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Nest site selection and nesting behaviour of the Black-necked Stork *Ephippiorhynchus asiaticus australis* in northern New South Wales

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We describe aspects of the nesting behaviour, including nest site selection, of the Black-necked Stork *Ephippiorhynchus asiaticus australis* in New South Wales over a four-year period (2003–2006). Nests were usually placed in the topmost foliage of tall trees, less than 100 metres from water and more than 200 metres from a road or house. The Forest Red Gum *Eucalyptus tereticornis* and Swamp Turpentine *Lophostemon suaveolens* were the most common nest tree species. The well-documented 'up-down display' was observed, as was a previously undescribed 'tree-top display'. The incubation period was 32 to 38 days.

INTRODUCTION

The breeding biology of the Black-necked Stork *Ephippiorhynchus asiaticus australis* in Australia is poorly known with mostly anecdotal or unconfirmed reports on most aspects (Marchant and Higgins 1990). This paper presents the results of a survey of breeding Black-necked Storks in New South Wales focussing on aspects of nests, nest site selection, displays and mating.

METHODS

The nests studied included those that were known previously to GPC, those found during 2002–2005 and others reported by members of the public (including bird clubs, bird watchers etc.). They covered the whole area of New South Wales occupied by the species. Nest checks (<30 mins) were carried out to determine whether a nest was occupied and, if so, what stage had been reached, and nest watches (>30 minutes) were made during which activity was quantified. Information on whether nests were active was also added from other observers. A total of 386 brief visits (of < 30 minutes each, total > 48 hours) was made to 25 nests to check on the presence/absence of birds. In addition, data were collated from 296 watches (320 hours) at 18 nests in the 2003, 2004 and 2005 breeding seasons. Nest watches varied from 30 minutes to four hours duration. Additional brief visits (n = 63) were made during the 2006/2007 season. Other information on nest activity was provided by local birdwatchers and residents.

A nest watch involved one, two or more observers viewing a nest from at least 100 metres. Observation points were partly screened by vegetation to avoid disturbing birds on the nest. Observations were made through one or two spotting scopes (x25 and x32) and Bushnell 8x42 binoculars. Nest visits occurred at all times of the day, although visibility during some early morning visits was affected by fog. Activity at or near nests was recorded to the nearest minute on pro formas during nest watches. The date, location, start and finish times of observations and individual activities, weather conditions (sun, cloud, rain, fog, wind) and temperature were recorded. Adult birds at the nest were sexed by iris colour (dark brown in males and yellow in females). Young were deemed to be present when adults brought food to the nest.

Nest site characteristics were recorded during the non-breeding period to avoid disturbing breeding birds. The location, tree species, tree height, nest height, DBH (diameter at breast height), spread, distance to other trees, and distance to water were recorded. The spread of nest trees was calculated using two measurements from the farthermost tips of the foliage – one at the maximum width and the other at 90 degrees to the maximum width. These two measurements were combined and divided by two to give an average canopy spread. The land use within a 500-metre radius was assessed. Distance to the nearest road and house, and altitude were measured subsequently from maps. Descriptions of old nest trees and sites were also made. This resulted in different totals for a number of the different nest site characteristics discussed in the results.

RESULTS

Nest locations and sites

With the exception of the nest near Moree, all sites were at coastal or near-coastal locations. Nests were found on, or adjacent to, floodplains at altitudes of less than 10 to 160 metres asl, with most (94.4%) below 70 metres (Fig. 1). All nest trees occurred within 1.5 kilometres of a water body (mean ± s.d.: 162.3 ± 259.3 m), with most (60%) either standing in, or less than 100 metres from, water (Fig. 2). Storks were seen foraging in most of these water bodies (46 or 72% of nests).

Nest trees were located from 50 to 2375 metres from formed roads (mean ± s.d.: 611 ± 458 m) (Fig. 3). These roads varied from gravel access roads to highways – tracks and driveways were excluded. Most nests (67.6%) were situated between 200 metres and one kilometre from a road with only 11 nest

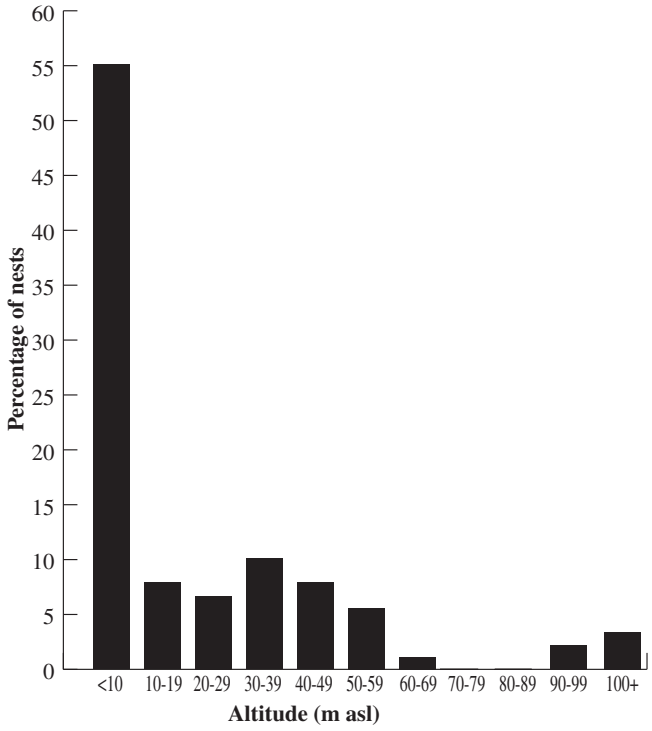

Figure 1. *Percentage of Black-necked Stork nests (n = 89) at increasing altitudes.*

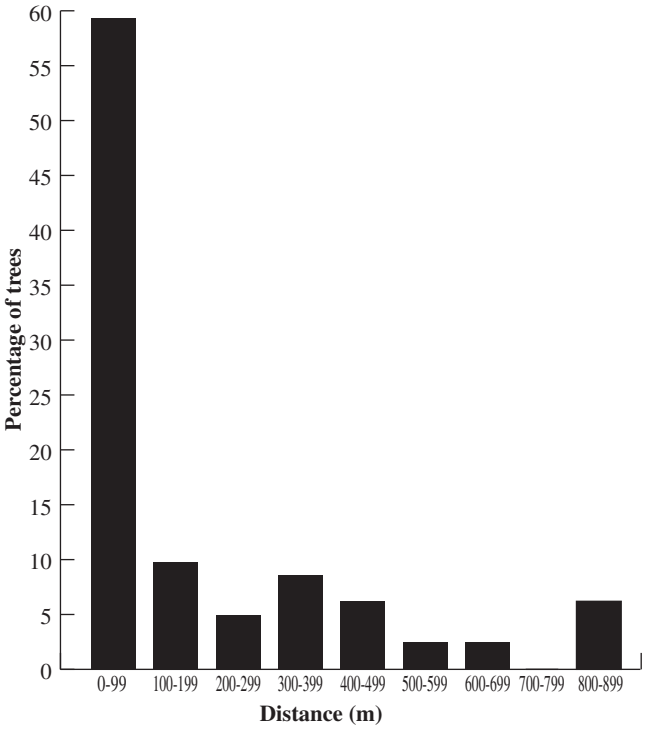

Figure 2. *Percentage of Black-necked Stork nests (n = 81) at increasing distances from the nearest water body.*

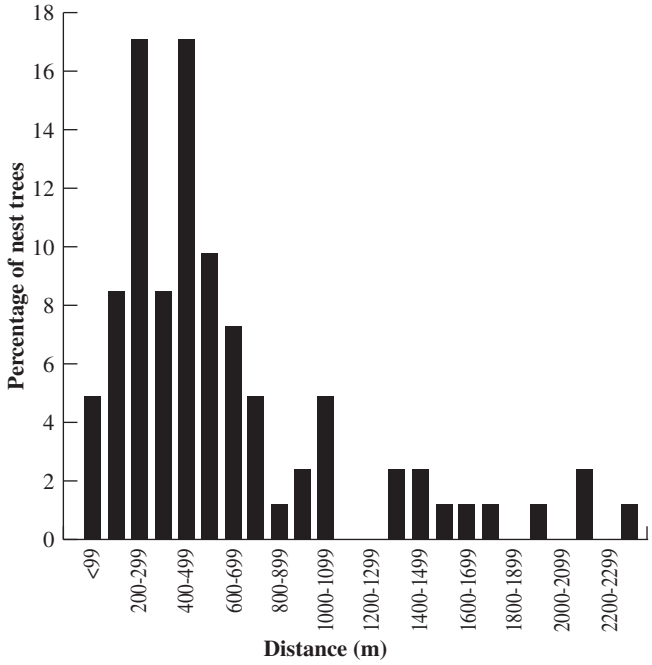

Figure 3. *Percentage of Black-necked Stork nest trees (n = 81) at increasing distances from the nearest road.*

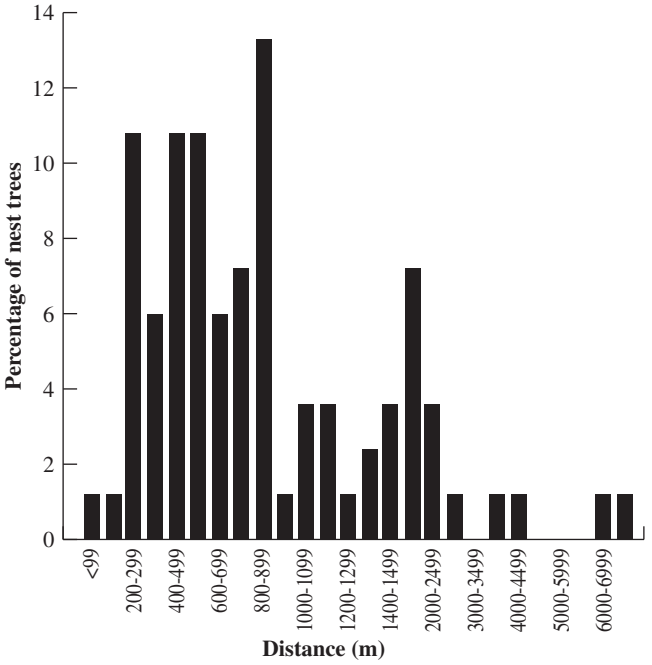

Figure 4. *Percentage of Black-necked Stork nest trees (n = 83) at increasing distances from the nearest house.*

trees (14.4%) less than 200 metres from a road and 15 (18%) greater than one kilometre from a road. The nearest houses to nests ranged from 25 to 10 125 metres in distance (mean ± s.d.: 1082.5 ± 1398 m). Only two nest trees (2.4%) were less than 200 metres from a house (Figure 4). Nest trees were usually in remnant trees in cleared agricultural land, with the surrounding land use being beef cattle grazing (86.2%) (Table 1).

The Forest Red Gum *Eucalyptus tereticornis* was the most common nest tree species, followed by Swamp Turpentine *Lophostemon suaveolens* and Broad-leaved Paperbark *Melaleuca quinquenervia* (Table 2). About 85 per cent of nest trees were species of Myrtaceae and most (81%) were living. Nest trees ranged from one to 44 metres high (mean ± s.d.: 18.8 ± 9.7 m), and nests from one to 41 metres high (mean ± s.d.:

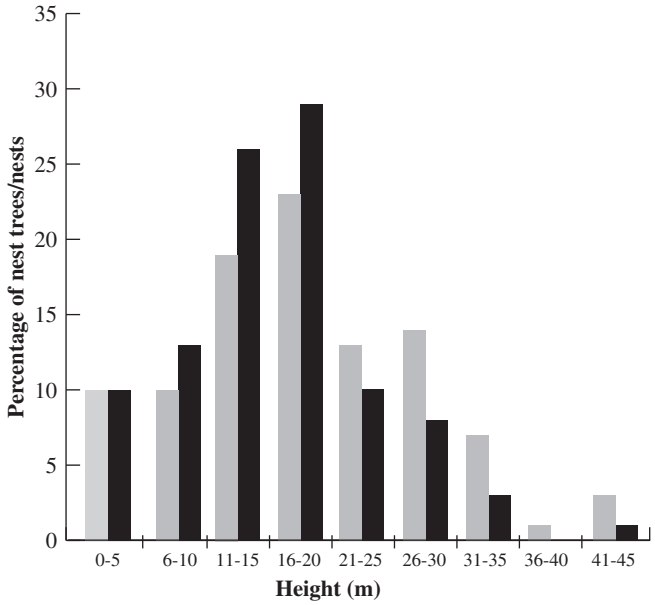

Figure 5. *Percentage of Black-necked Stork nest trees (grey) (n = 70) and nests (black) (n = 70) at increasing heights above ground level.*

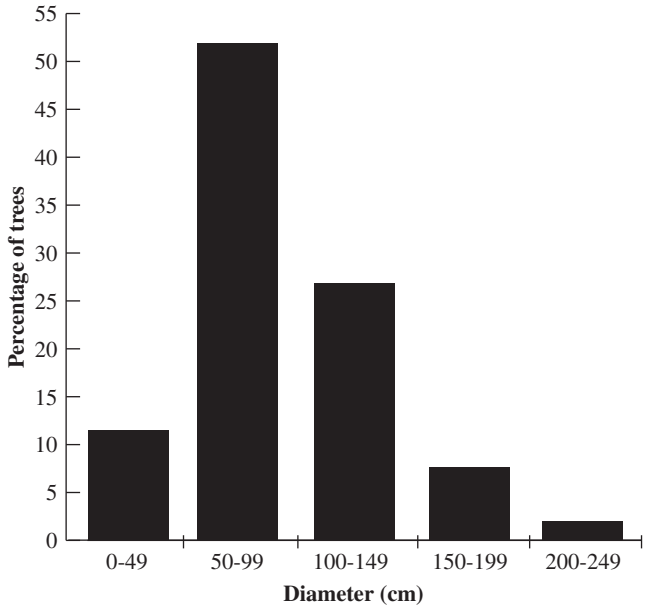

Figure 6. *Percentage of Black-necked Stork nest trees (n = 52) at increasing diameters.*

TABLE 1
Major land use within 500 m of Black-necked Stork nest trees.

Land Use	No. of nests	% of nests
Beef cattle	75	86.2
National park/nature reserve/crown reserve	7	8
Residential	5	5.7
Sugar cane	4	4.6
Tree plantation	4	4.6
SEPP 14 wetland	4	4.6
Native forestry	3	3.4
Quarry/mining	2	2.3
Dairy cattle	2	2.3
Golf course	1	1.1
Piggery	1	1.1
Horticulture	1	1.1
Poultry farm	1	1.1
TOTAL	87	126.1*

*there were multiple land uses at some nests

TABLE 2
Tree species in which Black-necked Stork nests were placed.

Tree species	No. of nest trees	% of nest trees
Forest Red Gum *Eucalyptus tereticornis*	24	30.4
Swamp Turpentine *Lophostemon suaveolens*	17	21.5
Other eucalypts	8	10.1
Broad-leaved Paperbark *Melaleuca quinquenervia*	9	11.4
Other paperbarks *(M. alternifolia, M. linariifolia, M. sieberi)*	5	6.3
Unidentified paperbark	3	3.8
Hoop Pine *Araucaria cunninghamii*	4	5.1
River Oak *Casuarina cunninghamiana* ssp. *cunninghamiana*	4	5.1
Swamp Oak *Casuarina glauca*	1	1.3
Belah *Casuarina cristata*	1	1.3
Others	3	3.7
Total	79	100

16.1 ± 8.1 m) (Fig. 5). Most nests (75.7%) were at a height of between 10 and 30 metres and were placed at a mean of 2.78 ± 3.92 metres below the top of the tree, with 66 per cent less than two metres from the top. Nest height was correlated with tree height (nest height = r^2 = 86.4%, p = 0.000).

Nest trees that were measured ranged in size (DBH) from five to 203 centimetres (95 ± 40.7 cm), with most (78.8%), between 50 and 149 centimetres (Fig. 6). The spread of measured nest trees ranged from three to 22 metres (mean ± s.d.: 9.8 ±5.7 m) with 69 per cent being between three and 10 metres.

Nests were large structures of sticks (Photograph 1), usually within foliage on the top of trees or occasionally on low shrubs in wetlands. Flat-topped trees were generally selected. Most nests were difficult to see from the ground and were only readily detected when birds were present. Of all nest sites documented, including former nest sites, 18 were in open sites such as dead trees or broken limbs of large trees. Sticks were collected from the ground and were usually gathered from under *Eucalyptus/Corymbia* trees. Nest lining was also collected from the ground and from standing clumps of vegetation such as reed beds. It comprised sugar cane trash, rushes and sedges, melon stems (*Cucumis* sp.) and dried grass. Both sexes collected nest material.

Principal Component Analysis of nest sites

Because many of the variables were probably correlated Principal Component Analysis was carried out to reduce the variables to a few main components (Table 3). The first Principal Component (PC1) accounts for 44.9 per cent of the variance and separates nests on the basis of height and size of

Photograph 1. *Nest in Swamp Turpentine, Swan Creek.*

tree. PC2 accounts for an additional 16.5 per cent of the variance and separates nests by altitude and distance from water. Those at higher altitudes are closer to water. PC3 accounts for a further 13.3 per cent of the variance and separates nests by distance to nearest road

Displays and mating

Two separate displays were observed, the 'up-down display' and a 'tree top display'.

The 'up-down display' often, but not always, occurred as one adult bird arrived at the nest to relieve the other. It was initiated by both males and females. One bird would initiate the display by spreading its wings and tail, the other bird would join it and would mirror its partner, with both shaking their wings vigorously and stretching their necks upwards and holding their bills slightly lower than horizontally. This was accompanied by a loud clapping of their bills. The whole display would last for about five to 10 seconds.

The 'up-down display' was recorded 15 times at or near nests, 10 of these immediately after an adult male had landed on the nest. Four displays occurred during the pre-egg stage, six during the egg stage and five while nestlings were on the nest. Two displays occurred while a third adult was present. The 'up-down display' was also observed away from the nest eight times during the study and twice before the study. Six of these displays occurred while a third adult was present, once while an additional adult pair of storks was present, once when an adult female landed in a wetland near an adult male, once while a juvenile stork was nearby, and once as a White-bellied Sea-Eagle *Haliaeetus leucogaster* flew low overhead.

The 'tree top display' was observed twice. First, one adult landed rather precariously in the top of a tall tree after a short period of low circling by the pair. The second bird attempted to land, failing to do so or causing the first bird to lose its balance and fly off. The first bird then circled around and landed in another tree and the process was repeated.

Mating occurred on the nest and was witnessed only during nest construction, and possibly early incubation, between May and August. It was not associated with any display within 30 minutes, which was the shortest period between mating and the performance of the 'up-down display'.

Table 3

Principal Component Analysis of nest sites. Variables that contribute substantially to each Principal Component are in bold.

	PC1	PC2	PC3
Altitude	0.251	**0.534**	-0.206
Tree Height	**0.521**	-0.039	-0.175
DBH	**0.483**	-0.153	0.021
Nest Height	**0.532**	0	-0.124
Distance to Water	0.037	**-0.746**	0.222
Distance to Road	-0.161	-0.319	**-0.921**
Distance to House	-0.351	0.179	-0.12
Eigenvalue	3.1397	1.154	0.931
Propn of Variance	0.449	0.165	0.133
Cumulative Propn	0.449	0.613	0.746

Table 4

Stage of breeding and temperature readings when water was brought to nest by Black-necked Storks

Month	Stage of breeding	Temperature ºC
July	Egg	20º, 22º, 24º, 23º, 23º
August	Egg	18º, 26º, 21º, 17.5º
September	Nestling	26.5º
November	Nestling	34º

Incubation

The clutch size could not be determined due to the height and inaccessibility of active nests. The incubation period at one nest was recorded as at least 32 days and two unsuccessful attempts lasted 33 and 38 days. Both parents regurgitated water over the contents of the nest during both the egg (observed 16 times) and nestling (14 times) stages (Table 4). This was not confined to hot days.

DISCUSSION

Nest sites

Black-necked Storks typically nested below 70 metres altitude (the altitude of coastal floodplains) with over half of the nests being less than 10 metres. This is probably because their nest trees are normally close to wetlands, where storks forage. In contrast, Marabou Storks *Leptoptilos crumeniferus* nest colonially well away from rivers, drainage lines or water bodies in Swaziland (Monadjem 2005), and they also spend much of their time feeding away from water. Nest trees were usually greater than 200 metres from roads and houses, suggesting that nesting Marabou Storks may be sensitive to human disturbance. Asian Openbill Storks *Anastomus oscitans* in India also nested away from the greatest human disturbance, and nested higher following disturbance (Datta and Pal 1993).

The predominant land use around nest sites was beef cattle grazing, because this is the most common agricultural pursuit on the coastal floodplains. Hardwood and softwood plantations are replacing beef cattle grazing in some areas. This could reduce the availability of nest trees near foraging sites, unless adequate controls on clearing of large remnant trees are imposed.

Most nests were placed within two metres of the top of tall trees (11–30 m) and hidden in the foliage. These trees were mostly situated in a cleared paddock. This location provided good views of the surrounding area (as noted by Campbell 1900), and was easy for the Storks to approach, while being hard for predators such as humans and monitor lizards to locate. A few were in a low shrub in the middle of a wetland. About 90 per cent of Greater Adjutant Stork *Leptoptilos dubius* nests in India were built on the top of the canopy (Singha *et al.* 2002), and Jabirus *Jabiru mycteria* also nest 15–30 metres above the ground in Belize, close to water (50% < 100 m) (Barnhill *et al.* 2005). Most nest trees belonged to the family Myrtaceae because these were the most common large trees.

Both adult Black-necked Storks collected sticks from the ground near to nest trees. Hence, the presence of other large trees is probably important in choosing a nest tree. Nest lining was freely available in the form of long grass and aquatic vegetation. Both adult Black-necked Storks also collected nesting material in India (Maheswaran and Rahmani 2005). Nests are approximately one to two metres across and one metre high (Hume 1890; Campbell 1900). Nests were not measured in this study, but most would have been about this size or larger.

A study of Black-necked Stork nests in India using Principal Component Analysis found significant loadings for canopy spread, DBH, distance to road, distance to other species nest (potential predator) and tree height indicating that tree size and avoidance of disturbance were the most important factors in nest site selection (Ishtiaq *et al.* 2004). The findings of this study were generally similar although canopy spread was more variable and did not appear to be important and the distance to predator nests such as those of the White-bellied Sea-Eagle and Wedge-tailed Eagle *Aquila audax* was only known for a few nests and was therefore not included.

Displays and mating

The 'up-down display' occurs in all stork species (Hancock *et al.* 1992; Slikas 1998), but the 'tree top display' has not previously been described for any stork species. The up-down display was used at nests during the breeding season, or when a third adult stork entered the breeding territory but away from the nest. When the display was directed at an intruder, the intruder departed. This display possibly strengthens the pair bond as it usually occurs when paired individuals meet after a short absence.

Purcell (1993) recorded anxiety displays, allopreening, erect gape display, territorial dance displays and greeting displays at a nest in the Richmond River Valley. The latter two may refer to the 'up-down display'. Purcell (1993) also observed an adult male on the ground walk in slow circles, throw back his head, and noisily clap his bill.

Mating was only recorded in the pre-egg laying or early stages of incubation and occurred on the nest. Mating in storks has been described as a display, known as 'Copulation Clattering' (Kahl 1973; Slikas 1998), which involves both sexes spreading their wings and the male bill-clattering.

The 'Flap-Dash' display has been described in the Black-necked Stork, Saddle-billed Stork and the Jabiru by Kahl (1973) and Slikas (1998). This was never observed when a second adult bird was present. This display has not been reported subsequently in the species in India, despite many hours of observation recently (Maheswaran and Rahmani 2002, 2005). It is very similar to the foraging technique 'actively running down prey' (Clancy 2008), and should not be regarded as a display.

Kahl (1973) also described the 'Erect Gape' and 'Anxiety Stretch' displays in the Black-necked Stork. Birds may stand erect on the nest while panting due to heat stress, and may also stretch in response to a disturbance. These displays may be more elaborate and therefore more effective in colonial nesting species, as solitary nesters tend to have far less elaborate courtship rituals (del Hoyo *et al.* 1992).

Incubation

Stork pairs share nest duties (del Hoyo *et al.* 1992; Hancock *et al.* 1992) and it was assumed that Australian Black-necked Storks shared incubation (Marchant and Higgins 1990), but this was not confirmed until this study. When not incubating, parents spent time on the nest, repairing the nest, collecting nest lining, transporting water to the nest or just standing. Water was transported to the nest between May and August, during the dry season and would appear to be done to increase the moisture of the nest and eggs rather than to regulate temperature. The maximum temperature recorded during this activity was 26ºC and the minimum was 17.5ºC. Similarly in India an adult bird drank 21 times from a marsh and returned to regurgitate water over the nest (Kahl 1971, 1973).

Captive Black-necked Storks at Port Douglas, North Queensland, incubated for 35 days, with egg laying and hatching intervals being 2.5–3 days (Terry J. Carmichael in litt. 28/06/2005). An incubation period of around 34 days was recorded at a nest at Urunga, NSW (Crompton 2002). These compare with the 32–38 days found in this study. Most stork species have an incubation period of between 25 to 38 days (del Hoyo *et al.* 1992).

This study confirmed behaviours that have been reported previously and contributed to knowledge of the breeding biology of the species, in particular details of nests and nest site characteristics, displays and incubation of eggs were documented, mostly for the first time. The nesting behaviour is similar to that of the species in Asia and other similar stork species in other countries.

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