THE INFLUENCE OF FOOD CHARACTERISTICS AND FRUIT PHENOLOGY ON FOOD CHOICE OF TWO SYMPATRIC HORNBILL SPECIES (AVES : BUCEROTIDAE) DURING THEIR BREEDING SEASON IN HUAI KHA KHAENG WILDLIFE SANCTUARY, THAILAND

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ABSTRACT

A study of how food characteristics and fruit phenology influenced the food choice of two sympatric hornbill species (the Great Hornbill, *Buceros bicornis* and the Rufous-necked Hornbill, *Aceros nipalensis*) during their breeding season was carried out in Huai Kha Khaeng Wildlife Sanctuary in western Thailand from January to July 1999. Both hornbill species selected fruit with heavy pulp, dark color and large diameter, but without large seeds. The Rufous-necked Hornbill also selected fruit with a high sugar level and fruit species with abundant ripe-fruiting trees in the study area more so than that selected by the Great, Both hornbill species selected animal food for heavy body weight, but tended to avoid too long body length. This research provides important information for future management of hornbill food resources, which will be essential for successful hornbill conservation.

INTRODUCTION

Hornbills (Family Bucerotidae) are frugivorous birds in old world tropical forests which can adapt themselves to eat a more omnivorous diet during the breeding season (KEMP, 1995). Their ability, compared with other avian forest frugivores, to open and swallow large, ripe fruits, and their regurgitation of the seeds undamaged, makes them ideal dispesers (KALINA, 1988 ; LEIGHTON & LEIGHTON, 1983).

Fruits that are adapted to be eaten by birds frequently offer substantial nutritional rewards. The pulp is usually rich in carbohydrate, lipid and / or protein in addition to water and indigestible fiber (MOERMOND & DENSLOW, 1985). Highly frugivorous birds, such as hornbills, often have color vision, making it possible for plants to attract them with visual displays. So characteristics of fruits dispersed by highly frugivorous birds are large drupes or arilatted seeds, dark color (black, blue, red, green or purple), non-aromatic, and lipid or starch-rich (HOWE & WESTLEY, 1988).

In Thailand, studies of food characteristics have mainly emphasized the nature of fruit food (Poonswad,1993). More study is needed of the food choice of hornbills as influenced by these factors. We therefore present our study of the relationship between hornbill food choice and these factors (food characteristics and phenology) in Huai Kha Khaeng Wildlife Sanctuary.

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STUDY AREA

The study area was in hill evergreen forest and dry evergreen forest located between $15^{0}27'$ - $15^{0}29'$ N and $99^{0}19'$ - $99^{0}21'$ E in Huai Kha Khaeng Wildlife Sanctuary, western Thailand (Figure1). Common trees in this area include the genera *Dipterocarpus*, *Lithocarpus*, *Castanopsis*, *Cinnamomum*, *Ficus*, *Syzygium* and *Polyalthia* (OUITHAVON, 2000).

Figure1. The study area was in hill evergreen forest and dry evergreen forest in Huai Kha Khaeng Wildlife Sanctuary, western Thailand

METHODOLOGY

Food and Feeding

Active nests of the Great and the Rufous-necked Hornbill were examined at intervals of 4-7 days from January to June 1999. Observations were recorded between 07.00 and 17.00 on each observation day. Frequency of feeding visits and total amount of food brought by the males were recorded. Food items were identified using binoculars or a telescope. Regurgitated seeds and dropped food, as well as faeces, were collected to identify of some food items.

Food characteristics

Fruits food samples were collected and prepared for studying characteristics such as total weight, pulp weight, total length, seed length, overall diameter, seed diameter, sugar content and color tone. Also animal food samples were collected and characteristics such as total weight and length measured. Food samples were sent to the Forest Herbarium and laboratory room, Royal Forest Department to confirm the identity of some food species. These food characteristics were then related to the food choice of the hornbills.

Fruit phenology

A 3-km trail in the study area was established for fruit tree tagging. These trees were monitored weekly to ascertain the period of flowering, green fruiting, ripening and fall thought out the breeding season in 1999 and then related to the food choice of the hornbills.

RESULTS

Fruit food characteristics

From 21 fruits species which were eaten by the two hornbill species during the breeding season in 1999, sample of 15 were collected from this study area. From these samples, 11 species were one-seed fruits. We recorded their characteristics as shown in Appendix 1 and some of these fruit species are presented in Figure 2.

When analyzing the correlation between fruit consumption and fruit characteristics, it was found that the Spearman's rank test was significant with pulp weight (GH : $r = 0.776$, $P < 0.01$ / RNH : $r = 0.648$, $P < 0.05$) and fruit diameter (GH : $r = 0.622$, $P < 0.05$ / RNH : $r = 0.555$, $P < 0.05$). High sugar content was more positively correlated to the Rufous-necked Hornbill's food choice than the Great's (GH : $r = 0.604$ / RNH : $r = 0.800$, $P < 0.01$). In addition, seed diameter and seed length tended to be negatively correlated to quantity eaten, especially with the Rufous-necked as shown in Table 1.

(a)

(b)

(c)

(d)

(d)

(e)

(f)

(g)

Figure 2. Some fruit species eaten by hornbills

(a) *Polyalthia simiarum* (b) *Beilschmiedia gammicana*

(c) *Knema laurina* (d) *Ficus virens*

(e) Lauraceae 1 (MA-MUANG-LING) (f) *Litsea hansenii*

(g) *Chisocheton ceramicus* (h) *Dysoxylum macrocarpum*

Table 1. Correlation (r) of hornbill's eaten fruit quantity and fruit characteristics

(GH = the Great Hornbill, RNH = the Rofous-necked Hornbill)

Fruit characteristics	Hornbill's eaten fruit quantity (gm)					
	GH			RNH		
	r	N	P	r	N	P
Total weight (gm)	0.503	12	0.095	0.484	13	0.094
Pulp weight (gm)	0.776**	12	0.003	0.648*	13	0.017
Total length (cm)	0.406	12	0.191	0.357	13	0.231
Fruit diameter side A (cm)	0.503	12	0.095	0.555*	13	0.049
Fruit diameter side B (cm)	0.622*	12	0.031	0.462	13	0.112
Seed length [a] (cm)	0.167	8	0.693	-0.115	10	0.751
Seed diameter side A [a] (cm)	0.119	8	0.779	-0.030	10	0.934
Seed diameter side B [a] (cm)	0.214	8	0.610	-0.115	10	0.751
Sugar content [b] (%)	0.604	9	0.085	0.800**	9	0.010
Color [b]	0.300	9	0.433	0.516	9	0.155
Color	0.490	12	0.106	0.227	13	0.456

Remark : a only one-seed fruits

b only fruits that could be tested for sugar content

* ($P < 0.05$)

** ($P < 0.01$)

When considering the correlation between fruit food preference and these characteristics, we found the results were different from those for quantity eaten. The Great selected fruits which had high pulp weight more so than the Rufous-necked (GH : $r = 0.589$, $P < 0.05$ / RNH : $r = 0.304$). Color was highly correlated to the hornbill's food preference (GH : $r = 0.587$, $P < 0.05$ / RNH : $r = 0.188$) which was most clear in fruits which could be tested for sugar content (GH : $r = 0.744$, $P < 0.05$ / RNH : $r = 0.667$, $P < 0.05$) as shown in Table 2.

Table 2. Correlation (r) of hornbill's fruit food preference and fruit characteristics (GH = the Great Hornbill, RNH = the Rufous-necked Hornbill)

Fruit characteristics	Sum score of fruit food preference					
	GH			RNH		
	r	N	P	r	N	P
Total weight (gm)	0.393	12	0.206	0.271	13	0.370
Pulp weight (gm)	0.589*	12	0.044	0.304	13	0.312
Total length (cm)	0.428	12	0.165	0.360	13	0.227
Fruit diameter side A (cm)	0.389	12	0.211	0.243	13	0.423
Fruit diameter side B (cm)	0.477	12	0.117	0.144	13	0.639
Seed length [a] (cm)	0.084	8	0.844	0.153	10	0.672
Seed diameter side A [a] (cm)	0.012	8	0.978	0.092	10	0.800
Seed diameter side B [a] (cm)	0.096	8	0.821	-0.129	10	0.723
Sugar content [b] (%)	0.452	9	0.222	0.475	9	0.197
Color [b]	0.744*	9	0.022	0.667*	9	0.050
Color	0.587*	12	0.045	0.188	13	0.539

Remark : a only one-seed fruits

b only fruits that could be tested for sugar content

* ($P < 0.05$)

** ($P < 0.01$)

The Spearman's rank test shows that for one-seed fruits there is a positive relationship between quantity eaten and total weight, pulp weight, diameter and color, especially with the Great Hornbill, but not significantly. For the Rufous-necked, seed diameter and length were negatively correlated to quantity eaten as shown in Table 3. A very similar relationship was also found between these fruit characteristics and the hornbill's fruit food preference (Table 4).

Table 3. Correlation (r) of hornbill's eaten fruit quantity and one-seed fruit characteristics (GH = the Great Hornbill, RNH = the Rufous-necked Hornbill)

Fruit characteristics	Hornbill's eaten fruit quantity (gm)					
	GH			RNH		
	r	N	P	r	N	P
Total weight (gm)	0.452	8	0.260	0.224	10	0.533
Pulp weight (gm)	0.667	8	0.071	0.503	10	0.138
Total length (cm)	0.310	8	0.456	0.042	10	0.907
Fruit diameter side A (cm)	0.500	8	0.207	0.297	10	0.405
Fruit diameter side B (cm)	0.548	8	0.160	0.212	10	0.556
Seed length (cm)	0.167	8	0.693	-0.115	10	0.751
Seed diameter side A (cm)	0.119	8	0.779	-0.030	10	0.934
Seed diameter side B (cm)	0.214	8	0.610	-0.115	10	0.751
Color	0.485	8	0.223	0.203	10	0.573

Table 4. Correlation (r) of hornbill's fruit food preference and one-seed fruit characteristics (GH = the Great Hornbill, RNH = the Rufous-necked Hornbill)

Fruit characteristics	Sum score of fruit food preference					
	GH			RNH		
	r	N	P	r	N	P
Total weight (gm)	0.323	8	0.435	0.055	10	0.880
Pulp weight (gm)	0.515	8	0.192	0.104	10	0.774
Total length (cm)	0.228	8	0.588	0.129	10	0.723
Fruit diameter side A (cm)	0.383	8	0.349	0.006	10	0.987
Fruit diameter side B (cm)	0.455	8	0.257	-0.067	10	0.853
Seed length (cm)	0.084	8	0.844	0.153	10	0.672
Seed diameter side A (cm)	0.012	8	0.978	0.092	10	0.800
Seed diameter side B (cm)	0.096	8	0.821	-0.129	10	0.723
Color	0.520	8	0.186	0.219	10	0.543

With color, we found that both hornbills ate fruit in the color range from black, purple, dark-red, red, orange to yellow. The Great's eaten quantity tended to be more highly related to fruit color than the Rufous-necked's (GH : r = 0.490 / RNH : r = 0.227). Fruit color was also significantly related to the Great's fruit preference more so than with the Rufous-necked (GH : r = 0.587, $P < 0.05$ / RNH : r = 0.188). When testing independence among 3 different color tones (black tone, dark red-red tone and orange-yellow tone), there was a significant chi-square test among fruit food frequency in each tone of fruit color ($\chi^2 = 439.28$, df = 2, $P < 0.001$). This indicates that fruits in the dark red-red tone were consumed more by the Great, while fruits in the black tone were consumed more by the Rufous-necked.

Animal food characteristics

From 46 animal species which were eaten by the two hornbill species, we were able to collected samples of 21 from this study area. Characteristics such as body weight and length were recorded (Appendix 2) and some of these species are presented in Figure 3.

(a)

(b)

(c)

(d)

(e)

(f)

Figure 3. Some animal species eaten by the hornbills

(a) Crab (Unidentified species)

(b) Frog (Ranidae)

(c) Cicada (Cicadidae)

(d) Scarabaeidae (Unidentified species)

(e) Lizard (*Acanthosuara crucigera*)

(f) Snake (*Trimeresurus* sp.)

Of all the hornbill's animal food, snakes had the heaviest weight (> 70 gm) and longest body (> 40 cm), and were only eaten by the Great Hornbill. The smallest animals eaten such as wild cockroachs, crickets, grasshoppers, caterpillars and larvae, were no less than 1 gm in weight and 2.5 cm long, and were eaten by both hornbills.

When analyzing the correlation between animal food quantity and animal characteristics, the Spearman's rank test showed a positive correlation with body weight (GH : $r = 0.537$, $P < 0.05$ / RNH : $r = 0.535$, $P < 0.05$) (Table 5). However with animal food preference, the Great tended to select prey of heavier and longer body than the Rufous-necked, but not significantly (Table 6). This indicates that although the Great did not always select long bodied animal food, such as snakes, the Rufous-necked did tend to select short bodied animal food such as cicadas and insects.

Table 5. Correlation (r) of hornbill's eaten quantity and animal food characteristics (GH = the Great Hornbill, RNH = the Rufous-necked Hornbill)

Animal prey characteristics	Hornbill's eaten quantity (gm)					
	GH			RNH		
	r	N	P	r	N	P
Body weight (gm)	0.537*	20	0.015	0.535*	16	0.033
Body length (cm)	0.293	20	0.210	0.459	16	0.074

Remark : * ($P < 0.05$)

Table 6. Correlation (r) of hornbill's animal food preference and animal food characteristics (GH = the Great Hornbill, RNH = the Rufous-necked Hornbill)

Animal prey characteristics	Sum score of animal food preference					
	GH			RNH		
	r	N	P	r	N	P
Body weight (gm)	0.387	17	0.125	0.110	14	0.708
Body length (cm)	0.352	17	0.165	-0.101	14	0.730

Fruit phenology

From weekly monitoring of fruit phenology along the 3-km trail through the study area, 31 species of the hornbill's fruit food were found (326 trees). The number of ripening trees in each month per species are shown in Table 7. We found that *Knema laurina* had the greatest number of ripening fruit trees in the study area. The number of ripening fruit trees increased at the end of breeding season which corresponded with the time that the hornbill chicks left the nests.

Table 7. Number of hornbill's fruit food trees ripening in each month

Fruit tree species	No. of trees	No. of ripening trees					
		Jan.	Feb.	Mar.	Apr.	Jun.	Jul.
Family Moraceae							
Ficus spp. (Figs)*	9	-	1	2	5	3	1
Ficus sp. (Small figs)*	1	-	1	-	-	-	-
Ficus nervosa (Red figs)*	2	-	-	1	2	1	1
Ficus virens (Purple figs)*	1	-	-	-	1	-	-
Ficus altissima (Big-figs)*	1	-	1	1	1	-	-
Arthocarpus lakoocha	1	-	-	-	-	-	-
Family Lauraceae							
*Cryptocarya pallens**	29	-	-	-	-	1	-
Cryptocarya sp.	6	-	-	-	-	-	-
*Beilscmiedia gammicana**	13	-	4	4	-	-	-
*Litsea hansenii**	6	-	-	-	-	-	-
Litsea cubeba	1	-	-	-	-	-	-
Lauraceae 1 (MA-MUANG-LING)*	2	-	-	-	-	-	-
Lauraceae 2 (Unk.)	1	-	-	-	-	-	-
Cinnamomum sp. (SURAMARID)	7	-	-	-	-	-	-
Phoebe paniculata	40	-	-	-	-	-	-
Family Icacinaceae							
Platea latifolia	2	-	-	-	-	-	-
Family Annonaceae							
*Polyalthia simiarum**	42	-	-	1	6	14	7
Family Myristicaceae							
*Knema laurina**	34	-	9	16	28	29	10
Knema sp.*	25	-	-	-	-	6	14
Horsfiedia sp.	1	-	-	-	1	1	-
Family Meliaceae							
Melianoidae*	24	1	3	2	-	9	5
*Aglaia cucullata**	20	-	1	1	1	1	-
Aglaia macrocarpa	12	-	-	-	2	9	5
*Aglaia lawii**	1	-	1	1	1	1	-
*Dysoxylum macrocarpum**	1	-	-	-	-	-	1
*Chisocheton ceramicus**	3	-	-	2	3	3	3

Table 7. (Cont'd)

Fruit tree species	No. of trees	No. of ripening trees					
		Jan.	Feb.	Mar.	Apr.	Jun.	Jul.
Family Burseraceae *Canarium subulatum**	10	-	-	-	-	-	-
Family Olacaceae *Strombosia* sp.*	1	-	-	-	-	-	-
Family Myrtaceae *Syzygium cumini**	20	-	-	-	-	-	-
Family Elaeagnaceae *Elaeagnus latifolia**	4	-	-	-	-	-	-
Family Palmae *Livistonia speciosa*	5	-	-	-	-	-	-
Total	326	1	21	31	51	78	48

Remark : * Fruits which the hornbills selected to eat in the study period.

Unknown scientific name.

The Spearman's rank test between fruit food quantity and number of ripening fruit trees showed a significant correlation for the Rufous-necked, but not significant for the Great (GH : r = 0.359, P = 0.110, N = 21 / RNH : r = 0.494* , P = 0.023, N = 21). This indicates that the number of ripening fruit trees was more important for the Rufous-necked's consumption than the Great's. With the total quantity of eaten fruit food for all hornbill nests throughout the breeding season, the Spearman's rank test was significant (r = 0.600***, P = 0.000, N = 126) as shown in Figure 4. It indicates that the hornbills tended to eat fruits with a high number of ripening trees. However, this relationship is unclear, and as can be seen there is a wide spread amongst the data points. This can be explained by the hornbills eating some fruit species in high quantity even though they were found infrequently along the phenology study trail. Some fruit species were found in great numbers, but the hornbills did not select them. Therefore, we can assume that the factors influencing the hornbill's fruit food choice were fruit food characteristics and the hornbill's food resource range, as well as the number of ripening fruit trees.

The Spearman's rank test for eaten fruit quantity of each hornbill species in each month of the breeding season, was significant for the Rufous-necked, but not significant for the Great (GH : r = 0.543, P = 0.543, N = 6 / RNH : r = 0.829*, P = 0.042, N = 6) as shown in Figure 5. This indicates that the Rufous-necked's fruit consumption was clearly increasing while the number of ripening fruit trees was increasing. In April, fruit consumption decreased because during this period the chicks were hatching leading to a shift to a more protein-rich, animal food diet necessary for the

chicks' growth. At the end of the breeding season which corresponded to a period of decreasing ripe fruit availability, the eaten fruit food quantity of each hornbill species was also fast decreasing in order to motivate the chicks to leave their nests.

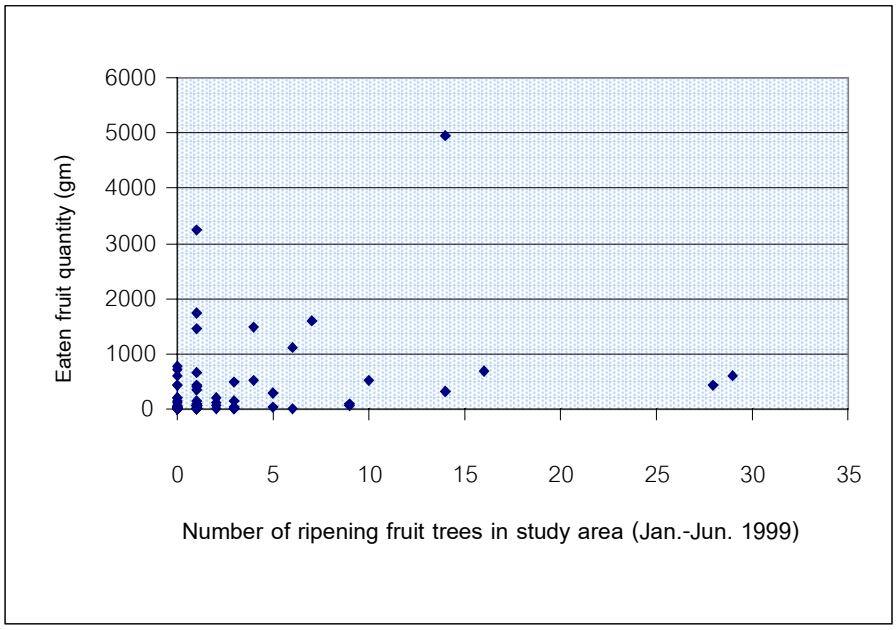

Figure 4. Relationship between eaten fruit quantity and number of ripening fruit trees in the study area throughout the breeding season 1999

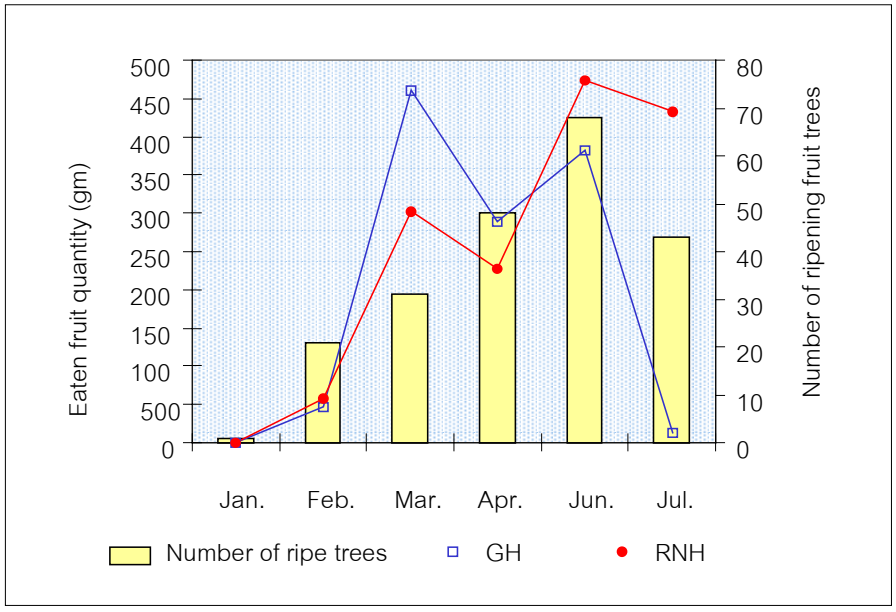

Figure 5. Relationship between eaten fruit quantity and number of ripening fruit trees in the study area in each month of the breeding season 1999

DISCUSSION

Fruits food characteristics

This study found that both hornbills tended to choose fruits with high pulp weight and big diameter, but without too large a seed. This result illustrates aspects of plant and animal co-evolution very well where the hornbill's fruit food must be a suitable size for carrying. The high pulp weight of these fruits helps the hornbills eat a high total food mass. They tended to neglect the fruits with large diameter seeds because they might have less pulp and may not pass though the narrow nest-hole while feeding or regurgitating the seed out. In addition, we agree with HOWE & WESTLEY (1986) regarding fruit color of highly fruigivorous birds such as hornbills, in that they prefer black, blue, red or purple tones with a form of drupe or arillate seeds.

Appendix 1 shows that the fruits eaten by the Great were smaller than those eaten by the Rufous-necked. This can be explained by the Great preferring to eat figs, which were generally smaller than the seed-fruits, and found in higher quantity and more diverse species. But we found that both hornbills tended to choose large fruits (< 3 cm) more than small. So, the Great ate *Ficus altissima*, which are large figs, in the highest quantity, and the Rufous-necked preferred to eat large-sized fruits within both high and low preference ranks. High sugar content was not a factor effecting the Great's fruit food choice, but the Rufous-necked ate high sugar content fruit in high quantities and with a high preference rank.

Animal food characteristics

The Great Hornbill tended to choose long bodied animals such as snakes and lizards more than the Rufous-necked, but they did not have a high preference rank nor high quantity. The Rufous-necked Hornbill tented to choose heavy and large bodied animals in relatively high quantity, while light and short bodied prey such as insects also had a high preference rank. This suggests that one factor influencing choice of prey was ease of carrying. Crabs and insects were common found in the area and presumably easily found by the hornbills which partly explains their importance in the hornbill's diet.

Fruit food phenology

This study found that *Polyalthia simiarum* was the most preferred fruit of both hornbills which differs from CHIMCHOME ET AL. (1998) who studied the Rufous-necked Hornbill in the same area and found that they consumed *Cryptocarya pallens* in the highest quantity. We can hypothesize that the seed-year interval of each fruit species was different in each year.

Polyalthia simiarum had a pre-ripening sign of changing color from early to late ripening (yellow, orange, red, red-purple, dark-purple to black respectively) as shown in Figure 6. This characteristic might be attractive for hornbills and deserves further study.

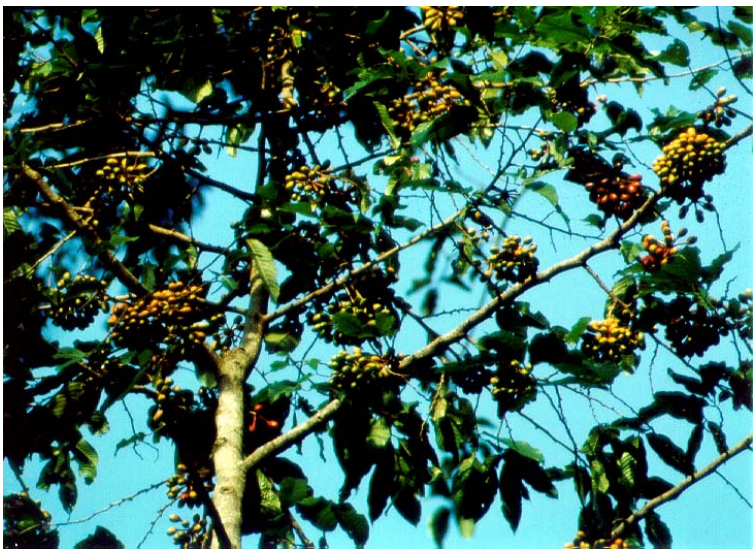

Figure 6. Pre-ripening sign characteristic of *Polyalthia simiarum* fruits

However, some fruits eaten by the hornbills had high productivity only after the breeding period, for example, *Litsea hansanii* and *Knema* sp. So we cannot conclude that the hornbills did not prefer them. Therefore one factor clearly influencing hornbill food choice was the fruiting period which enabled the hornbills to utilize them.

These results demonstrate that food choice specialization and fruit phenology are key factors depended on by the hornbills which might make them prone to local extinction. We recommended that primary forest stands in all protected areas must be declared strictly inviolate within the range of the hornbill. Also hornbill's fruit food trees should be planted to improve the quality of their foraging habitat in certain areas.

CONCLUSIONS

Fruit food with high pulp weight, large diameter (< 3 cm) and not too large seed diameter (< 3 cm) were the preferred choice of both hornbills. However, the Rufous-necked tended to select larger sized fruits and higher sugar content than the Great. With animal food, both hornbills tended to select high weight and short body, but the Rufous-necked tended to consume short bodied animals such as insects more than the Great.

Throughout the period, *Polyalthia simiarum* was found in the greatest number, but *Knema laurina* had the greatest number of ripening trees. We found that the Rufous-necked selected fruits by greater number of ripening trees more so than the Great.

Therefore, we can conclude that these two sympatric hornbills species rely on the fertility and diversity of their food resource for survival. Hornbill's fruit food tree, with their year-round pattern of

ripe fruit availability, play a great role in the conservation of hornbills. Therefore the conservation of fruit trees is vital for the maintenance of the whole forest ecosystem.

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Appendix 1. Characteristics of fruits food which eaten by hornbills during the breeding season 1999

No	Fruit species	W	P	L	Dia.(A)	Dia.(B)	LS	Dia.S(A)	Dia.S(B)	Sugar	Color	Form
1	*Polyalthia simiarum*	7.52±1.57	3.98±0.98	3.17±0.36	2.05±0.17	2.04±0.17	2.47±0.36	1.45±0.19	1.42±0.15	14.01±3.45	Black	Aggregate
2	*Beilschmiedia gammicana*	5.36±1.01	2.58±0.71	2.13±0.20	1.96±0.15	1.94±0.16	1.86±0.13	1.53±0.10	1.55±0.11	10.18±1.07	Black	Drupe
3	Lauraceae 1(MA-MUANG-LING)	7.88±2.32	4.90±1.81	1.84±0.32	2.50±0.24	2.48±0.26	1.55±0.38	1.89±0.28	1.77±0.16	10.07±3.33	Red	Drupe
4	*Litsea hansenii*	7.29±1.81	5.01±1.05	2.18±0.18	2.44±0.24	2.28±0.39	1.54±0.25	1.41±0.43	1.43±0.45	11.77±1.53	Orange	Drupe
5	*Knema laurina*	11.42±1.86	6.47±1.53	4.19±0.43	2.46±0.20	2.43±0.19	3.25±0.23	1.70±0.09	1.70±0.10	10.66±2.18	Red	Arillate
6	*Knena* sp.	7.18±2.69	3.44±1.34	2.71±0.43	2.04±0.33	2.08±0.37	2.19±0.37	1.58±0.30	1.57±0.29	10.58±2.10	Red	Arillate
7	*Ficus* spp.	1.89±0.47	1.89±0.47	1.65±0.13	1.66±0.13	1.68±0.14	-	-	-	8.23±2.69	Orange-red	Syconium
8	*Ficus nervosa*	0.79±0.20	0.79±0.20	1.15±0.09	1.29±0.12	1.15±0.10	-	-	-	7.63±4.07	Red	Syconium
9	*Ficus virens*	1.56±0.22	1.56±0.22	1.04±0.09	1.18±0.10	1.15±0.09	-	-	-	6.68±1.72	Purple	Syconium
10	*Ficus altissima*	6.18±1.57	6.18±1.57	3.04±0.41	2.04±0.31	2.05±0.29	-	-	-	9.05±3.02	Dark-red	Syconium
11	*Syzygium cumini*	1.25±0.29	0.92±0.28	1.58±0.07	1.12±0.10	1.13±0.12	1.34±0.07	0.72±0.04	0.71±0.05	22.55±5.39	Black-purple	drupe
12	*Aglaia cucullata*	5.96±1.33	1.10±0.30	2.93±0.17	1.88±0.21	1.78±0.18	2.70±0.32	1.82±0.18	1.64±0.18	-	Red	Capsule
13	*Chisocheton ceramicus*	11.34±2.01	3.04±0.85	1.93±0.32	2.91±0.41	3.15±0.27	1.72±0.16	2.68±0.39	3.10±0.19	-	Yellow	Capsule
14	*Aglaia lawii*	1.79±0.48	0.65±0.26	2.14±0.22	1.32±0.14	1.10±0.12	1.86±0.22	1.09±0.12	0.94±0.11	-	Red	Capsule
15	*Dysoxylum macrocarpum*	8.91±1.19	3.84±0.53	3.30±0.13	2.16±0.33	2.11±0.32	3.02±0.13	1.60±0.34	1.73±0.42	-	Black	Capsule

Remark : W = Total weight (gm), P = Pulp weight (gm), L = Total length (cm), Dia.(A) = Fruit diameter side A (cm), Dia.(B) = Fruit diameter side B (cm), LS = Seed length (cm)

Dia.S(A) = Seed diameter side A (cm), Dia.S(B) = Seed diameter side B (cm), Sugar = Sugar content (%), Color = Fruit color, Form = Fruit form.

Appendix 2. Characteristics of animals food which eaten by hornbills during the breeding season 1999

No	Animal species	Body weight (gm)	Body length (cm)
1	Bird's chicks	10.53±7.19	3.62±0.79
2	Lizards	21.60±9.41	9.20±0.73
3	Flying lizards	9.95±2.40	7.83±0.76
4	Skinks	16.10±1.55	8.48±0.92
5	Snakes	71.66±17.56	42.40±8.38
6	Frogs	29.02±32.98	5.98±2.23
7	Crabs	30.05±46.19	5.25±2.01
8	Elongate millipedes	12.58±2.23	12.55±4.30
9	Broad-rounded millipedes	3.58±2.00	4.44±1.50
10	Snails	17.52±14.84	4.91±0.79
11	Cicadas 1	1.61±0.72	3.49±0.68
12	Cicadas 2	2.71±0.77	4.86±0.18
13	Insects	1.91±1.10	3.87±0.87
14	Beetle	1.99±0.76	3.55±0.69
15	Scarab beetle	1.80±0.85	3.37±0.20
16	Wild cockroach	1.15±0.36	3.29±0.68
17	Buffalo dung beetle	1.83±0.47	2.93±0.24
18	Grasshopper	2.96±0.98	2.86±1.12
19	Leaf-grasshopper	2.00±0.49	6.64±1.72
20	Caterpillar	1.18±1.07	4.11±1.21
21	Earthworm	1.58±0.42	8.41±0.24