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Breeding behaviour in the Spangled Drongo *Dicrurus bracteatus*

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Abstract. Over a period of five breeding seasons (between November 2008 and January 2013) the breeding behaviour—including nest-site selection, nest building, incubation and care of nestlings and fledglings—of the Spangled Drongo *Dicrurus bracteatus* was observed at Coowonga on the central Queensland coast, and from this the breeding success was estimated. The breeding season was from November to January, with a consistent start date from year to year. The incubation and nestling periods were also consistent from year to year. A nest was generally positioned in a tree near a clearing and in the outer part of that tree. Several factors contributed to nest-site selection: nest-tree species, habit and height, diameter of the tree's outer branches, availability of dead branches, proximity of the nest-tree to a clearing and to water, and height of the nest above the ground. New findings were the frequent attachment of a nest to dead twigs and the consistent placement of a nest on the first branch below the spreading canopy of the tree. The occurrence of colonial breeding was more difficult to determine, with many features of this behaviour (such as group nesting and co-operative defence against predators) being evident, but nests were widely dispersed over a large area. Rotation of nest-sites may be used to minimise predation, with some Drongos using a nest-site one year, but not the next, and then returning to that nest-site the following year.

Introduction

There is limited understanding of the breeding ecology of the Spangled Drongo *Dicrurus bracteatus,* constrained by previous studies recording nesting behaviour over only a very short time frame. This study was therefore designed to investigate the breeding behaviour of the Drongo over an extended period (five breeding seasons). This approach was used to build on previous observations by North (1892) on nest construction and location, clutch-size and egg metrics, by Banfield (1908) on nest construction and location, and by Longmore & Scoular (1989) on nest location. Further, a study by Wood (1996) analysed Royal Australasian Ornithologists Union (RAOU) and other records to present information on nest-site, habitat, nest building, clutch-size, incubation, nestling and dependence periods, breeding season and success, nesting associations and brood-parasitism.

The Spangled Drongo, in the family Dicruridae, the only drongo in Australia, occurs along the eastern coast from southern New South Wales (NSW) through to far north Queensland, as well as the Northern Territory inland to Katherine and the Kimberley region of Western Australia; elsewhere, it occurs in New Guinea, Indonesia, the Solomon Islands and South-East Asia. Within Australia, it inhabits the fringes of rainforest, eucalypt forest, mangroves and woodlands as well as urban parks and gardens (Higgins *et al*. 2006). It is a resident that breeds from October to February, exhibits some fidelity to nest-sites, and has been observed breeding in colonies (Higgins *et al.* 2006).

This study aims to add more detailed observations, such as influences on the commencement of breeding, nest-site selection, nest building, incubation and nestling periods, and factors influencing breeding success, from a single location on the central Queensland coast over an extended time. In addition, colonial breeding, which has been recorded previously by North (1892) and Vernon (1968), is considered in relation to breeding success. Detection of predators is considered to be one of the major reasons for colonial breeding in other species (e.g. Ehrlich *et al.* 1988). Higgins *et al*. (2006) noted that no detailed studies of breeding have been conducted for the Spangled Drongo, so the present study will make an important contribution to addressing key gaps in knowledge.

Methods

This study took place between November 2008 and January 2013 at Coowonga, ~23 km north-east of Rockhampton, Queensland (23°17′S, 150°42′E). The study site was in a continuous stretch of subtropical open forest dominated by eucalypts, and encompassed an area of 500 m x 500 m. Nest-sites were identified by searches during November and December. Known nest-sites were checked every second day to determine the commencement of nest building, and other potential nest-sites were checked at the same time. Newly located nests were included with those being monitored as each site became active. Twelve nest-sites were monitored every second day from the beginning of the breeding period in November to the end of January. Inspection of each nest was dependent on the phase of breeding activity: before nest building, known nest-sites were observed for *c.* 2–3 minutes; during incubation for *c.* 5 minutes; and during feeding of nestlings for *c.* 30 minutes. Observations were made using binoculars from a vantage point that allowed a view of a nest at a near-horizontal level, but did not allow views into the cup of the nest. The study site was hilly, and close vantage points (within 30–40 m) could be found for most nests. Nests were rarely lined, and sometimes their contents could be seen through the nest when the bird was not incubating (as noted by Vernon 1968), which often allowed the eggs to be counted.

Data were collected on nest building, incubation, fledging and number of chicks that fledged (Table 1). Heights of the nest-tree and of the nest above the ground were

Table 1. Data on breeding of the Spangled Drongo at Coowonga, central Queensland.

Date nest building commenced
Number of nests built
Date incubation commenced
Date adults commenced feeding nestlings
Date nestlings fledged
Number of nestlings fledged
Number of successful nests
Date of nest depredation
Species of nest-tree
Height of nest-tree (m)
Location of nest at extremity of first branch off main trunk
Height of nest above ground (m)
Distance between nests (m)
Type of twigs used to secure nest (dead or live)
Materials used for nest construction
Behaviour of Drongos at nest-site
Distance of nest from clearing (m)
Distance of nest from water (m)
Daily rainfall (mm)

determined by triangulation. The locations of nests were determined using a GPS and this information was then plotted on a map from Google Earth to determine distances between nests, and the distances of nests to water and to the nearest clearing (an open space in a forest with no trees or understorey). A broad definition of the breeding season—as the period from nest building to fledging—was used, which is consistent with Thomson (1965), Blakers *et al.* (1984) and Campbell & Lack (1985). To investigate the possibility of rainfall having an influence on the commencement of the breeding season, rainfall data were collected for the whole of the 5-year period and compared with the commencement of nest building.

There are many measures of breeding success (e.g. Murray 2000). For this study, a nest was deemed to be successful if at least one young fledged but not successful if all nestlings died or were preyed upon. Data were collected on nests that produced nestlings, but not on the number of eggs that were successful, as it was not possible to determine the number of eggs for all nests (see p. 83).

The four factors determining nest-site selection (i.e. species and height of nest-tree in relation to height of nest above the ground, proximity to water, and nest location in the nest-tree) were compared using a ranked coefficient of variation allowing standardisation of measurement scale. This approach also facilitates comparisons between factors: the factor with the lowest variance indicates the strongest selection preference.

Results

The same 12 nest-sites were observed each breeding season over the 5-year period, between November 2008 and January 2013, but not all were used each season, with a maximum of seven and minimum of five nests being used in any year. Over the 5-year period, 32 nests were built but, because of predation, bad weather or nests being abandoned, only 14 produced fledglings (Tables 2 and 3).

Breeding season dates and influence of rainfall

The earliest that nest building was observed was 11 November (2011), and the latest was 30 December (2011). Within an annual cycle, the earliest fledging occurred on 27 December (2011), and the latest on 25 January (2009), although one nest that was destroyed had nestlings that would have fledged in early February. This indicates that the breeding season is from early November to January or perhaps early February, a period of 3 months.

Rainfall was recorded each day throughout the breeding season to determine if there was any correlation between this and the commencement of nest building. These data showed that a minimum of 16 mm occurred before nest building in any year (Table 4).

Selection of nest-sites

The following factors appeared to be important for nest-site selection:

(1) **Nest-tree species.** Lemon-scented Gum *Corymbia citriodora* (11 nests) and Poplar Gum *Eucalyptus platyphylla* (1 nest) were the two species of nest-tree used during this study.

(2) **Heights of nest-tree and of nest above the ground.** The lowest nest-tree was 15.5 m and the tallest was 44.6 m (mean 25.6 m). The lowest nest was 7 m and the highest 26 m above ground-level (mean 12.7 m).

Table 2. Spangled Drongo nest-sites used (x) over the five breeding seasons between November 2008 and January 2013 at Coowonga, central Queensland.

Breeding season	*Nest-site*												*Totals*
	A	B	C	D	E	F	G	H	I	J	K	L	
2008–2009	X	X	X	X				X					5
2009–2010	X		X	X	X	X	X		X				7
2010–2011	X	X	X			X	X		X	X			7
2011–2012	X	X						X	X	X	X	X	7
2012–2013		X		X			X	X	X		X		6
Total no. of times used	**4**	**4**	**3**	**3**	**1**	**2**	**3**	**3**	**4**	**2**	**2**	**1**	**32**

Table 3. Spangled Drongo breeding at Coowonga, central Queensland: successful nests and nestlings fledged. Breeding success for the colony per nest = number of nestlings fledged divided by number of nests with eggs in the colony; average breeding success per successful nest = number of nestlings fledged divided by number of successful nests.

Breeding season	*No. of nests built*	*No. of successful nests (i.e. chicks fledged)*	*No. of nestlings fledged*	*Total no. of nests with eggs in the colony*	*Breeding success for the colony per nest*	*Average breeding success per successful nest*
2008–2009	5	2	6	5	1.2	3.0
2009–2010	7	3	7	7	1.0	2.3
2010–2011	7	4	9	7	1.3	2.3
2011–2012	7	1	2	3	0.7	2.0
2012–2013	6	4	11	6	1.8	2.8
Totals	**32**	**14**	**35**	**28**		
					Mean for all nests	**2.46**
					Standard deviation	**0.4**

(3) **Location of nests relative to water and clearings in woodland.** The three nests (H, I and K) along a dirt road (which created an open area in the woodland/forest habitat) were the farthest from water, at 200, 230 and 120 m, respectively. The other nine nests were grouped around a creek, all within 120 m of the creek. The amount of water in the creek varied according to rainfall; sometimes the creek was flowing but there were always waterholes.

All of the nests were located either adjacent to a clearing or along a road. Three of the nests (H, I and K) were in trees along the edge of a dirt road with a thick understorey of regrowth *Acacia* spp., Swamp Mahogany *E. robusta* and Poplar Gum with a dominant tall canopy of Red Bloodwood *Corymbia erythrophloia* and Lemon-scented Gum on one side and a large clearing within 100 m. The other nine nests were located around the edge of a clearing with a thick mixed forest behind. All of the nests were built on the edge of a thick forested area that gave way to either a road or a clearing.

(4) **Location of nest in nest-tree.** A nest was always located on the first main branch off the trunk and near the end of one of the twigs on the outer branch, generally ~1 m from the end. It was always built in a horizontal fork that often had one dead twig and more frequently two dead twigs (slender woody shoots growing from a branch, with a diameter of 8–12 mm and usually located at the termination of a branch).

Coefficient of variance analysis ranked the following factors as determinants of nest location (from most to least important): nest-tree height (0.32), height of nest above ground (0.41), distance to clearing (0.63), and distance to water (1.24). Although height of nest-tree is the most important factor, the height of the twig selected for the nest location is dependent upon tree height since the higher the tree the higher will be the first branch off the main trunk.

Nest building

Some variation in nest building was observed, especially with regard to its commencement at different nest-sites.

Table 5 compares the start date (mean and range) of nest building for nests built in November. When breeding occurred in November, there was a variation of 10 days in the commencement of the breeding season, which corresponds to a difference of just 0.1 h in the daily amount of daylight across the 10 days. There was a clear preference for nest building in November (88% of nests built) rather than December.

Nest materials

A nest was built from the narrow neck of the fork outwards. Nest materials were coiled vine tendrils, collected from Orange Trumpet Creeper *Pyrostegia venusta* (an ornamental garden species) and native vines *Cassytha* spp., which were collected by birds pulling vigorously until the tendrils broke off. Straight vine stems were also collected, using the same method, and wrapped around the nest-site twigs to form a shallow hammock nest. All nests contained vine tendrils; other nest material included

Table 4. Rainfall and daylight hours at commencement of nest building by Spangled Drongos for nests built in November at Coowonga, central Queensland, between 2008 and 2013.

	Breeding season				
	2008–2009	*2009–2010*	*2010–2011*	*2011–2012*	*2012–2013*
Median date of commencement of nest building in November (range in parentheses)	25 (24–27)	25 (12–30)	21 (18–23)	15 (11–17)	19 (18–21)
Number of hours of daylight/day	13.2	13.2	13.2	13.1	13.2
Rainfall (mm) in November (dates in parentheses)	18 (9), 31 (20), 34 (21)	17 (25)	12 (5), 10 (9), 23 (20), 47 (21)	16 (13)	38 (11)

Table 5. Nest building by Spangled Drongos at Coowonga, central Queensland: mean start dates for nest building for nests built in November, and numbers of nests built in November and December.

	Breeding season				
	2008–2009	*2009–2010*	*2010–2011*	*2011–2012*	*2012–2013*
Mean start date of nest building for nests built in November	25.4	25	21.3	15.3	19.7
Range of dates for start date of nest building for nests built in November	24–27	12–30	18–23	11–17	18–21
No. nests built in November	5	6	7	6	4
No. nests built in December	0	1	0	1	2

fine grass, small twigs (diameter <8 mm) and plant fibre. Spiders' webs were also used, and these were often wrapped around the fork twigs before the vine tendrils were put in place and, because of their sticky nature, may have been used to secure the nest.

Participation in nest building

Both male and female contributed to nest building, although one bird seemed to do most of the building and the other supplied materials. Sexes are similar in the Spangled Drongo and difficult to determine in the field, but while one bird flew off to seek materials the other of the pair either sat on a nearby branch and watched or occasionally collected nest materials and brought them to the nest, indicating that both male and female participated in nest building.

During early nest building, some Drongos stripped leaves off the twigs of adjacent trees. This behaviour was seen only three or four times at one to two nest-sites each season during the study period. An individual plucked a leaf and then let it fall, with this happening several times in quick succession so that a flurry of leaves fell at the same time. The leaves were not seen to be used for any purpose so this behaviour may be part of a courting/bonding ritual, but further study is required to clarify this. The other bird sat in a nearby tree apparently observing the leaf stripping. This leaf-stripping behaviour was observed on two occasions during the incubation/nestling period, but was more commonly seen during nest building. Leaf-stripping behaviour during nest building was performed by different individuals at different nest-sites from that occurring during the incubation/nestling period.

Most nest building took place in the morning, especially in the cool part.

Building and rebuilding a nest

Some nest building occurred where the nest was not used for breeding. In one instance, a pair of Spangled Drongos built six nests in three different trees and did not use any of them. Two of those nests were only partially built to an unfinished condition, whereas four were constructed to a finished condition. Once, a nest was constructed, and the birds stayed in the area and visited the nest location but did not lay eggs.

Drongos were observed to build a second nest, usually in a nearby tree, if the first had been depredated. This was observed on three occasions where nests had been depredated, destroyed or abandoned (n = 18 nests). However, not all depredated nests were rebuilt.

Incubation and nestling periods

For 16 nests with eggs that hatched, the mean time between laying and hatching was 21 ± 1 days. Of the 14 nests with nestlings that fledged, the mean time between hatching and fledging was 20 ± 1 days.

Distance between nests

For the 12 nests observed in this study (not all used at the same time), the closest distance between two nests was 30 m, and the greatest was 390 m (mean 104 m, standard deviation 105 m).

Breeding success

The mean breeding success per successful nest was 2.46 young fledged (range 2–3) (Table 3). Comparing the number of successful nests with the number of nests built (14/32), the success rate is 44%. Of the 18 nests that were not successful, three failures were attributed to bad weather, five nests did not have eggs laid in them, and ten nests were depredated. Of the depredated nests, nine had eggs taken, and only one had nestlings taken. As depredation was not actually observed, it was not possible to determine the predators responsible. When depredation took place, a nest was torn apart and virtually destroyed. Possible predators could include Pied Currawong *Strepera graculina* and Laughing Kookaburra *Dacelo novaeguineae*, both of which were observed in the study area.

Discussion

Breeding ecology

The breeding season, and incubation and nestling periods observed in this study correspond with those of Wood (1996), who examined 42 Spangled Drongo nest records north of 27°S, and found that the breeding season commenced in early November and lasted until January, with an incubation period of 19 ± 1 days and a nestling period of 22 ± 1 days.

Colonial breeding

We have used the definition of colonial breeding of Wittenberger & Hunt (1985, p. 3): "a place where a number of individuals or pairs nest…. At a more or less centralized location from which they regularly depart in search of food". Higgins *et al.* (2006) considered the social organisation and colonial breeding behaviour of Spangled Drongos to be poorly known. North (1892, p. 87) reported

that "Mr. C. C. L. Talbot found [Spangled Drongo] breeding on Collaroy Station, near Broad Sound, Queensland" and that he found 12 nests in trees 50 yards [~46 m] apart. Vernon (1968) reported Drongos often nesting ~ 45 m apart, and Holland (1967) reported two nests 91 m apart.

In the first year of the present study, five nest-sites were used, but nest-site K was not found until the second year. In the second, third and fourth years, seven nest-sites were used, and in the fifth year six nest-sites were used. Because of fidelity to nest-sites, it is likely that the same individual birds were breeding each year. If rotation of nest-sites had been occurring, there did not appear to be any obvious pattern, with some nest-sites being used 4 years in a row and others used only once in the 5 years. This means that at least five nest-sites were not used in any one year and those that were used varied from year to year (Table 2). This may suggest rotation of nest-sites as a means of avoiding predation. Predation events triggered the abandonment of a nest-site in the year of predation but not in subsequent years, since six nest-sites were used the year after the nests had been depredated. It is possible that the advantages of colonial breeding, such as the early detection of predators and co-operative assault to drive away predators, outweigh the risks of predation. Further research is needed over a longer period to determine the potential reasons for this.

Robertson (1967) reported that Spangled Drongo nests were built at the same site near Murwillumbah, NSW, for eight successive years, Longmore & Scoullar (1989) found Drongos nesting in the same locality for 2 years near Coffs Harbour, NSW, and Wood (1996) noted that the same site was used by this species for at least three out of four years. Beruldsen (1980) and Pizzey (1980) both described that many pairs use the same site for years if left undisturbed and that the Drongo tends to return annually to the same nest-site. These reports indicate that the Drongo is faithful to a nest-site and has been seen nesting in small colonies.

Other co-operative behaviour that can be attributed to colonial breeding was observed in the present study. Spangled Drongos from adjacent nests were observed to meet in a tree midway between the nests and engage in singing and display flights before moving off for what may have been joint foraging. They also visited each other's nest-sites, again singing and conducting aerial displays. This behaviour seemed to take place only between birds of adjacent nest-sites. Birds from adjacent nest-sites were also observed mobbing predators such as the Whistling Kite *Haliastur sphenurus* and Black Kite *Milvus migrans.*

Overall, it is unclear what purpose this group breeding served, as nests were too far apart to provide co-operative early warning of the approach of a predator as suggested by Lack (1968), and further investigation is needed.

Breeding success

Breeding success of the Spangled Drongos in this study was 44%, which is lower than reported by Wood (1996) (67%). As sample sizes in both these studies were small, however, the results should be treated with caution.

Breeding habitat

In this study, Spangled Drongos used Lemon-scented Gums and (once) Poplar Gum for nesting. Nests of this species have also been observed in Queensland Blue Gum *Eucalyptus tereticornis* near Rockhampton, Queensland (AB pers. obs.). Elsewhere, Banfield (1908, p. 178) stated that the Drongo "invariably selects the Moreton Bay Ash [*Corymbia tessellaris*] for nesting" on Dunk Island; Cooper Creek Wilderness (2010) reported a Drongo nesting in a Blue Quandong *Elaeocarpus grandis* at Daintree, Queensland; and Morecombe (2003) mentioned Blackbutt *Eucalyptus pilularis* and other eucalypts as nest-trees. Other authors have identified additional nest-tree species: Grey Ironbark *E. paniculata* (Longmore & Scoullar 1989); Cuban Royal Palm *Roystonea regia* and Carpentaria Palm *Carpentaria acuminata* (Higgins *et al.* 2006); and Poplar-leafed Gum *E. alba* (= Poplar Gum *E. platyphylla*), Moreton Bay Ash, Brush Box *Lophostemon confertus*, Blue Quandong, Flooded Gum *E. grandis,* Native Frangipani *Hymenosporum flavum,* Guioa *Guioa semiglauca* and Kurrajong *Brachychiton populneus* (Wood 1996).

Given the wide variety of nest-trees used, it seems that it is not the species but the habit of the tree that is important. In all cases, the trees grow to a minimum of 20 m, and mature trees have the first branch leaving the trunk >10 m above the ground (Centre for Plant Biodiversity Research 2006). In this study, the Spangled Drongo always nested at the end of this first branch, and this affords a nest-site below the spreading canopy of the tree and with an unobstructed view of the area below the tree. The canopy above may help to conceal the nest from predators, and the open view below may allow early detection of approaching aerial predators such as a Pied Currawong or Laughing Kookaburra. Wood (1996) analysed 53 RAOU nest records and although the tree species, height of nest above ground, tree height and proximity of the nest to the end of a branch were frequently recorded, none mentioned the nest positioned at the end of the first branch off the trunk. This finding will need to be examined at other locations to determine if it is consistent behaviour for the species.

Influences on commencement of the breeding season

Circannual rhythms are processes that occur at an interval of *c*. 1 year and are considered to be the most important influence on the commencement of the breeding season for many bird species (Burton 1985; Gwinner 2003). However, Gwinner (2003, p. 772) stated that the "circannual mechanism is replaced or supplemented in older birds by mechanisms formed on the basis of learning and memory". This could mean that local conditions such as rainfall could influence the commencement of breeding, as appeared evident in the current study.

Location of nest in a tree

This study showed three key factors in nest-site selection by Spangled Drongos: a nest is positioned on the first branch off the main trunk, it is placed ~1 m from the end of the branch, and it is usually attached to dead twigs. Most of the nests in this study were built around the dead twigs at the end of a branch; nine out of 12 (75%) were placed on at least one dead twig, with four (33%) of those on two dead twigs. This suggests that dead twigs are favoured but not essential for nest-site selection. A possible reason for the use of dead twigs for a nest-site may be that for

eucalypts, which shed their bark in October–November, the branch surfaces change from being a dull-brown colour to various shades of light green to light brown, all of which make a nest more visible, so the use of dead twigs may camouflage the nests to some degree. One nest was built in a cluster of dead Box Mistletoe *Amyema miquelli* that provided excellent camouflage. Nest location at the end of a thin twig may also prevent tree-climbing predators, such as goannas *Varanus* spp., from reaching a nest. Nest-support twigs (measured from fallen branches) were 8–12 mm in diameter, and would probably not support the weight (average 6 kg: King & Green 1999) of a goanna.

Based on 30 RAOU nest records (Wood 1996), Spangled Drongo nests are usually placed <2 m (mostly <1 m) from the end of a branch. However, the current study also highlights the importance of dead twigs and placement of a nest on the first main branch off the trunk (which thus positions the nest below the canopy of the nest-tree). Although some dead twigs would eventually break off, the birds build a nest in subsequent years in a similar location in the same tree, but still mostly around dead twigs.

Nest materials

The use of vine tendrils in nest construction is consistent with reports cited in Higgins *et al.* (2006). Le Souef (1902), Mathews (1914) and Holland (1967) all reported nests made from tendrils collected from the bootlace vine dodder *Cassytha* spp., sometimes lined with fine material but often unlined. As in the present study, Mathews (1914) also reported the use of spiders' webs.

Height of nest-tree in relation to height of nest above the ground

This study shows that the nest-tree must be tall enough for a nest placed on its lowest branch to be 7–12 m above the ground. Wood (1996) reported a mean height of Spangled Drongo nests above the ground of 11 m (range 4–30 m) and a mean nest-tree height of 17.8 m (range 8–50 m). The present results [mean height of nest above ground 12.7 m (range 7–26 m); mean nest-tree height 25.6 m (range 15.5–44.6 m)] thus broadly concur with Wood's (1996) study. The height of the lowest branch on the tree appears to be as significant as the height of the nest-tree for selecting a nest location.

Nest location within the landscape

The whole study area (500 m x 500 m) was examined to determine the location of suitable nest-trees. Given that suitable nest-trees were identified inside forest locations away from a clearing and within 120 m of water, the proximity to a clearing potentially has a strong influence on nest-tree selection. Suitable trees in thick forest were not selected even if they were close to water. This factor of nest proximity to a clearing has not been discussed in other studies and its significance for nest-site selection needs to be confirmed by observations at different geographical locations.

In the present study, all Spangled Drongo nests were built at a maximum of 56 m above sea-level (asl), which is consistent with Wood (1996), who concluded that this species nests at altitudes <100 m asl. Several factors may influence this, such as preferred habitat, availability of insects, nectar and fruit, and temperature.

Nest building

The results showed a variation of 10 days in the start of the breeding season when breeding occurred in November and a difference of just 0.1 h in the daily amount of daylight across these 10 days. There are *c.* 13 h of daylight around 2–3 November each year in the study area, and soon after that nest building commences. This consistent start to nest building indicates that the length of daylight has a strong influence on the time of year when breeding commences. However, other factors are also likely to contribute.

Of the four nests built in December, the latest day that building commenced was 24 December, with 13.6 h of daylight, a difference of 20 minutes compared with the day length of the earliest date in November. As there was a variation of 43 days in the commencement of nest building, however, this raises the question of what other influences could affect the commencement of nest building. Wikelski *et al.* (2008, p. 411) stated that "Circannual clocks are synchronized with the environment by changes in photoperiod, light intensity and possibly temperature and seasonal rainfall patterns". Elkins (2010) indicated that, in general, rainfall is an important influence on the commencement of nest building for both the collection of suitable nest material and for the availability of food. Using rainfall records for November, there is a strong correlation between rainfall and nest building, with a rainfall event of a minimum of 10 mm occurring before nest building in each year (Table 4). However, this does not explain the anomaly of why some birds delayed nest building until December. In 2012, two nests were built in December, one on 12th and one on 24th, with very light rain of only 2 mm on three occasions late in the month. The nest built on 30 December 2011 was built after very heavy rain (233 mm) fell in the middle of the month. The other nest built in December was in 2009, when good rain fell (25 November: Table 4) after nest building had been completed.

Why these birds delayed nest building until ~3–4 weeks after the usual November rain may be attributed to a variety of factors, such as learning and memory (Gwinner 2003), fitness (physical condition) (Verhulst & Nillsson 2008), and availability of food (Perrins 1970). Availability of food can determine physical condition, as also will disease and age. This shows a complicated set of causal factors that needs more detailed research to determine.

Although length of day and rainfall appear to influence the commencement of nest building, there may be other factors (e.g. temperature and light intensity) that require further investigation. Older birds may find some fitness benefit (derived from learned behaviour) from delaying breeding. Future investigation over a longer period of time is necessary to elicit more meaningful insights.

Conclusion

The present study of Spangled Drongo breeding agrees with Wood's (1996) analysis of records from the Australian literature. It also adds new information on nest-site selection (such as tree habit, the use of dead twigs for the placement of a nest, and proximity of the site to a clearing) and influences on the commencement of the breeding

season (such as day length and rainfall). Other interesting observations included leaf stripping, perhaps as a part of courting and/or bonding, and the possibility of nest-site rotation to avoid predation. Further work is needed to determine the significance of these observations. Although a small sample size of 12 nests studied over only 5 years has limitations, the congruence of this study with the findings of other authors indicates valid methodology and also points to interesting areas for further study.

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