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Observations on breeding success and flocking of Australian Sarus Cranes *Grus antigone gillae* and Brolgas *G. rubicunda* in the Gulf Plains bioregion, north-western Queensland, Australia

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Abstract. Known breeding sites of the Australian Sarus Crane *Grus antigone gillae* are concentrated in the Gulf Plains bioregion of north-western Queensland, where this species is sympatric with the Brolga *G. rubicunda*. Breeding success in cranes may be highly variable and roadside surveys in the Gulf Plains on 11 days in April–June 2014 showed that breeding success (number of young as a proportion of the number of pairs) was low, at 28% for Brolgas and 21% for Australian Sarus Cranes. This might have resulted from excessive flooding after heavy cyclonic rains during the height of nest initiation in February. At the 90 roadside sites occupied by only one species, Australian Sarus Cranes showed a significant preference for wooded habitats, whereas Brolgas were more likely to prefer open habitats and were the only occupants of saline areas. Both species were present at two grassland (open) sites and three moist woodland sites. Opportunistic observations showed that flocking (aggregations of ≥10 birds, including families) was well established on one cattle station (Miranda Downs), where both species foraged on a recently harvested hay paddock with readily accessible artificial water sources. Other foraging and wetland sites on this property were also shared by both species, suggesting that close association between them occurs more often, and earlier after the breeding season, than previously thought.

Introduction

The phylogenetically distinct Australian Sarus Crane *Grus antigone gillae* is the most genetically and morphologically differentiated as well as the least known of the four global Sarus Crane populations (Nevard *et al.* 2020a; Nevard & Scambler 2023). Its known breeding sites are concentrated in the Gulf Plains bioregion, on floodplains draining into the southern and eastern Gulf of Carpentaria, Queensland. Brolgas *G. rubicunda* also breed in the Gulf Plains. Hitherto, the only published data on breeding success were for the 2016–2017 wet season, estimated from landscape-scale roadside surveys of pairs with recently fledged young, still occupying breeding territories: 50% for Brolgas and 60% for Australian Sarus Cranes (Sundar *et al*. 2019). Nesting of both species was initiated after the first fortnight of high rainfall, but most nests were initiated later, immediately after the first major rains, and over a longer period for Australian Sarus Cranes (Sundar *et al*. 2019).

In the nonbreeding season, most cranes are gregarious and may form flocks to forage, and/or roost communally in shallow wetlands (Mirande & Harris 2019). Flocking theory for cranes is not well developed, but the most likely reasons for flocking are the exploitation of foraging opportunities, and opportunities for mate selection for unpaired birds (Sheldon 2004 and references therein), as well as learning for the young (Scambler *et al*. 2023). For both species in Australia the extent of aggregation in the nonbreeding season is not well known (Marchant & Higgins 1993). In 1997–2017, up to ~3200 Australian Sarus Cranes were estimated to flock on the Atherton Tablelands, Far North Queensland, sharing many foraging and roost sites with Brolgas (Nevard *et al*. 2019; Scambler *et al*. 2020).

The Gulf Plains are considered to be the source of most mid-year migration of Australian Sarus Cranes to the Atherton Tablelands (Mirande & Harris 2019; Nevard *et al*. 2020b) but it is possible that at least as many birds remain in the Gulf Plains throughout the year (Sundar 2019; J.D.A. Grant pers. comm.). Flocks of Brolgas in the Gulf Plains may contain some Australian Sarus Cranes (e.g. Garnett & Bredl 1985) but there have been no systematic studies in the nonbreeding season and social structure (including the extent and timing of flocking, and inter-species sharing of foraging and roost sites) is largely unknown. Moreover, opportunistic records of cranes are rare in the Gulf Plains from December to April, when seasonal flooding significantly curtails road access. In this paper we report observations by TDN of Australian Sarus Cranes and Brolgas in the Gulf Plains between 9 April and 5 June 2014 – at the end of the breeding season and beginning of the flocking season.

Study area and methods

Study area

The study took place within ~125 km of the Gulf of Carpentaria coast, mainly in the Gilbert and Norman River catchments. The Gulf Plains are a Key Biodiversity Area significant for birds including cranes (Dutson *et al*. 2009). Rainfall is strongly seasonal, falling mostly in January to March (Bureau of Meteorology 2023), and inundating extensive floodplains. The wetlands of the Smithburne–Gilbert Fan Aggregation, extending to ~2505 km^2, are listed as nationally important in the Directory of Important Wetlands in Australia (DIWA) and are significant for many avian and other species (BirdLife International 2024). Other permanent and ephemeral wetlands are scattered

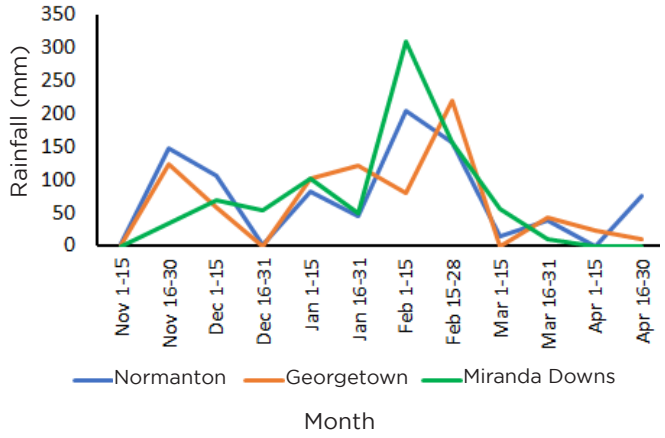

Figure 1. Fortnightly rainfall in the 2013–2014 wet season at three sites on or near the Gulf Plains (Bureau of Meteorology 2023).

throughout the bioregion (Pusey & Kennard 2009) and cranes in the Gulf Plains breed in a variety of shallow wetland types in the wet season (Archibald & Swengel 1987; Marchant & Higgins 1993; Sundar *et al*. 2019).

Average daily temperatures are highest in the study area in December (29–37°C) and lowest in July (17–29°C) (Bureau of Meteorology 2023) and we defined seasons not based directly on rainfall but on temperature and the expected extent of standing water in the landscape following seasonal rains: wet season January–April, early dry season May–August, late dry season September–December. We obtained rainfall data for the 2013–2014 wet season at Normanton (Norman River catchment), Miranda Downs (lower Gilbert catchment) and Georgetown in the upper Gilbert basin, which contributes strong flows in the wet season to downstream floodplains (Figure 1; see also Bureau of Meteorology 2023, 2024a). Total rainfall in the wet season at Normanton and Miranda Downs was slightly above average, and at Georgetown was below average. However, all three locations had high rainfall for the month of February, as a result of Tropical Cyclone Fletcher: Miranda Downs 473 mm (average 231 mm), Normanton 360 mm (average 204 mm) and Georgetown 307 (average 214 mm) (Bureau of Meteorology 2023). Rainfall in the first 2 weeks of February at Miranda Downs (308 mm) was higher than the highest fortnightly totals (200–250 mm across three catchments) reported by Sundar *et al*. (2019). Tropical Cyclone Fletcher made landfall just south of the Gilbert River mouth on 3 February, persisting in that vicinity with heavy falls on the Gulf Coast on 3–9 February (Bureau of Meteorology 2024b).

Apart from large saltpans and fringing mangroves in coastal areas, the Gulf Plains are characterised by extensive tropical grasslands and diverse grassy (especially eucalypt) woodlands. Cattle grazing has been the dominant land use in the bioregion for nearly 150 years (Crowley & Garnett 2023) but woodlands and grasslands are largely uncleared, although there have been significant ecological changes from weeds, feral animals, grazing and burning regimes (Kutt *et al*. 2009; Vanderduys & Kutt 2011). Vegetation mapping of the bioregion is available in two resolutions: Broad Vegetation Groups (BVGs, 1:1 million: Neldner *et al*. 2017) and Regional Ecosystems (Res, 1:100,000: Queensland Herbarium 2023).

Field methods

Field observations were made by TDN between 9 April and 5 June 2014 as part of fieldwork investigating interactions between Brolgas and Australian Sarus Cranes (Nevard 2019). Roadside surveys were conducted over a total of 793 km on 4 days in the wet season and 7 days in the early dry season. Surveys were mostly in the Gilbert and Norman catchments, and 5 km, 17 km and 160 km of roads were surveyed in the Staaten, Flinders and Mitchell catchments, respectively. Survey trips were separate from logistical travel to and within the study area. A four-wheel-drive vehicle was driven at 20–40 km/h to scan the roadsides for cranes. When cranes were observed, the vehicle was stopped and observations made using 10 × 40 binoculars, with locations recorded by a handheld GPS unit. In areas where vegetation height reduced visibility or cranes moved away before numbers or certain identification was possible, immediate follow-up observations were made by standing on the rear vehicle tray. In more open areas, most cranes were identified within 150 m of the road, but when roadside vegetation was dense, this curtailed visibility to 50–75 m. When a stretch of road was re-driven, all crane sightings were checked against earlier records and only clearly new observations were retained for analysis. Three birds were unidentified to species in roadside surveys and these were excluded from analysis.

Numbers and species of cranes were also recorded opportunistically on 3 days in the wet season and 17 days in the early dry season while observing inter-species interactions at wetlands and foraging sites on two cattle stations, Double Lagoon (17°17′S, 141°12′E) and Miranda Downs (17°19′S, 141°52′E). At Double Lagoon, observations were made at various natural and artificial wetland types in a mosaic of grassy, mostly moist woodlands (Queensland Herbarium 2023). The Miranda Downs homestead is located in an area of native grassland of ~2000 ha, with nearby moist grassy woodlands (Queensland Herbarium 2023). Approximately 6 ha of grassland had been cleared for infrastructure, including airstrip and dams, and 88.7 ha had been recently harvested for hay (‘hay paddock’).

Analysis of data

Following Sundar *et al*. (2019), we defined social units of cranes as ‘single’; ‘pair’ (pair with no young) or ‘family’ (pair with young of the season). However, for aggregations other than pairs or families we distinguished ‘groups’ (2–9 birds) from ‘flocks’ (≥10 birds) (Sheldon 2004).

We estimated abundance of each species in the roadside surveys from numbers recorded per kilometre of road surveyed (encounter rate: Sundar *et al*. 2019). More precise estimates of density were not possible as we lacked data on detectability in the different habitats. Fisher’s Exact Test was used to determine if there was any significant difference between Australian Sarus Cranes and Brolgas in the number of pairs that did and did not have young. We assumed that unfledged young would survive to fledge.

Table 1. Categories of Broad Vegetation Groups (BVGs) used in analysis of Australian Sarus Crane and Brolga habitat preferences in roadside surveys. All woodlands have a grassy understorey. O = open, W = wooded.

Category	*BVGs*	*Details*
Moist woodlands (W)	16a, 16b, 16c, 22c	*Eucalyptus* spp. dominated open forest and woodlands on drainage lines and alluvial plains and *Melaleuca* woodlands and forest on seasonal swamps
Dry woodlands (W)	18c, 19c, 21b	*Eucalyptus* or *Melaleuca* woodlands or open woodlands on sandplains or depositional plains
Wetlands (O)	34c, 34d	Permanent and ephemeral swamps, including fringing vegetation
Grasslands (O)	31a, 32a	Closed and open tussock grasslands and forblands
Saltmarshes (O)	35b	Bare saltpans ± areas of samphire (sparse forblands) and/or tussock grasslands

We calculated breeding success for each species at the time of survey as the proportion of pairs that had young (Sundar *et al*. 2019), and also as the average number of young per breeding female (Sundar 2011). Because of the relatively small number of observations, we chose the coarser scale of BVGs for analysis of habitat data for roadside surveys. To simplify analysis of sites occupied by each species by BVG, we grouped site habitats in five categories (moist woodlands, dry woodlands, wetlands, grasslands and saltmarshes), which were classed as either 'wooded' or 'open' (Table 1). Of 793 km of roads surveyed, an estimated 35% traversed open habitats and 65% traversed wooded habitats. We excluded five sites (three wooded and two open) where both species were recorded (as these are not independent for the purpose of statistical analysis) and used Fisher's Exact Test to identify species' preference for wooded or open habitats at the remaining 90 sites.

On the two cattle stations, although some individual cranes were readily recognisable, there were no marked birds and so the same individuals were almost certainly recorded multiple times at some sites, so those results are presented descriptively. To indicate the full extent of flocking (Scambler 2022), we included records of unidentified cranes. In order to examine the species and social groups utilising the same habitat features, we grouped sightings with the same date, time and place. Habitats at these sites were noted descriptively, referring to REs and wetland mapping (Queensland Herbarium 2023; Queensland Government 2024).

We also searched online databases (Atlas of Living Australia 2023; Birdata 2023; eBird 2023) for records of cranes in the Gulf Plains during the study period. To consider the extent to which birdwatchers report mixed-species flocks of cranes in the Gulf Plains we searched the

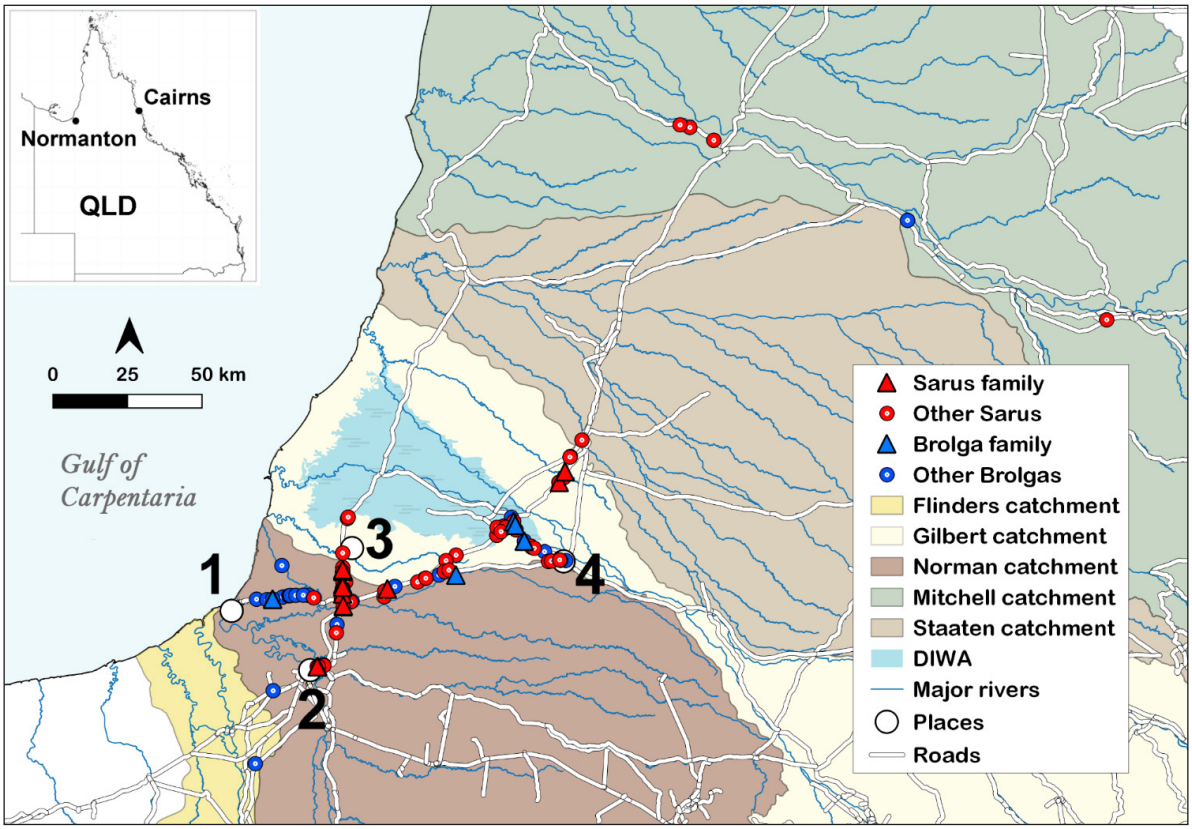

Figure 2. Location of 2014 study in the Gulf Plains bioregion, Queensland, and sites of crane records in roadside surveys. Places: 1 = Karumba, 2 = Normanton, 3 = Double Lagoon Station, 4 = Miranda Downs Station. DIWA = Gilbert–Smithburne Fan Aggregation, a DIWA (Directory of Important Wetlands in Australia)-listed nationally important wetland.

Table 2. Number and percentage of social units of cranes recorded in roadside surveys in the Gulf Plains, north-western Queensland, between 9 April and 4 June 2014. Social units are defined in Methods.

Unit type	*Number (%) of social units*		
	Brolga	*Australian Sarus Crane*	*Total*
Group	5 (11%)	0 (0%)	5
Family (No. of young)	8 (18%) (6 x 1, 2 x 2)	9 (13%) (5 x 1, 4 x 2)	17
Pair	28 (62%)	53 (79%)	81
Single	4 (9%)	5 (7%)	9
Total	**45 (100%)**	**67 (100%)**	**112**

Figure 3. Brolga (female) and young chick near Normanton, 25 April 2014. Photo: Timothy D. Nevard

Atlas of Living Australia (2023) for Brolga and Australian Sarus Crane sightings in the bioregion in all years and months from 1970 to 2023.

Results

Roadside surveys

Sites of cranes recorded in roadside surveys are shown in Figure 2; 112 social units were recorded across 95 sites, mostly pairs without young (Table 2). There were five groups of three to five Brolgas, but no groups of Australian Sarus Cranes and no flocks of either species. Most young (77%) were fledged, except for one Brolga chick and five Australian Sarus Crane chicks (including two siblings) (Figures 3–4). Eight of 36 Brolga pairs (22.2%) and nine of 62 Sarus Crane pairs (14.5%) had young. The average number of young per breeding female was 0.28 for Brolgas, and 0.21 for Sarus Cranes. There was no significant difference in breeding success between the species [Fishers Exact Test, P = 0.24 (pairs with young) and P = 0.41 (average number of young per breeding female)]. Australian Sarus Cranes comprised 63% of 111 cranes recorded in the Gilbert catchment, and 50% of 139 cranes recorded in the Norman catchment, and over the 793 km surveyed the abundance (encounter rate) per km was 0.12 for Brolgas and 0.16 for Australian Sarus Cranes.

Figure 4. Australian Sarus Crane (female) and older unfledged chick, Van Rook Station, ~70 km north-east of Double Lagoon, 26 April 2014. Photo: Timothy D. Nevard

Table 3. Number (and percentage) of individual Brolgas and Australian Sarus Cranes recorded in each habitat category in roadside surveys in the Gulf Plains, north-western Queensland between 9 April and 4 June 2014. Excludes young of the season. Habitat categories are defined in Table 1. O = open, W = wooded. Total number of sites = 95; number of sites for each habitat is shown in parentheses.

Habitat type	*Number (%) of cranes*	
	Brolga	*Australian Sarus Crane*
Moist woodlands[1] (W) (57)	43 (45%)	88 (70%)
Dry woodlands (W) (7)	4 (4%)	7 (6%)
Wetlands (O) (2)	1 (1%)	2 (2%)
Grasslands[2] (O) (26)	39 (41%)	28 (22%)
Saltmarshes (O) (3)	8 (8%)	0 (0%)
Total	**95 (100%)**	**125 (100%)**

[1]Both species occurred at three sites.
[2]Both species occurred at two sites.

Both species were observed in woodlands, wetlands and grasslands (Table 3), with Australian Sarus Cranes showing a stronger preference for woodlands (especially moist woodlands) than Brolgas; only Brolgas occupied saltmarshes. Most sites occupied only by Australian Sarus Cranes (42/57, 74%) were wooded, whereas 17/33 (52%) of sites occupied only by Brolgas were in open habitats (wetland, grassland and saltmarsh), the difference being significant (Fisher's Exact Test, P = 0.005). Both species were observed more often in woodlands than grasslands, and the preference for woodlands (especially moist woodlands) was stronger for Sarus Crane than Brolga (Table 3).

Observations at Double Lagoon and Miranda Downs cattle stations

At Double Lagoon, there were 63 observations over 11 days at a range of waterholes, dams and swamps. No flocks were seen. Singles, pairs and families of Brolgas were recorded, but no groups. Australian Sarus Cranes were recorded as singles, pairs and families, and groups

Figure 5. Part of a flock of Australian Sarus Cranes over the hay paddock, Miranda Downs, 15 May 2014. Photo: Timothy D. Nevard

of two to eight were seen at five sites. No family of either species had more than one young and all young were fledged. Four Australian Sarus Crane families and two Brolga families were seen foraging simultaneously in separate areas at Box Hole, a freshwater seasonal swamp of ~16 ha with a narrow fringe of woodland vegetation (Queensland Herbarium 2023; Queensland Government 2024).

At Miranda Downs, 157 observations were made over 8 days, notably on the recently harvested hay paddock, where both species were observed feeding on unidentified species of crab prised from deeply cracked clay (Scambler *et al*. 2023); at nearby dams of up to 2 ha, close to the homestead and airstrip; and at Stuarts Lagoon, a freshwater sedge and herb swamp of ~17 ha (Queensland Government 2024). Groups, pairs, and families were recorded for both species, including multiple sightings of pairs with two young. However, as the young were fledged and thus mobile, it is unknown if these were resightings of the same birds. One unfledged Brolga chick was observed at Stuarts Lagoon. Flocks were observed every day: 10–42 Australian Sarus Cranes (Figure 5) were seen on 6 days, 14–33 Brolgas on 3 days, and 10–65 unidentified cranes on 6 days. There was one mixed flock of 22 Brolgas and 30 Australian Sarus Cranes. Although no attempt was made to inventory social units within flocks, it was noted that all flocks that could be identified to species included families.

Excluding two records of either Brolgas or Australian Sarus Cranes with unidentified cranes, there were 33 records of different social units, identified to species, simultaneously using the same foraging site or water source at Miranda Downs. More than 80% of these records comprised both species, including the mixed-species flock noted above. Two communal roosts were identified, one of Brolgas on a stretch of water in the mainly dry bed of the Smithburne River, close to the hay paddock, and one of Australian Sarus Cranes on Stuart's Lagoon (TDN unpubl. data).

Searches in online databases between 9 April and 5 June 2014 found two records (both of single Brolgas) in the Gulf Plains and no records of Australian Sarus Cranes but, on 25 May 2014, two Australian Sarus Cranes and four Brolgas (two adults and two young) were recorded at a waterhole in low woodland east of Gregory Downs, in the western Gulf Plains (A. Freeman pers. comm.). In 1970–2023, birdwatchers reported 2064 observations of Brolgas and 792 of Australian Sarus Cranes in the Gulf Plains, mainly in June, July and August (Atlas of Living Australia 2023). There were nine records of mixed flocks, mostly of small numbers of Australian Sarus Cranes in flocks of up to 50 Brolgas.

Discussion

Allowing for incubation of *c*. 31 days and 90–95 days to fledging (Herring 2001; Sundar & Choudhury 2003), the presence of fledged young in April 2014 shows that – consistent with the findings of Sundar *et al*. (2019) – both species initiated nesting following the first fortnight with high rainfall in late November–early December 2013. Based on the pattern observed by Sundar *et al*. (2019), we would expect that most nests would have been initiated after the onset of heavy rains in early February 2014, with chicks fledging in early to mid June. It was not possible to distinguish between breeding and nonbreeding sites and territories, as cranes can move significant distances from nest sites once their chicks are fully ambulatory or fledged (TDN pers. obs.). Interestingly, few unfledged young were recorded in this study, and the number of pairs with young was lower for both species compared with that in 2016–2017 (Sundar *et al*. 2019), especially so for Australian Sarus Cranes. Even in years affected by low rainfall and conversion of wetlands to other uses, pairs of Sarus Cranes in Uttar Pradesh, India, achieved at least 0.28 young per breeding female (Sundar 2011). The average recruitment rate for Australian Sarus Cranes in flocks on the Atherton Tablelands in 1997–2002 was 6.58%, considered low in comparison with crane populations globally (Grant 2005). The recruitment rate on the Tablelands in 2014 was particularly low (4.8%: J.D.A. Grant unpubl. data), supporting our finding of low breeding success for Australian Sarus Cranes in 2014. If the heavy cyclonic rainfall in February caused excessive flooding, then the likely impacts would have been nest desertion or destruction of eggs, and loss of food supplies in breeding territories with early chick mortality – more so for Australian Sarus Cranes, if they extended nesting over a longer period than Brolgas.

On roadsides, the concentration of Australian Sarus Cranes in wooded habitats, but with some presence in grasslands, confirms the preferences noted in previous studies in the breeding season (Archibald & Swengel 1987; Sundar *et al*. 2019). Although in our study 45% of Brolgas observed on roadsides were in woodlands, this is likely to be because of the high proportion of woodlands (65%: Queensland Herbarium 2023) along the roadsides surveyed. Even so, our results show the Brolga's relative preference for open habitats. The Brolga has a nasal gland that excretes salt, unique among cranes (Hughes & Blackman 1973), and the occurrence of only Brolgas at relatively saline sites in this study, including a pair with an unfledged chick, is consistent with nesting observations near Townsville, North Queensland, and near Karumba in 2017 (Blackman 1983; Nevard *et al*. 2024).

Flocking of both species (aggregations of ≥10 birds, including families) was well established at Miranda Downs,

although absent from roadsides and Double Lagoon. We suggest that this was a response to foraging opportunities provided by the large area of short grass in the recently harvested hay paddock at Miranda Downs, and readily accessible artificial water sources. For example, arthropod prey, an important source of protein for young cranes (Scambler *et al*. 2023) would require more intense (and dispersed) search effort in long savanna grasses or woodland.

Use of the open hay paddock habitat immediately after breeding (mostly) in woodlands underlines adaptability of Australian Sarus Cranes to exploit new or enhanced resources, in this case enabled by graziers. Although no sharing of roosts was observed, sightings of a mixed-species flock, and of other social units of Brolgas and Australian Sarus Cranes simultaneously using the same foraging sites and water sources, suggest mingling similar to that observed on the Atherton Tablelands (Nevard *et al*. 2019; Scambler *et al*. 2020). This implies that close association between the two species in the Gulf Plains can occur more often, and sooner after the nesting period, than previously thought.

Population size of the Australian Sarus Crane is unknown, and Nevard & Scambler (2023) have recommended a structured, annual volunteer roadside survey in the Gulf Plains over 1 week in September, initially for 3 years, to take place immediately after the annual BirdLife Northern Queensland flocking survey on the Atherton Tablelands. These surveys would also provide useful information on habitat use in the Gulf Plains and social structure, including flocking, in the late dry season.

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