The breeding biology of the Great Hornbill *Buceros bicornis*, Rhinoceros Hornbill *Buceros rhinoceros* and Helmeted Hornbill *Rhinoplax vigil* in the Temengor Forest Reserve, Perak, Malaysia

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Abstract: Three species of hornbills in Temengor Forest Reserve, Perak, Malaysia was observed during their breeding period from January 2009 to September 2009. There is a lack of information on the breeding biology in the wild, thus the nesting and feeding behaviour of the Great Hornbill *Buceros bicornis*, two pairs of the Rhinoceros Hornbills *Buceros rhinoceros* and one pair of Helmeted Hornbill *Rhinoplax vigil* (n = 4) were observed. The female Great Hornbill spent 56-87 days inside the cavity. The fruits fed on by the Great Hornbill originated from families; Annonaceae, Elaeagnaceae, Moraceae, Sapotaceae. However, their breeding attempts failed during this study. Both the female Rhinoceros Hornbills from two different nest cavities successfully raised one chick each and the females spent 82-111 days and 50-79 days in the nest cavity, respectively. The fruits consumed by the two pairs of Rhinoceros Hornbill originated from families; Annonaceae, Arecaceae, Cornaceae, Elaeagnaceae, Moraceae, Meliaceae, Myristicaceae and Sterculiaceae. One of the Rhinoceros Hornbill pairs chose to nest in a tree identified as *Koompassia malaccensis* Maing. ex Benth. (family: Leguminosae). The female of the Helmeted Hornbill spent 140-162 days inside the cavity. The male brought mainly non-fig fruits to the inmates. The pair successfully raised one chick and their nest tree had been identified as *Dysoxylum grande* Hiern (family: Meliaceae). In addition, a Wreathed Hornbill nest tree was identified as *Terminalia bellirica*, though it was inactive during this study period.

Keywords: hornbill, Great Hornbill, Rhinoceros Hornbill, Helmeted Hornbill, hornbill breeding behaviour, Temengor, nest cavity, hole nesters, hornbill preferred fruits

INTRODUCTION

There are 10 species of hornbills in the Belum-Temengor Forest Complex in Perak, Malaysia and we made additional studies on the breeding biology of three hornbill species in Malaysia. Generally for

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Asian hornbills, upon mating, the female will seal itself inside the cavity, leaving a narrow slit for which the male will use to pass food material to the female. Nest sanitation is observed, as both chick and female will squirt out faeces through the narrow slit of the cavity (Poonswad and Kemp 1993).

The breeding behaviour of the Helmeted Hornbills is poorly studied (Kemp 1995; del Hoyo et al. 2001). Preferring a knob shaped nest cavity (Chong 2011; Davison et al. 1995; Thiensongrusamee et al. 2005), the Helmeted Hornbill nests primarily in *Hopea* sp. and *Shorea faguetiana*. The height of the nest tree ranges from 26-70 m while the diameter at breast height (dbh) of the nest tree ranges from 105-216.6 cm. These nest trees were found growing at altitudes ranging from 300 - 535 m asl, usually on slopes (Thiensongrusamee et al. 2005). Both the Helmeted *Rhinoplax vigil* and the Red-knobbed Hornbills *Aceros cassidix* have been documented as the longest imprisonment, which can last between 167 - 172 days (Kinnaird and O'Brien 2007).

The first nesting record in Malaysia of a pair of nesting Helmeted Hornbills lacked information on breeding (Wells 1999). Although the second nesting record had been observed and described in more depth by (Chong 2011), the nest was located in a sub-montane region in Genting Highlands, Malaysia, unlike this study, which involved a lowland type forest. Described as the 'hollowed stump of a broken branch', the cavity was located 30 m from the ground, at an 800 m asl on a steep slope. The sealing process, carried out entirely by the female, took 13 - 14 days to be completed. The estimated period of the incarceration of the female is between 154 - 167 days. Chong (2011) did not address feeding and nest tree species preferences. Therefore, in the proposed study, more observation time had been allocated for the Helmeted Hornbill to address the knowledge gaps.

Several studies have been conducted on captive Rhinoceros Hornbill *Buceros rhinoceros*, such as Reilly (1988), Strehlow (2001), and Urban et al. (1999). In Malaysia, wild-nesting Rhinoceros Hornbills have been reported to nest in *Shorea paucifolia* tree (Johns 1982). Research in Sumatra by WCS Indonesia Program revealed that the nesting cycle of Rhinoceros Hornbill may last as long as 115 - 143 days. Their incubation period lasts 37 - 46 days, and the nestling period 78 - 82 days. As for the female, it stayed within the cavity for 86 - 97 days and leaves the nest cavity before the chick fledges. In addition, the nest trees have been documented to have a dbh of 111.6 cm with the height of the nest at 31 m (Kinnaird and O'Brien 2007).

The breeding behaviour of captive Great Hornbills *Buceros bicornis* have been studied by Choy (1980), Nehls (2000), Poulsen (1970) and Golding and Williams (1986). Their nesting cycle in the wild lasts up to 140 days with 1 - 4 days for pre-laying, an incubation period of 40 days, and 72 - 96 days for the nestling period (Poonswad and Kemp

1993). The male makes three trips in a day to the nest cavity to provide food, spending 15 - 20 minutes per day to feed (Ali et al. 1970). The height of the nest from the ground ranged from 10.5 – 30 m with a 54 – 157 cm dbh. Nest trees were found at altitudes ranging from 700 - 850 m asl (Poonswad and Kemp 1993).

Great Hornbills have the tendency to utilize a nest cavity with an elongated entrance (Thiensongrusamee et al. 2005). Both the female and male use their faeces and food materials to seal the entrance. The sealing is then placed by a sideways tapping of the bill, to the sides of the nest hole (Golding and Williams 1986). Great Hornbills do not use mud as sealing material (Golding and Williams 1986; James et al. 2007). Among the 27 nest trees utilized by Great Hornbills in Thailand, 11 nest sites were *Dipterocarpus* trees and seven were *Syzygium* trees. The others belonged to the genera *Altingia, Lithocarpus, Cinnamomum, Tetrameles,* and *Shorea*. (Poonswad and Kemp 1993). In Arunachal Pradesh, Great Hornbills, Wreathed Hornbills and Oriental Pied Hornbills have been reported to use *Tetrameles nudi lora* as their nesting tree, a deciduous tree found in lowlands (Datta et al. 2004).

In addition, the nesting behaviour in Malaysia of Bushy-crested Hornbill *Annorhinus galeritus* was described by Madge (1969) and Styring et al. (2002), while the nesting behaviour of Oriental Pied Hornbill *Anthracoceros albirostris*, of the southern race *convexus*, was described by Pan (1987). Thus, this study brings forth new knowledge concerning the hornbills in Malaysia for further comparisons.

MATERIALS AND METHODS

Study area

Located in the north of Peninsular Malaysia, the Temengor Forest Reserve covers 148,870 ha. The forest is mainly hill dipterocarp forest (e.g. mainly *Dipterocarpus* and *Shorea* tree spp.) and the hilly and mountainous regions within this area are part of the central forest spine. The Temengor Lake (152 km^2) came into existence in 1978, for the purposes of hydroelectric power generation (Davison et al. 1995).

Methods and materials

A cash reward was offered to the locals for the discovery of active nest trees. Observations began in January to September 2009 and two weeks were then allocated to the discovered nest trees for each month. The observation methods were based on Poonswad and Kemp (1993). Full day observations (> 500 minutes) were conducted from dusk to dawn, as permitted by sunlight (0700 - 1900 hours). All data was recorded on a standardized survey sheet. A temporary hide was constructed to keep

the observers out of view during the nest observations. To document food preferences, a large plastic sheet (1.5 m x 1.5 m) was placed under the nest cavity, almost touching the nest tree. The fallen debris were examined and collected after every feed, in the absence of the male. The food materials were categorized as fig, non-fig and animal matter. Binoculars (Bushnell 8 x 42 Field 6.0º 105 m / 1000 m) and a spotting scope (Leica APO – TELEVID 77, T77: 20x–60x, T62: 16x–48x) were used to observe the hornbill's behaviour. In addition, the use of a video camera (Panasonic AVCCAM HD 3CCD) and digital cameras (Olympus E3) aided in the documentation process.

RESULTS

The trees with hornbill nest cavities were measured to record their height, circumference and cavity height. Additional information such as tree condition and its species were provided whenever possible (Table 1).

Breeding behaviour of Great Hornbill

During the nest sealing activity, the Great Hornbill female used new sealing material in the absence of the male. The male did not engage in this activity. In one day, the longest time spent by the female for sealing activities was 330 minutes. It was seen sealing the nest cavity over a span of 23 days.

In the incubation phase, on a one-time occasion, the female regurgitated almost half the quantity of fruits it had received from the male and allowed it to fall to the ground. The male hornbill did not engage in any nest cleaning activities. To exit the nest, the female broke the sealing material, using its bill to chip away at the sealing material. This 12-minute struggle began by the female putting its whole head outside the cavity, followed by its left wing. During its exit, the male called softly. Upon releasing itself from the cavity, it flew to perch on a branch on the nest tree and began preening. The pair then joined in a duet call. There were no signs of any chick(s). The estimated nesting schedule of the Great Hornbill is depicted in Figure 1.

The number of nest visitation by the male increased during week one to week four. The visitations then decreased towards week nine, and subsequently had completely ceased after the female exited the nest cavity (Figure 2).

In the absence of the male hornbill, visits were made to the base of the nest tree, to retrieve fallen fruits and seeds accumulated in the netting sheet below the tree (Table 2). The most number of deliveries recorded in a day was three times, while the least number of food deliveries was two

times in a day. From 14 observed visits, the mean of minutes spent at the nest cavity was 3.07 (SD ± 2.40). The longest time spent at the nest cavity was eight minutes and the least number was one minute. 77.36% of the fruits delivered were non-figs and 22.64% consisted of fig fruits. As for animal matter, the female Great Hornbill consumed a giant millipede (Harpagophoridae) (*Thyropygus* sp.) and a gecko (Gekkonidae) (species unknown). The male did not deliver these items. Instead, they were captured at the nest entrance and consumed by the female hornbill.

Breeding behaviour of Rhinoceros Hornbill (RHB01-06)

Three feathers retrieved from the base of the nest tree suggested molting of the female's feathers. Nest sanitation was observed by both chick and female. They would turn around to face their cloaca at the nest entrance and eject faeces. After an hour of struggling, the chick emerged from the nest one morning by pecking and breaking the sealing material. At that time, the adults remained close within the area. The estimated nesting schedule of the Rhinoceros Hornbill (RHB01-06) is depicted in Figure 3. The most number of food deliveries in a day was six and the least number of deliveries in a day was two. From 11 observed visits, the mean of minutes spent at the nest cavity was 3.81 (SD ± 2.71). The longest time spent at the nest cavity was nine minutes and the least number was one minute. 45.87% of the food delivered was non-fig fruits followed by 43.89% of fig fruits and 9.90% of animal matter. The animals consumed by the hornbill were a scorpion (unknown species), a bird (unknown species), a rodent (unknown species) and a giant millipede Harpagophoridae (*Thyropygus* sp.)

Breeding behaviour of Rhinoceros Hornbill (RHB02-06)

Six feathers retrieved from the base of the nest tree suggested molting of the female's feathers. During a visit, the chick was seen engaged in nest resealing activities by itself. It patted the sealing material down with its well-developed bill and even added a feather. The estimated nesting schedule of the Rhinoceros Hornbill (RHB02-06) is depicted in Figure 4.

In the absence of the male hornbill, visits were made to the base of the nest tree, to retrieve fallen fruits and seeds accumulated in the netting sheet below the tree (Table 3).

Breeding behaviour of Helmeted Hornbill (HHB01-07)

The Helmeted Hornbill would perch on the stump-like nest cavity and regurgitate fruits one by one to feed. It would not hang onto the nest cavity, unlike the Great Hornbill and Rhinoceros Hornbill. On one occasion as it remained perched at the nest cavity, it called out *'kok'*

88 times and ended its call by bursting into a 'maniac laugh' call. The female responded with a similar call.

Fallen fruits lying around the nest cavity were re-offered to the inmates. The most number of fruits fed by the male Helmeted Hornbill in one feeding session was 168 small fig fruits, and the feeding activity took 35 minutes to complete. At times, the fruit became lodged inside the roof of its bill, causing the male to struggle to free it by shaking its bill, jerking its head backwards and rubbing each side of its bill around the nest cavity. During the nestling phase, unusual feeding behaviours were noted:

- 16 June 2009 - The nest area was being visited by a flock of Oriental Pied Hornbills. While feeding, the male swallowed a piece of fruit then hopped on to the nest tree and knocking sounds were heard.
- 25 June 2009 - A flock of Rhinoceros Hornbills were present within the nest tree area. The male returned to the nest cavity with a fruit. Then, it hopped up the tree and knocking sounds were heard. It returned to the nest cavity with fruit in bill. The sound of wings could be heard, and the male did not feed. Instead it hopped up the nest tree yet again. Minutes later, the male returned to feed with the same fruit again. It swallowed the fruit, then regurgitated it and hopped upwards on the nest tree. There were also Dusky Leaf-monkeys *Trachypithecus obscurus* present in the nest area.
- 22 July 2009 - The male fed 15 small fruits then hopped up the nest tree with fruit still in its bill. Half an hour after the feed, the male returned to feed fruits but then flew away yet again with fruit in its bill. At the same time, a White-crowned Hornbill *Berenicornis comatus* began calling and flying around the nest area.
- 23 July 2009 - The male flew to the cavity to feed, with a fruit seen in its bill but it stayed perched on the nest cavity and did not feed. It then hopped up the nest tree. There was a ruckus caused by a few dusky leaf monkeys in the canopy. The male flew away from the nest tree. Two hours after the last attempted feed, there were sounds of wings heard. The male flew to the nest cavity but did not land. It hovered (for a split second) and then flew back to a nearby tree. One minute later, the male flew to the cavity to feed.

The male ended feeding sessions by picking up faeces and food remains with its bill sideways and tossing them away. Cleaning practices were not continued after the departure of the female. Prior to the female's departure and late into the nestling phase, the male returned with fruit but did not feed. This behaviour was noted on several occasions as follows:

- 24 July 2009 - The male returned to feed 22 fig fruits but the 23rd fig was offered by the male several times but it was taken.

- 19 August 2009 - The male returned to feed 12 large dark, oval red figs. The 13th fruit was regurgitated yet swallowed back.
- 20 August 2009 - The whole head of the female could be seen. For 15 minutes, the male offered one fruit 12 times but the inmates did not take it. The male resumed feeding as usual.

On the day of the female's departure, its head was seen outside of the nest cavity. The male offered a fruit a few times, and then it merely stayed perched. The male called *'kok'* softly while the female continued breaking sealing material, flinging pieces of it out as it tried to struggle out of the cavity. The male called out, breaking into a 'maniac laugh' and the female responded with a similar call.

Knocking sounds were heard from inside the cavity when the female pulled its head back into the cavity. Then, the female broke out of the nest cavity swiftly. The male returned to feed with 22 fig fruits without hesitation. The male made soft calls when it fed the chick *'kok'*. The female did not participate in feeding activities for five days after its exit.

During the nestling phase, the male returned to feed and the first fruit was offered twice but not received by the chick. The last fruit though regurgitated was swallowed back by the male. The chick was heard calling out in a typical Helmeted Hornbill 'maniac laugh' call. As the days progressed, the chick placed more of its head outside the nest cavity. The female made her first visit, fed the chick and gave a long deep growl like call. It placed its head into the cavity several times before it hopped up the nest tree. On 31 August 2009, the chick began breaking the nest cavity sealing. The observers returned to the nest site on the 7 September 2009, and discovered the nest cavity was empty and that the chick had fledged. The estimated nesting schedule of the Helmeted Hornbill is depicted in Figure 5.

The Helmeted Hornbill male made up to seven food deliveries in a day. The least amount of food deliveries made in a day was two. From 33 observed visits, the mean of minutes spent at the nest cavity was 5.08 (SD ± 4.03). The most time spent at the nest cavity was 20 minutes and the least was half a minute. 57.59% of the food delivered was non-fig fruits, 39.97% were fig fruits and 2.44% of the food material was animal matter. Animal matter which was delivered consisted of several stick insects (unknown species), a snake (unknown species) and a centipede (unknown species). The mean number of nest visitation by the male increased from week six to week nineteen. The visitations then decreased towards week twenty-three (Figure 6).

DISCUSSION

Nesting cycle begins in the dry season (Poonswad et al. 1987; Kinnaird et al. 1999), when the conditions inside the cavity are most suitable (Poonswad 1993). In this study, the hornbills nested during a period of lower rainfall. Based on available rainfall data for certain months in 2009, the rainfall for January was measured less than 100 mm. February and June received less than 50 mm of rainfall. Rainfall increased in July, with rainfall up to 150 mm and 250 mm for August (Department of Irrigation and Drainage Malaysia 2009).

Nest tree characteristics

The nest cavity opening for Helmeted Hornbill differed from that of the Great and Rhinoceros Hornbills. It used a knob-like nest cavity. This unique behaviour has been attributed to its heavy head and the prevention of wear and tear of the tail feathers (Thiensongrusamee et al. 2005). In this study, the Helmeted Hornbill spent the most amount of time perched at the nest cavity perhaps due to its comfortable perch.

All three species of hornbills nested in live instead of dead trees. The conditions in a nest cavity may be at its optimum in living trees, largely due to the natural processes that take place such as photosynthesis and respiration (Poonswad 1993). It is unlikely that hornbills choose a specific tree species to nest inside. Hornbills would seek large, tall and common trees with suitable cavities to meet their nesting needs.

In Thailand, the Plain-pouched Hornbills nested in the most commonly found tree, *Tetrameles nudiflora*, a tree species favoured by large woodpeckers (Chimchome et al. 1998; Datta et al. 2003 in Kinnaird and O'Brien 2007). *T. nudiflora* has also been reported as the Sumba Hornbill's preferred nest trees (Marsden et al. 1997). The Great, Wreathed and Oriental Pied Hornbills preferred *T. nudiflora*, followed by *Ailanthus grandis*. Emergent trees were chosen based on height, cavity height, commonness and softness of its wood for easy cavity creation (Datta et al. 2004).

Nest sealing

The Great Hornbill female spent the longest time sealing the nest entrance. The sealing material contained fig seeds and it was applied to the nest entrance sides with a sideways tapping of the bill, similar to what had been observed in captive pairs (Poulsen 1970; Golding and Williams 1986). There were also large intervals between the male's visit and the appearance of new sealing material, suggesting that the materials were obtained by the female from inside the nest cavity and not from its

mate. In India, male Great Hornbills do not participate in nest sealing activities (James and Kannan 2007). In Thailand, only four out of 15 males were observed supplying sealing materials (Poonswad 1993). Nest sealing provides protection from predators (Kemp 1970) and ensures mate fidelity (Kinnaird and O'Brien 2007).

Feeding

The diet of hornbills in this study was predominately non-fig fruits. Fig fruits were the second highest consumed food for these three hornbill species. Great Hornbills have been reported to favour a non-fig diet (Datta et al. 2003) but the diet differs from that of the Great Hornbills found in Thailand, which was reported to rely heavily on fig fruits instead (Poonswad et al. 1998).

The Rhinoceros Hornbill had been reported to prefer a more fig-based diet (Leighton 1982; Hadiprakarsa 2000). Hornbills select fruits that are abundant, even if they are low in nutritional value. *Polyalthia* spp. and *Ficus* spp. trees produce many fruits and thus these trees were favoured among hornbills (Poonswad 1993). *Polyalthia* spp. seeds were often collected in this study, under the nest trees of the Great and Rhinoceros Hornbills.

The Rhinoceros and Great Hornbills in this study had been seen consuming giant millipedes, a food item that has been reportedly used as sealing material (Kemp 1995). Further feeding observations were interrupted at nest tree RHB01-06 when it became inaccessible due to the presence of a tiger within the area. Feeding observations were also unsuccessful at nest tree RHB02-06 because the male hornbill kept detecting the presence of the observers and would not visit the nest.

Great Hornbills prefer an insect diet once the chick has hatched (Golding and Williams 1986). The absence of a chick may account for the lack of protein-rich food such as animal matter, being delivered by the male to the nest site. The female Great Hornbill in this study spent between 56 - 87 days in the nest cavity before abandoning the nest, exceeding the average 40-day incubation period of the Great Hornbill (Poonswad and Kemp 1993). Due to the absence of protein foods in its food deliveries, the assumption was that no eggs had hatched.

The Helmeted Hornbill preferred a non-fig fruit diet. In a study in Sumatra, Helmeted Hornbills fed exclusively on figs, despite the low fig density in southern Sumatra (Hadiprakarsa et al. 2004). Figs have been documented as an important food source for hornbills and these fruits are available in abundance all year round (Poonswad 1993; Plongmai et al. 2005). A diet consisting of figs helps hornbills maintain a sufficient balance of calcium (Balasubramanian 2004; O'Brien et al. 1998).

Helmeted Hornbills feed on lizards, other birds and their eggs (Kheng 1998). The intake of animal matter increases when a chick hatches as the protein helps the development of the chick. In this study, several stick insects were brought to the nest during the nestling period. The brooding female consumes mostly fruits (Poonswad and Kemp 1993).

In this study, a lone Rhinoceros Hornbill was observed on the ground, on an enormous rotting log. Though hornbills usually forage within the canopy, an Oriental Pied Hornbill had been photographed on the forest ground consuming a fallen fig in Khao Yai National Park (Kitamura et al. 2009). Kemp (2001) had also reported that the Great, Wreathed and Oriental Pied Hornbills descend to the ground to obtain fruits.

Food handling

Among all three species of hornbills observed, the Great Hornbill female regurgitated and dropped the fruits it had been fed. The hornbill's vision makes it most capable of viewing the tip of its own bill. This allows for accurate bill control which helps in feeding activities that involve regurgitation, grasping, swallowing and tossing (Martin et al. 2004). Thus, it appears that the fruits were deliberately allowed to fall. It appears that the male is capable of oversupplying food to the female. The longest time the male Great Hornbill would perch at the cavity was eight minutes, while the shortest time to perch at the cavity was one minute.

Agonistic behaviour

In this study, the Helmeted Hornbill refusal to feed the inmates and loud knocking sounds on the nest tree, were perhaps a means to intimidate and chase the other hornbills away from its nesting area. Both the Rhinoceros and Helmeted Hornbills are known to live as resident territorial pairs (Kemp 1995). The Helmeted Hornbill male, female and chick emitted loud calls at the nest tree in this study, an ideal forest transmission to caution others within a widespread territory (Kemp 1995).

Nest sanitation

All the three species of hornbills in this study practised good sanitation by ejecting faeces out of their nest cavity. Due to the nature of the nest cavity of the Helmeted Hornbill, an accumulation of faeces and fallen fruits often occurred, perhaps due to the young chick(s) inability to defecate outside the nest cavity accurately. Thus, the male Helmeted Hornbill had developed a routine in which after its feeding session, it would fling off debris that had accumulated around the nest cavity's rim. A similar behaviour had been observed in male Indian Grey Hornbills *Ocyceros birostris* (Charde et al. 2011). Observing proper nest sanitation

prevents infestation of parasites and pathogens (Welty et al. 1988; Charde et al. 2011). It also avoids unwanted attention of predators (Weatherhead 1984) and prevents injury to the young chicks caused by the broken sharp egg shells (Charde et al. 2011).

Female departure

The male may have been enticing the female to exit the nest as it remained perched on the nest cavity for 20 minutes, a day before the female's exit. The duet calls of the breeding pair hours before the female's exit may have been a form of encouragement, to persuade the female into leaving the nest. The female did not participate in feeding activities for five days after its exit. This sort of behaviour had also been observed by (Kinnaird et al. 1999) among the female Sulawesi Red-knobbed Hornbill *Aceros cassidix*. According to Kinnaird et al. (1999), if imprisoned for too long, females risk the loss of body mass and atrophy of flight muscles. Thus it is plausible that the female's body was negatively affected and required time to recover upon exiting the nest cavity.

Chick fledging

In most species, it has been learned that food delivery declines as the breeding period proceeds and the breeding pair increases visits to the nest site without food. The adults entice the chick by calling and withholding food, despite begging calls made by the chick (Kinnaird et al. 1999; Kinnaird and O'Brien 2007). A similar behaviour was observed here, with the male using food to entice the chick to abandon the nest. The male made visits to the nest merely to perch with fruit clearly displayed in its bill.

The act of the chick pecking on the sealing material is an indication of its intention to fledge. This behaviour was observed in both the Helmeted and Rhinoceros Hornbill chicks. In captivity, a chick was observed pecking the sealing material, and had emerged the following day (Golding and Williams 1986). The Rhinoceros Hornbill chick (RHB0206) resealed the nest cavity by itself after the female's departure indicating that the source of sealing material originated from within the nest cavity itself. Not all hornbill chicks reseal their nest cavity upon the departure of the female and it is believed to be a natural response from chicks living in low-positioned nest cavities. It helps protect the chick against predators (Kinnaird et al. 1999). In this study, the cavity position was 12 m from the ground.

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Table 1. Hornbill nest tree preferences.

Nest Code	Elevation	Tree Description	Photo of Nest Cavity
GHB01-06	267 m asl	Species: Unidentified Height: ~21.3 m Circumference: 3.94 m dbh Cavity height: ~12.2m Tree condition: Alive Status: Active	 Photo credits: Sanjitpaal Singh
HHB01-07	238 m asl	Species: *Dysoxylum grande* Hiern. Height: ~19.8 m Circumference: 2.6 m dbh Cavity height: ~13.7 m Tree condition: Alive Status: Active	 Photo credits: Sanjitpaal Singh
RHB01-06	247 m asl	Species: Unidentified Height: ~ 28.9 m Circumference: 1.91 m dbh Cavity height: ~ 21.3 m Tree condition: Alive Status: Active	 Photo credits: Sanjitpaal Singh
RHB02-06	245 m asl	Species: *Koompassia malaccensis* Maing. *ex* Benth. Height: ~ 19.8 m Circumference: 1.93 m dbh Cavity height: ~12.2 m Tree condition: Alive Status: Active	Not available
RHB03-07	350 m asl	Species: Unknown Height: ~ 24.4 m Circumference: 4.2 m dbh Cavity height: ~ 15.2 m Status: Inactive	 Photo credits: Lim Kim Chye
WRHB01-07	278 m asl	Species: *Terminalia bellirica* (Gaertn.) Roxb Height: ~30.5 m Circumference: 2.7 dbh Cavity height: ~16.8 m Tree condition: Alive Status: Inactive	 Photo credits: Lim Kim Chye

Note: GHB = Great Hornbill, RHB = Rhinoceros Hornbill, HHB = Helmeted Hornbill, WRHB = Wreathed Hornbill

Table 2. Fallen fruits identified as the fruit preferences of Great Hornbill.

Family	**Species**
Moraceae	*Ficus* sp.
Sapotaceae	Unknown
Annonaceae	*Polyalthia* sp.
Elaeagnaceae	*Elaeagnus* sp.

Table 3. Several fallen fruits identified indicating the fruit preferences of the Rhinoceros Hornbill.

Family	**Species**
Moraceae	*Ficus* sp.
Annonaceae	*Polyalthia* sp.
Arecaceae	*Oncospermum* sp.
Sterculiaceae	*Sterculia* sp.
Cornaceae	*Mastixia* sp.
Meliaceae	*Dysoxylum* sp.
Myristicaceae	*Myristica* sp.
Elaeagnaceae	*Elaeagnus* sp.

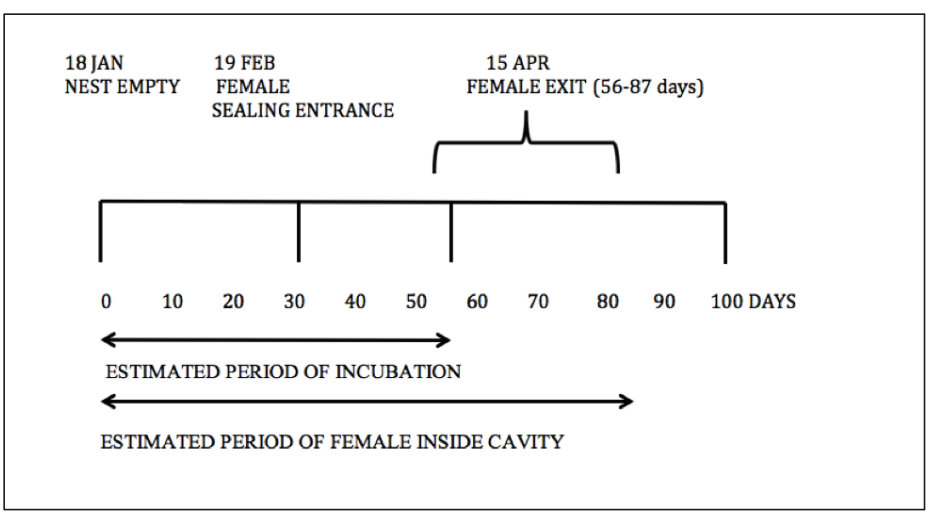

Figure 1. The estimated nesting schedule of the Great Hornbill.

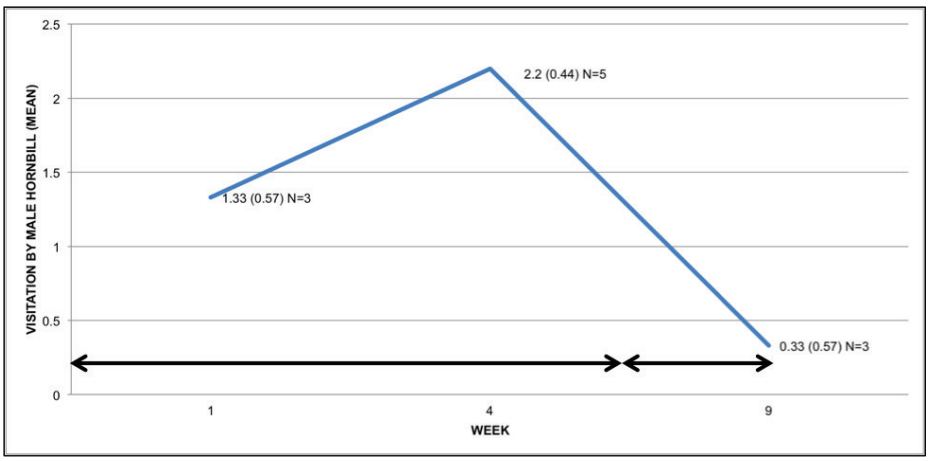

Figure 2. Mean nest visitation by the male Great hornbill by weeks. Standard deviation in parentheses. Only full day observations (8-11.5 hours) presented in this graph.

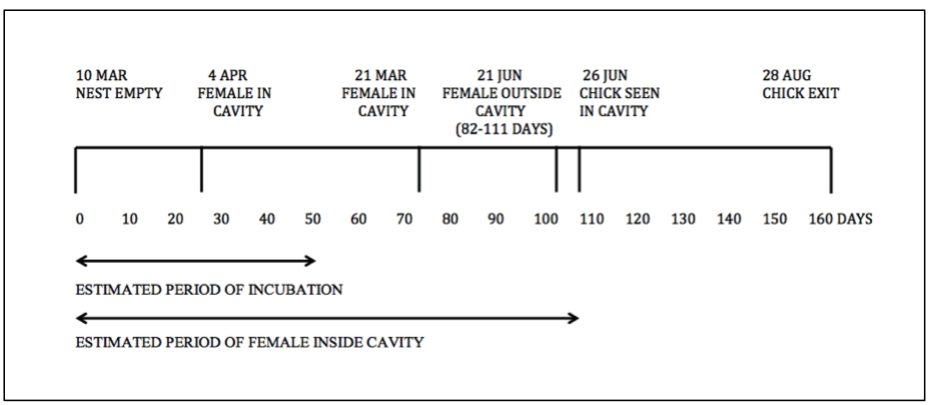

Figure 3. The estimated nesting schedule of the Rhinoceros Hornbill (RHB01-06).

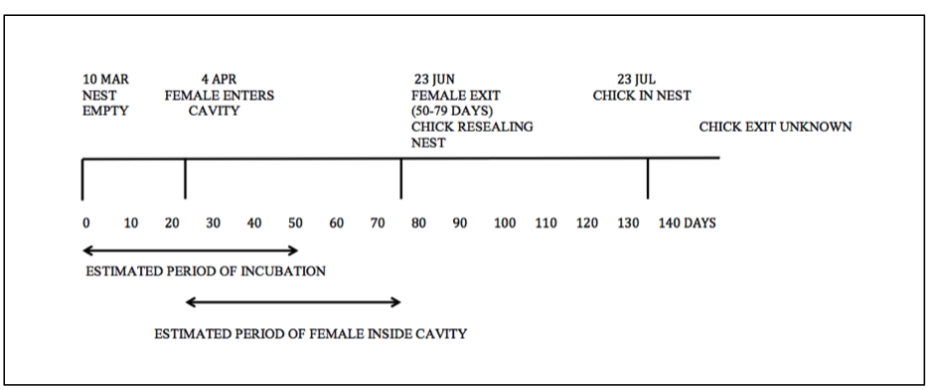

Figure 4. The estimated nesting schedule of the Rhinoceros Hornbill (RHB02-06).

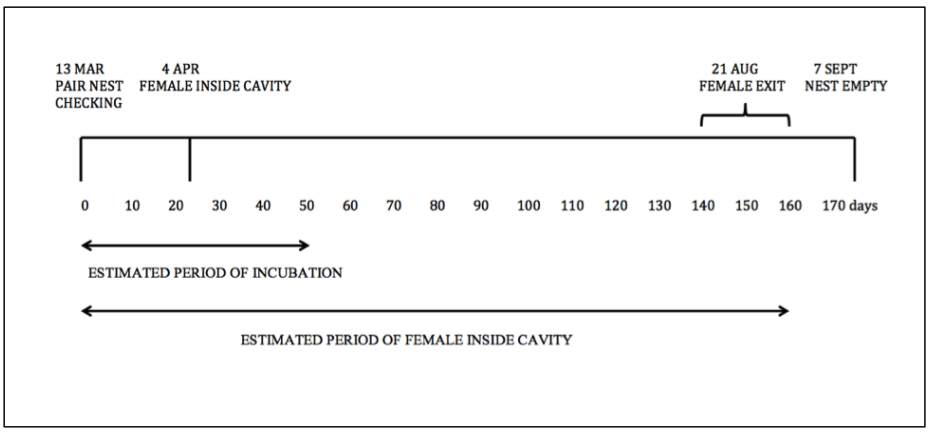

Figure 5. The estimated nesting schedule of the Helmeted Hornbill.

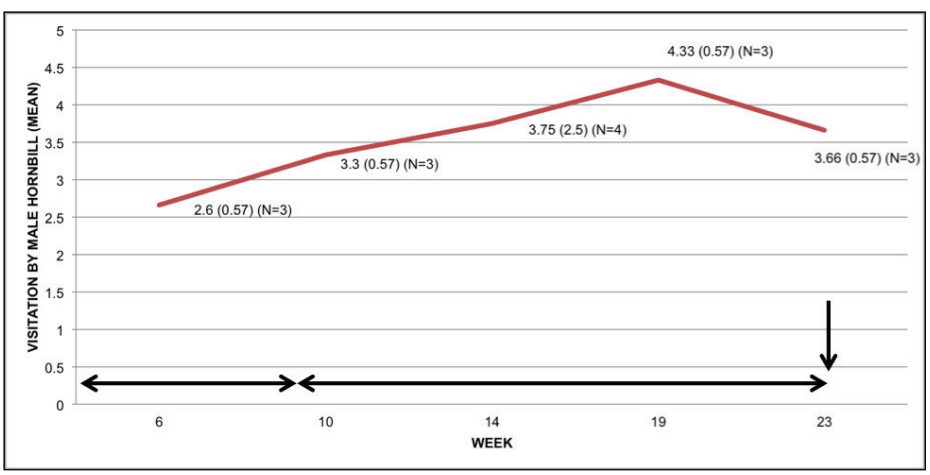

Figure 6. Mean nest visitation by male hornbill by weeks. Standard deviation in parentheses. Only full day observations (8-11.5 hours) presented in this graph.