' 44" S, 139º 24' 36" E.

E2b 19 August 2012, two birds were seen ~ 1.4 km south-west of E1a, 24º 48' 02" S, 139º 25' 00" E.

E2c. 19 August 2012, one bird was seen ~ 2 km west of E1a, 24º 47' 30" S, 139º 24' 20" E.

Cooper Creek

C1. 4 November 2012, three or four birds were seen ~ east of Tooley Wooley Waterhole, 27º 50' 09" S, 141º 52' 16" E.

C2. 5 November 2012, at least four birds were seen ~ eight km south of Little Tooley Wooley Waterhole, 27º 57' 02" S, 141º 51' 41" E.

C3. 5 November 2012, two birds were seen ~ four km south of C2, 27º59' 19" S, 141º 51' 58" E.

C4a. 6 November 2012, two birds were seen ~ seven km south of Wooroogoorah Waterhole, east of Ballera Gas Centre, 27º 25' 39" S, 141º 58' 43" E.

C4b. 6 November 2012, two birds were seen ~ 400 m north-west of C4a, 27º 25' 29" S, 141º 58' 37" E.

C4c. 6 November 2012, one or more birds were seen ~ 300 m north of C4b, 27º 25' 19" S, 141º 58' 34" E.

C4d. 6 November 2012, one or more birds were seen ~ between C4a and C4b, 27º 25' 34" S, 141º 58' 37" E.

C4e. 13 September 2013, two were heard and one seen 200 m east of C4b and north of C4a, 27º 25' 30" S, 141º 58' 47" E.

C4f. 13 September 2013, two were heard and one seen 200 m east of C4c and north of C4e, 27º 25' 24" S, 141º 58' 43" E.

C5. 21 May 2013, at least two birds were heard in rain but not seen ~ six km east of Bogaller Waterhole, 27º 19' 41" S, 142º 03' 16" E.

C6. 23 May 2013, three birds were seen ~ three km east of Widindra Waterhole, in Buncheeda Swamp, 26º 53' 26" S, 141º 57' 34" E.

C7. 11 September 2013, two birds were heard and one seen briefly near the northern end of Widindra Waterhole, 26º 52' 25" S, 141º 54' 15" E.

C8. 12 September 2013, two birds were seen at a locality in Buncheeda Swamp where possible calls had been detected in May, 26º 52' 28" S, 141º 58' 32" E.

Note that sites C4a to C4f are close to Cooper Creek site 2 of 14 December 2001, listed in the main text.

North-east of Goyder Lagoon

G1a, b. 13 August 2012, two sightings, each of two birds, about 300 m apart, north-east of Moongara Crossing, ~ 26º 29' S, 139º 36' E.