Corella, 2023, 47: 65-76

Foraging areas and habitat utilisation of Bulloo Grey Grasswrens (*Amytornis b. barbatus*) in Narriearra-Caryapundy Swamp National Park, north-western New South Wales

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Received: 20 June 2023
Accepted: 16 August 2023

The threatened Bulloo Grey Grasswren (*Amytornis b. barbatus*) was studied over a 6-year period in the ephemeral flood channels of the Bulloo River system, within the Narriearra-Caryapundy Swamp National Park, NSW. Building on earlier work, this study aimed to better delineate the size of foraging areas and determine the vegetation communities in which these birds forage and roost. VHF radio tracking was used to obtain multiple point locations for each of 13 individual birds, through time. These were used to estimate the size of individual foraging areas. Vegetation communities were mapped over orthomosaics generated from drone-captured images. Bird point locations were then plotted over vegetation communities to assess habitat utilisation. Roosting and foraging occurred primarily within Lignum thickets (52.6%), and birds foraged in Old Man Saltbush (30.6%), Swamp Canegrass (5.6%) and mixed Old Man Saltbush/ Swamp Canegrass (11.2%) communities. The average adult Grey Grasswren foraging area (43.7 ha) far exceeded those published for congeners. The size of the average male foraging area (61.9 ha) was much larger than females (34.6 ha). Males also made the longest movements within a day, suggesting that males may be more nomadic within their limited habitat than females. In 2022, a pair of tracked females was found to remain with a juvenile bird for 19 days, highlighting the need for further investigation into group dynamics and possibly cooperative breeding in this species. This species requires large areas of flood channel containing multiple vegetation communities for long-term persistence.

Keywords: Grey Grasswren; radio-tracking; foraging areas; habitat utilisation; drone survey

INTRODUCTION

Grey Grasswrens *Amytornis barbatus* inhabit the Channel Country of S-W Queensland, N-W New South Wales and N-E South Australia where they occur in isolated areas along sections of the Bulloo, Warburton and Diamantina Rivers, and the Eyre and Cooper Creeks, especially where these water courses broaden into flood plains and/or swamps/lagoons (Black *et al.* 2015). Two subspecies have been formally recognised *A. b. barbatus* and *A. b. diamantina* with the later found along the Diamantina River and Eyre Creek. A poorly studied isolated population restricted to the Cooper Creek drainage system may be a genetic mix of both subspecies (Black and Gower 2017).

The Bulloo Grey Grasswren *Amytornis b. barbatus* (hereafter Grey Grasswren) is an elusive species and its isolated semi-arid habitat makes it a difficult species to study. Its recorded distribution is restricted to the river channels, ephemeral lakes and swamps along the lower reaches of the Bulloo River in north-western New South Wales and south-western Queensland. Its preferred habitat encompasses tall thickets of Lignum *Duma florulenta* and Swamp Canegrass *Eragrostis australasica* within flood channels and around the edges of lakes and swamps, and adjacent areas of Old Man Saltbush *Atriplex nummularia* and Samphire *Tecticornia* spp. (Hardy *et al.* 2021). Its diet consists of seeds, insects (including larvae, ants and beetles) and aquatic snails (Baker and Vestjens 1984).

The Grey Grasswren is listed as *Endangered* at both national and Queensland state levels (Environment Protection and Biodiversity Conservation Act 1999 and Nature Conservation Act 1992 respectively) and *Vulnerable* in New South Wales (Biodiversity Conservation Act 2016). In the 2010 Action Plan for Australian Birds, the conservation status of this species was *Endangered*, but due to the establishment in 2020 of the Narriearra-Caryapundy Swamp National Park (N-CSNP) (Fig. 1) and an estimated increase in numbers in the Bulloo System north of the NSW/Q'ld border (Jaensch *et al.* 2013, 2014) this was reduced to *Near Threatened* in 2020 (Hardy *et al.* 2021).

Our research was carried out in N-CSNP (Fig. 1) which was dedicated in 2020 when the NSW Government acquired *Narriearra Station*. In early 2023 the *Thurloo Downs* grazing property, adjoining the eastern boundary of N-CSNP was also acquired for a proposed new national park (Department of Planning and Environment 2023). This as yet unnamed new national park together with N-CSNP will permanently reserve virtually all of the Grey Grasswren potential habitat and known distribution in New South Wales. A small population has been reported (W. O'Connor previous owner of *Narriearra Station*, *pers. comm.*) occurring within a small portion of Caryapundy Swamp in the north-eastern corner of the cattle grazing property *Onepah* which adjoins N-CSNP to the west, although this has not been confirmed (Fig. 1).

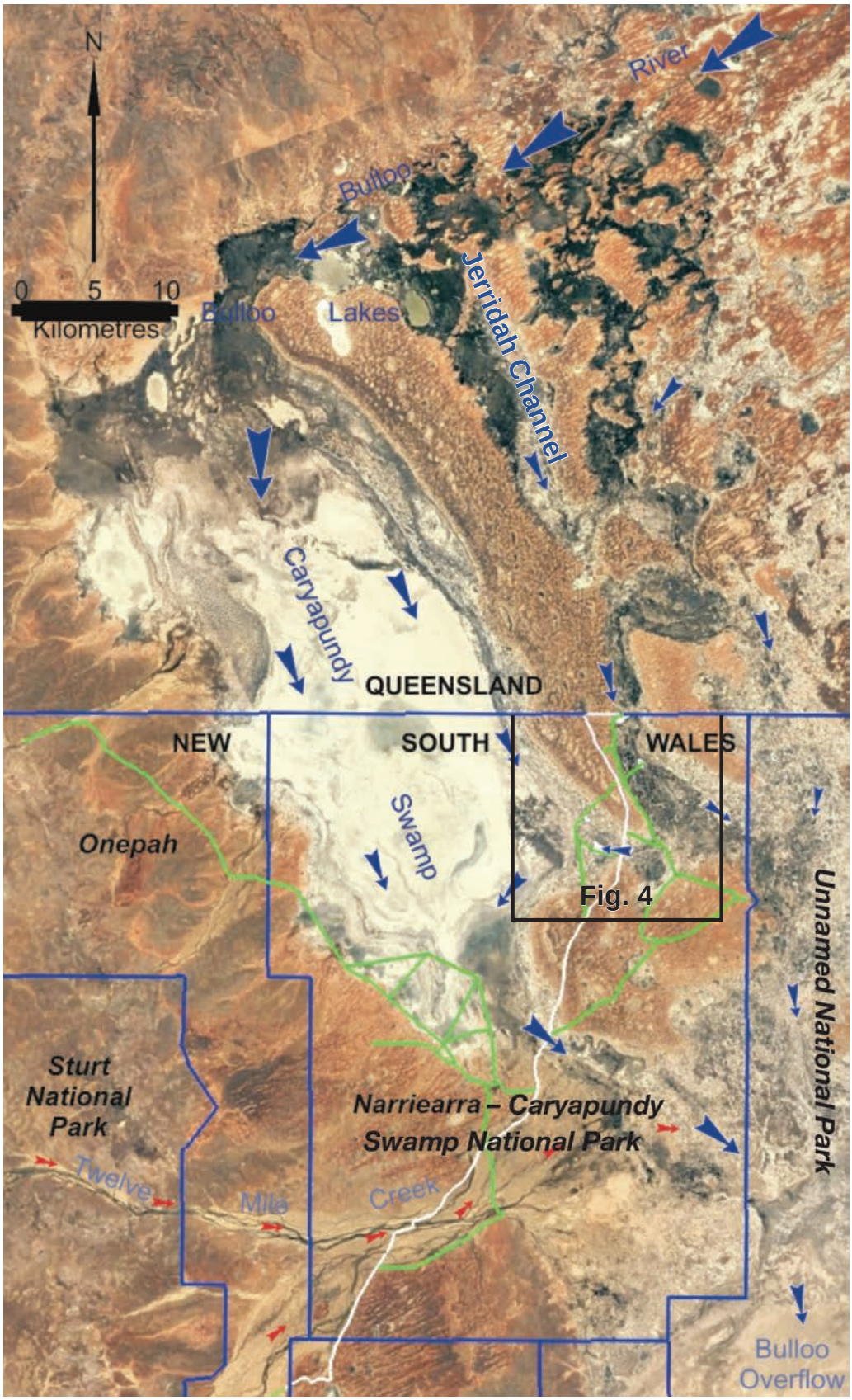


Figure 1. *Satellite image of Narriearra-Caryapundy Swamp National Park showing flow directions of flood waters as they cross the New South Wales/Queensland border and terminate in the Bulloo Overflow. White line = main road to Adelaide Gate; green lines = service tracks (after Farrell et al. 2018).*

Image courtesy of Google Earth

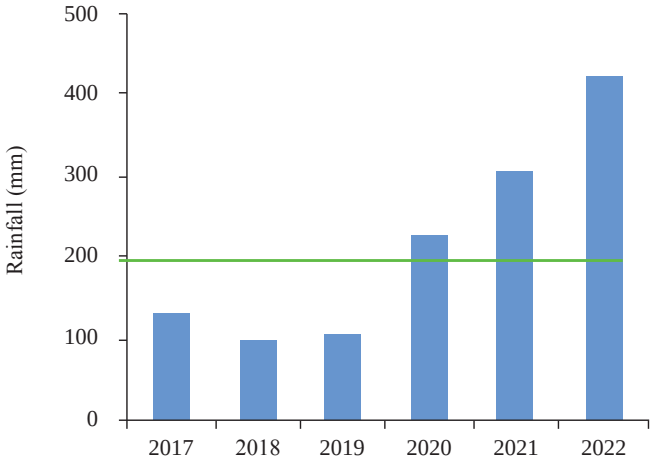


Figure 2: *Total rainfall (mm) at Tibooburra Airport from 2017-2022. Green line indicates long-term annual average (BOM).*

South Wales/Queensland border, approximately 70 km east of Tibooburra. It covers an area of approximately 152 000 ha (Fig. 1) and encompasses a range of habitats from gibber flats, sand dunes, claypans, woodlands to ephemeral rivers, creeks, lakes and swamps. The Bulloo River, the major water source for the N-CSNP, is situated within an isolated drainage system in south-western Queensland.

This arid region is prone to droughts and periods of extensive heavy rain leading to flooding (Figs 2-3). The 2017 pilot radio-tracking study data were collected at the commencement of a major drought period. Drought conditions persisted into 2019**,** turning it into one of the most devastating in living memory (W. O'Connor previous owner of *Narriearra Station*, *pers. comm.*; Bureau of Meteorology 2023). Above average rainfall then progressively increased over the following 3 years with the accompanying rejuvenation of vegetation.

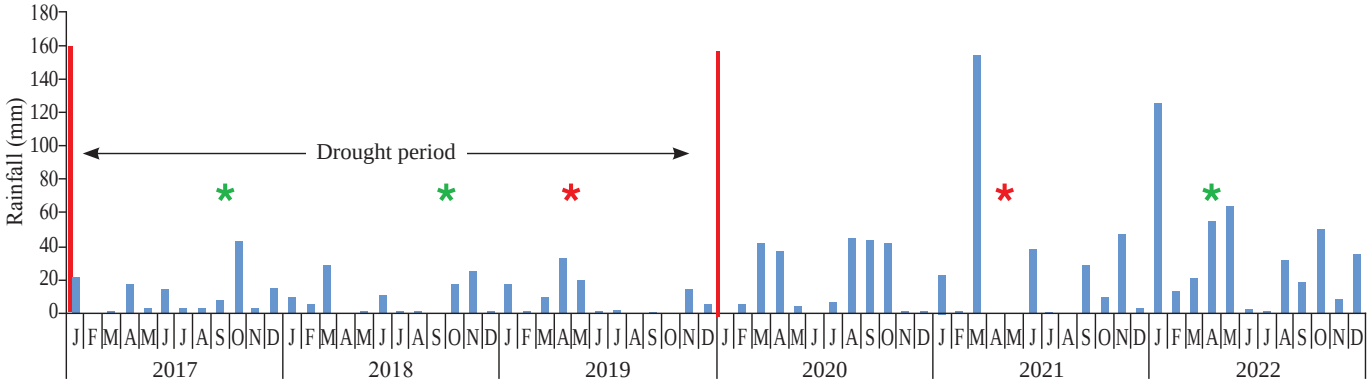


Figure 3: *Monthly rainfall registered at Tibooburra Airport (BOM). Green asterisks = visits to site where Grey Grasswrens were captured; red asterisks = visits that were aborted on arrival.*

A radio-tracking pilot study of Grey Grasswrens on N-CSNP was carried out in 2017 (Farrell *et al.* 2018) and 4 grasswrens were successfully tracked over a period of 11 days. Our primary aim was to extend this program and to hopefully track at least 15–20 birds over the following 2–3 years to better delineate their movements and the size of their foraging territories, and understand habitat utilisation. In doing so, we also aimed to gain understanding about roosting habitat, group cohesion and responses to variation in climate patterns.

Research in this semi-arid region brings many challenges and these caused the project to be extended to 5 years due to: strong winds and dust storms (2018), flood waters that originated from local torrential storms which completely blocked access to the study area (2019), restricted travel due to COVID -19 (2020) and storms that delivered extensive local rainfall in addition to residual 2019 Bulloo River floodwaters made tracks across the area impassable (2021).

METHODS

Location

The study was conducted in N-CSNP, which is situated in arid north-western NSW Channel Country adjacent to the New

Study Area

The study area is situated within a flood channel of the Bulloo River (80 – 85 m asl) and extends from the NSW/Q'ld border to Bullagree Tank. It is constricted by sand ridges to the west, east and south. These ridges feature NE-SW trending dunes which are punctuated by small to large claypans (Fig. 4).

The flood channel can be partly filled by local rain but water only flows when rain from cyclones or monsoons falls over the river's upper catchment. Flood waters then flow in a general southwards direction, filling the river's many overflow channels and lakes (Fig. 1). They enter the study area through the Jerridah Channel at Adelaide Gate and flow in a mainly southerly direction, firstly broadening and then splitting into two channels with the shallower eastern channel flowing through the new unnamed national park and directly south into the Bulloo Overflow. The westerly flood channel passes between two sand ridges and along a shallow river channel which then broadens into a large embayment to the south. At Bullagree Tank the channel again narrows. Water then flows into the broad depression of Caryapundy Swamp and terminates at the Bulloo Overflow where it eventually evaporates (Figs 1 and 4). Most of the flood channels in the study area are akin to a reticulated braided system (Shelley 1976). Sandy hillocks, 1-3 m in height

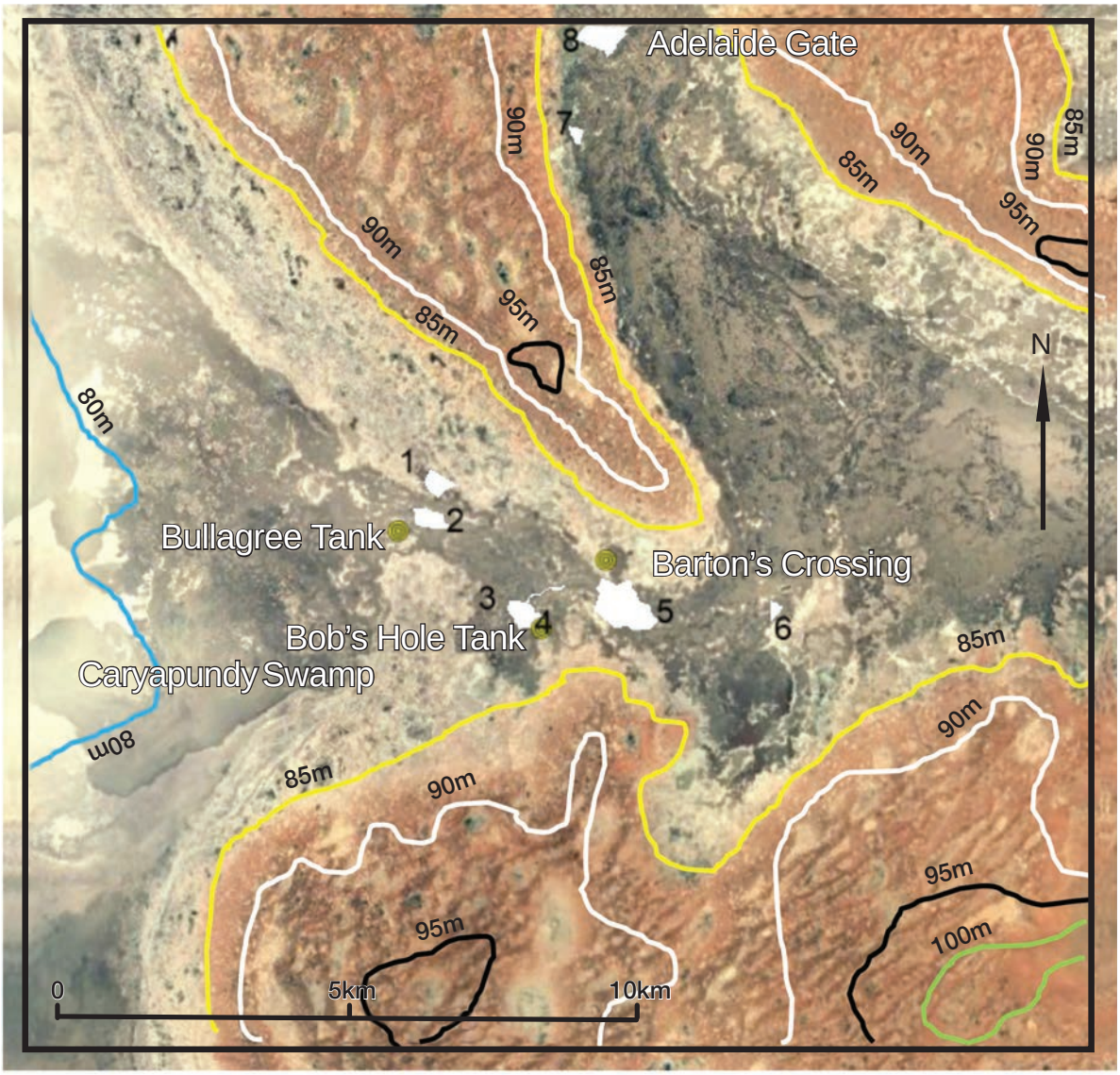


Figure 4. *Study area showing contours and study sites: 1. Bullagree Tank North; 2. Bullagree Tank East; 3. Bob's Hole West; 4. Bob's Hole East; 5. Barton's Crossing; 6. Barton's Tank; 7. Adelaide Gate South; 8. Adelaide Gate. (after Farrell et al. 2019).*
Image courtesy of Google Earth

and held together by various plants (predominantly Old Man Saltbush), are distributed intermittently along these channels. In between these hillocks are many small to large claypans.

Vegetation in the study area was not seriously impacted during the drought in 2017, but as these conditions continued to worsen through 2018 only the hardiest larger clumps of Lignum and saltbush survived (Farrell *et al.* 2019).

During our banding projects (Hardy 2010: Farrell *et al.* 2014, 2015, 2019), the number of study sites was gradually increased to 8 (Fig. 4) to monitor Grey Grasswren numbers and distribution along the flood channel from Adelaide Gate to Bullagree Tank. These were chosen as Grey Grasswrens were either sighted or trapped there previously.

Radio tracking

Individual Grey Grasswrens were captured using 2-4 shelf mist nets (31 mm mesh size) with the bottom shelf-string positioned on the ground. A metal band was placed on the birds' right legs and their sex and morphometric measurements were recorded. Then a small VHF radio transmitter (PicoPip glue-on transmitters LT5-337 (15 mm x 8 mm; frequency ranges 149.000 –152.999 MHz; 57 ppm (10 msec) with 150 mm aerial, weighing 0.6 g and a battery life of approximately 14-21 days)) was attached to the interscapular area of each bird (see Farrell *et al.* (2018) for method details), during surveys in the autumn of 2017 and 2022, and the spring of 2018.

To establish the point locations of individual birds, compass bearings in the direction of the strongest transmitter signal obtained by the receiver (Australis 26K™ (149.0000 to 152.9999 MHz) with a folding Yagi three element type, hand-held (151MHz) omnidirectional antenna) were taken from three (2017) and then, due to terrain and weather restrictions, two (2018 and 2022) known reference points in the field. These point-direction combinations were subsequently mapped as lines, with their intersection denoting the coordinates of the point

Table 1

Number of tracked positions located within each listed plant community for 13 birds radio-tracked in 2022, 2018 and 2017 and the total number of days each was tracked. Percentage of different plant community utilisation by individual birds at each site.

Plant Communities	2022							2018		2017				
	Bird Codes													Total
	1	2	3	4	5	6	7	B_1	B_2	BNA	BCB	BCC	BHD	
	Site 5				Site 3	Site 2		Site 2		Site 1	Site 5		Site 3	
Lignum	10	9	14	6	7	3	2	13	11	10	7	8	3	103
Old Man Saltbush	5	5	6	4	1	0	0	11	10	8	3	1	6	60
Canegrass	1	0	1	0	1	0	0	1	4	0	2	1	0	11
Lignum/Canegrass	4	8	1	1	0	0	0	0	0	0	3	5	0	22
Total No of points	20	22	22	11	9	3	2	25	25	18	15	15	9	196
Total No of days	9	10	10	5	5	1	1	9	7	6	7	7	5	82
Percentage														**Average**
Lignum	50	41	63	55	78			52	44	56	47	53	33	52.6
Old Man Saltbush	25	23	27	36	11			44	40	44	20	7	67	30.6
Canegrass	5	0	5	0	11			4	16	0	13	7	0	5.6
Lignum/Canegrass	20	36	5	9	0			0	0	0	20	33	0	11.2

location. Fieldwork logistics and the limited range of the small transmitters meant that different numbers of point locations were collected among the birds that were radio-tagged. Furthermore, the signal from the VHF transmitter travels in a direct line, so birds may also have been occupying very dense thickets of Lignum, or were behind sand dunes, when a transmitter signal could not be detected. The field data required to establish point locations was collected twice (sometimes three times) per day, for a varying number of days (Table 1).

Habitat assessment

One of the main aims of this research was to increase understanding of Grey Grasswren habitat utilisation. Earlier results, which are incorporated in this study, found that individuals can often range over many hectares in a short period of time (Farrell *et al.* 2018)**,** so to maximise survey efficiency in this remote field location, we elected to use remote sensing to obtain habitat data. Freely available satellite images from Google Earth and SixMaps (NSW Government Spatial Services) were used in a previous report to the NSW Office of Environment and Heritage (Farrell *et al.* 2019) to outline the broad extent of vegetation communities. However, this imagery was not sufficiently high in resolution to enable accurate definition of vegetation communities as Grey Grasswren habitat. To obtain high-resolution images, a drone (DJI Mavic Pro) was utilised to capture images over most of the areas where Grey Grasswrens were captured. Pix4Dcapture (4.13.1(1), Pix4D, Switzerland) was installed on an Apple iPad and used to delineate the area to be photographed and to set the parameters for the drone's flight and camera settings (flight height = 50 m; front overlap = 80%; side overlap = 70%; camera angle = 90º; picture trigger = fast; drone speed = fast). Once individual flights were programmed in this way, drone flights were run automatically using Pix4Dcapture.

Orthomosaic made up of drone-captured images were produced using Pix4Dmapper Pro (4.0.25, Pix4D, Switzerland). Individual bird point locations from tracking were plotted over these high-resolution (~2-cm pixel) orthomosaics to establish the underlying vegetation community. Basemaps (ESRI ArcMap 10.8.2) were incorporated where drone orthomosaic coverage was unavailable.

Vegetation

Three distinct, virtually mono-specific communities (Old Man Saltbush; Lignum; Swamp Canegrass) occur within the foraging areas of tracked Grey Grasswrens (Fig. 5; Farrell *et al.* 2018). These communities are formally described in Farrell *et al.* (2019) with a preliminary map showing the extent of these communities across the study area. While there are areas where these communities predominate, there are other areas where they blend. Old Man Saltbush is generally found growing on sand ridges and sand hummocks within flood channels, while Lignum and Swamp Canegrass generally grow along flood channels and in claypans.

RESULTS

In 2018, although an extensive survey of our 8 sites was carried out (Fig. 4), it resulted in the capture and radio-tracking of only 2 Grey Grasswrens at Bullagree Tank East (Site 2). Trips in 2019 and 2021were aborted on arrival due to flood waters preventing access to all of our study sites. In 2022 our team was restricted to a smaller study area of just 4 sites (Nos 1, 2, 3 and 5) due to heavy rainfall in the area which flooded many claypans, particularly to the north and east of Barton's Crossing. Although 7 Grey Grasswrens were trapped, 2 (both males) dispersed from their capture site at Site 2 just 2 days after capture and, even after extensive searching; their signals were not recorded again. The data for these two individuals was very limited, so we did not use it further. The final data set used for this study included point locations for 11 birds (Table 1). These were the other 5 birds tracked in 2022 (Hardy 2022), the 2 birds tracked in 2018 (Farrell *et al.* 2019) and the 4 individuals captured and monitored in 2017 (Farrell *et al*. 2018) – bringing the total number of radio-tracked Grey Grasswrens to 11 birds.

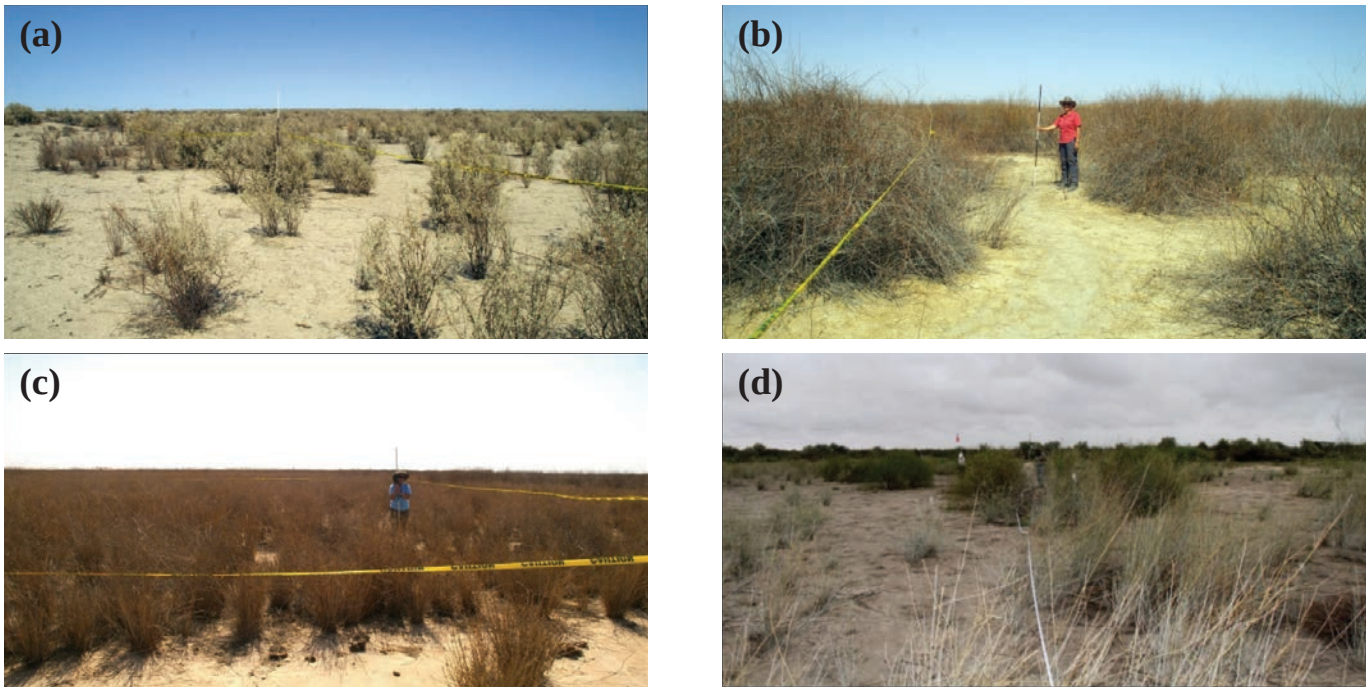


Figure 5. *Photographs of (a) Old Man Saltbush Community; (b) Lignum Community; (c) Canegrass Community; (d) Lignum/Canegrass mix. The poles in each photograph are 2 m in length.*

The results presented below utilised data collected from 2017, 2018 and 2022 which encompassed both drought and above average rainfall periods.

Foraging areas

Estimation of the area of animal foraging areas using point locations obtained from radio telemetry requires an adequate number of points, such that the size of the area reaches a point where it does not substantially increase with the addition of new locations (Kernohan *et al.* 2001). To check whether the area used by individual birds had stabilised at the conclusion of tracking, the effect of increasing the number of point locations on the area of minimum convex polygons encompassing the points was visually inspected (Fig. 6). The area of minimum convex polygons had stabilised, i.e., ceased to increase, for seven birds (BCB, BCC, BTN, B2, 1, 2 and 3) of the 11 individuals. As such, averages presented for Grey Grasswren foraging areas do not include the 4 birds with foraging areas that showed an increasing trend (BHW, B1, 4, 5).

The area of minimum convex polygons around the set of point locations are presented in Table 2. The size of Grey Grasswren home ranges was highly variable across seasons and years (Figs 6-8, Table 2). The average area of foraging areas for adults was 43.7 ha (range 15.7 – 108.1 ha). The foraging area for the juvenile was much smaller at 6.2 ha. It appears from our limited data that males on average use larger foraging areas than females (61.9 and 34.6 ha respectively). The average area is conservative given that some of the birds with increasing ranges were using larger areas than the average for birds with stable ranges. During the tracking period most individual adults made one or two longer movements away from their core foraging areas and then returned. This was not the case for two males (Nos 4 and 5) which moved away from their initial foraging area to a new area 1.3 and 1.7 kms away respectively and did not return during our tracking period (Fig. 8). Birds 4 and B_2 recorded the greatest maximum distances travelled in one day – 1.3 km and 1.6 km respectively (Farrell *et al.* 2019).

Roost sites

In 2017, radio tracking showed that one male and female bird at the Barton's Crossing (Site 5) roosted in close proximity to each other in an approximately 4.6 ha area on all nights that tracking occurred (Farrell *et al.* 2018). The two male birds tracked at Bullagree Tank (Site 2) in 2018 didn't follow this pattern and were tracked roosting separately in Lignum thickets at various different locations within their foraging areas and didn't seek out the same location on successive nights. Seemingly these two males were opportunistic and roosted in the nearest Lignum thicket when night fell (Farrell *et al.* 2019).

Group cohesion

We sought to increase understanding of the extent to which this species forages in groups or as individuals. On the morning of 18th April 2022 4 Grey Grasswrens (2 females (Bird 1 and 3), 1 male (Bird 4) and a juvenile (Bird 2)) were captured simultaneously in the same net at Barton's Crossing (Site 5) and transmitters attached and checked that they were functioning before being released. In that afternoon only Bird 3 was detected near the release site (Fig. 9A) – the rest had vacated the area. On the following morning (19th), Bird 3 had joined Bird 4 and were located together 1.1 kms to the north of the release site (Fig. 9A). Later that morning Bird 2 had returned to the release site and Bird 3 and Bird 4 had moved towards Bird 2 (Fig. 9B). By the afternoon of the following day (20th) all 4 birds were in close proximity to each other near the capture site (Fig. 9C).

On the afternoon of the 22nd Birds 1, 2 and 3 were located together but Bird 4 was not detected (Fig. 9D) at the site. Three days later on the morning of 25th, Bird 4 was recorded 1.3 kms to

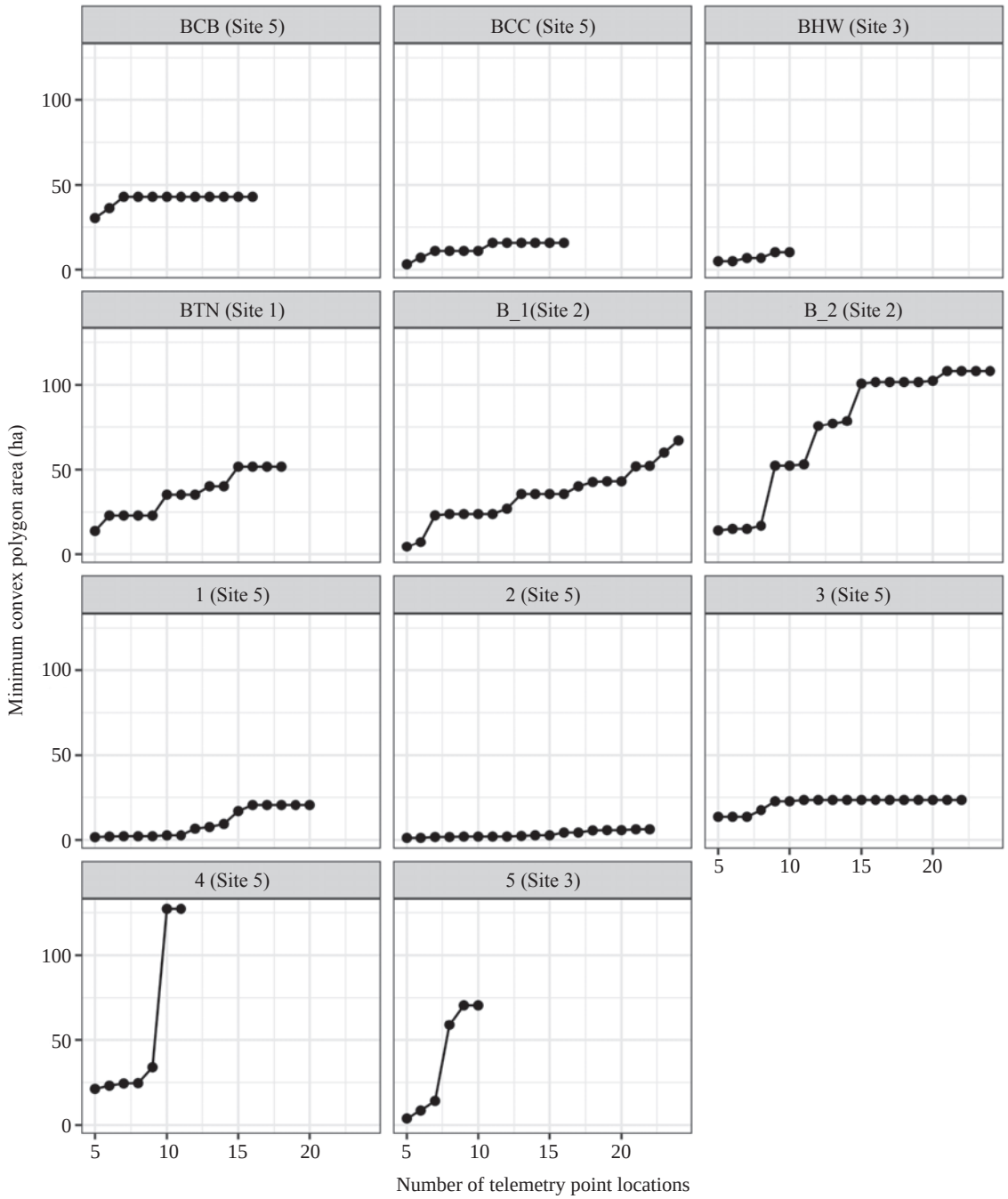


Figure 6. *The effect of increasing the number of telemetry point locations on the area of minimum convex polygons representing habitat space use by individual Grey Grasswrens during radio-tracking.*

the west (Fig. 9E). This was the last record we obtained for Bird 4 and we surmised that it continued to travel farther away and out of range of our receiver. We continued to track the remainder of this group which was still together on 5th May (a total of 19 tracking days) when our research was concluded (Fig. 9F).

The juvenile (Bird 2) had the smallest foraging area and did not venture far from it. Bird 2 was attended by the other three birds at the beginning of the study but then by only the females after 5 days post capture. It is possible that even though the birds dispersed after release, they came back together to reestablish their group within their foraging area and to attend to the juvenile bird.

An adult male (Bird 5) captured at site 3 (Fig. 9G) on 22nd April was recorded approximately 0.5 kms north on 24th before returning to the initial area on 25th. It was not recorded again until 5th May when it was recorded in the general area of the cohesive group mentioned above. It is not clear if this male joined this group as tracking was terminated at this point due to inclement weather.

Habitat utilisation

Drone images allowed a clear delineation of the distribution of plant communities within the foraging areas used by tracked birds. This allowed more precise calculations of the habitat

Table 2

Minimum convex polygon areas for all tracked birds. Birds with stabilised foraging areas over the tracking period denoted by *.

Year Tracked	Bird ID (Adult/Juvenile - Sex)	Min. convex polygon (ha)
2022	1(AF)*	20.5
2022	2(J)*	6.2
2022	3(AF)*	23.4
2022	4(AM)	127.2
2022	5(AM)	70.6
2018	B_1(AM)	67.1
2018	B_2(AM)*	108.1
2017	BCB(AF)*	42.7
2017	BCC(AM)*	15.7
2017	BHW(AM)	10.2
2017	BTN(AF)*	51.7

utilisation by birds than those presented in Farrell *et al.* (2019). When all foraging areas over our three surveys (Table 1) are combined, the Lignum community was the most frequently visited community, recording 52.6% of all visits with the Old Man Saltbush community at 30.6%, the mixed Lignum/Cranegrass community at 11.2% and Swamp Canegrass community 5.6% (Table 1). The Lignum community coupled with the Old Man Saltbush community represented over 80% of bird point locations. All 4 communities were used for foraging but Lignum thickets provided much better cover.

DISCUSSION

In this study, Grey Grasswrens were located in the three major plant communities and in the mixed Lignum/Swamp Canegrass community, within the flood channel. A summary of habitat utilisation for both subspecies, *A. b. diamantina* and *barbatus*, by Black *et al.* (2011) found that they used the three major communities found in our study site as well as samphire and a range of sedges and rushes associated with flooding. Janensch *et al.* (2013) state that Grey Grasswrens in the Bulloo Lakes wetland system (Fig. 1) were only detected within cojoined Lignum clumps but they did not investigate Old Man Saltbush habitat in the area (A. Black *pers. comm.*). Tracked birds spent half their time foraging within areas of Lignum, and also moved into the Old Man Saltbush and Swamp Canegrass communities to forage, before returning to Lignum thickets. The dense lignum thickets presumably provided better protective cover than smaller patches of Old Man Saltbush growing on the sandy hummocks within the flood channels. Robertson (1973) observed that Grey Grasswrens always made for Lignum thickets when danger threatened. They went into hiding when crows flew over and kept under cover when a Nankeen Kestrel was hovering nearby.

We did not record any Grey Grasswrens travelling away from the flood channels and onto the major sand ridges. As such, Grey Grasswrens appear to use resources across multiple vegetation communites within the flood channels, so management that maintains the Bulloo River as an unregulated system and promotes a suitably distributed mix of favoured communities is likely to be important for the ongoing persistence of this species.

Some of the Grey Grasswrens in the present study were trapped together and/or were found to co-occur in the tracking results, which in terms of group cohesion is broadly consistent with the findings of other studies. Janensch *et al.* (2013) recorded Grey Grasswrens in pairs or possibly 3 birds at 9 sites within the Jerridah Channel (Fig. 1), while in a later study encompassing the Bulloo Lakes area (Janensch *et al.* 2021), they recorded some groups of 5 or more Grey Grasswrens. Grasswren spp. can form groups of 4-7 members but are generally found in pairs (Black and Gower 2017). Hardy (2002) reported that large numbers of Grey Grasswrens congregated in a small 11 ha study area on the north-western fringe of Caryapundy Swamp on the Queensland side of the border in the early 1990s. In 1991, 47 Grey Grasswrens were captured over a 4-day period, 33 were captured over a 3-day period in 1992 and 82 were captured over 4 days in 1994. On a subsequent visit in 2000 this grasswren habitat had been destroyed due to ringbarking of Lignum branches by rabbits and the uprooting of thickets by pigs (JH, *pers. observ.*).

In 2022, evidence of cohesive group associations within established foraging areas was found that may suggest some form of cooperative breeding, in that two adult female birds remained with the juvenile during the tracking period. It has been suggested that other grasswren species (e.g. Striated, Black, White-throated, Carpentarian and Dusky) may participate in cooperative breeding but direct observations of helpers at nests are limited to only Western and Thick-billed Grasswrens (Black and Gower 2017). The largest group encountered in this study was 5 birds; 4 of which were radio-tracked at site 5. The composition of this group comprised 2 females, 1 male, a juvenile and 1 unknown sex. The male only remained with the tracked group for 4 days before vacating the area, while the females remained with the juvenile for the total tracking period (19 days).

In our study, foraging areas for adult Grey Grasswrens averaged 43.7 ha. This is larger than the averages recorded for some other grasswrens species: White-throated Grasswren *A. woodwardi* = 10 ha (Noske 1992); Thick-billed Grasswren *A. modestus* = 8 ha (Louter 2016); Western Grasswren *A. textilis* = 1 ha, and Striated Grasswren *A. striatus* = 8–12 ha (Black and Gower 2017). The high variability in the size of Grey Grasswrens' foraging areas may be a reflection of the variability of resources during drought and ideal conditions. The substantially larger foraging areas used by male birds compared with females also contributes to the total variation in foraging area size for the species.

Viable locations for Grey Grasswren foraging across the wider area may contract to local refugia during drought periods. After visiting our sites 1-8 (Fig. 4) during the 2018 drought period, several birds were sighted at Site 7 and 5 and along the river channel between Sites 4 and 5, with 2 birds being captured and radio-tracked at Site 2. The area along the flood channel between Sites 1 and 6 may be a refuge during drought periods, as the channel bed is deeper along parts of this stretch and pooled water would provide greater moisture availability to support the vegetation during dry periods. In addition 3 tanks (dams) are situated along this area, i.e. Barton's Tank at Site 6, Bob's Hole Tank and Bullagree Tank (Fig. 4). Rain water which fills these tanks persists into dry periods. Jaensch *et al.* (2021) suggested that a refuge might exist in the northern parts of the Bulloo Lakes floodplain which receives the initial influx of water from the Bulloo River before it disperses across the floodplain.

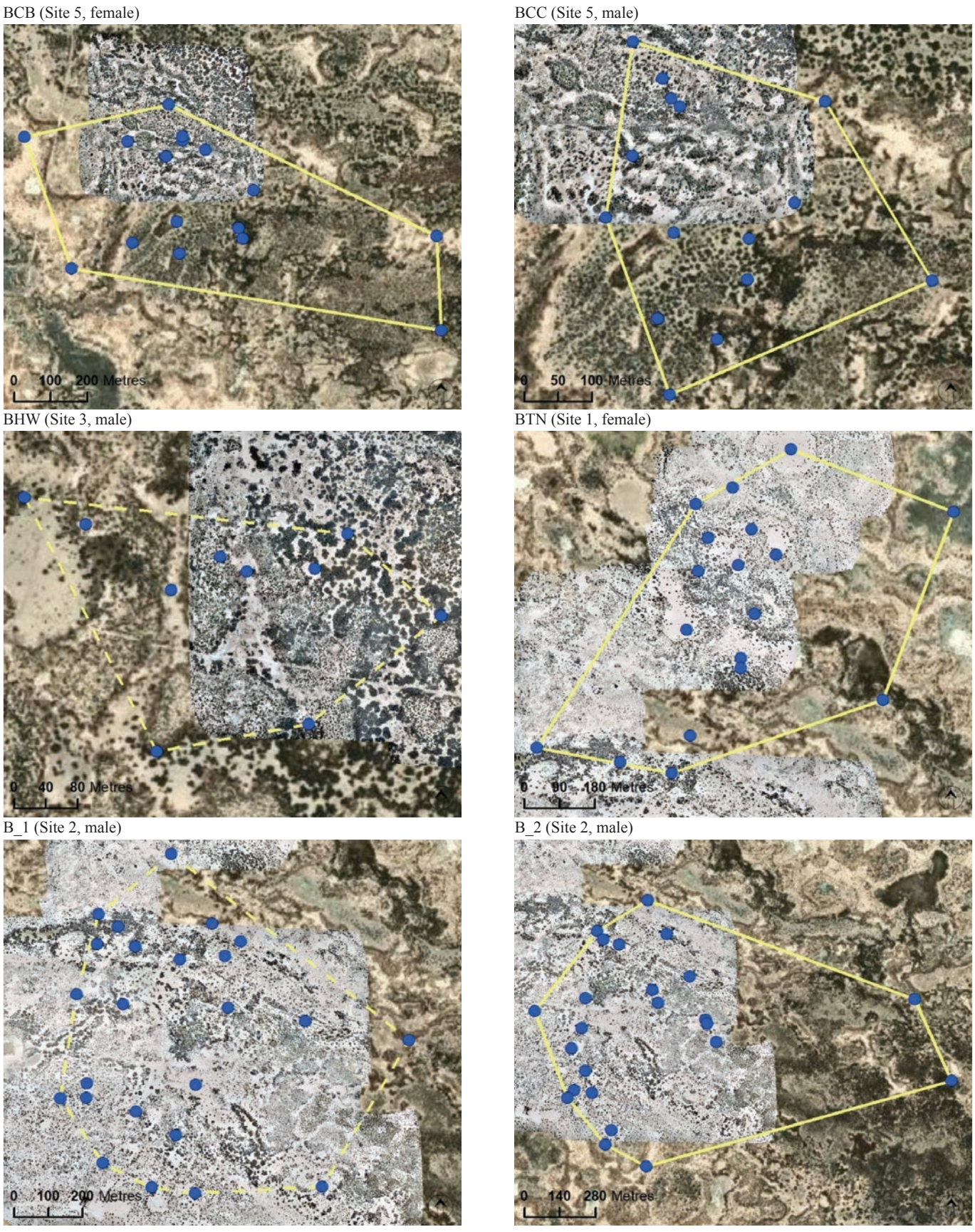
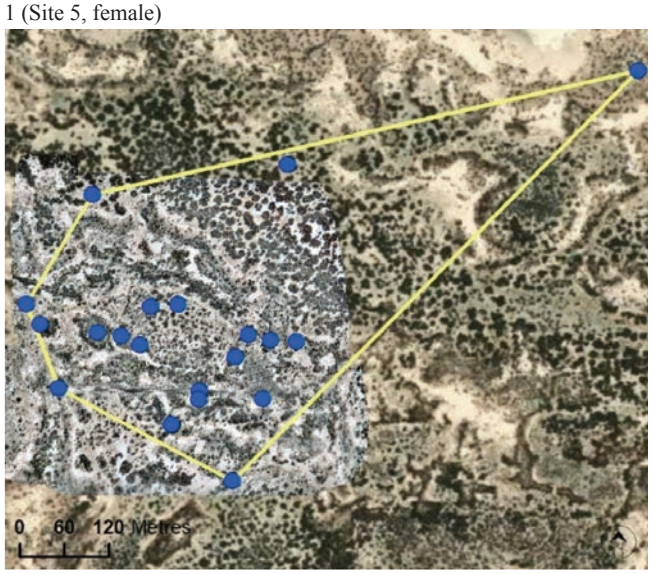
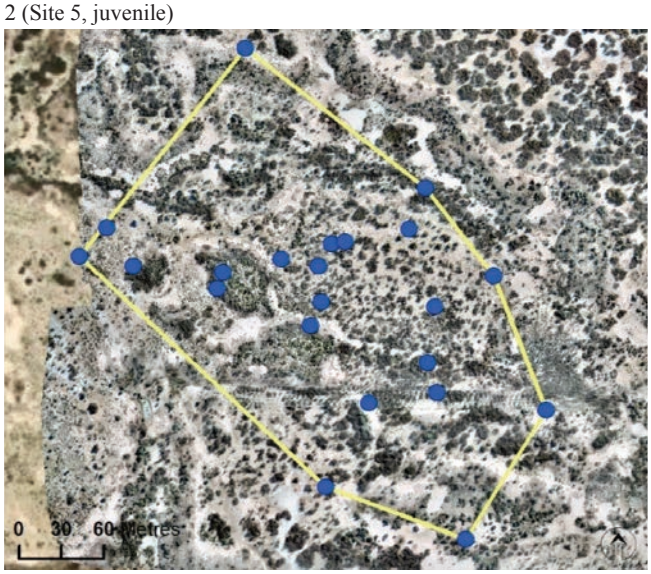


Figure 7. *Bird point locations obtained from radio telemetry during 2017 and 2018 (blue circles) with minimum convex polygons (yellow lines). Solid lines indicate that the size of individual ranges had stabilised and dashed lines show that individual habitat space use was increasing (Figure 6). Basemaps (ESRI) are overlaid by orthomosaics produced by the authors from drone-captured images.*

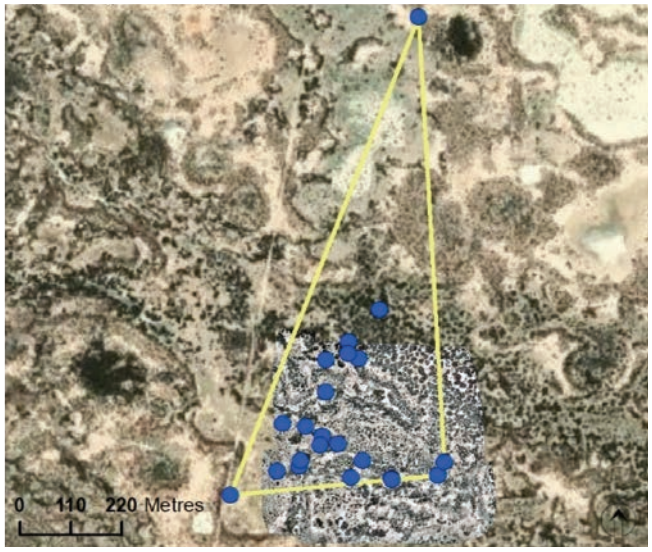
1 (Site 5, female)



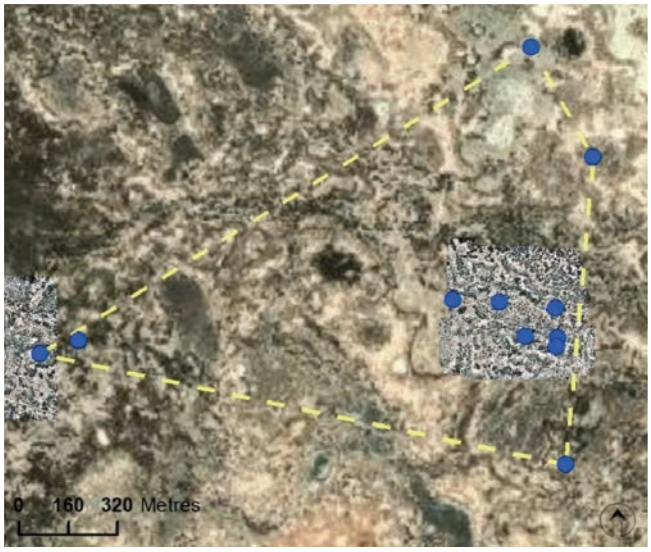
2 (Site 5, juvenile)



3 (Site 5, female)



4 (Site 5, male)



5 (Site 3, male)

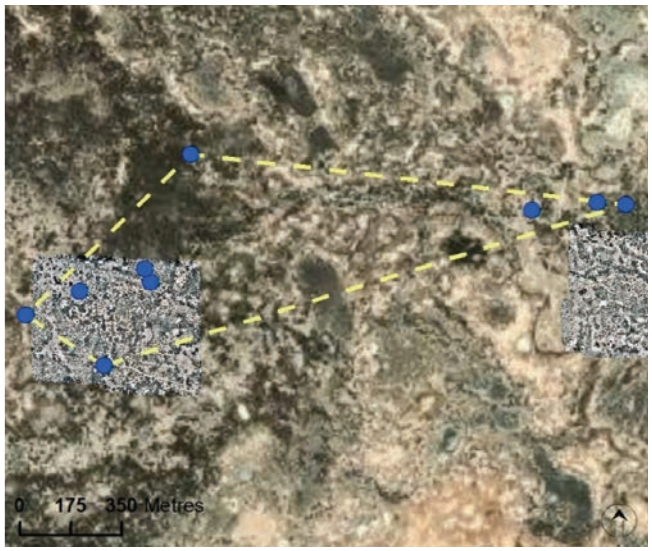
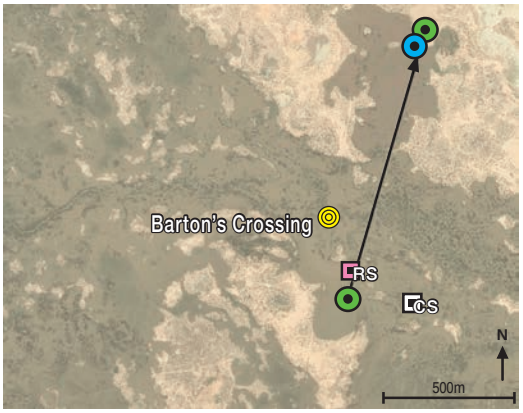
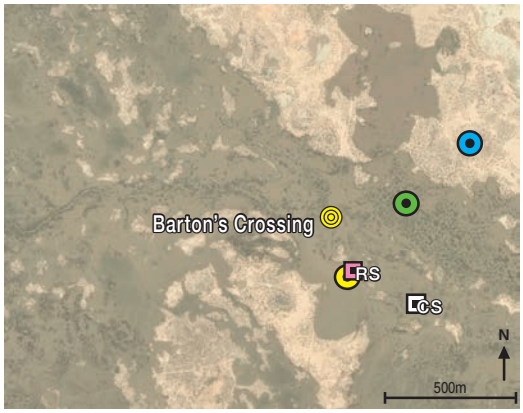


Figure 8. *Bird point locations obtained from radio telemetry during 2022 (blue circles) with minimum convex polygons (yellow lines). Solid lines indicate that the size of individual ranges had stabilised and dashed lines show that individual habitat space use was increasing (Figure 6). Basemaps (ESRI) are overlaid by orthomosaics produced by the authors from drone-captured images.*

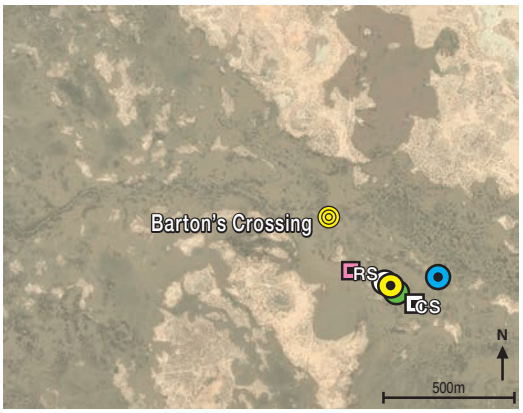
A) April 18 pm (B3) – April 19 am1 (B3 & B4)



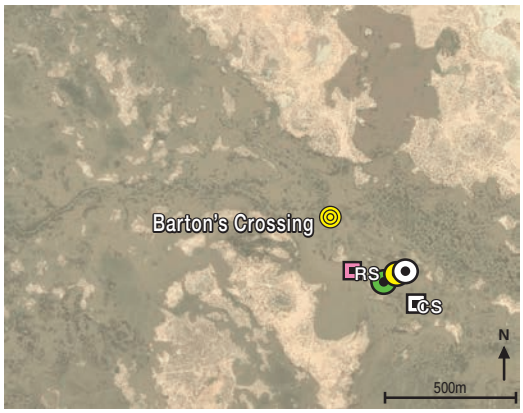
B) April 19 am2



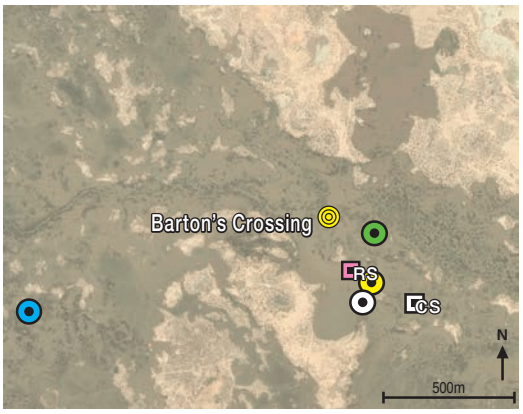
C) April 20 pm



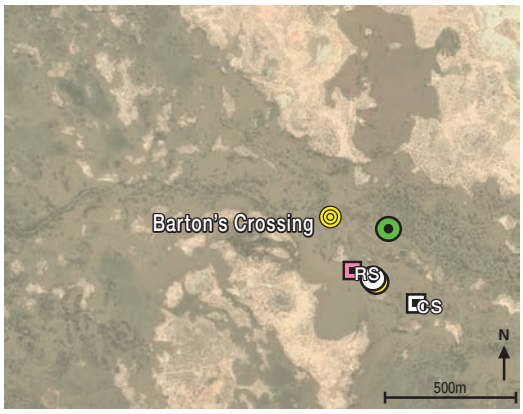
D) April 22 pm



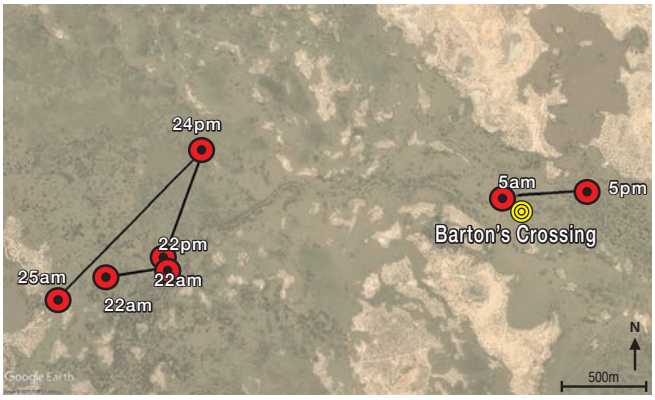
E) April 25 am



F) May 5 pm



G) Bird No. 5



Legend:
CS = Capture site
RS = Release Site
Bird 1 = White
Bird 2 = Yellow
Bird 3 = Green
Bird 4 = Aqua
Bird 5 = Red
24pm = 24 April afternoon
5am = 5 May morning

Figure 9: *Tracked positions of Bird Nos 1, 2, 3, 4 and 5 for selected dates from April 18 to May 5.*

The juvenile bird captured during 2022 had the smallest foraging area of all tracked birds at 6.2 ha. This juvenile was potentially the impetus for the return of the 3 adults to reform the group. After returning, the females remained with the juvenile, and the male travelled over 1 km away. From our limited data it appears that adult males may range farther across their habitat and travel greater distances than females.

The entire confirmed distribution of the Grey Grasswrens in New South Wales is now secure within national parks, so the prospect for their continued survival is much improved. During the course of this study, regeneration of vegetation has been noted after periods of cattle overstocking, so the permanent removal of cattle will undoubtedly result in greatly improved habitat. Nevertheless, onging management of fire and feral pest species e.g. pigs, goats, horses and rabbits, is required.

In this study, we found that Grey Grasswrens move as individuals, pairs, or in small groups over wide areas to forage in different vegetation communities in the flood channels of the region. Despite its inevitable logistical challenges, more research is required to comprehensively understand the ecology of this elusive species. An important area for future reasearch is how this species adapts to radically changing environments due to droughts and floods, which may have implications for the persistence of the species under climate change.

ACKNOWLEDGEMENTS

We wish to acknowledge the assistance of the following people: Richard Allen, Wendy Holland, Judy Little, Greg Little, Darryl McKay, Genevieve Kyi, Heather Parsons, Phillip Brown, Lorna Mee and Cassandra Taylor. A special thanks to Ros Farrell for assistance in tracking and the compilation of all the recording data on our 2022 visit. Jamie Hayman again gave permission to access the dingo fence maintinance track. We extend our gratitude to Dan Hough and Adam Watson (NSW NPWS officers) for escorting out team out of the national park through flooded and muddy tracks when we had to evacuate the area. This paper was enhanced by comments and suggestions from the two reviewers: Andrew Black and Reece Pedler. This project wouldn't have been as successful without funding and support from national park personnel involved with the Saving our Species Program of the NSW Department of Planning and Environment; Biodiversity and Conservation Division. This research was conducted under the authority of NSW National Parks and Wildlife Service Scientific Licence SL101091 and Animal Ethics Authority RVF21/76(2). Bands were supplied by the Australian Bird and Bat Banding Scheme.

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