Observations at a nest of Helmeted Hornbill *Rhinoplax vigil* in Borneo, Malaysia

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Little is known about the nesting behaviour of the Helmeted Hornbill *Rhinoplax vigil* because it occurs in low numbers and nests are difficult to locate. The nest cavity is usually high and hidden amidst thick foliage and the cavity's opening is inclined upwards, making it hard to see from the ground. A nesting pair of Helmeted Hornbills was observed in the Kinabatangan Wildlife Sanctuary between 2013 and 2017. We sought to determine the nesting period and associated behaviour, and to identify the type and amount of food provided to the female and chick over the nesting cycle. The nest was located inside the nub of a broken branch of a *Shorea pauciflora* tree, 37 m up on the trunk. The pair began nesting in May, in the drier months, and the single chick fledged in November the same year. The pair and the fledged young stayed together for at least six months. The male made a maximum of 11 visits per day to bring food to the nest midway through the breeding period. Food brought to the nest consisted of mainly figs, including *Ficus stupenda*, *F. benjamina*, *F. stricta* and *F. crassiramea*. The adult Helmeted Hornbills delivered stick insects, beetles and praying mantis, while the chick itself caught and consumed a giant millipede at the nest entrance. The specific fig diet and nest cavity preferences make the species extremely vulnerable to environmental changes caused by logging and agricultural expansion. The added pressure from hunting it for casques may be driving it to extinction. Therefore we recommend that their nests be located and offered protection by local authorities and communities through nest adoption schemes.

INTRODUCTION

The Helmeted Hornbill *Rhinoplax vigil* is the largest Asian hornbill in the family Bucerotidae (Kinnaird & O'Brien 2007). It stands out among the Asian hornbills because of its distinctive calls, solid casque and long central tail-feathers (Plate 1). The species is territorial and it usually occurs in primary forests (Smythies 1981, Wells 1998). The species is classified as Critically Endangered as it is threatened by habitat loss and hunting for its solid keratin casque, which can be carved into decorative articles (Collar 2015, Beastall *et al.* 2016, Krishnasamy *et al.* 2016, BirdLife International 2018).

Disconcertingly little is known about the basic biology and ecology of the species. Nesting occurs during the dry season when conditions inside the nest cavity are suitably dry (Poonswad 1995, Utoyo *et al.* 2017). Helmeted Hornbills prefer cavities with a protruding entrance that bears its weight and does not damage its long central tail-feathers (Thiensongrusamee *et al.* 2001, Chong 2011, Utoyo *et al.* 2017). In Thailand, birds favour trees at altitudes of 300–800 m with a diameter at breast height of 105–216 cm and a height between 26 and 70 m (Thiensongrusamee *et al.* 2001, Poonswad *et al.* 2013). They nest primarily in trees of the family Dipterocarpaceae, including *Hopea* spp., *Shorea faguetiana*, *S. curtisii* (Thiensongrusamee *et al.* 2001), *Dipterocarpus humeratus* (Utoyo *et al.* 2017) and others such as *Koompassia parviflora* (syn. *K. excelsa*) (Kemp 1995), *Scaphium macropodum* (Thiensongrusamee *et al.* 2001) and *Dysoxylum grande* (Kaur *et al.* 2015). They have one of the longest nesting periods of all the hornbills—between 167 and 172 days (Kinnaird & O'Brien 2007). Hornbills seal their nests to protect the female and chick from strong winds, rain and predators. In a process that can take two weeks, the female Helmeted Hornbill seals herself inside the nest cavity for the majority of the period (Kinnaird & O'Brien 2007, Chong 2011). A pair usually has a single chick (Chong 2011, Kaur *et al.* 2015).

In all seasons figs make up 98–99% of Helmeted Hornbill diets, while the rest is small animals (Hadiprakarsa & Kinnaird 2004, Kinnaird & O'Brien 2007). A diet of figs provides hornbills with calcium, magnesium and fibre while being moderate in sugars, lipids and proteins (Balasubramanian *et al.* 2004, Kinnaird & O'Brien 2007). This diet meets the various needs of the birds, such as calcium for eggs and skeleton growth and amino acids for growth of feathers (Poonswad *et al.* 2004).

Here we add to the limited data about the breeding behaviour and nesting ecology of the Helmeted Hornbill, by reporting our observations at a single nest in Kinabatangan, Sabah, Borneo, between 2013 and 2017. While such information may only bear indirectly on the conservation of the species, it is of value in highlighting the degree of specialisation of this dangerously threatened bird and we hope it will stimulate a greater understanding among wildlife managers responsible for the design and implementation of successful conservation initiatives.

Plate 1. Female Helmeted Hornbill *Rhinoplax vigil* perched at the natural cavity in Lower Kinabatangan Wildlife Sanctuary, Sabah, Malaysian Borneo, 31 October 2017.

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STUDY SITE AND METHODS

The study took place in the 27,960 ha Lower Kinabatangan Wildlife Sanctuary, Sabah. The sanctuary was officially gazetted as a protected area by the Sabah State government in 2005 (Abram *et al.* 2014). The area consists of largely fragmented secondary forests surrounded by extensive oil palm plantations and mills, tracks and roads, villages, orchards and small farms (Ancrenaz *et al.* 2015).

These patches are linked to 15,000 ha of forest that are protected as Virgin Jungle Forest Reserves. The climate is warm, wet and humid, with a temperature range of 21°C to 34°C and an annual average precipitation of about 3,000 mm (Ancrenaz *et al.* 2004).

A Helmeted Hornbill nest, located in a living *Shorea pauciflora* tree, was discovered by chance by staff of the HUTAN-KOCP orang-utan conservation NGO in June 2011. Due to the hunting issues faced by the Helmeted Hornbill, details of the site are withheld here. To ensure consistency in note-taking, four observers undertook the nest observations, always two at a time in various combinations, with one of the observers present throughout the data collection period. We observed the nest in strict silence from a hide in an elevated position at a distance of 50 m, based on methods in Poonswad & Kemp (1993). Nest watches were carried out sporadically due to financial constraints. However, in 2013 observations took place on 40 days between July and November (most intensively in August), after the female sealed herself in the nest. In 2017, thanks to the availability of funds and equipment, we were able to make systematic observations of the nest on two days each week, commencing in May on the day the female began sealing herself in the cavity, and finishing on the day the chick fledged. Therefore 2013 and 2017 yielded good-quality data that allowed comparisons to be made.

Observers used a 15–45×60 mm telescope and 8×42 mm binoculars for close examination of food items, and a DSLR camera with long lenses. Observations began before sunrise in fair weather (i.e. no strong winds and rain) and continued for eight to ten hours, between 06h00 and 16h00. Short observations were made every morning (06h00–11h00) in October to avoid missing two key events, the female leaving the nest and the chick fledging, as these events usually occurred in the fifth and sixth months of the nesting period respectively. During observations, food deliveries, types of food and any noteworthy behaviour of the nesting pair or by other hornbills within a 10 m radius of the nest tree were recorded.

A canvas sheet was placed beneath the nest tree to collect fruits dropped by the birds. Fallen whole fruits were collected (when adults were absent, to avoid causing them stress) and weighed using a digital scale to determine the weight of individual fruits. Samples and images of the fruits were shown to a botanist who assisted us in their identification. Although fallen fruits could be picked up and weighed, they could often not be identified to species level.

In due course, the observers became familiar with the distinctive shape, colour and size of the fig species most frequently supplied to the nest, and were confident to identify them to species level. By counting the number of identified fruits fed and multiplying by their average weights, we estimated the approximate weight of fruits in a feed to gain insight into how much food was consumed per day by the birds in the nest. This was only possible when we were able to identify every single fruit, from the first to the last observed feed of the day. The fig fruit weights in Shanahan (2000) were used to check that our fruit weights were in the same range.

Images enabled us to recognise individual birds based on their casque markings, just as drawings have been used in the past to differentiate individuals (Leighton 1982). The sexes can be told apart with relative ease, as the female has a light blue gular pouch and the male's is red. Video footage provided the opportunity to review behaviour and feeds, and to count fruits in the event of an oversight.

RESULTS

Here we present a comparison of nesting season observations in 2013, 23,683 minutes in 40 days, and 2017, 20,445 minutes in 38 days (including 21 days of all-day observations). Systematic and detailed observations were made only in 2017 and these results are presented in greater detail. Only brief checks were made on the nest during 2014 and 2015.

Nest tree aspects

The *Shorea pauciflora* nest tree, with a circumference at breast height of 3.8 m, stood 50 m tall at an altitude of 71 m, and the nest cavity, 37 m from the ground, was located on the main trunk where a branch had broken off. The nest rim protruded forward, serving as a perch.

Helmeted Hornbills used the cavity in 2013, 2014, 2015 and 2017 but not in 2016 or 2018. Images of cracks and folds on the casque and bill indicated that the male of the pair was the same individual in 2015 and 2017, but poorer images from earlier years prevented certain identification. The cavity was an occasional object of interest to other hornbill species in the area. The empty nest was briefly inspected by a male Wrinkled Hornbill *Rhabdotorrhinus corrugatus* in March 2015 and, when it was vacant in July 2016, a female Oriental Pied Hornbill *Anthracoceros albirostris* visited it briefly; we made no further checks that year but, because it was outside the breeding season (typically from December to May, pers. obs.), we assume that the Oriental Pied did not breed in the cavity. In 2017 a female Rhinoceros Hornbill *Buceros rhinoceros* and female Wrinkled Hornbill made single brief visits to the active nest, when the Helmeted Hornbill chick was inside. In 2018, while the Helmeted Hornbills were still supporting the juvenile which fledged in 2017, the nest cavity was used by a group of co-operatively breeding Bushy-crested Hornbill *Anorrhinus galeritus* until their chick fledged in September 2018.

Nesting behaviour

In March 2017, our identified pair was observed feeding on a fig tree near the nest tree, and they engaged in a duet call. In the following month, their calls could be heard near the nest tree, although on 26 April the nest was empty. Then the female was seen inside the cavity on the 19 May and subsequently seen sealing herself into the cavity on the 23 May (Plate 2 a,b). Nest sanitation was observed throughout the nesting period, as the female squirted faeces through the narrow slit in the seal. The chick did likewise, but was not as adept as the female and the faeces tended to aggregate on the rim of the cavity. The male, and the female after she emerged, removed the faeces accumulated on the nest rim. Throughout the nesting period the male and then later the female preened near the nest tree (Plate 3).

In 2013, 2014 and 2017 the female left the cavity in October (on 3 October in 2017); the date of her exit in 2015 was not determined. In all four years the chick fledged in November; in 2015 the chick was identified as female and in 2017 as male. After the adult female's exit in 2017 she made three visits to the nest but fed the chick only once. The chick was seen resealing the cavity on the same day the female left, by defecating on the rim and using the faeces as sealing material (Plate 2d). This bird's fledging was the only one actually seen, on the morning 1 November 2017. At 06h30, the fledging bird picked up old feathers and faecal matter from inside the cavity and discarded them outside, then chipped away the sealing material, with short breaks, for a period of 105 minutes. With the male absent and the female perched nearby, the fledgling stepped out of the nest and fell from view, but we soon found it perched quietly under the canopy. The female visited the empty cavity and peered inside. The male returned, eventually locating the fledgling (which appeared to be the same size as the male), and began feeding it, calling incessantly *hahahau hahahau hahahau*. Later in the day, while the adults were away, the fledgling kept flapping its wings and preening itself. When the parents returned, all three birds flew to a *Ficus crassiramea* tree 50 m from the nest and the male gave his full call, ending with the maniacal laugh, and the fledgling and female responded in the same manner.

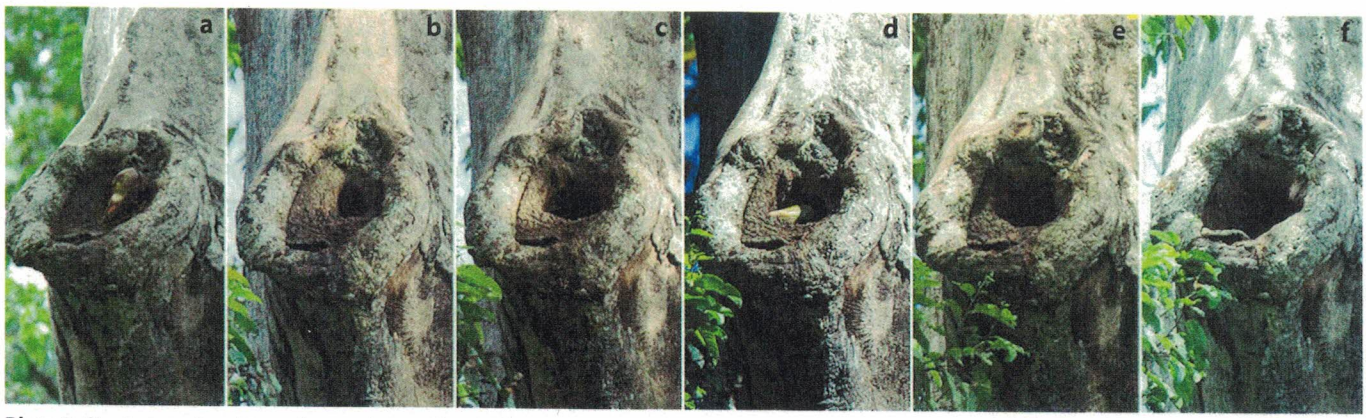

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Plate 2. Six stages of cavity sealing and unsealing in the nesting cycle (left to right): (a) the female sealing the cavity; (b) the sealed cavity; (c) state of the sealing material after the female's exit; (d) and (e) the chick's attempts at resealing the cavity; (f) the cavity after fledging.

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Plate 3. Male Helmeted Hornbill preening and using its preen gland, Lower Kinabatangan Wildlife Sanctuary, 5 October 2017.

In May 2016 the young female that fledged in November 2015 was seen with her parents about 5 km from the nest tree, feeding on a *Ficus benjamina*; the family were identified from the male's bill markings. The juvenile's casque was still only slightly developed (Plate 4a). The male chick that fledged in November 2017 was seen with its parents in January 2018 in the nest tree area; its casque was undeveloped (Plate 4b).

Diet

The daily food delivery rate (number of figs/hour) in 2013 was calculated using the method of Pawar *et al.* (2018). The food delivery rate by the male Helmeted Hornbill in July and August was consistently less than 15 figs/hour, but it doubled towards the end of August, decreased sharply in mid-September just before the female left the nest and then rose higher than before at the end of September and still further in October, to almost 30 figs/hour, a month before the chick fledged. The number of visits per day to the nest made by the male was between two and six (Figure 1).

In 2017, the daily food delivery rate by the male during the initial nesting period was low, under 10 figs/hour. In due course, however, it rose sharply in August and September. In early October it decreased, as the day of the female hornbill's exit from the nest cavity approached. After she emerged it increased again and remained mainly on the higher side. The daily food delivery rate then peaked again in October at almost 50 figs/hour, 15 days before the chick fledged. The number of visits per day made by the male was between three and eleven (Figure 2).

In 2017, the diet consisted mainly of figs throughout the nesting period (Table 1). It was noted that the male would mash the fig fruit

Table 1. The type and amount of fruits in grams consumed by the female and chick during two important phases in 2017.

Date	Phase	Weight (gm)	Ficus type	Hours of observation	Occupant
28 May	Incubation	254	*F. stupenda* *F. benjamina*	9	Female
31 May	Incubation	240	*F. stupenda* *F. benjamina*	9	Female
22 August	Nestling	794	*F. crassiramea* *F. stupenda* *F. benjamina*	8	Female and chick
16 October	Nestling	978	*F. stricta* *F. crassiramea*	8	Chick
19 October	Nestling	1,908	*F. stricta* *F. crassiramea*	7.5	Chick

Plate 4. Juvenile female (left), six months after fledging, 17 May 2016; and the young male (right) on the day of fledging, 1 November 2017.

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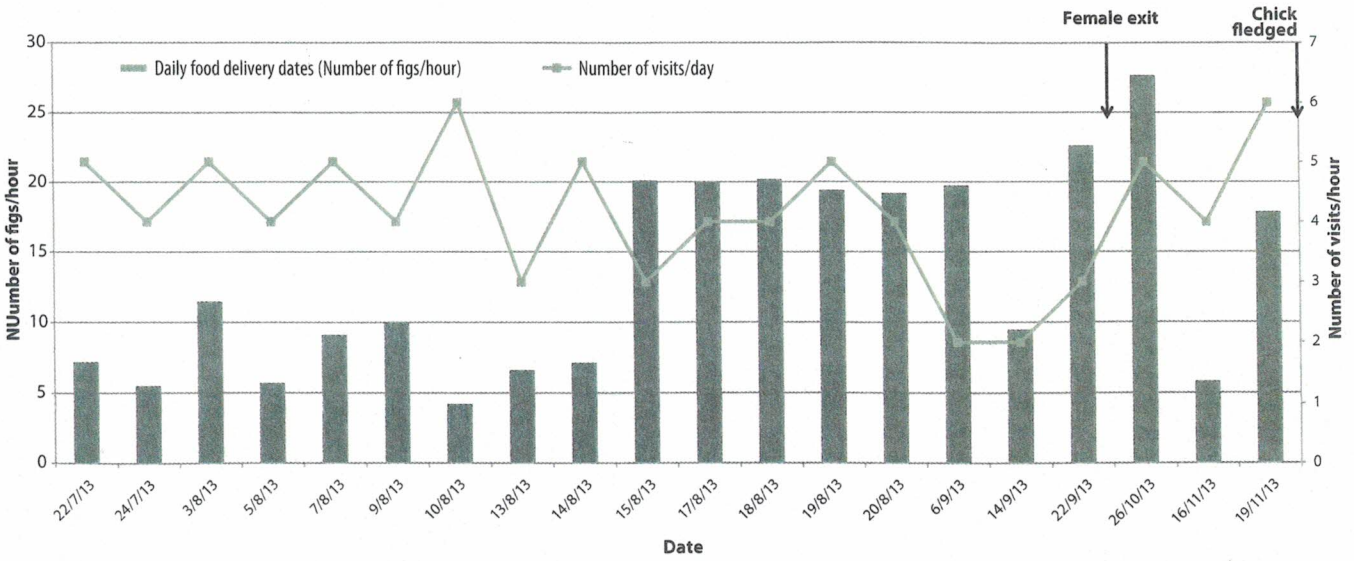

Figure 1. The daily food delivery rates and number of visits by the male Helmeted Hornbill over 20 days in 2013.

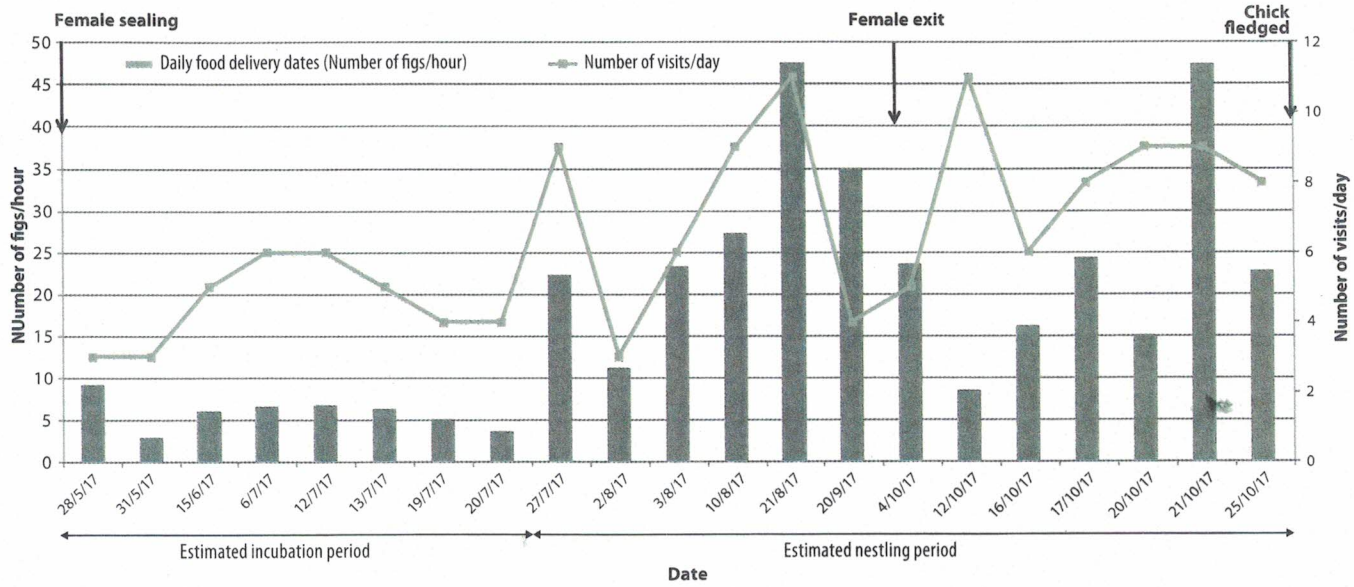

Figure 2. The daily food delivery rates and number of visits by the male Helmeted Hornbill over 21 days in 2017.

in its bill and feed the female and chick, causing the fig seeds to rain on the cavity. This behaviour started in August, in the fourth month of nesting, and continued until October. The Helmeted Hornbills also delivered five stick insects in total, with one being identified as a female *Phobaeticus redtenbacheri*, plus a beetle, a praying mantis and five other unidentified insects. On one occasion, on its own, the sealed-in chick caught and ate a giant millipede that ventured near the entrance of the nest cavity.

In 2017 on the day the female left the cavity, she spent most of the time preening. She then made three visits to the nest but did not feed the chick. The following day, she fed it one fruit. The following week, she made two to four visits per day, and fed 11 to 124 fruits. However, the male supplied more fruits than the female at each feed.

DISCUSSION

Nest tree aspects

The nest cavity described by Chong (2011) as 'a hollowed stump of a broken branch' seems similar to the cavity in our study. In southern Sumatra five Helmeted Hornbill nests were in the stubs of broken branches of dipterocarp trees (Kinnaird & O'Brien 2007). Unfortunately, such cavities are known to be susceptible to storm damage (Poonswad 1995).

The species *Shorea pauciflora*, in which our nest was found, may be an important nest tree for large-bodied hornbills in Malaysia; two pairs of Rhinoceros Hornbills used *S. pauciflora* as a nest tree even when the tree was dead (Johns 1982 in Kemp 1995). It is therefore of concern that this tree species is listed as Endangered on the IUCN Red List (Ashton 1998) and that seedlings of *S. pauciflora* experience one of the highest mortality rates of the genus, if they germinate during drought and under shaded conditions (Turner 1990).

In a large-scale study of the lower Kinabatangan area, only 19% of the total 520,269 ha was mature dipterocarp forest (Abram *et al.* 2014), suggesting that the rest of this regenerating landscape lacks the old trees needed by large-bodied hornbills for nesting. The interest shown by various hornbill species in the nest cavity in this study may therefore have been an indication of the paucity of suitable natural cavities. Scarcity of nest sites has indeed already been noted by Poonswad *et al.* (2012). This may explain why in October 2017, after exiting the cavity, the female Helmeted Hornbill tended

to stay near the nest tree most of the time, suggesting a guardian role. In fact, in one incident she lowered her head to display her casque at a visiting Rhinoceros Hornbill.

Nesting behaviour

Our study indicates that the Helmeted Hornbill nesting season in northern Borneo commences in May. This is similar to the northern side of Peninsular Malaysia, where the female was sealed inside in April after the pair was seen inspecting the nest in March (Kaur *et al.* 2015), but differs somewhat from the southern side, where the species is reported to begin nesting in February (Chong 2011).

In Khao Yai National Park, Thailand, the hornbill's nesting cycle begins in the dry season and ends with the female and chick emerging early in the rainy season (Poonswad *et al.* 1987). We observed the same timetable in northern Borneo; the driest months (Harun *et al.* 2014) coincide with the species's nesting period and the chick fledged at the start of the heaviest rainfall season, which occurs between October and March.

The Helmeted Hornbill has one of the longest periods of self-imprisonment, between 167 and 172 days (Kinnaird & O'Brien 2007). In our 2017 study the female Helmeted Hornbill spent an estimated 138–160 days inside the nest cavity. As noted above, just before it fledged the chick ejected old adult feathers, presumably from the female. This suggests that the female underwent a moult in the nest and the old feathers were used to line it; such lining materials may level out the nest floor (Kemp 1995) and moulting may mitigate high temperatures in the cavity (Gill 1994).

Our record of the 2015 fledgling feeding with its parents in May 2016 is matched by an observation made by Leighton (1986) in which a Helmeted Hornbill pair was still feeding a chick six months after fledging, and also perhaps indicates why the pair made no nesting attempts that year. About 18 months after the chick fledged, the pair bred again in 2017. The production of a single chick every second year is an indication of the naturally slow breeding rate of this species.

Diet

In this study the Helmeted Hornbills selected *Ficus crassiramea*, *F. stricta*, *F. benjamina* and *F. stupenda*, similar to reports from Sumatra (Hadiprakarsa & Kinnaird 2004). They are also known to feed on *F. dubia*, *F. kerkhovenii*, *F. sinuata*, *F. subcordata* (Shanahan 2000), *F. albifila*, *F. altissima*, *F. drupacea*, *F. microcarpa*, *F. sundaica* (Hadiprakarsa & Kinnaird 2004), *F. trichocarpa borneensis*, *F. pellucido-punctata*, *F. subtecta* and *F. xylophylla* (Leighton 1982), and *Parkia speciosa* seeds (Kemp 1995). Fig fruits that we handled sometimes contained wasps, and this additional source of protein may be appealing to the bird (Galama *et al.* 2002). Since these tree species are a food source for Helmeted Hornbills, reforestation projects should consider them in their replanting programmes.

This study also sheds light on the amount of food required by a female and chick during their incarceration, if captive breeding is ever considered in the future. In 2017, the lowest amount of food delivered is consistent with the female's low energy usage during the incubation period. During this period the female consumed less than 250 g of fruits a day (Table 1). We assume that the 51-day incubation period (Kinnaird & O'Brien 2007) occurred in June and July and that the abrupt rise in feeds on 27 July coincided with the hatching of the chick. After the female left the nest, the chick consumed 900–1,900 g of fruits per day (Table 1).

The male was absent from the nest tree area for more than 80% of the observation time; he was presumably mostly foraging. Long foraging times hunting small animals were reported in another study of Helmeted Hornbills (Leighton 1986). Chong (2011) and Kaur *et al.* (2015) reported that the species consumed snakes and sometimes centipedes during their nesting period. Lizards, birds (Smythies 1981) and squirrels *Sciurus tennuis* (Leighton 1986) have also been reported as a food source but it is unclear if these were taken during the nesting period. Stick insects were the most favoured source of protein in our study and that of Kaur *et al.* (2015). This may be due to the fact that Helmeted Hornbills spend most of their time in the upper canopy (Hadiprakarsa & Kinnaird 2004), where they can more easily find slow-moving stick insects.

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Plate 5. Male Helmeted Hornbill in heat loss position, near the nest site, 26 September 2017, as described by Frith & Douglas (1978).

In both 2013 and 2017 there appeared to be a dip in the number of visits by the male just prior to the female's departure from the nest cavity. This behaviour may simply be a way to entice the female to leave the nest cavity (Kinnaird & O'Brien 2007). In 2017, once the female had left the nest, the food delivery by the male doubled and remained more or less the same for over a month until the chick fledged; it supplied more food to the chick than the female.

As the fledging of the chick approached, the male and female brought unripe figs, as noted elsewhere (Chong 2011). Unripe fruits are a poor source of sugar and protein and the seeds are immature (Kinnaird & O'Brien 2007). The explanation of this phenomenon is unknown, but it may indicate a shortage of fruit or possibly the birds were overheating and unable to fly far to supply the needs of the chick (Plate 5).

Conclusion

Helmeted Hornbills take six months to produce one chick and, if successful, another six months (at least) to raise the chick to independence, as a result of which it appears that a successful pair may not breed in the following nesting season. This investment of time and effort in raising one chick, combined with their specialised diet and nest tree preferences (both requiring primary forest), makes them extremely vulnerable to threats such as logging and agricultural expansion. The newly added pressure from hunting certainly risks driving these birds to extinction. Helmeted Hornbills are rare in the Lower Kinabatangan Wildlife Sanctuary, but the nest that we studied is under continuing protection. We recommend that other nests be located and protected by local authorities and communities through nest-adoption programmes. At present, Malaysia has vast protected areas and the Helmeted Hornbills should be able to survive in these forests as long as the adults are protected from poachers. Large mature cavity-bearing trees should also be spared during selective logging practices.

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