**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, Huai 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 (Nakahashitien & Stewart-Cox 1990). More than 30% of the vertebrate species in Huai Kha Khaeng were thought to be cavity users (Nakahashitien & 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.

**Nest-site selection and nesting ecology of Red-breasted Parakeet**

*Psittacula alexandri* in dry dipterocarp forest, western Thailand

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

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

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, 5 = 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 this model and the minimum AICc model; w, AICc weight (AICcW); cumulative weight (Cum. Wt), cumulative Akaike weights.

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; ΔAICc, difference in AICc between this model and the minimum AICc model; w, AICc weight (AICcW); cumulative weight (Cum. Wt), cumulative Akaike weights.
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 erythropygus, 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 nests 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 acellata (cavity 49), 4.2 m above the ground, in a 16.5 m tall tree. Other potential cavity-nest predators included Pallás’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 Argentinean 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

D. M. BROOKS & H. C. MIRANDA JR.

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/km² (Caleda 1993). The species has several different introductions. The palawan Peacock Pheasant Polyplectron napoleonis 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/km² (Caleda 1993). The species has several different introductions.

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