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The season, frequency, parental care and success of breeding Black-necked Storks *Ephippiorhynchus asiaticus australis* in northern New South Wales

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The Black-necked Stork *Ephippiorhynchus asiaticus* is a large waterbird native to Australasia whose breeding biology is poorly known. They are known to breed as solitary pairs within large home ranges making detailed breeding studies difficult. We investigate the breeding biology of eleven regularly monitored pairs over a four-year period (2003–2006) in northern New South Wales. They were found to breed from May to January, with incubation from May to October, nestlings from July to January and fledging from September onwards. Individual pairs bred approximately twice over the four-year period. There was no tendency for successful years to be followed by a non-breeding year and pairs were capable of rearing young in successive years. Both parents shared nesting duties, with males spending more time than females brooding the nestlings (68%).The first three years had average or below average rainfall, but 2006 had good rain in summer and autumn. More Storks bred in that year and produced more fledglings per active nest (1.7) than in the previous three years (mean of 1.3 fledglings/active nest). Juveniles remained with their parents for at least two months, though they started foraging by themselves soon after leaving the nest. One young bird was found dead 400 kilometres NNE of its nest, within four months of fledging. The production of at least 64 young in four years suggests that the recruitment rate is likely to be adequate to maintain the state's population of this presumably long-lived species.

INTRODUCTION

The Black-necked Stork (*Ephippiorhynchus asiaticus*) is native to south and south-east Asia, where it is threatened and declining, and has its core populations in New Guinea and northern Australia (*E. a. australis*). A small population is also established in New South Wales (NSW), where it is regarded as *endangered* (Marchant and Higgins 1990). Although there have been studies in India (Sundar 2003; Maheswaran and Rahmani 2005; Sundar *et al*. 2007), the breeding biology of the species in Australia is poorly known and based mostly on anecdotal or unconfirmed reports (Marchant and Higgins 1990). Black-necked Storks nest high in tall trees, close to water on coastal and riverine plains, but far from human activity (Clancy and Ford 2011). Unlike most large Australian waterbirds which breed colonially in response to heavy rain (Kingsford and Norman 2002), the Black-necked Stork is a solitary breeder within a large home range (Clancy and Andren 2010). Hence, it is difficult to collect substantial information on its breeding season, frequency, parental care and productivity.

Black-necked Storks have been recorded breeding from May to November in NSW (Gosper 1981, Gosper and Holmes 2002), and from March to August in Queensland and the Northern Territory (Frith and Davies 1961; Boekel 1980; Marchant and Higgins 1990; Chatto 2006). The timing corresponds to the end of the wet season in northern Australia, and follows summer and autumn in coastal NSW, which tends to be the period of highest rainfall. Breeding in India also follows the wet season (monsoon – Sundar 2003).

Black-necked Storks produce from one to three, occasionally four, nestlings in India (Sundar *et al*. 2007) and Queensland (Richards 2005). The incubation period is at least 32 days (Clancy and Ford 2011), and the nestling period is approximately 80 days (Crompton 2001, 2002). Thus, the breeding season is long, and hence, pairs may not breed every year. There is apparently no information on breeding frequency from Australia, but in India pairs may not nest in years when food is scarce (Maheswaran and Rahmani 2005).

In this paper we present details of the breeding season, frequency of breeding, development of nestlings, division of parental care, nest productivity and post-fledging dependency of the Black-necked Stork in northern New South Wales. We examine whether there are differences between years in breeding effort and success and whether this relates to previous rainfall.

METHODS

The study was based in the Clarence Valley, north-eastern New South Wales, with more limited observations on nest sites elsewhere in New South Wales south to Bulahdelah, north of Newcastle. Thirteen nest sites (breeding territories) were visited each year from 2003 to 2006, inclusive. Four sites were visited in three of these years, one in two years and five in a single year. The territories are listed in Table 1, and a map of their locations is shown in Fig. 2 of Clancy and Andren (2010).

We calculated the mean annual rainfall from three Clarence Valley sites (Tullymorgan, South Grafton and Levenstrath) for each year of the study and long-term average (1966–2006) from historical records. Both 2003 (1034 mm) and 2004 (1039 mm) had rainfall close to the long-term average (1091 mm), whereas 2005 was dry (849 mm) and 2006 was a wet year (1179 mm). The average monthly rainfall for each year, and long-

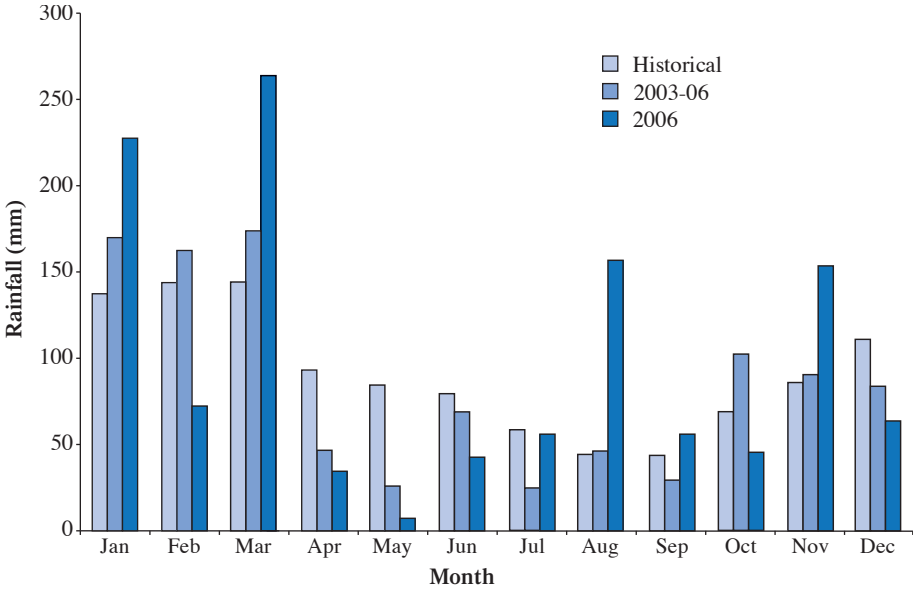

Figure 1. *Average monthly rainfall from various Clarence Valley sites, averages of three sites from 2003 to 2006 and rainfall for 2006.*

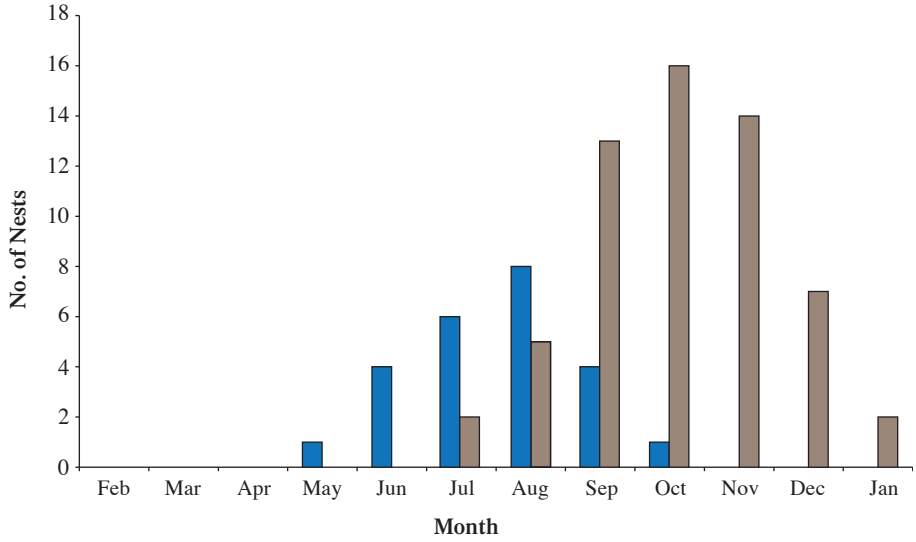

Figure 2. *Monthly distributions of nests with eggs or young 2003-2007 (blue = eggs grey = young).*

term average, is shown in Fig. 1. Monthly rainfall in 2006 was higher than the long-term averages in January, March, August, September and November, leading to increased water levels in most wetlands but not widespread flooding (Fig. 1).

Nests were checked fortnightly for activity by GPC during the predicted breeding season. The presence or absence of Storks was recorded as was any evidence of breeding. At any subsequent visit to an active nest we recorded how many storks were present and what they were doing. We assumed that birds were incubating if they sat on the nest for a long period. We recorded the behaviour of the breeding birds and calculated the contributions to parental care made by each sex at each stage of nesting. The sexes were differentiated based on iris colour (females have a yellow iris, males a dark brown iris) (Kahl 1972). Active nests were visited close to the expected time of fledging to record the number of fledglings. Nestlings in five nests were colour-banded using bands supplied by the Australian Bird and Bat Banding Scheme. Opportunistic observations were also made on some recently fledged birds.

RESULTS AND DISCUSSION

Breeding season

Breeding activity, including nest construction or repair, egg laying and incubation, nestlings and fledging of young, was recorded between May and January, but mostly between June and December at the regularly watched nests (Clancy 2008). This is somewhat later than previously recorded in the Richmond River Valley, NSW where breeding was noted from March to October (Gosper 1981; Gosper and Holmes 2002). Nest construction, repair, and rearranging of nest material, commenced as early as May and continued throughout the period when eggs and nestlings were present, but ceased in November. Mating, which occurred on nests, was recorded from May to August. Eggs (inferred from incubating behaviour and egg rolling) were

recorded in nests from May to October, peaking in August, and nestlings were present from July to January, peaking in October (Fig. 2). Young fledged from September to January.

Stork breeding in New South Wales occurred when wetlands were more likely to be full following summer and/or autumn rain and food more plentiful. Storks in the Northern Territory and Queensland appear to breed earlier than those in New South Wales. In the Northern Territory, Storks had eggs or small young from March to May, with most nesting being finished by July/August although some birds were still incubating in July (Frith and Davies 1961; Boekel 1980; Chatto 2006). In Queensland, egg-laying occurs mostly from March to May with a nest on Stradbroke Island containing eggs in May 1972 (Beruldsen 1972). Interestingly, the Birds Australia Nest Record Scheme reported occupied nests in all months in Queensland (Marchant and Higgins 1990). The earlier breeding in northern Australia probably reflects the more marked wet and dry seasons compared with New South Wales. In northern India, egg-laying begins in early September, following the monsoon (July to September), with most chicks hatching by mid-January and fledging by mid-March, before the hottest and driest part of the year (Sundar 2003). Therefore, there is a tendency for Black-necked Storks to breed after rain. Breeding dates of the Jabiru *Jabiru mycteria* in Belize are also influenced by seasonal rainfall patterns in the transition from the wet to the dry season (Barnhill *et al.* 2005).

Breeding frequency

Only one stork pair attempted to breed in every year out of the 13 nests that were monitored every year (Table 1). Six pairs attempted to nest in three out of four years. Of these, three did not nest in 2003, two in 2004 and one in 2005. Two pairs nested in two years and three pairs in only one year. One pair did not nest at all. So pairs nested in 56 percent of years in which nests were checked. For pairs checked in only some years, active nests were found in 15 out of 19 potential nesting opportunities (79%). More pairs nested in 2006 than in each of the earlier years, ($\chi^2_{(1)} = 4.79$, $P < 0.05$, comparing 2006 with 2003–2005 combined for all nest sites).

The long period of breeding activity in the species (up to 12 months from egg-laying to juveniles reaching independence) leaves little time for the adults to recover and breed again in successive years but there was no tendency for successful pairs to forgo breeding the year following a successful breeding event ($\chi^2_{(1)} = 1.30$, $P > 0.05$). Ten out of 25 pairs that bred successfully in one year did so in the following year. Similarly in the Jabiru *Jabiru mycteria* in Venezuela, fewer than half of the active pairs in one season bred in the following one and only 25 percent of successful pairs bred successfully in a second consecutive season due to the demands of breeding (Gonzalez 1996).

Rainfall was higher in 2006 than in other years, including heavy rain in January and March, and thus more Storks nested. This suggests that good rainfall before the breeding season encourages a nesting attempt. Although 2005 was the driest year, 2004, with average rainfall, had the fewest active nests among those observed regularly. It is likely that factors other than rainfall, such as those that affect food supply, may influence the likelihood of breeding. In India Maheswaran and Rahmani (2005) thought that limited food resources, leading to competition for food between the members of a pair, influenced whether a pair nested in any year. We have no data to test this hypothesis in New South Wales. The related Saddlebill Stork *Ephippiorhynchus senegalensis* in Zimbabwe also bred more in wet years than dry years (Ewbank 2003).

Table 1

Activity and nest productivity at regular and additional sites from 2003 to 2006. NC = not checked. DNN = did not nest. *n* is number of fledglings, a fraction indicates some nestlings did not fledge, e.g. 1/2 means that one chick fledged from two nestlings.

Nest site	2003	2004	2005	2006
Regular nest sites – visited all years				
Mongogarie	DNN	DNN	DNN	1/1+
Coraki	2	0/1	1	1/1+
Bungawalbin Creek	2	DNN	1	1
Arndilly North	DNN	0/1+	1	2
Arndilly South	1	DNN	2	2
Woodford Island	2	2	DNN	2
Tyndale	DNN	DNN	0	2/3
Bunyip Creek	1/2	DNN	DNN	3
Swan Creek	DNN	0	1	1
Chaffin Creek	1	DNN	DNN	2/2+
Waterview	DNN	DNN	DNN	DNN
Coutts Crossing	DNN	1	1	3
Bulahdelah	2	DNN	DNN	DNN
Nest sites only visited some years				
Main Camp 2	DNN	1/2	DNN	NC
Crowsnest	1/1+	1/1+	NC	DNN
Urunga	1/1+	NC	1	1
Maria River	NC	2	DNN	1
Gumma	NC	NC	2	2
Stratheden	NC	2/2+	NC	NC
Main Camp 3	NC	1/1+	NC	NC
Barretts Creek	NC	NC	3	NC
Belmore River	NC	NC	NC	2
Harrington	NC	NC	2/2+	NC
No. Regular nests active	7	5	7	11
No. All nests active	9	10	11	15
No Fledglings/Regular nests	11	3	7	20
No. Fledglings/All nests	13	10	15	26
No Fledged/Active nest	1.4	1	1.4	1.7

Parental care at nests

Nestlings were observed on nests for up to 87 days (Fig. 3). Males and females spent similar amounts of time on the nest during the *incubation* and *nestling* stages (Table 2), incubating, guarding and feeding the young (19 times by female, 21 by male: all $t < 1.55$, $P > 0.05$). When both adults were on the nest and one was incubating, the other collected nesting material, repaired the nest, transported water to the nest or rested. Males did significantly more brooding than females (Table 2; $t = 4.16$, $P < 0.001$).

Adult Storks regurgitated food onto the nest throughout the day, often re-eating most of it shortly afterwards. They did not usually feed young directly, but nestlings picked up small food items. An adult male regurgitated eight eels onto a nest, which it methodically picked up and swallowed again. A small nestling attempted to eat a large eel, but did not manage to swallow it,

Figure 3. *Nestlings in nest at Tullymorgan.*

Table 2

Percentage of time spent by male versus female Black-necked Storks on ten nests at various stages of nesting behaviour. P = pre-laying; E = eggs in nest; I = incubation; N = nestling/s in nest; B = brooding of nestling/s.

Nest/sex	P	E	I	E+I	N	B	N+B
Male %	54.5	59	43	45.7	41.5	68	53.5
Female %	45.5	41	57	54.3	58.5	32	46.5
t test	t = 0.91	t = 0.07	t = 0.67		t = 1.55	t = 4.16***	
Total time (minutes)	745	1276	6576	7852	2786	2290	5076

*** significant at p< 0.001

so the adult took it from the nestling and swallowed it. Possibly, large food items need to be well digested before small chicks can consume them. Two small nestlings attempted to swallow the same eel from different ends, resulting in a tug-of-war. One eventually wrestled the eel from the other and swallowed it. Eels, mostly greater than 300 millimetres in length, constituted the only identified food delivered to nests. There may have been smaller prey regurgitated but observers were too far from the nests to sight these. Nestlings were observed to drink water from the bill of adult birds on four occasions.

In India, both sexes spent similar amounts of time feeding the young (Maheswaran and Rahmani 2005). The regurgitation of large quantities of food at the nest after the young hatched, was also recorded (Maheswaran and Rahmani 2005). Black Storks *Ciconia nigra* in the Czech Republic brought larger prey as the chicks became older (Hampl *et al.* 2005), but we have no evidence of this in Black-necked Storks.

Regurgitation of water over a nest with nestlings, and dribbling water from the bill for nestlings have also been recorded in India, especially on hot days (Maheswaran and Rahmani 2005).

Marchant and Higgins (1990) stated that young are left unattended at 30 days of age, but we regularly observed adults at nests until young were about 2 months old. At one nest a juvenile died of starvation shortly after fledging, although it was still being attended by adults. Therefore, early desertion of young may only occur occasionally, for instance when food is scarce. White Storks *Ciconia ciconia* in Switzerland constantly guarded their young for the first 20 days, after which adults spent progressively more time foraging (Moritzi *et al.* 2001).

We had insufficient data to determine nestling period, but it is at least 87 days, compared with 78 and 80 days at Urunga, NSW (Crompton 2001, 2002) and 87–100 days in captivity (Terry Carmichael pers. comm.).

Post-fledging

Not all families were followed after fledging of young, but ten fledglings stayed with their parents for at least three months, with two still with adults seven and eight months after fledging. Eight nestlings were colour-banded during the study (2 in 2003, 3 in 2005 and 3 in 2006). These young remained close to nest sites shortly after fledging. Three juveniles remained within 300 to 400 metres of the nest for the first month and then moved up to 3.5 kilometres by two months and 5.5 kilometres by just over four months. They also moved back towards the nest during this period. Juveniles were often left alone on wetlands but adults regularly returned to feed them. Another juvenile moved two kilometres within the first 11 days and was 3.75 kilometres from the nest 22 days post-fledging. Its sibling was 3.8 kilometres from its nest 14 days after fledging, where it joined an adult pair and their two, slightly older and larger, juveniles and was also fed by the foster mother. It was still 4.4 kilometres from

Table 3

Average number of young fledged from active nests for various species.

Species	Mean	Range	No. of nests#	No. of Years	Source
Black-necked Stork *Ephippiorhynchus asiaticus*					
NSW	1.42	1.0-1.7	45	4	this study
India	2.1	1.6-2.5	25	3	Sundar (2003)
Wood Stork *Mycteria americana*					
Georgia USA	1.37	0.09-2.65	243	6	Coulter and Bryan (1995)
Venezuela	1.67	1.0-3.0	180	1	Gonzalez (1999)
Painted Stork *M. leucocephala*					
India	2.2	2.0-2.6	370	3	Urfi (1993)
Jabiru *Jabiru mycteria*					
Belize	2.0*	1.3-3.0	69	7	Barnhill et al. (2005)
Venezuela	0.97	0.94-1.00	38	2	Gonzalez (1996)
Marabou *Leptoptilos crumeniferus*					
Uganda	0.9	0.74-1.80		7	Monadjem (2005)
Swaziland	0.41		27	1	Monadjem (2005)
White Stork *Ciconia ciconia*					
Normandy	3		167		Chartier (2001)

includes repeated nesting at same nests in subsequent years * reported as 1.53 in paper

its nest at one month and seven days. Both of these related birds were together over three months after fledging and both associated with the two other juveniles. Two other juveniles at Tullymorgan were observed within 1.75 kilometres of their nest for up to five months. A juvenile colour-banded as a nestling at Bulahdelah in November 2003 was found dead near Casino (400 km NNE) in April 2004, over five months after banding and an estimated 3.5 months after fledging.

Immature birds (1-2 years old) were recorded within the natal territory up to 18 months post-fledging but the possibility that they were birds from other territories could not be ruled out. Aggressive interactions between adults and juveniles were recorded twice, the earliest at just over eight months post-fledging.

We never observed fledglings returning to the nest, in contrast with observations at a nest at Urunga, NSW, where the young returned to the nest at dusk to be fed by their parents (Crompton 2002). Juveniles attempted to forage for themselves within days of fledging, and appeared proficient within two weeks, although they may have lacked the skills to be independent for some time. Juvenile Storks appeared to be dependent on their parents for about seven months, and were tolerated by them for about eight months although some young appeared to leave their natal area about four months after fledging. In India, adults were aggressive towards juveniles five months after fledging, but the young remained in the natal territory until seven to 10 months post-fledging (Sundar 2003). Juvenile Jabirus in Venezuela were dependent on their parents for up to two months (Gonzalez 1996).

Breeding success

The size of broods ranged from one to three birds, with a mean of 1.6 ± 0.8 (Table 1). Broods of three were more common in 2006 than in 2003-2005, but this was not significant for either nestlings ($\chi^2_{(2)} = 3.439$; $P > 0.05$) or fledglings ($\chi^2_{(2)} = 4.00$; $P > 0.05$). Brood size may have been underestimated because small nestlings that died shortly after hatching would not have been detected.

At least 64 storks fledged in New South Wales during the four breeding seasons 2003 -2006, 41 from nests that were observed in every year. Three died shortly after fledging in 2003 and one died after fledging in 2005. Annual productivity varied between 1.0 and 1.7 (average 1.4 ± 0.75 for four years) young per active nest or 1.4 to 1.7 young (average 1.6 ± 0.63 for four years) per successful nest. The regularly observed pairs produced 0.8 fledglings per year, including years in which they did not attempt to breed, four nesting attempts failed to produce any fledglings, three of them in 2004. A large nestling died, presumably of starvation, at the Coraki nest in 2004 and one of two nestlings from that nest died shortly after fledging in 2003.

Breeding productivity differed between years ($\chi^2 = 15.50$, $P < 0.01$, using numbers of nests producing zero, 1, 2 or 3 young in each year). Significantly more young were produced per nest and overall in 2006, the wettest year and fewer young in 2004, a year of average rainfall. Hence, as for many other large waterbirds in Australia, rainfall appears to stimulate breeding of Black-necked Storks and improve their breeding success (Kingsford and Norman 2002). Breeding success in the White Stork in Normandy was also affected by the weather, but for this species heavy rain killed nestlings (Chartier 2001).

Most Black-necked Stork broods range from one to three (this study, Sundar 2003), though four chicks have been recorded in India (Sundar *et al.* 2007) and Queensland (Richards 2005). The Marabou Stork *Leptoptilos crumeniferus* in Swaziland usually produces one or two fledglings from a typical clutch of three eggs (Monadjem 2005), Wood Storks *Mycteria americana* in Georgia had an average of 2.7 ± 0.74 nestlings (Coulter and Bryan 1995) and White Storks in Tunisia had broods of two to four chicks (Azafzaf 2002).

We recorded several cases of loss of nestlings, though we never saw dead nestlings being thrown from the nest by parents or cannibalism, as has been recorded in India (Maheswaran 2003). Infanticide has been recorded in both the White Stork and Black Stork (Zielinski 2002).

Breeding success in this study was slightly lower than for Black-necked Storks in India (Table 3). However, the birds in India foraged in an artificially managed wetland where water levels were maintained throughout the breeding season. Other stork species produce an average of 1.6 young per active nest, ranging from below one in the Marabou Stork to 3.0 in the White Stork (Table 4). The White Stork is more productive than other storks, because it has a larger clutch size of one to seven eggs (average 4), and a very different ecology, being more terrestrial and insectivorous.

Nest site variables and breeding success

Higher nests tended to be re-used more frequently than low nests were ($F_{1, 19} = 11.06$, $P = 0.004$, $\%r^2 = 28.2\%$). There have been no previous studies on the relationship between nest height and nesting frequency of success in Black-necked Storks.

CONCLUSIONS

This study showed that Black-necked Storks may breed annually in New South Wales, from late autumn to early summer. However, individual pairs do not always breed every year. Although the breeding season, including the period of dependency of young, is long, Storks are capable of breeding successfully in successive years. High rainfall before the breeding season appears to encourage breeding and lead to higher productivity, as found in numerous other Australian waterbirds (Kingsford and Norman 2002). At least 64 young storks fledged during the study (mean of 16 young per year), despite three of the four years having below average rainfall. Over all four years, the pairs studied produced 0.9 young per year. Although little is known about the survival rate of Storks, this productivity is probably adequate to sustain the breeding population of the species in New South Wales, which is about 80 pairs (Clancy and Andren 2010).

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