Australian Field Ornithology 2018, **35**, 95–101
http://dx.doi.org/10.20938/afo35095101

Breeding biology and behaviour of a pair of Pacific Bazas *Aviceda subcristata* in central-coastal Queensland over 10 years

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Abstract. Over ten breeding seasons (2007–2008 to 2016–2017) the nesting of a pair of Pacific Bazas *Aviceda subcristata* on the central Queensland coast was observed, including nest-site selection, nest building, breeding behaviour and success. Nest success was 73%, giving an average of 1.7 ± standard deviation 1.3 young fledged per attempt and 2.5 ± 1.2 raised per year. The breeding season (nest building to fledging) was from mid September to 21 April with a consistent start date from year to year (laying in October, with replacement clutches in November–February). The incubation and nestling periods averaged 32 ± 1 days and 35 ± 1 days, respectively. Nests were positioned in the fork of a tree in a similar general location (within ~3 ha) each year. Several factors contributed to nest-site selection: tree species (mostly eucalypts), height of tree (15.5–21.5 m), height of nest above the ground (12.5–17.0 m), and the use of old nests of other species. New findings included the influence of predation on extending the length of the breeding season, feeding frequency (mean 10.6 minutes between deliveries), types of prey items (phasmatids 81%, tree frogs 19%; *n* = 63), food preparation, and pre- and post-fledging behaviour.

Introduction

For the Pacific Baza *Aviceda subcristata*, Marchant & Higgins (1993, p. 31) noted "Little known", Morgan & Morgan (2010, p. 132) said "there is a need for further detailed studies of the complete breeding cycle", and James (2004) commented that the species is one of Australia's least-known raptors. There is limited knowledge of its breeding ecology because the available information has been derived from anecdotal records, rather scattered (geographically) observations, and observations of nesting behaviour over only single breeding seasons (Marchant & Higgins 1993; Morgan & Morgan 2010). As there has been no detailed long-duration study, this study was designed to investigate the breeding events and behaviour of the Baza over an extended period of ten breeding seasons, and it builds on previous studies of Czechura (1993), James (2004) and Morgan & Morgan (2010) and those in Marchant & Higgins (1993).

The Pacific Baza can be found across northern Australia from southern New South Wales through to northern Western Australia, as well as New Guinea, the Solomon Islands and the group of eastern Indonesian Islands known as Wallacea (Marchant & Higgins 1993). It inhabits forests, woodlands, coastal lowlands, and urban areas, and prefers ecotones near watercourses (Marchant & Higgins 1993). It is a resident that usually breeds in October–February, exhibits some nest-site fidelity, and is a solitary breeder (Marchant & Higgins 1993).

This study aimed to add more detailed observations of parameters such as nest-site selection, nest building, incubation and nestling periods, pre- and post-fledging behaviour, and factors influencing breeding success from a single location on the central Queensland coast over ten breeding seasons.

Methods

The study took place between October 2007 and April 2016 at Coowonga, ~23 km north-east of Rockhampton, Queensland (23°16′S, 150°42′E). The study site was in a fragmented stretch of subtropical open forest dominated by eucalypts and encompassed an area of ~220 m × 135 m (~3 ha) where nesting occurred. Each year the nest-site was located by watching the adults' behaviour in September–October and nest building during late October. It was monitored every day from the beginning (late September–early October) to the end (between January and April the following year) of the breeding period. The duration of each nest inspection was dependent on the phase of breeding activity: during nest building, a short observation several times per day; during incubation, for *c.* 5 minutes each time the male and female were observed changing over (change-over was preceded by a clucking call that identified when this would occur and allowed the whole behaviour to be observed); and during feeding of nestlings, for *c.* 1 hour each day. Observations were made using binoculars from a vantage point that allowed a view of the nest at a near-horizontal level but not into the nest-cup. The study site was adjacent to my residence, allowing regular viewing of all nests within the study area.

Data were collected on the length of the breeding season, nest-site selection and location, nest building, incubation, fledging and number of chicks that fledged, diet, and post-fledging behaviour. Heights of nest-trees and of nests above the ground were determined by triangulation. The spatial location of nests was determined using a GPS, and this information was then plotted on Google Earth ™ (Google Inc.) to determine the distance between nests and the total area of the nesting location over the study period.

Breeding season

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). In addition, the recording of laying dates (± 1 day) (from the behaviour of the adults) for first and subsequent clutches gave more precision to characterising the breeding season.

Breeding success and nest-site selection

There are many measures of reproductive success (e.g. Murray 2000). For this study, a nest was deemed to be successful if at least one young fledged. Data were collected on nest success, but not on egg success as it was not possible to see inside nests to determine the number of eggs. Data were also collected on the incubation period and the time from hatching to fledging. Breeding success was calculated as a percentage of inferred eggs/chicks surviving to fledging compared with the total number of eggs/chicks predated or lost.

Four attributes of nest-sites were recorded (species and height of nest-tree, height of nest above ground, location of nest in tree) and whether the Bazas used the nests of other bird species.

Incubation and nestling periods

Mating behaviour, the incubation period, participation of the male and the female in incubation and feeding of nestlings, identification of prey items delivered and frequency of feeding, vocalisations of nestlings and adults, as well as development of plumage in nestlings and growth to fledging were all recorded in detail.

Behaviour of fledglings

Both pre-flight nestling and post-flight fledgling behaviours were recorded, with fledglings observed at regular intervals and for as long as possible to determine dependence after fledging.

Identification of adult male and female Bazas

The undertail-coverts of the male were distinctively coloured more orange-buff than in the female. The male was identified during mating.

Results

The nests in the territory of a pair of Pacific Bazas were observed over ten breeding seasons, 2007–2008 to 2016–2017 (Figure 1). Over that period, 15 nests were built or rebuilt but, because of predation or bad weather, chicks fledged from only ten of these (Tables 1a–b). It is assumed that it was the same pair (or at least one member of a previously established pair) of Bazas since the birds returned to a similar location each year.

Breeding season and breeding territory

The earliest nest building commenced on 26 September, and the latest on 13 December (which was a third nesting attempt: Tables 1a–b). The earliest fledging of a chick was on 19 December, and the latest on 21 April. This indicates a breeding season of *c*. 7 months. The factor that extended the breeding season was nest-predation. In the 2014–2015 season, the nests were depredated twice, resulting in a third and finally successful breeding attempt. Dates for the start of incubation of first clutches ranged from 15 October to 29 October, and for replacement clutches from 18 November to 13 February. It was not possible to determine the breeding territory of the Bazas, but foraging was predominantly within 3 km^2.

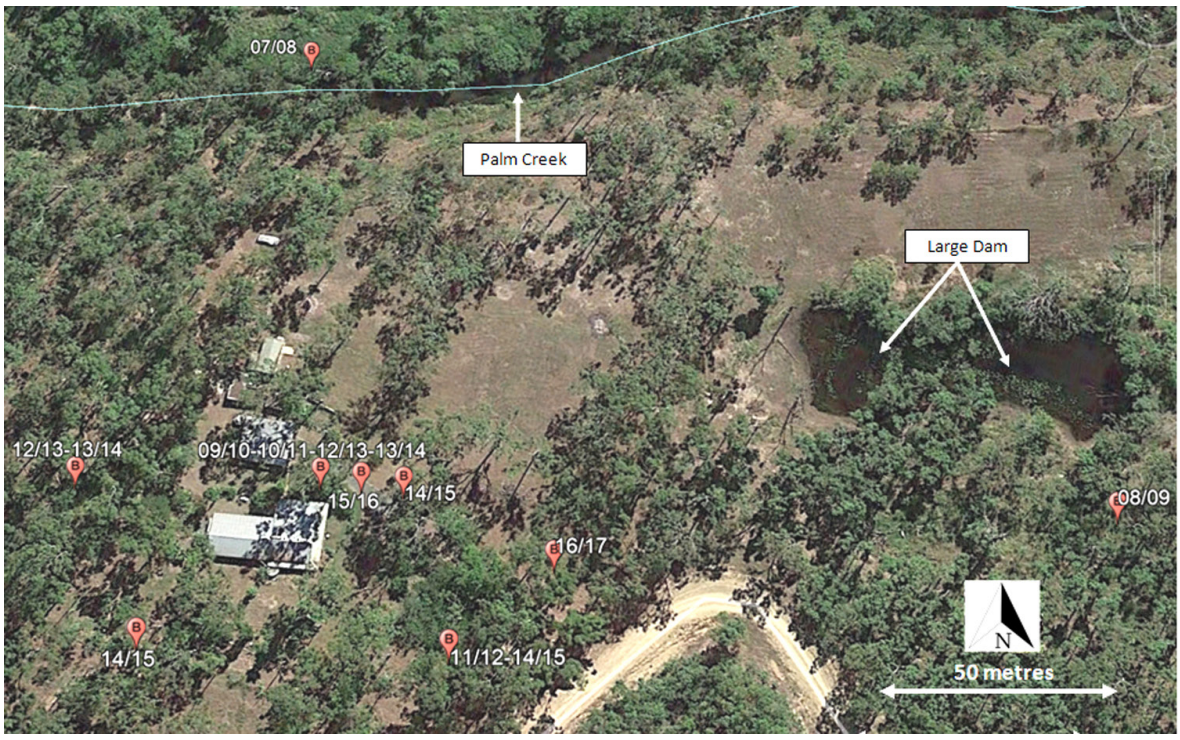

Figure 1. Nest-site locations (red balloons) of Pacific Bazas near Rockhampton, Queensland, over ten breeding seasons, from 2007–2008 to 2016–2017. Map data Google Earth TM © 2018 Google Earth. For clarity, breeding season is indicated thus: 07/08 = 2007–2008, etc.

Table 1a. First nesting attempts of a pair of Pacific Bazas near Rockhampton, Queensland, over ten breeding seasons, from 2007–2008 to 2016–2017: characteristics of nest-site (nest-tree species and height) and nest (height above ground, and whether old or new); dates of start of nest building, incubation, and feeding of nestlings; fate of nest; number of chicks and fledglings; and dates of fledging. Nest-tree species: LSG = Lemon-scented Gum, PB = Pink Bloodwood, RS = River Sheoak, YS = Yellow Stringybark; nestling period = number of days (± 1 day) from first feeding to fledging of first chick.

	Breeding season									
	2007–2008	*2008–2009*	*2009–2010*	*2010–2011*	*2011–2012*	*2012–2013*	*2013–2014*	*2014–2015*	*2015–2016*	*2016–2017*
Nest-tree species	RS	PB	PB	PB	LSG	PB	PB	LSG	LSG	YS
Height of tree (m)	21.0	16.0	15.5	15.5	17.0	15.5	15.5	19.0	16.0	21.5
Height of nest (m)	14.6	13.0	12.5	12.5	14.0	12.5	12.5	16.0	12.5	16.0
Old or new nest?	New	New	Old magpie	Old magpie	New	Old magpie	Old magpie	New	New	New
Building started	3 Oct	7 Oct	2 Oct	4 Oct	2 Oct	1 Oct	26 Sep	8 Oct	6 Oct	8 Oct
Incubation started		29 Oct	16 Oct	20 Oct	19 Oct	17 Oct	15 Oct	24 Oct	24 Oct	15 Oct
Feeding started		28 Nov	13 Nov	19 Nov	20 Nov	18 Nov			23 Nov	14 Nov
Incubation (days)		31	29	31	33	33			31	30
Nest depredated? (and date)	No (blown down)	No	No	No	No	No	Yes, 26 Oct (3 eggshells)	Yes, 12 Nov (3 eggshells)	No	No
Predator							Pied Currawong	?		
No. chicks	0	3	2	3	3	2	0	0	3	3
1st chick fledged		2 Jan	19 Dec	23 Dec	25 Dec	21 Dec			29 Dec	19 Dec
2nd chick fledged		3 Jan	20 Dec	24 Dec	25 Dec	21 Dec			30 Dec	20 Dec
3rd chick fledged		3 Jan		24 Dec	27 Dec				31 Dec	21 Dec
Nestling period (days)		36	37	35	36	34			37	35
No. chicks fledged	0	3	2	3	3	2	0	0	3	3

Nest-site

Several factors were important for nest-site selection.

Lemon-scented Gum *Corymbia citriodora,* Pink Bloodwood *C. intermedia,* Yellow Stringybark *Eucalyptus muelleriana* and River Sheoak *Casuarina cunninghamiana* were the four species of nest-tree in this study (6, 6, 2 and 1 nests, respectively: Tables 1a–b).

Nest-tree height for first nesting attempts ranged from 15.5 to 21.5 m (mean 17.2 m ± standard deviation 2.4 m). Height of nest above the ground for all nesting attempts ranged from 12.5 to 17.0 m (mean 14.2 ± 1.8 m).

The nest was usually located in a vertical fork on or near the main trunk of the tree, within the canopy and often within a leafy clump providing camouflage and shade. The Bazas often returned to the same tree, rebuilding a nest built by another species, with the same old Australian Magpie *Gymnorhina tibicen* nest used four times and the same Pied Currawong *Strepera graculina* nest used twice. Throughout the study period, all 15 nests were built within a small area of ~3 ha near an ephemeral creek, with 12 of those being constructed in an even smaller area of 0.4 ha (Figure 1).

There was typically considerable activity by both adults in selecting the nest-site. In the early mornings they flew to various trees, some with an old Pacific Baza nest, some with an old nest of another species and some without an old nest, with the female sitting in the old nest or in the fork which had nest-site potential. The male perched on a nearby branch and sometimes joined the female. This routine took place for an average of 1 h every day for 16–21 days before nest building began. On arrival, the birds made the *ee-chew* call and when on the nest they constantly clucked to each other.

Nest building and materials

The start of nest building was very consistent between years, ranging over a period of 12 ± 3.4 days from 26 September to 8 October for first breeding attempts (Table 1a).

The nest was built from small twigs and twiglet sprays with leaves attached. The twigs were woven into a shallow cup-shaped structure with projecting twigs. On the one occasion when a nest fell to the ground, it could be seen that it was lined with leaves. The method of collection of building material was for the bird to grasp a twig with both feet and hang upside down, using its weight and wing-

Table 1b. Subsequent nesting attempts of a pair of Pacific Bazas near Rockhampton, Queensland, over ten breeding seasons, from 2007–2008 to 2016–2017: characteristics of nest-site (nest-tree species) and nest (height above ground, and whether old or new); dates of start of nest building, incubation, and feeding of nestlings; fate of nest; number of chicks and fledglings; and dates of fledging. Nest-tree species: LSG = Lemon-scented Gum, PB = Pink Bloodwood, YS = Yellow Stringybark; nestling period = number of days (± 1 day) from first feeding to fledging of first chick.

	Breeding season										
	2007–2008	*2008–2009*	*2009–2010*	*2010–2011*	*2011–2012*	*2012–2013*	*2013–2014*	*2014–2015*		*2015–2016*	*2016–2017*
Nested again?	?	No	No	No	No	2nd	2nd	2nd	3rd	No	2nd
Nest-tree						LSG	LSG	LSG	PB		YS
Height of nest (m)						13.0	13.0	17.0	16.0		16.0
Old or new nest?						Old currawong	Old currawong	New	New		Used previous nest
Building started						2 Jan	30 Oct	20 Nov	13 Dec		3 Feb
Incubation started						12 Jan	18 Nov	25 Nov	30 Dec		13 Feb
Feeding started						11 Feb	20 Dec		1 Feb		17 Mar
Incubation (days)						31	33		33		32
Nest depredated ? (and date)						No	No	Yes (2 eggshells, 12 Dec)	No		No
Predator								?			
No. chicks						1	3	0	2		1
1st chick fledged						18 Mar	22 Jan		7 Mar		21 Apr
2nd chick fledged							23 Jan				
3rd chick fledged							23 Jan				
Nestling period (days)						37	34		36		35
No. chicks fledged						1	3	0	*		1

*Cyclone Marcia destroyed nest on 20 February; 1 chick survived, hand-raised for 15 days.

flapping to break the twig. The twig was sometimes taken to a nearby tree for the removal of leaves, or taken straight to the nest. Often the female sat in the nest while the male collected nest material, which he delivered to the female for placement. The finished structure had an external diameter of 30–40 cm, an internal diameter of 12–15 cm, and it was up to 15 cm deep. Nest refurbishment continued during incubation, with sprays of leaves being added to the nest. Apart from its tight fit in the fork of the tree-trunk or branch, there was nothing securing the nest to the tree, making it susceptible to being dislodged by high winds.

There were three occasions when a new nest was built after nest-depredation. On each occasion, the Bazas built nearby, but did not re-use the nest that had been depredated. However, nests that had been depredated in a previous breeding season were sometimes re-used in a subsequent one. Also, on one occasion (2016–2017 breeding season), the same nest was used a second time after a successful breeding event earlier in that breeding season had produced three fledged young (Table 1).

Pre-mating behaviour

Nest building took place in the early morning between 0700 and 0800 h and lasted for *c.* 1 h, after which the Bazas usually started soaring. Often the male left first and started soaring in circles, followed by the female, which soared underneath. This activity lasted for several minutes as they soared ever higher, then they broke off and glided downwind usually to the north-east. Occasionally, a single Baza repeatedly performed an undulating display flight accompanied by the *ee-chew* call, which is well described in the literature (e.g. Marchant & Higgins 1993). This behaviour occurred predominantly in the morning but occasionally late in the afternoon.

Copulation

Copulation was very brief (<5 seconds) and was observed on three occasions. It involved the male flying to a nearby branch, waiting for 1–2 minutes before flying directly to the perched female, and then mounting her from flight. The female splayed her wings and crouched in a horizontal

position during mating, after which the male dismounted to perch on a nearby branch.

Incubation and nestling periods

For all nests where eggs hatched, the mean time between laying and hatching was 31.7 ± 1.4 days (range 29–33 days, *n* = 11), with a nestling period of 35.5 ± 1 days (range 34–37 days, *n* = 10). Even though careful observation was maintained, the actual dates of the start of laying and hatching of chicks could only be estimated (± 1 day), because it was not possible to see directly inside nests, and incubation and feeding dates were inferred from the behaviour of the adults.

Participation in incubation

Both the male and the female participated in incubation, with the nest attended by one adult at virtually all times. Typically, with one bird on the nest, the other flew to the branch where the nest was located before both birds engaged in clucking calls. The change-over of incubation duties involved the incubating bird departing from the nest and within 2–3 minutes being replaced by its mate. During observations in 2012, change-overs were observed over 12 consecutive days, with definite morning (between 0600 and 1000 h) and afternoon (between 1400 and 1700 h) change-overs occurring.

Feeding of nestlings

Both the male and the female fed the nestlings, with one adult brooding the chicks for up to 6–7 days after hatching, after which both adults left the chicks to go hunting. A total of 63 feeding events was observed, when the nestlings were between 24 and 34 days old, with an average interval between feeds of 10.6 minutes (range 1.0–36.0 minutes). The female provided 55.5% of the food deliveries and the male 44.5%. The most common prey items were Pink-winged Phasmid *Podacanthus typhon* (~11 cm), Children's Stick Insect *Tropidoderus childrenii* (~11 cm), Spiny Leaf Insect *Extatosoma tiaratum* (11–20 cm), Goliath Stick Insect *Eurycnema goliath* (~25 cm) and Dainty Tree Frog *Litoria gracilenta* (Table 2). Phasmatids comprised 81% of the diet and frogs 19%.

Preparation of prey items for feeding to the nestlings involved the adult Baza flying to a nearby tree with the food item grasped in its talons. For phasmatids, the wings and legs were removed and the remainder of the body delivered in the bill; for frogs, the whole body was delivered in the bill. The dominant chick usually sat at the front of the nest, where food was delivered, and tried to monopolise food, but the adults shared food between the nestlings. As the adult flew to the nest with food, each nestling flapped its wings and emitted a high-pitched *peep* and opened its gape to invite feeding.

During the late nestling period, the adults did not brood the feathered chicks or shade them from the sun, as the adults were fully engaged in collecting food.

Growth of nestlings

The development of the downy chicks to feathered nestlings, and the growth of these until fledging were as already described by James (2004).

Fledging and post-fledging behaviour

A few days before fledging, the nestlings climbed out of the nest and up an adjacent branch, moving back to the nest and repeating the behaviour several times during the day. The dominant nestling was the first to do this and was always the farthest out on the branch. The nestlings also exercised their wings several times a day and, in the confines of a small nest, this resulted in other nestlings being hit by the flapping wings.

Fledging usually took place early in the morning, with the fledgling flying a short distance (5–10 m) to a nearby branch, then up to ~50 m farther afield. Distances of flights varied according to the location of the nest, but the pattern of short flights with wobbly landings was consistent. Upon reaching a distant tree, the fledgling typically made the *ee-chew* call to attract the adults' attention. The next feeds by the adults were at the nest, but eventually the adults found the chick that had fledged and continued to feed it. There was usually only 1 day separating fledging between chicks. Feeding by the adults continued as normal after fledging. After the first series of flights, the fledgling tended to stay in a tree for the remainder of the day. Fledging was not generally accompanied by calls from the adults, but happened spontaneously and apparently unelicited.

On each successive day, the fledglings moved a farther ~50 m, often roosting in the same tree as one another. The adults were seen to feed the fledglings up to 14 days after fledging, but after 30 days the fledglings were catching their own prey and feeding independently. On two occasions, at *c*. 42 days after fledging, a group of nine juvenile Bazas appeared around the nesting area engaging in circling, diving on one another and landing

Table 2. Prey items fed to Pacific Baza nestlings in the present study and reported by James (2004).

Present study (2007–2017)	*James (2004)*
Pink-winged Phasmid *Podacanthus typhon*	Stick insects (Phasmatidae)
Children's Stick Insect *Tropidoderus childrenii*	Dragonflies (Odonata)
Spiny Leaf Insect *Extatosoma tiaratum*	Grub-like or worm-like items (?larvae)
Goliath Stick Insect *Eurycnema goliath*	Unidentified insects
Dainty Tree Frog *Litoria gracilenta*	Grasshopper (Orthoptera)
Garden Mantis *Orthodera ministralis*	Mantis (Mantidae)
Mantis (Mantidae)	Tree frog *Litoria* sp.
Unidentified insects	

in trees. Diving behaviour consisted of sharp turns and swoops onto an individual in a tree, and that Baza then flew off, pursued by the swooping individual. The Bazas also circled just above the tree-tops and called with the *ee-chew* call. This behaviour lasted for *c*. 1 h before the Bazas moved away from the nesting area.

Reproductive success

Over 10 years, 25 nestlings fledged (including the one that fell out of a nest during a cyclone and was subsequently hand-raised), with eight eggs depredated (apparently all by birds) and one nestling killed in a cyclone, giving an overall breeding success rate of 73.5% per egg laid. Of 15 nests built, successful fledging occurred in 11, giving 73.3% nest success, with 1.7 ± 1.3 fledglings per nesting attempt and 2.5 ± 1.2 fledglings raised per year.

Factors influencing reproductive success

Of the four nests that were not successful, one failure was attributed to bad weather and three nests were depredated during incubation. In the only case where predation was observed, a Pied Currawong was identified as the predator; at other times, predation was inferred from the remains of eggshells found at the base of the nest-tree. Laughing Kookaburra *Dacelo novaeguineae* and Torresian Crow *Corvus orru* were two possible predators observed in the study area. Following predation, the Bazas built another nest and tried breeding again. In one season (2014–2015), the Bazas had three breeding attempts. In the case where predation was observed, a pair of Pied Currawongs worked together, with one attacking and driving the Baza off the nest, after which the other Currawong raided the eggs.

Clutch-size

Although eggs could not be observed in the nests, the clutch-size was inferred (from the number of hatched nestlings and from eggshells from depredated nests) as two–three eggs.

Discussion

Breeding season

With breeding commencing in mid September and finishing as late as 21 April, the breeding season was found to span a wider timeframe than in previous studies (Marchant & Higgins 1993; James 2004). With nest-predation resulting in a second or third breeding attempt, the breeding season extended to mid April, compared with either late December or early January without predation. Nest-depredation is therefore a major factor influencing the length of the breeding season.

An average incubation period of 31.7 ± 1 days matches closely the 33 days quoted by Marchant & Higgins (1993) and 29 days by James (2004). The average nestling period of 35.5 ± 1 days also matches closely the 32–35 days observed by Cupper & Cupper (1981) and 35 days by James (2004).

Breeding location

With the birds returning to the same breeding area each year, often using the same tree or nest, this shows considerable nest-site fidelity. The maintenance of the breeding territory from one year to the next may be critical for breeding success. Little is known about breeding territories or the spatial distribution of breeding pairs of Bazas across the landscape and is an area worthy of further investigation. Loss of habitat and the impact of this on breeding success also require further attention. The consistent timing (within a 1–2-week window in late September–early October) and location (within an area of ~3 ha) of nest building suggest that other pairs of Bazas may follow similar breeding patterns, potentially providing a great opportunity for monitoring and understanding breeding elsewhere.

Reproductive success

Marchant & Higgins (1993) commented that for the Baza there were no quantified data about reproductive success or about predators. This study, over ten breeding seasons, has provided detailed data on reproductive success and on the role that predators can have in influencing breeding success and season.

Prey

Phasmatids and frogs were the main prey items fed to Baza nestlings and fledglings (Table 2), which is consistent with the diet reported elsewhere (Marchant & Higgins 1993). James (2004) noted that all insect prey was >3 cm long (compared with ~11–25 cm for phasmatids in the present study), and the diet was more diverse than observed here (see Table 2). James (2004) also noted that from Day 23 of the nestling period all prey was provided whole, whereas in the present study all insect prey had wings and legs removed. Possibly the size of the prey influenced this behaviour.

Nest location

The general nest and breeding location is consistent with previous studies (Czechura 1993), in that Pacific Bazas favour nesting in an upright fork near the canopy of a tall tree, within forest, near an ephemeral creek. Elsewhere, this species has been recorded breeding in *Angophora*, *Eucalyptus* and *Melaleuca* trees (Marchant & Higgins 1993) whereas in the present study *Corymbia* and *Casuarina* trees were also used. The nest was usually within 3 m of the top of the tree and was often very difficult to see; it was necessary to watch the birds arrive and leave to pinpoint the nest's location. Concealment seems to be the reason for this nest location, with the added benefit of shading the eggs and chicks from the sun. In the study by Morgan & Morgan (2010), the breeding attempt failed because a storm blew the nest out of the tree, which also happened on one occasion in the present study, thus confirming the vulnerability of Baza nests to storms. This could be a more threatening process in the future, if predictions of increased extreme weather are correct (CSIRO and Bureau of Meteorology 2015).

Conclusions

One of the major findings of this study is that the breeding season of the Pacific Baza can extend to late April, and that a major influence on the length of the breeding

season is nest-predation. On each occasion when a Baza nest was depredated, the Bazas bred again, with three breeding attempts occurring in one season. The adults were attentive to eggs and young chicks, with one adult being present throughout incubation and during the first week after hatching. This resulted in a high nest success rate of 73%, 1.7 ± 1.3 fledglings per attempt and 2.5 ± 1.2 fledglings per year. In nine of the ten breeding seasons, at least one chick fledged.

Acknowledgements

I would like to thank Stephen Debus and Rohan Bilney for their assistance with the preparation of the manuscript.

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Received 25 October 2017, accepted 30 April 2018, published online 12 September 2018