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First observations of Australian Sarus Crane *Antigone antigone gillae* pairs attending three young and the incidence of three-egg clutches in the Brolga *A. rubicunda*

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Abstract. Clutch-size in gruine cranes is consistently two. Clutches of three eggs are very rare, and records of adults supporting three young even more so. We report two observations from the Atherton Tablelands, far north Queensland, of pairs of Australian Sarus Cranes *Antigone antigone gillae* accompanying three juveniles. Their ages and the behaviour of the groups suggested family relationships. These are the first observations implying that Australian Sarus Cranes may raise three young, and are more likely to be explained by successful three-egg clutches than by adoption. Very little is known of nests and eggs of wild Australian Sarus Cranes and further studies would contribute to the conservation of this crane. More three-egg clutches than expected were identified in Brolgas *A. rubicunda*, particularly in the Ayr–Townsville region of northern Queensland, where the current breeding status of this species is uncertain.

Introduction

Cranes are long-lived birds. First breeding is delayed until at least 3 years of age, clutch-size is small, and breeding pairs raise one or sometimes two young each year, with the period of care extending to the beginning of the next breeding season (Mirande & Harris 2019). In gruine cranes, including the Sarus Crane *A. antigone*, clutch-size is consistently two, with three-egg clutches being very rare (Allan 1996). There are four recognised populations of the Sarus Crane: in south Asia (India and Nepal); Myanmar; south-east Asia (Vietnam, Cambodia and Thailand); and Australia (Mirande & Harris 2019). A few three-egg clutches and pairs supporting three young have been recorded in Sarus Cranes in Asia (e.g. Sundar 2006), where mean clutch-size has been reported as 1.7–1.8 in India (*A. a. antigone*: Ramachandran & Vijayan 1994; Sundar & Choudhury 2008) and 1.9 in Cambodia (*A. a. sharpii*: Handschuh *et al.* 2010). Clutch-size in the closely related Brolga *A. rubicunda* has long been established as usually two (e.g. Campbell 1901), but with occasional three-egg clutches noted by Campbell (1913), Nielsen (1963) and Blackman (1971). Until our research, these constituted the only three-egg clutches documented for the Brolga, and there are no published observations of Brolga families including three juveniles.

In this paper, we report the first observations of pairs of Australian Sarus Cranes *A. a. gillae* supporting three young, and discuss possible relevant influences including clutch-size, resources, and adoption. Adoption has been suggested as an explanation for broods larger than usual in cranes (e.g. Miller 1973; Allan 1996) but has not previously been explored in detail. Clutch-size in the Australian Sarus Crane has not been reviewed since the scant data available in the early 1990s (Marchant & Higgins 1993), and the account of these authors of Australian Sarus Crane eggs is unclear in some respects. Three-egg clutches have not been recorded in Australia: Marchant & Higgins' citation (p. 484) from Walkinshaw (1973) that clutch-size in Sarus Cranes is "rarely three" applies to the south Asian population (see Discussion). In addition, they described the eggs from Archibald's 1984 study (Archibald & Swengel 1987, p. 113) as "in captivity", but this applies only to hatching; eggs were collected in the Gulf Plains, north-western Queensland, for transport to the United States of America. We therefore include the Archibald & Swengel (1987) eggs in a review of clutch-size in wild Australian Sarus Cranes. We also review the occurrence of three-egg clutches in the Brolga.

Methods

Study area and observations of cranes

The Atherton Tablelands (Figure 1), *c*. 50 km south-west of Cairns (16°55′S, 145°46′E), 400–950 m above sea level, has an upland tropical climate with seasonal rainfall mostly from November to April (Bureau of Meteorology 2020). Extensive, formerly forested areas have been cleared for grazing, cereal crops and horticulture (Tablelands Futures Corporation 2019). Sarus Cranes and Brolgas nest on floodplains adjoining the Gulf of Carpentaria (Figure 1; Archibald & Swengel 1987; Sundar *et al*. 2019), and some migrate to the Atherton Tablelands in the tropical dry non-breeding season (Nevard *et al*. 2020). The Atherton Tablelands is the only known concentrated wintering site for Australian Sarus Cranes, mostly in the 35,418-ha Atherton Tablelands Key Biodiversity Area (KBA) (Figure 1; Scambler *et al*. 2020). Sarus Cranes and Brolgas are present there from about May to November, and pairs with fledged young of the year arrive as early as May, but mostly from July onwards (Grant 2005). Significant communal night roosts include Bromfield Swamp (17°22′S, 145°32′E), a wetland within an extinct volcanic crater (Swaby 1983; Scambler *et al*. 2020) and, by day, the cranes disperse to forage mainly in pasture and crop stubbles (Nevard *et al*. 2019, JDAG unpubl. data).

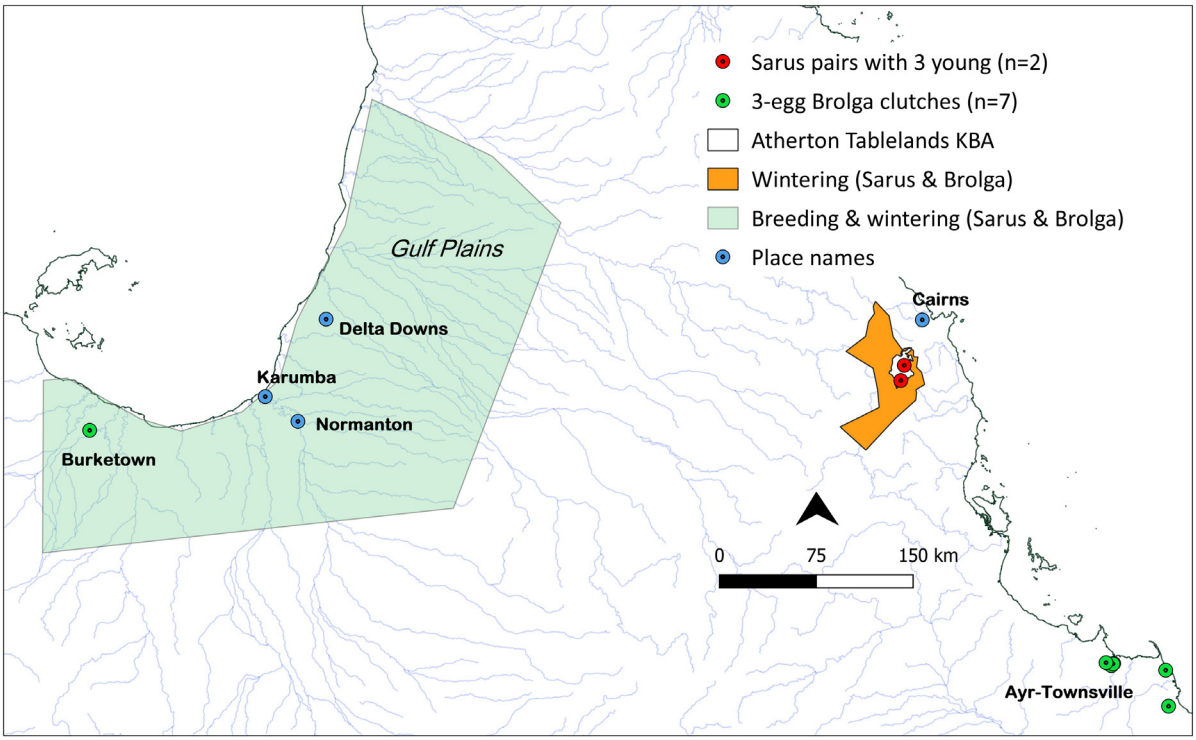

Figure 1. Sightings of pairs of Australian Sarus Crane with three young in the Atherton Tablelands wintering area, far north Queensland, and seven Brolga nests with three-egg clutches. Ayr–Townsville (six clutches) is a breeding and wintering area for Brolgas but not Sarus Cranes. The eighth 3-egg Brolga clutch was in south-eastern Australia (see Table 1). KBA = Key Biodiversity Area.

Intensive observations of wintering cranes were made on the Tablelands from 1995 to 2019, with collection of long-term data including brood-size.

Search of records

We searched published references and sought unpublished records of clutches of Sarus Crane eggs, and Brolga clutches of more than two eggs, across the species' ranges. We also searched for records of pairs of either species supporting more than two young where observers had noted behaviour and social context suggesting a discrete family group. For Australia, data were available from 22 years of recruitment studies of wintering Sarus Cranes on the Atherton Tablelands and 3 years of post-breeding studies on both species in the Gulf Plains (Grant 2005; Sundar *et al*. 2019; JDAG unpubl. data). We also sought information from Australian museums, which together hold >100,000 egg specimens of multiple bird species (Gill 2006; Atlas of Living Australia 2019), where a 'specimen' may comprise a single egg or a multiple-egg clutch. Online databases of major overseas collections were searched for specimens of Australian crane eggs, and we examined scans of records provided by the Natural History Museum, Tring, United Kingdom (NHM). For Australian Sarus Cranes, we excluded two single-egg clutches reported by Beruldsen (1997) as the stage of laying is unclear from his account. We also excluded the (very few) Australian Sarus Crane eggs held in collections, because in some cases clutch-size was unavailable, and some specimens are under review.

Results

Observations

On 3 July 2006, NGH observed a compact group of five Sarus Cranes at the Bromfield Swamp roost near Malanda, far north Queensland (17°22′S, 145°33′E). The birds were foraging in short, grazed pasture above the crater wetland roost, gradually moving uphill to within 10–15 m of the viewing platform. Despite morning mist, he was able to observe the birds clearly from 0800 h for *c.* 30 minutes. The group consisted of two adults closely following three same-sized young with similar plumage and skin characteristics, identified as juveniles of the year (Marchant & Higgins 1993; Grant 2005). The number and species of other cranes present could not be determined because of mist but none were within 100 m of the group under observation. Crane family groups found in searches over succeeding days by us and others at Bromfield Swamp and elsewhere in the area contained only one or two young.

On 7 October 2017, JDAG observed a family group of Sarus Cranes in a field of corn stubble near Yungaburra (17°16′S, 145°34′E) among a flock of 70 foraging Sarus Cranes. This family also included three juveniles with apparently identical size, plumage and skin characteristics. The adults were closely followed by all three juveniles, and the five birds stayed together while foraging among the other birds present, and several times moved away from the flock as an independent group. On 26 October, a family (presumed to be the same five birds) was seen

on the shoreline of Lake Tinaroo, 2.3 km away from the first observation. The juveniles appeared to be at the same stage of development as those seen on 7 October and, given the rarity of the observation, it was considered unlikely to be a different family. In this case, the five birds were watched foraging independently of other cranes for *c*. 30 minutes (the nearest other crane group was ~500 m away) and flew away from the site as a tight group.

Records of clutch-size

We identified 45 Australian Sarus Crane clutches observed in the wild (Walkinshaw 1973; Archibald & Swengel 1987; Hollands 2016; G. Archibald pers. comm.; R. Johnstone pers. comm.). Six of the 45 nests (13%) had one egg and 39 (87%) had two (mean = 1.87 eggs). From collections, observations and studies, over an estimated period of >170 years, reported for Sarus Cranes in south Asia, south-east Asia and Myanmar, we identified multiple one- and two-egg clutches, one four-egg clutch, five three-egg clutches (plus one from birds in captivity) and ~10 family groups with three similar-aged young (Table 1).

In Brolgas, we found eight records of three-egg clutches from observations and specimens, the earliest in 1898. Seven were from northern Queensland, particularly the Ayr–Townsville area (Table 1, Figure 1). No records of clutch- or family-size were available for the Brolga population in New Guinea. We found no records of Australian Sarus Cranes or Brolgas in family groups with three young: pairs

Table 1. Records of Sarus Cranes *A. a. antigone* (India and Nepal), *A. a. sharpii* (Myanmar and Cambodia) and *A. a. gillae* (Australia) and Brolgas *A. rubicunda* (Australia) with >2 eggs or young. ANWC = Australian National Wildlife Collection, Canberra ACT, Australia; MV = Museums Victoria, Melbourne VIC, Australia; NHM = Natural History Museum, Tring, United Kingdom. Dates are given as day.month.year.

Region	*Details*	*Reference*
Sarus Crane		
Eggs: Collections		
Etawah, India	Hume, 20.08.1867[1]	NHM 33-654
Captivity	Tring Park, 01, 04 & 07.08.1927	NHM 33-642
Eggs: Field observations		
India	Of >100 nests, *c*. 1850–1883, 2 x C/3[1]	Hume (1890, p. 373)
Myanmar	"one to three eggs"	Smythies (1953, p. 463)
India (& captivity?)	Of 132 clutches in museums or reports, 2 x C/3[2]	Walkinshaw (1973)
India	1 x C/4: 1 addled, 2 fertile hatched, 1 fertile abandoned	Sundar & Choudhury (2003)
India	1 x C/3: 2 eggs fertile, hatched; 1 addled	Kathju (2007)
Cambodia	Of 171 nests in 2 studies, 2 x C/3	Handschuh *et al*. (2010)
Family groups: Field observations		
India	"occasionally[3]…three young birds in company with an old pair"	Hume (1890, p. 373)
India	Two pairs with 3 juveniles <1 year old (in 11 years of detailed studies)	Sundar (2006)
Cambodia	Occasionally[3] 3 young with pairs in migrating flocks	G.W. Archibald in Sundar (2006)
Cambodia	Young of 2 x C/3 nests followed to 12 and 16 days, respectively	Handschuh *et al*. (2010)
Atherton Tablelands Qld	Two pairs observed attending 3 young (in 22 years of studies of wintering)	This paper
Brolga		
Eggs: Collections		
Burketown, Qld	1 x C/3 (Nov. 1898)	MV BE 830 (Campbell 1913)
Giru, Qld	1 x C/3 (Mar. 1968)	ANWC E 12215
Beachmount, Qld	1 x C/3 (Jan. 1976)	ANWC E 16443
Ayr, Qld	1 x C/3 (Jan. 1981)	ANWC E 19120
Giru, Qld	1 x C/3 (Feb. 1984)	ANWC E 19121
Eggs: Field observations		
Beachmount, Qld	1 x C /3 (9 nests observed: May 1963)	Nielsen (1963)
Mt Elliot, Qld	10 x C1, 40 x C/2, 1 x C/3 (1968–1971)	Blackman (1971)
Victoria	1 x C/3 (2006) (many nests observed)	M. Herring (pers. comm.)

[1]One of Hume's field observations presumably relates to NHM 33-654.

[2]See text for discussion.

[3]For calculation, we assumed that 'occasional' sightings totalled three observations per author.

were accompanied only by one or two young of the year (Marchant & Higgins 1993; Grant 2005; Sundar *et al*. 2019; JDAG unpubl. data).

Discussion

The mean clutch-size of 1.87 for Sarus Cranes in the 45 available Australian nest records is similar to that reported from studies in south and south-east Asia (Ramachandran & Vijayan 1994; Sundar & Choudhury 2008; Handschuh *et al.* 2010). The Indian studies monitored nests from start to completion of laying, so clutch-size estimates are probably unbiased by losses (e.g. from predation: Sundar & Choudhury 2008). In Cambodia, monitoring intensity varied and Handschuh *et al.* (2010) suggested that some clutches recorded with only one egg might have been incomplete or have suffered predation before discovery. This might also have occurred with at least some nests in Australia. Five of the six Sarus Crane one-egg clutches were recorded by Archibald (Archibald & Swengel 1987) but it is unclear how many of these nests were individually monitored to detect stage of laying or subsequent predation. The mean clutch-size that we report for Australia is therefore almost certainly an underestimate.

Based on observations and specimens, three-egg clutches are not as rare in Brolgas as previously thought (Table 1; and see e.g. Marchant & Higgins 1993). Six of the eight three-egg clutches are from the Ayr–Townsville region, including one from Blackman's (1971) study (mean clutch-size 1.8; three seasons, n = 51). However, this was not Blackman's complete dataset: his map of nests near Mt Elliot alone shows some 85 nest-sites (Blackman 1983) and the full results have not been published. Ayr–Townsville was thus an important Brolga breeding area and the incidence of three-egg clutches suggests that nest productivity might have been high, at least until the 1980s. Since that time, wetlands (e.g. in the Haughton sub-basin: Great Barrier Reef Marine Park Authority 2013) have been degraded by drainage and clearing for agriculture, and the current extent of Brolga breeding in the area is uncertain.

Accurate interpretation and citation of past literature are needed to avoid problems such as double counting in estimating the frequency of clutch-sizes or misconstruing change over time. In Table 1 we have clarified the publication record for three-egg Sarus Crane clutches in south Asia. Successive studies addressing clutch-size in Sarus Cranes have relied on Walkinshaw's somewhat diffuse account of the Sarus Crane in India (Walkinshaw 1973). Sundar (2006) and Kathju (2007) stated that Walkinshaw observed two nests with clutches of three in Keoladeo National Park, Bharatpur, Rajasthan, India. Ramachandran & Vijayan (1994) and Handschuh *et al*. (2010) went further, assuming that Walkinshaw had observed 132 complete clutches including two nests with three eggs at Keoladeo. Ramachandran & Vijayan (1994) compared these 132 clutches with their own results from Keoladeo National Park and concluded that clutch-size there had significantly declined, because of habitat change.

In fact, Walkinshaw (1973) saw eight Sarus Crane nests overall in India in 1965 (as stated in his Preface), of which six had two eggs, and two nests had none. Mukherjee (1999) noted the difference between Walkinshaw's actual nest records in India and his report of 132 clutches but without investigating the source of the latter. The two three-egg clutches reported by Walkinshaw (1973) are from his investigation of museum collections and the literature from *c*. 1860 to 1970, in which he considered that there were 132 complete clutches, including two with three eggs. It is not possible to reconstruct Walkinshaw's complete dataset from his text, but one of the three-egg clutches is clearly NHM 33-654 dated 20 August 1867 from the Hume Collection (Walkinshaw 1973), which is from Etawah, Uttar Pradesh, not from Keoladeo (Table 1). The other three-egg clutch cannot be identified, but Walkinshaw had details of the NHM collection and might have cited the Tring Park captive clutch (Table 1). Walkinshaw (1973) is also cited as the source for a three-egg clutch in Brolgas (e.g. Marchant & Higgins 1993) but in this instance Walkinshaw referred to the H.L. White collection clutch viewed by Campbell (1913) and now held by Museums Victoria (BE 830: Table 1). Reviewers of clutch-size may prefer to exclude museum specimens or treat them separately (Allan 1996), which is a further reason to clarify details of sources.

Explanations for observations of pairs of Sarus Cranes attending three young on the Atherton Tablelands include a successful three-egg clutch with all three young migrating after fledging, multiple same-season broods, nest-parasitism ('egg-dumping'), or integration of another pair's chick into the crane family ('adoption').

The juvenile Australian Sarus Cranes observed on the Atherton Tablelands are very unlikely to have come from separate same-season broods of one pair, based on their apparently identical size and plumage. In addition, in Sarus Cranes re-nesting within one season is known only after earlier clutch(es) are lost (Sundar *et al*. 2018). Nest-parasitism is also very unlikely: in cranes, three-egg clutches are almost certainly the progeny of a territorial pair, as nesting Sarus Cranes vigorously defend discrete territories against neighbouring pairs (Kathju 2007; Sundar & Choudhury 2008). A single (probable) instance of 'egg-dumping' has been recorded in Sandhill Cranes *A. canadensis* (Littlefield 1981), where a pair was noted for unusual behaviour in that both adults regularly left the nest at once. A third egg was observed in their nest with patterning characteristic of a neighbouring female, but this has not been reported in other crane species.

Could at least one of the Tablelands pairs of Sarus Cranes have acquired an additional, identical-age young by adoption? None of the records of three young (Table 1, and our observations) have been of marked birds, so the only verified siblings are from the Cambodian nests followed from laying up to 16 days post-hatching (Handschuh *et al.* 2010). Adoption requires both attachment by a juvenile crane to strange parents, and acceptance of the strange young by the adult birds. Adoption of a chick by a pair of cranes in breeding condition, but with no young, has been achieved in captivity (Voss 1974) but is unknown in the wild. Parental acceptance of lost or abandoned chicks from another pair is highly unlikely where pairs strongly defend breeding territories, either permanently as in Uttar Pradesh, India, where Sundar's first (2006) pair with three young was observed, or in seasonally defended breeding territories as in the Australian Gulf Plains (Sundar *et al*. 2019; JDAG unpubl. data).

Even away from the breeding grounds in wintering flocks, pairs of Sarus Cranes with young exhibit localised

territoriality and can be distinguished from other pairs with or without young, and from unpaired birds (Walkinshaw 1973). The behaviour of the pairs of adults on the Atherton Tablelands closely following or followed by three young, and the visible separation of the families from other cranes foraging at the same sites, are consistent with Latt's (2001) observations of Indian Sarus Crane family behaviour in the months after fledging. This behaviour is also typical of families that have joined flocks in the Australian Gulf Plains in April–May each year, shortly after their young have fledged (JDAG unpubl. data), making it unlikely that juvenile birds might be 'adopted' (accepted by strange parents) at this stage. Some families may migrate directly, or almost directly, from a defended breeding territory to the Tablelands, in which case it is also unlikely that an additional first-year bird could join, and be integrated into, a family group before arriving on the wintering grounds.

There are no detailed records of a first-year crane attempting to integrate with another family group of the same species in the wild. Miller (1973) observed a pair of Sandhill Cranes with two young of differing size and coloration, which he suggested might be explained by adoption (citing Masatomi 1972), but he gave no details of behaviour within the group. Allan (1996) also referred to Masatomi (1972) in relation to a suggestion of adoption in cranes. Masatomi studied the behaviour of a first-year Sandhill Crane in Japan that attached itself to a family of Red-crowned Cranes *Grus japonensis*, a pair with two first-year young. (Sandhill Cranes occur as regular stragglers in Japan where they are greatly outnumbered by other crane species.) The Sandhill Crane followed the Red-crowned Crane family, flew with them around the wintering site, and foraged beside them. It was often tolerated but at times was subjected to aggressive behaviour by the adult male Red-crowned Crane, and was never integrated into the family group, in contrast with the cohesive family behaviour in our observations and in other family groups. Masatomi described his observations as 'communal wintering' and—in our view, correctly—did not claim adoption, and we consider that Masatomi (1972) is inappropriate as an example of possible adoption of an additional juvenile by a pair of cranes.

Horwich (1996) suggested that imprinting can peak at a relatively late juvenile developmental stage, so it is possible that first-year juveniles could re-imprint on non-parents, for example following a traumatic incident such as death of both parents or accidental post-fledging abandonment during migration. However, the low likelihood of a pair of cranes accepting a strange chick (even if the chick attempts to integrate into the strange family) is underlined by the ontogeny of their calls. Cohesion within the family group, and separation from conspecifics within flocks, are probably reinforced by vocal cues (Klenova *et al.* 2009). Cranes have no vocal learning, and calls are innate (Archibald & Lewis 1996), so cranes bred in captivity exhibit the same ontogeny of calls as wild cranes of the same species. In (mainly) captive-bred Red-crowned Cranes, Klenova *et al*. (2009) found that the distinctiveness of chicks' calls, and parental recognition of them, were high during territorial breeding but increased further after fledging, at the commencement of the flocking season when the risk of 'losing' their own chick, or 'acquiring' one from another pair, was greatest. Distinctiveness of calls and their parental recognition declined significantly as the next breeding season approached and families separated. Although vocal development has not been studied in Sarus Cranes, the phenology of the period of parental care is very similar to that in Red-crowned Cranes (Mirande & Harris 2019) and comparable vocal development would be expected.

Examples of pairs of Sarus Crane supporting three young could be rare for reasons other than clutch-size. One or two eggs may be optimal for incubation based on nest architecture and egg orientation (Sundar & Choudhury 2005), and only two eggs may hatch successfully. In addition, in at least one Sarus Crane nest the second (fertile) egg was abandoned after two young had hatched from the first and third eggs (Sundar & Choudhury 2003). Causes of egg or chick loss in Australia are unknown, but Cattle *Bos taurus* are common on Sarus Crane breeding territories in the Gulf Plains and could trample eggs, and potential predators observed in or close to territories include large reptiles, raptors, corvids and feral pigs *Sus scrofa* (JDAG pers. obs.). A maximum of two chicks allows brood splitting in parental care, as observed in Sarus Cranes in India (Sundar 2006), which may be optimal for foraging support and protection of chicks. It may also prevent sibling aggression, which can occasionally be lethal (Allan 1996).

The high investment required of pairs of cranes to nurture and protect three young to fledging, and to undertake migration to the Atherton Tablelands wintering area, imply that abundant resources were available in 2006 and 2017. The latter was a year of exceptionally high recruitment (Sundar *et al*. 2019), with breeding success of 60% for Australian Sarus Cranes in the Gulf study area, a figure unprecedented in any previous studies of the species globally; 34% of families observed included twin offspring, also a high figure. These observations from a 'boom year' align with the hypothesis that resource abundance may result in larger clutches and could be responsible for occasional fledging of three-chick broods. In 2006, however, recruitment was estimated at only 3.9% (JDAG unpubl. data). This was well below average (mean recruitment 1997–2002 was 6.58%: Grant 2005), indicating that there is the potential for triplet broods to occur outside high-recruitment years. In this case, the brood might have come from a high-quality territory and could thus still be the result of resource abundance.

This study, and others (e.g. Sundar *et al*. 2019), highlight gaps in our knowledge of the breeding biology for both Brolgas and Sarus Cranes in Australia. Studies on nesting Brolgas have concentrated on the threatened south-eastern population and there are many gaps in knowledge in the north; for example, it is unknown whether the Ayr–Townsville region is still an important area for Brolga nesting. The nesting biology of Australian Sarus Cranes remains virtually unstudied, with <50 nests observed and only four published accounts since this taxon was first identified in Australia in 1966 (Gill 1969). In contrast, in south Asia where the estimated Sarus Crane population is similar to Australia (Mirande & Harris 2019), Sundar *et al*. (2018) were able to compile a joint database of some 5000 instances of Sarus Crane nesting over the previous 17 years. In the very small Myanmar population, 78 nests were recently monitored in one season (International Crane Foundation 2019). More work is needed in northern Australia to determine the current status and biology of

both crane species, and to identify conservation priorities for remnant breeding wetlands.

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