Original article

Feeding Ecology of Plain-pouched and Oriental Pied Hornbills in Mixed Deciduous Forest, Northwestern Thailand

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Received: Apr 3, 2020 Revised: Apr 15, 2020 Accepted: Apr 17, 2020

ABSTRACT

The aim of this study is to research the feeding ecology of Plain-pouched Hornbill *Rhyticeros subruficollis* (PPH) in the seasonally flooded mixed deciduous forests of Huai Kha Khaeng Wildlife Sanctuary, Thailand (HKK) in comparison to the Oriental Pied Hornbill *Anthracoceros albirostris* (OPH) which is a possible competitor of PPH during the breeding season. Nest trees found by the Thailand Hornbill Project in the past were checked and repaired in December 2016 prior to the start of the breeding season. Four out of seven repaired nests were found active (two nests of PPH and two nests of OPH) in February 2017. Each of these nests was then observed from the observation blinds between 7.00 a.m.-5.00 p.m. for 3-7 days. The results show that incubation and nestling phase of PPH were 27 and 70.5 ± 0.7 days, respectively, with 1 chick/nest (n=2). For OPH, these two phases were 15 and 68 days, respectively, with 2 chicks/nest (n=2). Both hornbill species consumed more fruit than animals. PPH consumed more non-figs than figs while OPH comparatively consumed more figs than non-figs. The diet of both species contained a high proportion of fruit and syconium fruit. Cicada was ranked highest in the animal diets of both species. Food preference was similar for both species but the Food Overlap Index was low, indicating low competition between PPH and OPH.

Keywords: Plain-pouched Hornbill, Oriental Pied Hornbill, breeding cycle, diet composition, food and feeding

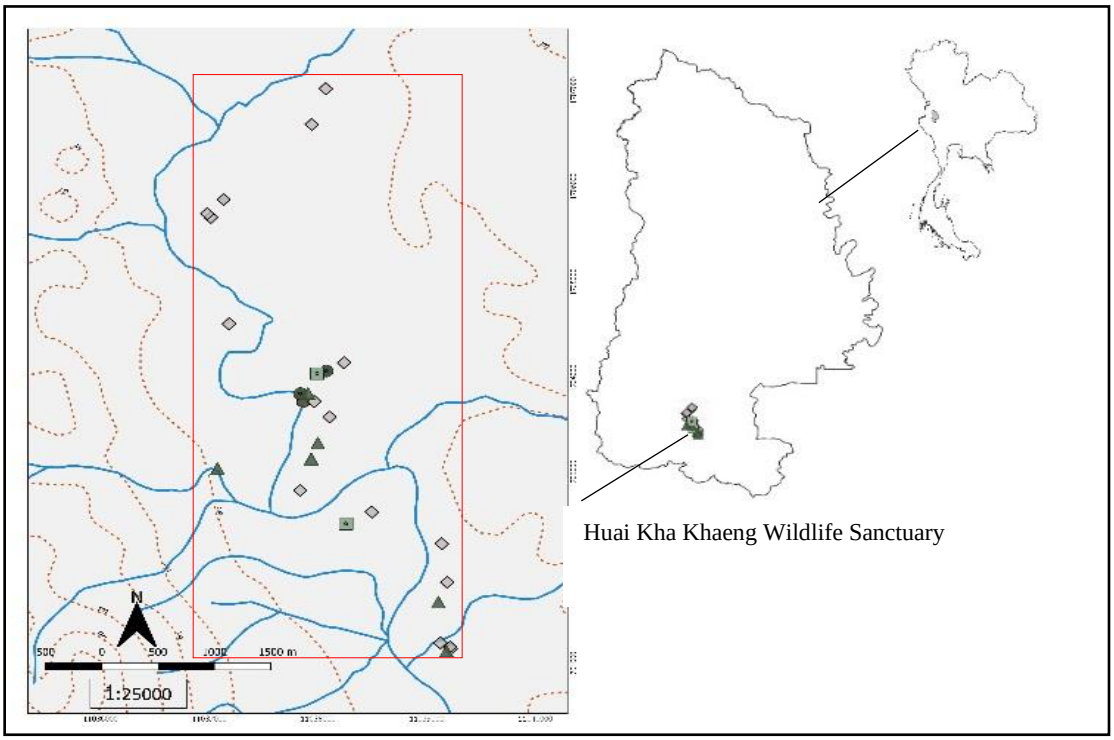
INTRODUCTION

Hornbills are the largest and the most conspicuous birds in the Old World tropical forests (Kemp and Kemp, 1974; Johns, 1987). Thirty-one out of 57 hornbill species of the world are found in tropical and subtropical Asia, and 13 species occur in Thailand (Kemp, 1993; Poonswad, 1993b). Hornbills are forest birds distributed throughout forested areas from mountainous evergreen forest to lowland evergreen forest, including tropical rain forest (Lekagul and Round, 1991). They are important ecologically as seed dispersers and predators (Poonswad *et al*., 1999). Although they are generally frugivorous, they can become omnivores especially during the breeding season (Poonswad *et al*., 1988).

In this study, we focused on the feeding ecology of Plain-pouched Hornbill, PPH (*Rhyticeros subruficollis)* since information on this species biology is limited, it has a globally restricted distribution and also it's conservation status is listed as Vulnerable (VU) (Birdlife International, 2017). Moreover, Trisurat *et al.* (2013) who evaluated hornbill species assessment and distribution in Thailand recommended that PPH should be listed as an Endangered species in Thailand. The aim of this study is therefore to provide more data on the feeding ecology of PPH in comparison with Oriental pied Hornbill, *Anthracoceros albirostris* (OPH), the sympatric species that is known as a nest competitor due to sharing nest trees with PPH (Thailand Hornbill Project, unpublished data). The existence and survival of PPH is challenging but possible through managing their nest trees and protecting forested habitat in HKK, Thailand World Heritage Site.

MATERIALS AND METHODS

The study was conducted in HKK, Western Thailand, which covers an area of 2,809 km^2 between latitude 15◦00'-15◦47' N and longitude 99◦00'-99◦27' E (Bunyavejchewin *et al*., 2016). HKK is composed of deciduous forest, dry dipterocarp forest and dry evergreen forest. Temperature in the wet season (May to October) ranges between 6 and 38 °C whereas the dry season (November to April) ranges between 10 and 29 °C. A short cold and dry winter takes place in December and January. The average annual rainfall is 1,552 mm with the maximum rainfall in October (370 mm) (National Parks Wildlife and Plant Conservation Department, 2014).



Note: Nest tree of OPH (17 nests) Nest tree of OPH, studied in 2017 (2 nests)
Nest tree of PPH (6 nests) Nest tree of PPH, studied in 2017 (2 nests)
Contour Stream
Study area

Figure 1 Study area in Huai Kha Khaeng Wildlife Sanctuary (HKK).

Hornbill nest tree locations were obtained from Thailand Hornbill Project, Mahidol University (Poonswad *et al*., 2010). PPH's nest has been searched during the middle stage of nesting period (February-April) from 1994 to 2016 by following the male flying alone or male from the ripen fruit trees to the same direction more than once assuming to the active nest trees. Nest trees were confirmed by feces, old seeds and seedlings of fruit trees under the nest (Poonswad *et al*., 2010). All PPH nests were found specifically in the seasonal flooded area of mixed deciduous forest along the stream covering 15 km^2 between latitudes 15◦07.837' -15◦07.074' N and longitude 99◦09.104'-99◦09.311' E, Ban Rai District, Uthai Thani Province (Figure 1). The forest has three-layer structure consisting of dominant tree such as *Lagerstroemia tomentosa* and *Tetrameles nudiflora* (Chimchome *et al*., 1998).

Nest trees were visited in December 2016 prior to the start of breeding season. Seven out of 18 potential nest trees were checked and if necessary the nest cavity were repaired (i.e., removing old nesting materials in the cavity, drilling a hole for draining water out if nest cavity is flooded, enlarging nest entrance if the entrance is too narrow or adding soil if the nest floor is sunk to ensure that they are suitable for nesting (Poonswad *et al*., 2010). In February–2017, 4 out of 7 nests were found to be active (2 nests of PPH and 2 nests of OPH). These were PPH6, PPH11, OPH 78 and OPH127 (1st 3 letters = hornbill species and number= sequences of nest tree found of each species in HKK). They were

observed from observation blinds at a distance of between 15-30 m without disturbing them. Observers used spotting scope and binoculars to identify and count number of food items brought to the female and brood by male. The characteristic of fruits and animals were noted *e.g.*, size, color and shape. The regurgitated seeds and fruits dropped under the nest tree were collected, identified and compared with the fruits and seeds from fruiting trees in the study area. The potential hornbill fruiting trees were tagged and to check fruit ripening period inside the 3 of 1 ha-plots belonging to THP including any fruit trees along the trail to all nests. When ripe fruits were detected, at least 30 fruits were collected to measure the size (length x width), fresh weight and color. Pulp was removed from the fruit and weighed to estimate fruit biomass consumed (Chaisuriyanun *et al*., 2011). Food and feeding behaviors were observed between 9-10 hours per day (starting between 7.00 a.m.-5.00 p.m.) for 3-7 days interval per nest. (Poonswad *et al*., 1999)

Data Analysis

1. Breeding cycle was divided into 3 phases: pre-laying, incubation and nestling phase and the fledging time of female and chick(s).
2. Food and feeding behavior:

2.1 Fruit characteristics

Type: (fleshy, berry, drupe, dehiscent, indehiscent etc.)

Shape: (round, elliptic, truncate, acute etc).

Size: following the distribution of fed fruits evenly by classifying into 3 classes (small, medium and large fruit).

Weight: Using digital balance 2 digits (TANITA 1476)

Color: Using color chart (The color Wheel Company)

Fruits consumed by both hornbill species during the breeding cycle were collected, described, and measured. Then calculated weight per feeding time (Ouithawon and Poonswad, 2005)

2.2 Diversity of fruits and animals consumed were calculated using Shannon-Wiener Diversity Index (H') (Ludwing and Renolds, 1988).

$$H' = -\sum_{i=1}^{s} (Pi \ln Pi)$$

H' = Diversity Index

S = Total number of species in the community

Pi = Proportion of weight of a particular food item

2.3 Food overlapped Index between PPH and OPH was used in order to investigate food competition using Horn's Index of Overlap (Ouithawon and Poonswad (2005)

$$Ro = \frac{\sum(Pij + Pik)\ln(Pij + Pik) - \sum Pij \ln Pij - \sum Pik \ln Pik}{2 \ln 2}$$

Ro = Niche overlap

Pij = Proportion weight of food species j per total weight of hornbill i's food

Pik = Proportion weight of food species k per total weight of hornbill k's food

2.4 Food preference of the diet consumed by these two hornbill species were identified by using number and frequency of food delivered to each nest including the total weight of each food species and then were ranked as the highest score was equal to the 1st rank and the least score as the lowest rank (Poonswad *et al*., 1998).

$$S = \sum_{i=1}^{p} f[N - (r_i - 1)]$$

S = Summed score of a given food item from different nests

r = Individual rank of the given food item for each nest

p = Total number of nests observed

N = Total number of food items to be ranked

2.5 In order to investigate how feeding behavior of males reacted to the different phases of breeding cycle and chick development i.e., pre-feeding, feeding and post-feeding during incubation and nestling phase**.** Proportion of average time (minutes) of feeding behavior of males for both species was compared.

RESULTS AND DISCUSSION

Results

Nest site and nest tree of hornbills were found specifically in mixed deciduous forest along the stream where it gets flooded during the rainy season. Within 15 km^2 in the study area, 8 PPH's nests were found with density of 0.53 nest/km^2. The nest trees were identified as *Tetrameles nudiflora* (5 trees, 62.5%) and *Ficus albipila* (3 trees, 37.5%). Nine OPH's nests were found with density of 0.6 nest/km^2. The nest trees were *Tetrameles nudiflora* (6 trees, 66.66%) and *Ficus albipila* (3 trees, 33.34%). Four active nests were observed with the total observation time of 25 days (168 hours) for PPH6, 32 days (216 hours) for PPH11. For the other species, OPH, the total observation time was 23 days (120 hours) for OPH127 and 25 days (215 hours) for OPH78.

Breeding cycle

Plain-pouched Hornbills (PPH)

The exact date of females PPH entering the nest cavities were unknown. However, we assumed that the breeding cycle from female entering the nest cavity to the chick hatching was 105 days according to Chimchome *et al*. (1998), we then estimated that female PPH11 Chick hatching was detected by chick calls between 13th - 15th March 2017. Emerging of female and 1 chick were observed between 7.00-9.00 am on 23th May 2017. For the other PPH's nest, female PPH6 entered nest cavity Chick hatching was also detected by chick calls between 31th March -2nd April 2017 and emerging time of female was observed on 12th June and 1 chick fledged one day after (Figure 2). Therefore, pre-laying phase was 7 days, incubation phase was 23-26 days and nestling phase was 70-72 days. On average, incubation phase was 27 ± 2.7, nestling phase was approximately 70.5 ± 0.7 with the total of 105 days for the whole breeding cycle (n=2).

Oriental Pied Hornbill (OPH)

Similar to PPH, the female entering period was not observed. However, according to breeding cycle of OPH previously studied was about 90 days (Poonswad *et al.*, 1999). Both OPHs were estimated to have started the re-laying phase about in the same time on 28th February, egg-laying and incubation on 6th March, chick hatching around 21st March and fledgling time of females and 2 chicks were observed on the same day (7.00 am.-11.30 am) of 28th May (Figure 2). On average, pre-laying phase was assumed to be 7 days, incubation phase was 15 days and nestling phase was 68 days (n=2).

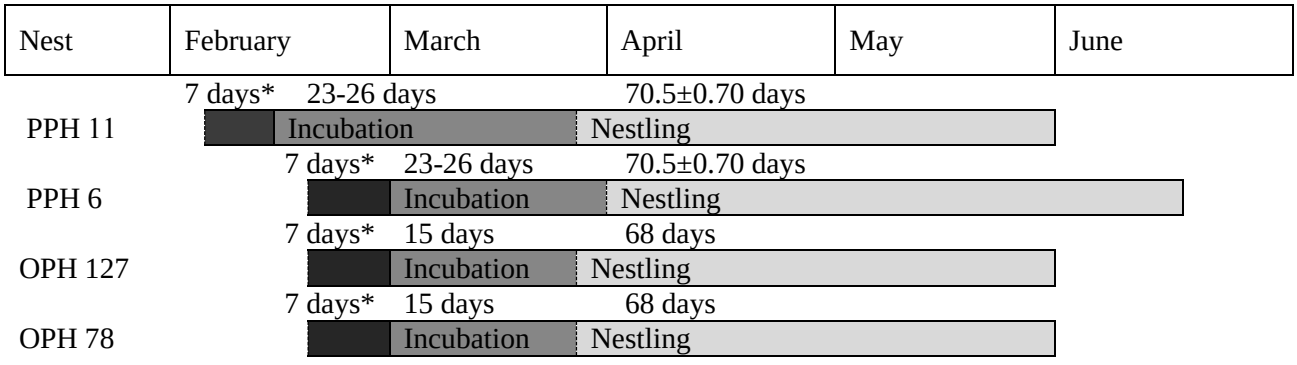


Figure 2 Breeding cycle of Plain-pouched (PPH) and Oriental Pied (OPH) Hornbills in Huai Kha Khaeng Wildlife Sanctuary (HKK), 2017.

During the incubation phase, 2 Yellow-throated Martens (*Martes flavigula*), YTM were observed at nest PPH11, on 18 February 2016 in the afternoon. They climbed up to the nest cavity and tried to break the nest sealing plaster. The PPH female defended her nest by making alarm calls. It took about 30 minutes for the YTMs to finally leave her nest.

Figure 3 Two Yellow-throated Martens climbed up to the nest cavity and tried to break the nest sealing plaster.

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Food and Feeding

Fruit characteristics consumed by hornbills

Both hornbill species tended to consume medium-sized fruits in the highest proportion (17.65-27.76 mm), such as *Polyalthia viridis* and *Beilschmiedia sp*. In the ranking second, PPH consumed small-sized fruits (7.44-17.54 mm). Whereas, OPH consumed large-sized fruits (27.66-37.76 mm). Both hornbill species consumed syconium fruits in the highest proportion such as *Ficus albipila*, *Ficus retusa*, and *Ficus kurzii.* Followed by dehiscent fruits consumed by PPH, such as *Sterculia pexa*, *Aphanamixis polystachya and Aglaia spectabillis*. However, OPH consumed drupe fruits in the second ranking such as *Polyalthia viridis* and *Putranjiva roxburghii.* Considering fruit color, PPH consumed orange-red fruits in high proportion (32.5%) such as *Alangium salviifolium*, *Aglaia spectabillis* and *Aglaia lawii*. Followed by purple-black fruit color such as *P. viridis*, *Beilschmiedia sp. and Sterculia pexa*. OPH tended to consume fruits in different colour order *ie*., purple-black fruit color in highest proportion such as *P. viridis* and *S. pexa* , followed by red fruit color, such as *A. polystachya* and *Ficus racemose* (Table 1)

Table 1 Fruit characteristics, total weight (g/hr) and proportion of fruits consumed (%) by PPH and OPH

Characteristics	Total weight (g / hr)		Proportion (%)	
	PPH	OPH	PPH	OPH
1. Size				
Small fruit (7.44-17.54 mm)	24.17	3.28	46.32	27.12
Medium fruit (17.55-27.65 mm)	26.14	5.23	50.10	43.24
Large fruit (27.66-37.76 mm)	1.87	3.58	3.58	29.63
2. Type				
Dehiscent	22.31	0.31	42.75	2.56
Drupe	6.40	2.78	12.30	23.00
Syconium	23.47	9.00	45.00	74.44
3. Color				
Red	7.21	3.71	13.82	30.69
Purple-Black	12.36	4.33	23.68	35.84
Orange-Red	32.50	1.92	62.29	15.89
Yellow-Green	0.11	2.13	0.21	17.58

Diversity of food

Plain- pouched Hornbill were omnivorous throughout the nesting period. Their diet consisted of 98.92% (52.41 g/hr) fruit and of 1.08% (0.57 g/hr) animal. Fruits delivered by the male were identified as belonging to 8 families, 9 genera and 17 species. These were 8 species of Moraceae such as *F. albipila, F. retusa, F. racemosa*; 3 species of Meliaceae consisting

of *A. polystachya, A. spectabillis* and *A. lawii*; 1 species of Annonaceae *i.e*., *P. viridis* and others. Moraceae was the major family of fruits consumed, contributing 44.78% (23.46 g/hr), followed by Meliaceae with 41.12% (21.55 g/hr). Other important fruits in the diet belonged to the families Annonaceae 10.35% (5.42 g/hr), Lauraceae 1.53% (0.79 g/hr) and Myristicaceae 1.35% (0.70 g/hr) (Figure 4). In the animal component of the diet, 4 groups were identified: 2 species of insects, 2 species of non-insect arthropods (centipede and millipede), 1 species of vertebrate and unidentified animal matter. Cicada was the major animal food contributing 35.61% (0.20g/hr) followed by bird chick 30.14% (0.17 g/hr), animal matter (unable to identify) 20.42% (0.11 g/hr) and centipede 6.81% (0.03 g/hr) (Figure 5). The Diversity Index of fruits and animals consumed by PPH was 2.27 and 1.45, respectively.

Oriental Pied Hornbill were also omnivorous throughout the nesting period. Their diet consisted of 93.35% (12.22 g/hr) fruit and 6.65% (16.40 g/hr) animal. Fruits delivered by the male belonged to 8 families, 8 genera and 16 species. These were 7 species of Moraceae such as *F. albipila, F. retusa* and *F. racemosa*, 1 species of Meliaceae: *A. polystachya*, Annonaceae: *P. viridis* and Putranjivaceae: *P. roxburghii*. Fruit from the Moraceae family was the major component in the PPH diet, contributing 73.62% (9 g/hr), followed by Annonaceae 9.81% (1.19 g/hr) and Euphorbiaceae 1.07% (0.13 g/hr) (Figure 4). The animal component consumed belonged to 3 groups: 4 species of insects, 3 species of non-insect arthropods and 2 species of vertebrates. Cicada was the major animal component, contributing 71.09 % (1.08 g/hr), followed by beetles 5.91% (0.08 g/hr), crabs 5.90% (0.08 g/hr) and butterfly lizards 5.89% (0.08 g/hr) (Figure 5). The Diversity Index of fruit and animal consumed by OPH were 2.13 and 1.59, respectively.

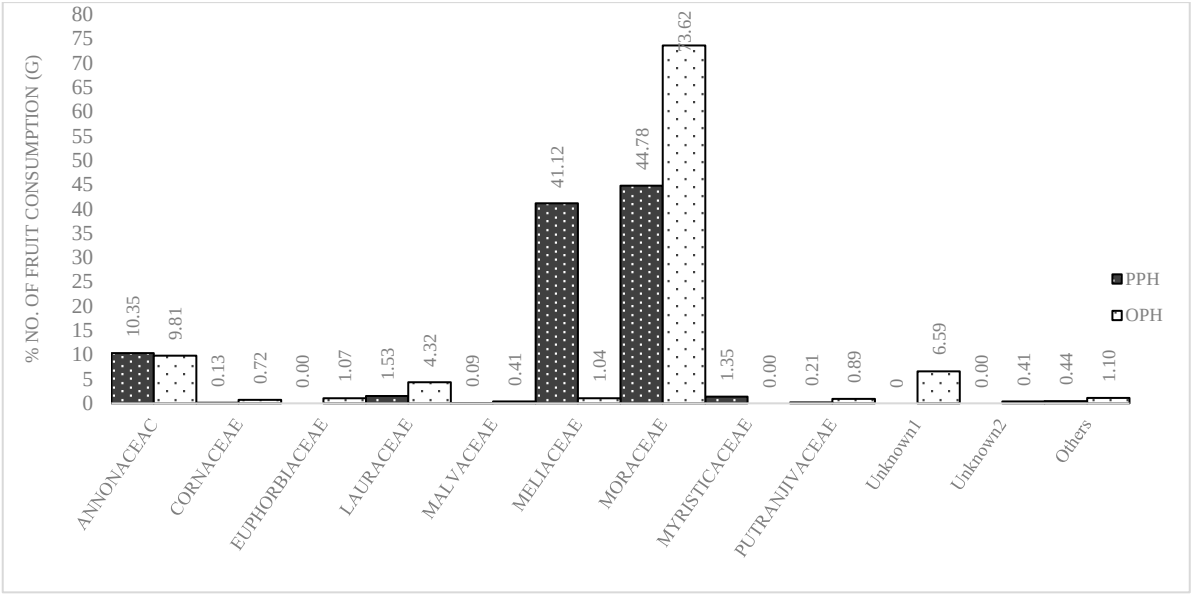

Figure 4 Percentage of fruits, based on weight, consumed by two hornbill species: Plain-Pouched Hornbill (PPH) and Oriental Pied Hornbill (OPH).

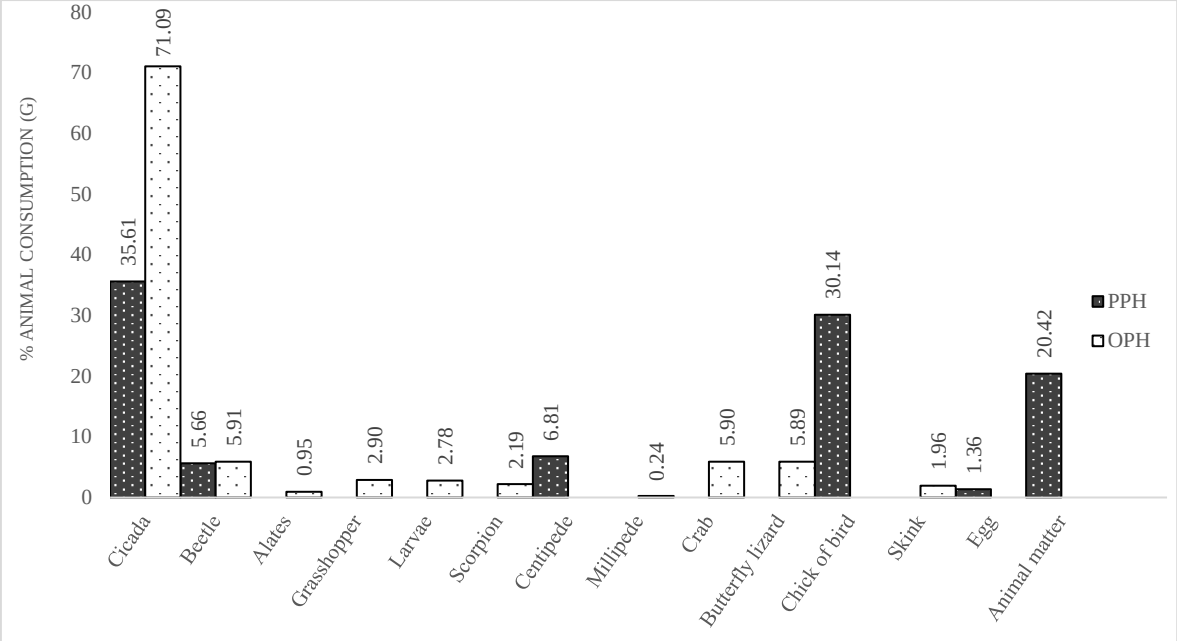

Figure 5 Percentage of animals, based on weight, consumed by Plain-pouched Hornbill (PPH) and Oriental Pied Hornbill (OPH).

Food preference and Food overlap Index

Based on the ranking of the calculated food preference score the most preferred fruits for both PPH and OPH were *F. albipila, F. kurzii, F. racemosa, P. viridis* and *F. retusa*. Within the animal diet of PPH and OPH, cicadas and beetles were the most preferred. PPH and OPH had a similar preference based on the calculated food preference score. However, the Food overlap Index of fruit and animal consumed by PPH and OPH was 0.259 and 0.223, respectively. The indices were interpreted as low *i.e.*, there was low food competition between these two hornbill species (Ouithawon and Poonswad, 2005).

Visitation and Feeding behavior

Incubation phase: visitation rate of PPH was 0.81/hr (n=2) during which PPH spent the highest proportion of time after feeding (73.17% (n=2)) followed by pre-feeding (15.92%) and feeding (10.91%). In contrast, visitation rate of OPH was 0.74/hr during which the highest proportion time was spent feeding (56.27%), followed by pre-feeding (21.88%) and after feeding (21.88%).

Nestling phase: visitation rate of PPH was 0.35/hr (n=2) during which the highest proportion of time was spent after feeding (65.61%), followed by feeding (20.15%) and pre-feeding (14.28%). While visitation rate of OPH was 0.86/hr (n=2) during which the highest proportion of time was spent after feeding (65.61%), followed by feeding (20.15%) and pre-feeding (14.28%). While visitation rate of OPH was 0.86/hr (n=2) during which the highest proportion of time was spent feeding (84.03%), followed by pre-feeding (7.72%) and after feeding (5.41%).

Food consumption rate

We investigated biomass of food (fruits and animals) delivered to the nest for both species during the incubation (week 1-week 4) and nestling (week 5-week 16) phases. It was found that during the incubation phase, fruit consumption rate of PPH was highest in week 2 (52.67 g/hr) and tended to decrease until chick hatched. The PPH male started feeding an animal diet in the last week before hatching (week 4). In the nestling phase, fruit consumption rate increased gradually starting in the first week after hatching (week 5) and increased significantly in the middle of nestling phase (week 9). Consumption rate of fruit fluctuated between week 9 - week 14 and increased to the highest rate in week 15. In the last week (week 16). Animal consumption rate fluctuated during the hatching phase with 2 high peaks on week 7 and week 9 (Figure 6). On the fledging date, the male was present at the nest, flew around and called repeatedly but did not feed.

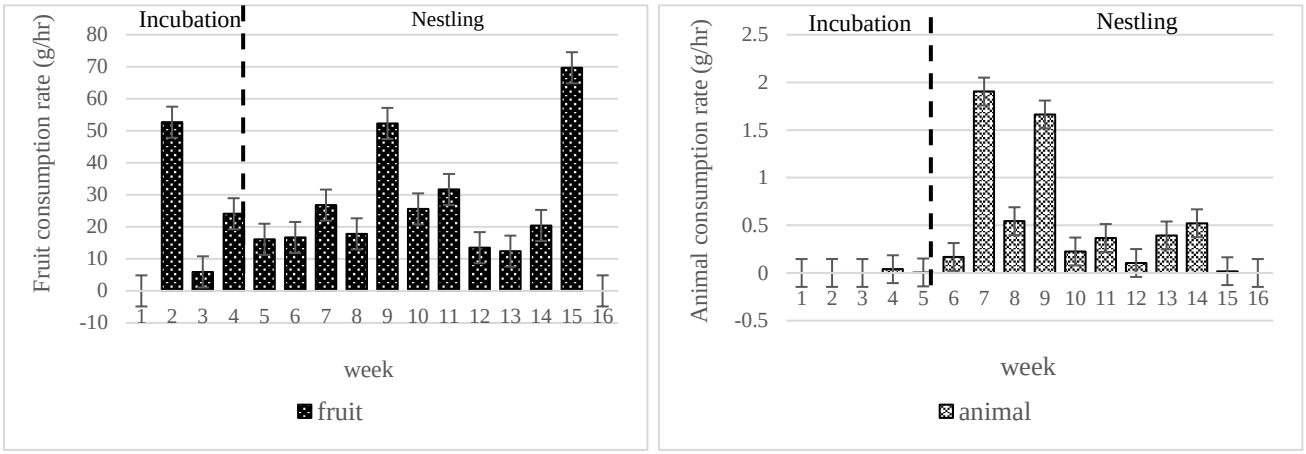

Figure 6 PPH's food consumption rate (g/hr) of fruits and animals by week.

Food biomass delivered by the OPH male during the incubation (week 1- week 4) and nestling (week 5- week 14) phases were estimated. However, we were not able to record amount of food in the first 3 weeks due to logistic problems. In the nestling phase, fruit consumption rate increased gradually after hatching and increased significantly in week 6. Consumption rate fluctuated between week 7-week 13 and increased to the highest rate in week 14. Animal consumption rate fluctuated during the hatching phase with 2 high peaks in week 10 and week 14 (Figure 7). We observed similar behavior of OPH male as with PPH male during the fledging time. The male was flying around calling without feeding.

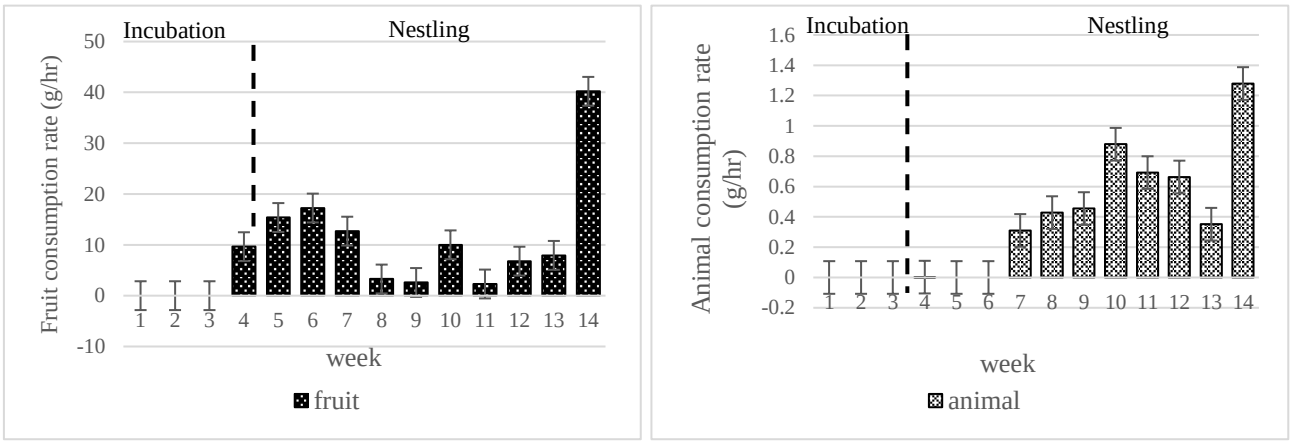

Figure 7 OPH's food consumption rate (g/hr) of fruits and animals by week.

DISCUSSION

Nesting ecology

Chimchome *et al.* (1998) first reported that PPH in HKK used seasonally flooded areas of mixed deciduous forest for nest sites and *Tetrameles nudiflora* was ranked the highest out of 5 trees according to Importance Value Index (IVI). In this study we found that most of the nest trees of PPH and OPH were *Tetrameles nudiflora* and *Ficus albipila* and these 2 tree species usually occur in moist areas along the stream (Bunyavejchewin *et al*., 2016). The distribution of these 2 species was clumped and the species did therefore not occur in the whole mixed deciduous forest of the study area. Jirawatkavi (2000) investigated bird utilization in a 50-ha plot, an area that overlapped with the area in this study. He found that hornbill nest tree species were not common especially in non-flooded areas of mixed deciduous forests. According to Hussain (1984), Kemp (1976) and Poonswad (1993a), it was considered that PPH and OPH might not have a specific preference for a tree species for nesting. Hornbills, in general, choose to nest in trees that are abundant, big, tall and within which the cavity position is high (Poonswad, 1995; Chimchome *et al*., 1998). An exception to these preferences is that a few species such as PPH, OPH and Tickell's Brown Hornbill (*Ptilolaemus tickelli*) were found to use old

nest-holes excavated by a large barbet or woodpecker. This is similar to what we found in this study where 90% of PPH nests were originally made by woodpecker, mainly the large Great Slaty Woodpecker (Poonswad *et al*., 2013).

When comparing nesting trees and nesting sites of these two hornbill species, it appeared that there were no significant differences and the 2 species were found to use the same nest tree in different years (THP, unpublished data). This study shows that there is nest competition between the 2 species even though PPH is bigger than OPH. However, when comparing the width of the bill at the nostril these two species have similar sized bills (PPH: 38.1-38.2 mm, n=2 and OPH: 32.9-38.4 mm, n= 3; THP, unpublished data; Kemp, 1988). The width of the bill and casque of hornbills is one of the criteria which determines the smallest width of the nest entrance for entering the nest cavity (THP, unpublished data). Therefore, both species can possibly use the same nest trees depending on which bird happens to arrive first. The breeding period starts about the same time for both species. BPPH only uses nest trees in flooded mixed deciduous forests along the stream (Chimchome *et al*., 1998), whereas OPH is opportunistic and can nest elsewhere, even in relatively small trees in the fringe of the forest (Poonswad *et al*., 2013). Therefore, the OPH is much more common compared to not only PPH but also other hornbill species in Thailand. For example, the density was as high as 21 bird per km^2 in Khao Yai National Park (KY) (Poonswad *et al*., 2013).

Food and Feeding

Both species clearly consumed more fruit (>93%) than animal (< 7%). However, the Food overlap Index was rather low indicating food competition was low. OPH consumed more fig than non-fig fruit which is similar to OPH and Wreathed Hornbill (WH) in KY (Poonswad, 1993a; Poonswad *et al*., 1998). The other species, PPH consumed more non-fig than fig which is similar to Sulawesi Red-knobbed Hornbill in Indonesia (Kinnaird and O'Brien, 1999) and Rufous-necked Hornbill in HKK (Chimchome *et al*., 1998).

Ficus was ranked in the top 5 of fruit food preferred by both PPH and OPH such as *F. albipila, F. retusa,* and *F. kurzii*. These species are the main food of hornbills, and they contain carbohydrates and high calcium (Poonswad, 1993a). Of the non-fig fruits, PPH consumed a high proportion of fruits from the family of Meliaceae while OPH consumed more from the family of Annonaceae (Poonswad *et al*., 1998; Mudappa, 2000). Both of these families of fruits have high fat content. Both hornbill species consumed a high quantity of cicadas and these insects were classified as the highest rank of animal food preferred. Boulard (2007) who studied growth of cicadas describes that nymphs developed in the soil and molted to the adult stage during the month of April which was simultaneous with the hornbill nestling phase. Cicadas were abundant at this time of the year and hornbills could hunt many in one tree and even brought up to 113 cicadas to feed at the nest at one time. This observation is similar to Poonswad *et al*. (1998), they mention that hornbills not only consume food with high nutrients, but they also choose to consume food that is abundant and easily accessible.

One of the most obvious characteristics of hornbill fruit is color indicating fruit ripening. PPH consumed mostly reddish-orange fruit whereas OPH consumed mostly purple-black fruit. These fruit colors were consistent with the fruit color of black tones and red tones eaten by Great (GH) and Rufous-necked Hornbill (RNH) in HKK (Ouithawon and Poonswad, 2005). Howe and Westley (1996) also found that frugivorous birds in Borneo mostly consumed and dispersed drupe and dehiscent fruits which were mostly black, red, green or purple, odorless and rich in fat and carbohydrate. PPH and OPH fed more on medium size fruits with diameter 17.55-27.65 mm which is similar to (Ouithawon and Poonswad, 2005). They found that GH and RNH in HKK consumed fruit with a diameter 10.0-30.0 mm. The preference for medium sized fruit in our study can, however, only be confirmed if we know the fruit availability.

In this study *i.e*., in seasonal flooded mixed deciduous forest, the Diversity Index (DI) of fruit eaten by PPH (H´= 2.27) and OPH (H´= 2.13) was higher than the DI of fruit eaten by Wreathed Hornbill (WH) (H´=1.56) and OPH (H´=1.89) in moist evergreen forest, KYNP (Poonswad *et al*., 1998) and even by Great (GH) (H´= 1.99) and Rufous-necked Hornbill (RNH) (H´= 1.58) in hill evergreen forest, HKK (Ouithawon and Poonswad, 2005). Surprisingly, WH, GH and RNH living in evergreen forest consume a higher diversity of fruits but the DI

was lower. This might be due to the effect by of the Evenness value as explained by Peterson (1975): Evenness is not restricted merely as diversity divided by species richness, but is rather a feature of species-abundance relations independent of any single way of measurement, or any theoretical abundance distribution, impacting the diversity index values. PPH and OPH in the seasonal flooded mixed deciduous forest of our study site had a rather low food overlap index compared to GH and RNH in dry and hill evergreen forest in HKK (Ouithawon and Poonswad, 2005). This low index indicates that PPH and OPH seem to avoid competition better when it comes to food preference (different quantity of fruit and animal in each species consumed) and continuity of habitat patches along the HKK stream.

When comparing the quantity of food delivered to the nest between incubation and nestling phase of PPH and OPH, the quantities were similar for both species. Food consumed was less during the incubation phase until chick hatching and then increased in the nestling phase and peaked in last week before female and chick fledged. This is similar to what was found by Poonswad (2004) who compared food consumed and estimation of nutrients delivered to nest inmates in different phases within the breeding season of four hornbill species in KY.

The proportion of feeding time in the different phases differed between the 2 hornbill species. During both the incubation and nestling phase PPH males tended to spend only a small proportion of their visitation time to the nest on feeding. The proportion of time before and after feeding was larger. This indicates highly cautious behavior at nest. On the other hand, OPH males spent a larger proportion of time during their visit on feeding than before and after feeding for both phases showing less awareness when it comes to feeding. This behavior shows how sensitive PPHs are of disturbances by intruders such as Yellow-throated Martin and the researchers.

CONCLUSION

Both hornbill species are omnivorous and their diet consists of fruits and animals, with a preference for fruits. A large proportion of the fruit consumed consisted of medium-sized fruits (1.7-2.8 cm) and syconium fruits. The color of fruit consumed, ranked from most to least preferred was orange-red, purple-black, red and yellow-green. Food preference was similar for both species but Food Overlap Index was low indicating low food competition. The quantity of food consumed by both species decreased during the incubation phase until the chick(s) hatched and then increased during the nestling phase and the quantity was highest during the last week of the nestling phase. The breeding success of both species was 100% even though a potential predator, the Yellow- throated Marten approached one of the PPH nests once. This study provides more information on the nesting ecology of PPH, which is a species with a globally restricted distribution, not only for biologists to learn but also for HKK managers to use as a baseline data to manage their population and habitat to save them from extinction.

ACKNOWLEDGMENTS

Foremost, special thank goes to the Thailand Hornbill Project staff and field assistants for all kinds of their support. We would like to thank Associate Professor Dr. George A Gale, KMUTT for constructive criticism of the manuscript. Thanks to Ng Bee Choo, HRF International coordinator and Petra Daniels, Buro Bakker, ecological consultancy, Netherlands for proof-reading and valuable comments. Sincere appreciation must be extended to the National Parks, Wildlife and Plant Conservation Department and HKK for granting research permission and providing accommodation and field assistance. This research was funded by Hornbill Research Foundation (HRF) and SHERA.

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