Nest-site selection and nesting ecology of Red-breasted Parakeet *Psittacula alexandri* in dry dipterocarp forest, western Thailand

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Introduction

The Red-breasted Parakeet *Psittacula alexandri* is relatively widely distributed from west Uttarakhand in north India, east through Nepal, Bhutan, east Bangladesh, Myanmar, Thailand and Indochina to southern China, and the Andaman Islands east to Java, Bali, extreme southern Borneo, islands in the Java Sea, and islands off west Sumatra, Indonesia (BirdLife International 2015); however, little is known about its natural history. It is resident in deciduous forest, dry forest, secondary growth, cultivated areas with residual tall trees and human settlements up to 1,500 m (Lekagul & Round 1991, Forshaw 2010, BirdLife International 2015). It has generally been recorded as breeding from December to April in natural cavities or old woodpecker and barbet excavations, and lays a clutch of 2–4 eggs. On Java it has been recorded nesting in all months except April (Juniper & Parr 1998).

The species has declined in Thailand and is rare on Java, probably because of capture for the cage-bird trade (Snyder *et al*. 2000). In northern Laos, Cambodia and Thailand the species has been affected by habitat loss and fragmentation. It is now considered Near Threatened and is listed under CITES Appendix II (BirdLife International 2015).

Understanding nest-site characteristics of Red-breasted Parakeets may provide valuable insights for managing their nesting habitat and developing conservation programmes. The objectives of this study were to determine the characteristics of trees and tree-cavities used for nesting by Red-breasted Parakeets in native forest habitat in Thailand.

Methods

Study site

The study was made in the 2,780 km² Huai Kha Khaeng Wildlife Sanctuary, part of the Thung Yai–Huai Kha Khaeng Wildlife Sanctuaries UNESCO World Heritage Site. The annual temperature range is 8–38°C (Khao Nang Rum Wildlife Research Station, Huiai Kha Khaeng, unpubl. data). Normally the lowest temperatures occur in January and the highest in April. During our study period in 2012–2013 the dry season (November–April) had a total rainfall of 477 mm and the wet season (May–October) a total of 1,519 mm.

The sanctuary has four main vegetation types, mixed deciduous forest (48%), dry evergreen forest (25%), hill evergreen forest (13%) and dry deciduous dipterocarp forest (7%) (WEFCOM 2004). Huai Kha Khaeng fauna has diverse biogeographic associations, including those with Sundaic, Indo-Chinese, Indo-Burmese, and Sino-Himalayan affinities (Nakhasathien & Stewart-Cox 1990). More than 30% of the vertebrate species in Huai Kha Khaeng were thought to be cavity users (Nakhasathien & Stewart-Cox 1990).

The study area was dry dipterocarp and old-growth mixed deciduous forest, at about 250 m altitude. Two plots were used, a 20 ha area (the Ring Road) and a 22.5 ha plot along the road that runs from Sub Fa Pha sub-station to Khao Nang Rum wildlife research station. As part of an associated project, the entire diurnal bird community was surveyed between November 2009 and February 2011 along a 350 m dirt track that ran through the study area. The track was surveyed from dawn to typically no later than 08h00. Distances and direction of all individual birds of all species seen or heard were recorded. Densities of all species for which there were sufficient detections, including Red-breasted Parakeet, were estimated using the programme DISTANCE.

Determination of cavity characteristics

We measured the diameter at breast height (dbh) of each tree ≥ 15 cm dbh because preliminary observations indicated that less than 2% of trees less than 15 cm dbh had cavities. To determine cavity availability we attempted to locate all potential cavities—those with an apparent entrance hole diameter ≥ 3 cm and horizontal depth ≥ 7.5 cm (Pattanavibool & Edge 1996). For each tree, we recorded the following variables: species, height, dbh, decay class (1 = live healthy, 2 = live unhealthy, 3 = recently dead with branches intact, 4 = long dead tree with only stubs of large branches or no branches remaining, following Cockle *et al*. 2011a), crown class (dominant, co-dominant or intermediate/understorey), and proportion of crown touching another tree. For each cavity, we recorded apparent cavity formation process—excavated or non-excavated. Cavities with round or oval entrances were considered excavated cavities, and those with irregular entrances and interiors were considered formed by decay (Cockle *et al*. 2011a). We recorded whether the cavity was in a live or dead tree (Blanc & Walters 2008), and then measured cavity height, branch order (main stem or branch), diameter at cavity height (dch), distance to next branch, distance to any vegetation, cavity order (when there was more than one cavity, they were numbered from bottom to top), number of cavities, cavity entrance angle (up/down/side), cavity compass direction, horizontal and vertical diameter of each entrance of cavity, horizontal and vertical depth of cavity, distance from lowest cavity entrance to a major visual obstruction from an angle of 45, 90, 135, and 180°.

Using a 9 m telescopic pole we measured the height of each cavity from the lower lip of the cavity entrance to the forest floor. The interior horizontal depth and diameter of the cavity was measured using an aluminium tube that had 5 cm marks along its length. The interior vertical depth of each cavity was measured using a plumb line calibrated in cm. Typically, the vertical depth was measured by climbing the tree and inserting the pendulum into the cavity. We used a 1.2 cm × 1.2 cm × 1.8 cm pinhole video camera attached to the telescopic pole to look inside cavities, following the methods of Cockle *et al*. (2011a). For cavities above 9 m, the tree was climbed and measured directly using a tape measure.

We considered a cavity to be suitable for Red-breasted Parakeet if it was at least 5 cm in diameter, 27 cm deep and more than 3.5 m above ground. As we did not have another independent dataset available for comparison, these represented the smallest diameter, shallowest and lowest of the cavities used by Red-breasted Parakeet measured in this study.

Cavity occupancy

Between October 2012 and July 2013, which roughly corresponds to the pre-breeding and breeding season of the species, we inspected all cavities ≥ 3 cm diameter and ≥ 7.5 cm horizontal depth in both plots using a pinhole video camera, approximately 10 days a month, from 07h00 to 16h00. Cavities were considered to contain an active nest if we saw eggs, nestlings or evidence of nesting such as feeding chicks. We also included data from cavities monitored during a 2009–2012 study of woodpeckers. Some potential cavities were more than 15 m high or otherwise unsafe to access, and could not be inspected with the video camera. We watched each of these potential cavities for 20 minutes per cavity, once a month, to determine evidence of nesting—adults seen feeding nestlings or spending sufficient time in the cavity to be incubating eggs. We recorded the date of nesting and number of eggs and/or nestlings of Red-breasted Parakeet.

Table 1. Activity of Red-breasted Parakeet at nests 2010 to 2013. The nests were monitored once per month from October 2012 to July 2013 using a pin-hole camera; prior to this period only sporadic observations were made.

Year	Cavity ID	First date check	Description	Last date check	Description
2011–2012	017	Jan 2012	nesting	Feb 2012	nesting
2012–2013	017	13 Nov 2012	3 chicks, 1 egg	14 Mar 2013	3 chicks
2012–2013	027	21 Jan 2013	1 chick	21 Feb 2013	1 chick
2012–2013	076	21 Jan 2013	3 chicks same size	26 Mar 2013	1 chick gone, 2 chicks in cavity (male & unknown)
2012–2013	109	21 Jan 2013	4 chicks 2 big 2 small	13 Apr 2013	3 chicks gone, 1 chick in cavity
2012–2013	142	24 Feb 2013	3 chicks	16 Mar 2013	3 chicks
2012–2013	059	25 Feb 2013	adult female fly in/out cavity	11 Apr 2013	female (unknown age) perching in front of the cavity
2012–2013	065	29 Nov 2012	adults fly into the cavity	16 Mar 2013	one female adult at the cavity entrance
2011–2012	020	Jan 2012	nesting	Feb 2012	nesting
2012–2013	020	19 Jan 2013	adults fly into the cavity/ perch at entrance	16 Mar 2013	adults flew into cavity/ perch at cavity entrance
2010	049	Jan 2010	nesting	Feb 2010	nesting
2011	049	Jan 2011	nesting	Feb 2011	nesting

Data analysis

We compared cavities selected by the species with cavities not used by it using logistic regression models. All analyses were made using RStudio Version 0.98.1056. Each cavity was included only once in the analysis; reused cavities were not counted as independent nests.

Results

Based on density estimates derived from distance sampling surveys conducted from November 2009 to February 2011, Red-breasted Parakeets were abundant (3.8 birds/ha) in the study area, but appeared to be largely absent during the post-fledging period May–August with no detections during June and July and only two detections each during May and August.

Characteristics of cavities chosen by Red-breasted Parakeet

Although the parakeets appeared to be common—they were frequently seen flying over the transect—few active cavities were found despite extensive searches, presumably because birds were nesting over a very large area, mostly outside our study plots. Red-breasted Parakeet nested in nine cavities a total of 12 times from 2010 to 2013. All the cavities were in live excavated trees. Three of the nine cavities were reused during this period. In 2010 and 2011 we recorded one cavity occupied by Red-breasted Parakeet in the beginning of each year, and in 2012 we recorded two new occupied cavities in January and February. In 2013, we found eight cavities and six of them were new. We recorded the first Red-breasted Parakeet activity at a cavity in November 2012 and the last activity at a cavity in April 2013.

The nine active Red-breasted Parakeet nests were found in trees 13–23 m in height, 29–47.5 cm dbh, in eight live healthy trees and one live unhealthy tree (Table 1). These cavities were 3.5–11.8 m above ground, 20–40 cm dch, 7–37 cm horizontal depth, and 27–60 cm vertical depth with minimum entrance diameter 5–8 cm (Tables 1 & 2). Five cavities faced west, two south, one north, and one east. Red-breasted Parakeet tended to select cavities angled downwards (seven of nine cavities). For the six cavities for which we were able to observe the cavity floor at least once, we were unable to confirm

Table 2. Red-breasted Parakeet cavity characteristics. Decay class: 1 = live healthy, 2 = live unhealthy, 3 = recently dead with branches intact, 4 = dead tree with only stubs of large branches or no branches remaining.

Cavity ID	Tree height (m)	Decay class	Diameter breast height (cm)	Cavity height (m)	Diameter cavity height (cm)	Vertical depth (cm)
017	15	2	29.0	3.50	20.0	60.0
027	14	1	29.4	5.46	32.0	42.5
076	20.25	1	32.1	4.65	37.0	50.0
109	15.75	1	39.2	4.05	27.0	27.0
142	13.25	1	30.1	4.73	26.0	46.0
059	23.25	1	47.5	5.63	32.0	27.0
065	18.75	1	45.3	8.52	22.0	48.0
020	18.75	1	47.0	11.75	24.7	37.0
049	16.5	1	31.0	4.21	40.0	43.0

Table 3. Ranking of logistic regression models comparing cavities used (n =9) versus cavities not known to be used (n = 188) by Red-breasted Parakeet. k, number of parameters; AICc, Akaike's information criterion corrected for small sample size; ÄAICc, difference in AICc between this model and the minimum AICc model; w, AICc weight (AICcW); cumulative weight (Cum. Wt), cumulative Akaike weights.

Model	k	AICc	ÄAICc	AICcW	Cum.Wt
Decay class	2	68.78	0.00	0.41	0.41
Tree height, decay class	3	69.63	0.85	0.27	0.68
Tree height, entrance diameter	3	73.20	4.42	0.04	0.72
Tree height	2	73.61	4.83	0.04	0.76
Tree height, cavity height	3	74.72	5.94	0.02	0.78
Entrance diameter	2	74.82	6.04	0.02	0.80
Distance to next branch	2	74.91	6.13	0.02	0.82
Vertical depth	2	74.96	6.18	0.02	0.84
Entrance diameter, vertical depth	3	75.13	6.35	0.02	0.85
Intercept-only model	1	75.15	6.37	0.02	0.87
Tree height, crown class	3	75.20	6.42	0.02	0.89
Tree height, proportion of crown touching another tree	3	75.62	6.84	0.01	0.90
Vertical depth, horizontal depth	3	76.98	8.20	0.01	0.9
Tree height, diameter at breast height	3	75.67	6.89	0.01	0.91
Diameter at breast height	2	76.09	7.31	0.01	0.92
Diameter at cavity height, entrance diameter	3	76.77	7.99	0.01	0.93
Cavity height, distance to next branch	3	76.97	8.19	0.01	0.94
Cavity height, entrance diameter	3	76.85	8.07	0.01	0.94
Diameter at cavity height, vertical depth	3	77.01	8.22	0.01	0.96
Distance to any vegetation	2	77.07	8.29	0.01	0.96
Average distance from cavity to major obstruction	2	77.07	8.29	0.01	0.97
Diameter at cavity height	2	77.12	8.34	0.01	0.98
Proportion of crown touching another tree	2	77.16	8.38	0.01	0.98
Cavity height	2	77.16	8.38	0.01	0.99
Horizontal depth	2	77.17	8.39	0.01	1.00
Cavity height, diameter at cavity height	3	79.16	10.38	0.00	1.00
Distance to any vegetation, average distance from cavity to major obstruction	3	79.10	10.32	0.00	1.00

whether they were lined and we never observed parakeets carrying nest material. Juniper & Parr (1998) indicated that cavities were lined with 'wood shavings'; although we could see woody debris in at least one of the cavity bottoms we were unable to ascertain if it was material intentionally brought in or simply debris remaining from the initial excavation and subsequent modifications.

The logistic regression model (Table 3) suggested that decay class and tree height were the most important factors for nesting. Red-breasted Parakeets tended to select taller, healthy trees for nesting. The top model included only decay class AICc weight = 0.41 (Table 3). The second best model, including tree height and decay class, and had 5.5-times more support compared to the third best model (AICc weight = 0.27; Table 3). These two variables accounted for 72% of the AICc weight (Table 3). Tree height was also included in four of the top five models. All other variables (vertical depth, horizontal depth, crown class, proportion of crown touching another tree, dch, dbh, average distance from cavity to major obstruction, distance to next branch, distance to any vegetation and cavity height) and the intercept-only model appeared to have little support. However, none of the other parameters was significant except decay class. While the top four models suggested possibly important variables, only one of these three parameters appeared to be statistically significant.

Cavity occupancy

We were able to observe nest contents in five nesting attempts in five different cavities. These five had 1–4 nestlings (mean clutch size was at least 3 eggs; Table 1). Four of the active cavities could not be reached with the video camera to inspect. The earliest date on which adults were seen preparing a cavity was 13 November 2012. The earliest egg date was 19 January 2013, the earliest date for nestlings was 19 February 2013 and the latest date with nestlings in a cavity was 13 April 2013 (Table 1). No fledglings were observed near these cavities.

Black-headed Woodpecker *Picus erythropygius*, Collared Falconet *Microhierax caerulescens* and Lineated Barbet *Megalaima lineata* used the same cavities later in the season. Cavities 17, 27, 49 and 76 were used by Black-headed Woodpeckers between April and July in 2011, 2012 and 2013; cavities 49 and 109 were used by Collared Falconets between February and April in 2011 and 2012; and cavity 49 was used by Lineated Barbet between February and April 2009 (Tables 1 & 2). The data suggest little or no direct competition for cavities if the parakeets typically enter cavities between November and January, but we do not have evidence as to whether other species might attempt to usurp the parakeets during February–April after nests have been initiated.

Discussion

In our study, all Red-breasted Parakeet nested in live trees, in contrast with studies in subtropical forest such as in Argentina where almost all secondary-cavity nesters nested in dead trees (Cockle *et al*. 2011a). There may be several reasons for this, including differences in abundance of live and dead trees, age of trees, tree species composition, tree hardness, biogeographical differences, and/or differences in abundance and behaviour of excavators in different regions (Carlson 1998, Bai *et al*. 2003, Cockle *et al*. 2011a,b). Nesting in dead wood may be more risky because cavities in decayed wood may suffer higher rates of predation (Wesołowski 2004), while dead branches or dead trees fall or disintegrate quickly, and are therefore an ephemeral nesting resource (Cockle *et al*. 2011b). At our site, we observed at least three dead trees with cavities which fell during the course of the study.

Although our sample size was small and a larger sample is required to verify these effects on reproductive success, our data also suggested that tall trees are important for nesting. Other studies show this may be true for other parakeet species. Taller trees were also selected by secondary-cavity nesters in Andean subtropical forests (Politi *et al*. 2009), European temperate forest (Wesołowski & Rowiński 2004), Swedish deciduous, mixed-deciduous and coniferous forest (Nilsson 1984) and Indonesian tropical lowland rainforest (Cahill 2003). Several studies indicated that secondary-cavity nesters selected taller trees with good visibility, perhaps to reduce risk of predation (Nilsson 1984, Renton & Salinas-Melgoza 1999, Cockle *et al*. 2011a), and cavity height seems more likely to be the characteristic that birds select directly. Mahon & Martin (2006) reported that predators of nests in taller trees may be species-specific and that higher cavities may be more difficult for predators such as squirrels to detect because sounds of begging nestlings in higher cavities may be less audible. We have limited data on predation, but we did record predation of a Black-headed Woodpecker nest by a Grey Cat Snake *Boiga ocellata* (cavity 49), 4.2 m above the ground, in a 16.5 m tall tree. Other potential cavity-nest predators included Pallas's Squirrel *Callosciurus erythraeus*, Himalayan Striped Squirrel *Tamiops mcclellandii*, Golden Tree Snake *Chrysopelea ornata* and Bengal Monitor Lizard *Varanus bengalensis*.

The use of excavated cavities by parrots seems to vary considerably from site to site. Parrots studied by Cockle (2008) and Cockle *et al*. (2011a) in Argentinian Atlantic forest generally nested in cavities formed by natural decay, rather than by excavators, in contrast with a study in Brazilian Atlantic forest, where 97% (36 of 37 nests) of parrot nests were in cavities excavated by woodpeckers (Guix *et al*. 1999), and with our study in dry dipterocarp forest, where Red-breasted Parakeets were only found in excavated cavities. We rarely observed excavations of nest cavities by any species during five years of observation in the area, suggesting cavity production was very slow. Additionally, 65.7% of all observed cavities in our study were in live, hardwood *Shorea* species. Since Red-breasted Parakeets appeared to depend on excavators (woodpeckers and barbets) for nesting, if populations of excavators in the area decreased significantly, this would presumably also impact Red-breasted Parakeet populations.

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Distribution of Palawan Peacock Pheasant *Polyplectron napoleonis* morphs

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Introduction

The Palawan island group is politically affiliated with the Philippines and lies at the edge of the continental shelf in South-East Asia (Figure 1). Palawan's fauna has traditionally been treated as most similar to that of Borneo (Huxley 1868, Holloway 1982). However, some investigators have found similar, if not greater, faunal affinity to the oceanic Philippines (McGuire & Alcala 2000, McGuire & Kiew 2001, Brown & Guttman 2002).

The Palawan Peacock Pheasant *Polyplectron napoleonis* is endemic to Palawan and is considered Vulnerable due to deforestation and hunting (BirdLife International 2015). It is one of the smaller species of pheasant with weights averaging 436 and 322 g for males and females respectively (Dunning 2008). It prefers pristine forest and can attain densities as high as 34 males/km^2 in prime habitat (Caleda 1993). The species has several different vocalisations, including the female *peeping* to alert chicks to food, the male hissing during an intense lateral courtship display, and the long call which is the most frequent vocalisation throughout the year (DMB unpubl. data). It is strictly monogamous, and the typical clutch size is two eggs with an incubation period of 19–20 days (Jeggo 1975).

Despite there being adequate knowledge of the conservation and ecology of Palawan Peacock Pheasant relatively little is known about its evolutionary history. Kimball *et al.* (2001) suggested that *P. napoleonis* is positioned basally to its congeners. Johnsgard (1999) noted that it is the most isolated member of the genus, separated from its closest relative Bornean Peacock Pheasant *P. schleiermacheri* on Borneo by approximately 150 km. It appears to occur in two morphs, which differ in the presence or absence of a distinctive white superciliary on the male. This was noted by Delacour (1957), but the geographic pattern of the character has not been studied, particularly in wild birds on Palawan. We investigated the spatial pattern of the two morphs and mapped their distribution. Blasius (1891) described the form with the white superciliary as *P. nehrkornae*, but today the species is considered monotypic (e.g., Beebe 1936, Madge & McGowan 2002). While examining images of study skins to determine whether superciliary variability characterised two distinct forms, we found hybridisation in the central part of the species's range. Our objective herein is to report our findings regarding possible divergence and secondary contact in this species.

Figure 1. Island of Palawan showing locations of specimens
Key: 1 = St. Paul's, 2 = Sabang, 3 = Puerto Princesa, 4 = Iwahig, 5 = Kabigaah, 6 = Quezon, 7 = Taguso. F = full superciliary, I = intergrade, N = no superciliary