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An assessment on artificial nest construction for hornbills in Budo-Sungai Padi National Park, Thailand

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Abstract: A total of 19 artificial nests were installed in Budo-Sungai Padi National Park, southern Thailand, in 2004. These nests were constructed by hand from fiber reinforced plastic and insulated with poly-urethane foam. Since 2006, the number of artificial nests that have been used by hornbills has increased continuously. The aim of this study was to determine the suitability of the artificial nests by comparing hornbill nesting behaviour between artificial nests and natural nests. Hornbills had similar behaviours both in natural and artificial nests: hornbill visiting frequencies during nest visiting period, which is the period in which they select nests, for artificial nests and natural nests were 2.16 times/12 hours ± 1.27 SD and 1.35 times/12 hours ± 1.00 SD, respectively; visiting durations for artificial nests and natural nests during nesting periods were 7.21 minute/time ± 6.95 SD and 8.09 minute/time ± 7.19 SD, respectively; and nesting duration for artificial nests and natural nests were 121.3 days ± 4.16 SD and 122.6 days ± 15.7 SD, respectively. Microclimates of both natural and artificial nests indicated that the natural nests have better temperature and humidity control capability than the artificial nests. Artificial nests are a successful tool to increase the number of suitable nest cavities for wild Great Hornbills.

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INTRODUCTION

Hornbills are large tropical forest birds; the largest species may reach 1.5 m long with a wingspan up to 2 m. They include some 57 living species, of which 12 are native to Thailand. Hornbills are well known for their unique nesting habits. Although hornbills nest in cavities, usually in large trees, they cannot excavate their own nest holes. They must use existing cavities in trees as nest sites.

A study of hornbills by Poonswad (1995) indicates that the availability of nesting cavities of appropriate size may be the most important population limiting factor. Hornbills nest only in cavities that suit the requirements of their breeding behaviour. Since hornbills are large birds, they need large nesting cavities that exist naturally only in large trees. Most nesting holes of hornbills occur in trees of the genus *Dipterocarpus* (Poonswad 1995), which are in great demand as the principal source of timber production in Thailand (Poonswad 1993). Hence logging is a main factor that seriously reduces both potential nest trees and suitable cavities.

The aim of the first part of this study was to explore the feasibility of using artificial nests as a means for hornbill conservation as well as to develop techniques for the practical use of artificial nests. The second part of this study assessed the suitability of the artificial nests by comparing them with natural nests using hornbill nesting behaviour as a criteria.

MATERIALS AND METHODS

Study site

Budo-Sungai Padi National Park is situated in Narathiwat Province, southern Thailand (Figure 1). The park has an area of 341 km^2 and covers parts of Narathiwat, Yala and Pattani provinces. It comprises of the Budo and Sungai Padi mountain ranges, which are forest patches separated and surrounded by human settlements and agricultural lands. This forest is part of the Indo-Malayan tropical region which supports a Malaysian or Sundaic flora (Poonswad 2005).

The study site has steep terrain (56% of the area having about 30% slope), and lies between 100 and 1,182 m asl (Royal Thai Survey Department 1981). The Budo mountain range supports six species of hornbills: the Great *Buceros bicornis*, Rhinoceros *B. rhinoceros*, Wreathed *Rhyticeros undulatus*, Helmeted *Rhinoplax vigil*, White-crowned *Berenicornis comatus* and Bushy-crested Hornbills *Anorrhinus galeritus*

(Poonswad 2005).

Research parameters

The suitability of artificial nests was determined based on the main hypothesis: if nest cavities are in suitable conditions and located in suitable habitat, nest selection by hornbills would not differ significantly from natural nests. This hypothesis attempts to explain the relationship between two variables: nest characters (independent) and selection of nest by hornbills (dependent). The independent variable was quantified as sub-parameters involving breeding behaviour and microclimate condition of nest interior. The sub-parameters for breeding behaviour are: nest visiting duration by hornbills in each breeding phase, length of each breeding phase and the whole breeding cycle, and the composition of nest sealing material. The sub-parameters for microclimate condition of nest interior are temperature and relative humidity (RH). The suitability of the artificial nest was determined by comparing the results between the artificial and natural nests. Unless otherwise stated, significance was recorded at the 5% level ($P < 0.05$).

Microclimate

Two parameters including temperature and humidity were monitored and recorded from three types of sample i.e. (1) inside a natural nest, (2) inside an artificial nest and (3) its surrounding environment (outside nest). In order to control the effect of the differences in environmental factors in the study, an artificial nest was installed beside a natural nest on the selected natural nest tree and temperature and RH were monitored and recorded at the same time within every interval by using three data loggers (Extech Model 42270); one was placed inside an artificial nest,one inside natural nest and another for ambient temperature and RH. Temperature and RH were continuously monitored every two-hour interval for six days.

RESULTS

Artificial nest design

The final design of the artificial nest is prototype 6 (Figure 2). The design direction for prototype 6 aimed to balance design criteria and production capability. This prototype was made from fiber reinforced plastic. The dimensions are 50 cm (length) x 50 cm (width) x 120 cm (height). A perching place is located at the left side of the nest entrance. Prototype 6 consists of six parts (four side faces, a roof and a base). All nest box parts were assembled bottom-up, and secured together with bolts. A total of 19 artificial nests were installed at the study site between 2005 and 2006.

Hornbill visits and use of artificial nests

In the first breeding season after the installation, one pair of hornbills was observed visiting an artificial nests. From the second year, the number of nests visited increased steadily (Table 1). No artificial nests were used by hornbills during the first year after installation. The first active nest box was recorded in the second year (Figure 3).

The Great Hornbill was the only species that used the artificial nests while Rhinoceros Hornbills frequently visited nest boxes but never used them. The number of nest boxes used by Great Hornbills steadily increased throughout the study period from 5.2% in 2006 to 29.91% in 2009 (Table 1).

The percentage of nesting attempts in natural nests was higher than in artificial nests in 2008, but lower than artificial nests in 2009 (Table 2). In 2008, 33.33% of all natural hornbill nests and 17.64% of all artificial nests were occupied by Great Hornbills. In 2009, 23.8% of all natural nests and 29.91% of all artificial nests were occupied. (It should be noted that in late 2008, some unsuitable natural nests had been modified by the Thailand Hornbill Project teams, so the total number of suitable natural nests in 2009 were more than in 2008 breeding season. This caused the usage rate in 2009 to decrease slightly. If modified natural nests are excluded, the percentage use in 2009 is 27.77%.). So the rate of natural nests use from 2008–2009 decreased (9.53%, Table 2) but for artificial nests the rate increased (13.33%, Table 1).

Microclimate

Temperatures inside artificial nests were similar to the ambient temperatures (Figure 4). The highest temperature (28 - 29^{o}C) occurred from 1400 - 1500 hours. Lowest temperatures were recorded between 0300 - 0500 hours (22^{o}C, Table 3, Figure 4). Temperatures inside natural nests fluctuated less than the ambient temperatures, with conditions in the nest remaining stable (maximum of 1^{o}C temperature fluctuations).

The paired comparison (Post Hoc Tests) indicates that the temperatures recorded from both the artificial nest and ambient were similar while the temperatures recorded from the natural nest in both day and night were significantly different (Table 5).

The humidity inside artificial nests was similar to the ambient levels (Figure 4). During the day, RH recorded from both environments decreased at noon and increased at night. The lowest RH, about 81-82% occurred at 1400-1500 hours and the highest humidity, 92-93% occurred at 0400-0500 hours (Table 3, Figure 5). The RH inside the natural nest remained constant. Differences in humidity inside natural cavity between day and night was not more than 1-2%. During the day, RH inside the natural nest differed significantly from ambient conditions, as well as conditions within the artificial nest (Table 4).

The humidity recorded during night time was more stable than daytime (Figure 4). During the day, RH in the artificial nest was similar to both the natural nest and ambient, while humidity recorded from the natural nest was significantly different from outside (Table 5). During night however, RH were compared, they can be arranged in decreasing order as follows: outside (93.4 ± 3.51), artificial nest (91.62 ± 4.95), and natural nest (91.002 ± 2.86) (Table 3). So it is possible that means of humidity recorded from all three environments were relatively similar with only 1-2% difference.

Temperature and RH recorded from both environments and the artificial nest were negatively correlated within and between groups (Table 6). In addition, the correlation between temperature and humidity recorded from inside the natural cavity was different from the temperature and humidity recorded from the above two environments because they are positively correlated within the group (Pearson's correlation = 0.871, P = .000). The temperature recorded inside the natural nest is positively correlated with the ambient temperature (Pearson's correlation = 0.826, P = .001) but negatively correlated with outside (Pearson's correlation = -0.678, P = .015). The humidity inside the natural nest is also positively correlated with outside (Pearson's correlation = 0.674, P. = 0.016) but is not correlated with the outside humidity (Pearson's correlation = 0.674, P = 0.119). Natural nest have a better temperature and humidity control capability than the artificial nest.

Nesting phase duration

The average duration of the nesting period for both artificial nests and natural nests was similar. Nesting periods in natural nests lasted 121.3 ± 41.16 days (Table 7), and in artificial nests 122.6 ± 15.27 days (Table 8). This supports data collected previously for this species (114-134 days, Poonswad et al. 1987). Nesting durations in each breeding phase were not significantly different between these two types of nest (Mann-Whitney U-test, two-tailed: nest sealing, 0.487; female sealed in nest, 0.827) (Table 9).

Nest sealing material properties

Results from both chemical testing and visual inspection indicate that nest sealing materials from a natural nest and an artificial nest have both the same composition and properties (Table 10). Wood dust, pieces of wood, seeds of fruit and some food debris were nest sealing materials that could be identified by visual inspection. Chemical analysis indicated the properties of nest sealing material from both artificial and natural nests were basic in nature, and the textire sandy loam. Percentages of organic matters of nest sealing material from both types of nest were high (24.6% for artificial nest and 25.8% for natural nest).

Visiting frequencies during nest visiting phase

Visiting frequencies at used artificial nests and used natural were significantly higher than at unused artificial nests (Tables 11,12 and 13). Hornbill visiting frequencies recorded from used artificial and used natural nests were similar (Table 14). Hornbills visited the nest that they would be using in that season about 1-2 times per day. A frequency lower than this suggests the nest would remain unused for the season (Table 14).

Visiting duration during the nesting phase

Mean visiting duration at artificial nests was not significantly different from natural nests (Table 15, 16 and 17; $P = 0.584$).

DISCUSSION

Artificial nest design

We recommended artificial nests to be installed in places that are shaded or only temporarily exposed to sunlight rather than exposing them directly to sunlight for most of the day. Artificial nests need to be installed for at least one year before hornbills start using them.

Microclimate

The temperature and humidity inside the natural nest recorded in this study are also very similar to that reported by Poonswad (1993). The stable microclimaste observed in natural nests is very hard to achieve in artificial nest designs tested in this study, unless other mechanical ways of controlling the microclimate condition are used. Although the artificial nest was less capable of controlling the temperature and humidity than the natural nest, the Great Hornbill successfully bred in the artificial nest.

Hornbill nesting behaviour and their reaction to both artificial nests and natural nests

Hornbill nesting behaviour and their reaction to both artificial nests and natural nests were similar in the entire breeding phase. The average visit duration recorded in this study (11 minutes) was shorter than those described in previous studies (12 minutes, Ouithavan 2005; 22 min

Sukanya 2005).

The nesting duration of hornbills recorded from both artificial nests and natural nests were similar in both nest sealing period and imprisoned period with mean of eight days for artificial nests and nine days for natural nests for nest sealing period, 121.3 days for artificial nests and 122.6 days for natural nests for imprisoned period. This supports data collected previously for this species (114-134 days, Poonswad et al. 1987).

At present, the rate of visiting artificial nests by hornbills has declined and most of nest boxes that had previously been visited by hornbills had by already been occupied. This seems to indicate that artificial nest use rate may be close to its highest point.

Artificial nest is a successful tool to increase the number of suitable nest cavities for wild Great Hornbills.

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Table 1. Numbers of installed artificial nests, broken artificial nests, total artificial nests available, nests that were visited by hornbills, and nests that were used by hornbills during 2005–2009.

Year	Installed artificial nests	Broken artificial nests	Total artificial nests available	Nests visited by hornbills	Nests used by hornbills
2005	11	–	11	1	–
2006	9	1	18	2	1
2007	–	1	17	4	1
2008	–	2	15	6	3
2009	–	–	15	3	5

Table 2. Number and percentage of used natural nests from 2008 to 2009.

Year	Nest modified	Total natural nests available	Used natural nests	
			Number of nest	Percentage (%) of total available nests
2008	-	18	6	33.33
2009	3	21	5	23.80

Table 3. Mean and SD. Numbers recorded from three environments.

Environment		Temperature		Humidity	
		Day (°C)	Night (°C)	Day (%)	Night (%)
Artificial nest	Mean	25.4	23.32	84.87	91.62
	SD	2.57	1.30	10.30	4.95
Outside	Mean	26.02	23.31	82.21	93.40
	SD	2.56	0.96	10.14	3.51
Natural nest	Mean	24.09	23.91	91.79	91.00
	SD	0.64	0.53	1.93	2.86

Table 4. The multiple comparison (Sig. level ≤ 0.05).

One-way ANOVA results	The multiple comparison of temperature recorded during day time				
	SS	df	MS	F	Sig
Between group	69.866	2	34.93	7.693	.001
Within group	476.80	105	4.54		
Total	546.67	107			
	The multiple comparison of temperature recorded during night time				
	SS	df	MS	F	Sig
Between group	8.60	2	4.30	4.416	.014
Within group	102.225	105	.974		
Total	110.855	107			

One-way ANOVA results	The multiple comparison of humidity recorded during day time				
	SS	df	MS	F	Sig
Between group	1760.40	2	880.20	12.39	.000
Within group	7454.605	105	70.996		
Total	9215.005	107			
	The multiple comparison of humidity recorded during night time				
	SS	df	MS	F	Sig
Between group	111.692	2	55.846	3.712	.028
Within group	1579.607	105	15.044		
Total	1691.299	107			

Table 5. Results of paired comparison (Post Hoc) of temperature and humidity recorded from the three environments (Sig. level ≤ 0.05).

Paired comparison (Post Hoc) of temperature recorded during daytime	**Mean difference**	**Std. error**	**Sig.**
Between artificial nest & natural nest	1.30556*	.50227	.029
Between artificial nest & outside	-.62500	.50227	.430
Between natural nest & outside	-1.93056*	.50227	.001

Paired comparison (Post Hoc) of temperature recorded during daytime	**Mean difference**	**Std. error**	**Sig.**
Between artificial nest & natural nest	-6.91389*	1.98601	.002
Between artificial nest & outside	2.66667	1.98601	.357
Between natural nest & outside	9.58056*	1.98601	.005

Paired comparison results (Post Hoc) of temperature recorded during daytime	**Mean difference**	**Std. error**	**Sig.**
Between artificial nest & natural nest	-.59722*	.23260	.031
Between artificial nest & outside	-1.77778	.23260	1.00
Between natural nest & outside	.6000*	.23260	.030

Paired comparison results (Post Hoc) of temperature recorded during daytime	**Mean difference**	**Std. error**	**Sig.**
Between artificial nest & natural nest	.62222	.91421	.775
Between artificial nest & outside	.00278	.91421	.131
Between natural nest & outside	-2.40*	.91421	.027

Table 6. Pearson's correlation test results of the microclimate data.

		Recorded from artificial nest		Recorded from outside		Recorded from natural nest	
		Temperature	Relative humidity	Temperature	Relative humidity	Temperature	Relative humidity
Recorded from artificial nest	Temperature	1.00					
	Relative humidity	-.979*	1.00				
Recorded from outside	Temperature	.940*	-.968*	1.00			
	Relative humidity	-.827*	.899*	-.965*	1.00		
Recorded from natural nest	Temperature	.930*	-.881*	.826*	-.678**	1.00	
	Relative humidity	.884*	-.724*	-.674**	-.475***	.871*	1.00

* Sig. ≤ .01 ** Sig. ≤ .05 *** Not Sig. > .05

Table 7. Hornbill nesting duration recorded from three artificial nests.

Artificial nest code	Nest sealing period (number of days)	Imprisoned period (number of days)	Total	Average	SD
2	~9	~109	~118	121.3	4.16
6	~9	~111	~120		
14	~6	~120	~126		

Table 8. Hornbill nesting duration reorded from three natural nests.

Artificial nest code	Nest sealing period (number of days)	Imprisoned period (number of days)	Total	Average	SD
GH82	~13	~115	~128	122.6	15.27
GH78	~7	~128	~135		
GH48	~9	~99	~108		

Table 9. Comparison of nesting durations between artificial nests and natural nests (Sig. level ≤ .05).

	Mann-Whitney U-test Asymp. Sig. (two-tailed)
Comparison of nest sealing duration between artificial nests and natural nests	.487
Comparison of imprisoned period between artificial nests and natural nests	.827

Table 10. Chemical analysis results of nest sealing materials.

Sample Type		**pH**	**Organic Matter (%)**	**Texture**
Artificial nest	Sealing material	7.90	24.62	Sandy loam
	Floor soil	7.40	27.71	-
Natural nest	Sealing material	7.72	25.76	Sandy loam
	Floor soil	7.53	28.45	-

Table 11. Observation results during nest visiting phase from used natural nests in 2009.

Nest code	**Observation duration (minutes)**	**Hornbill visiting frequency**	**Hornbill visiting frequency / 12 h (observed from 0600-1800 hours)**	**Mean**	**SD**
GH1	1280	2	2.25	1.35	1.00
GH61	1295	1	0.55		
GH74	1522	1	0.47		
GH38	1005	0	0		
GH82	1316	3	1.641		
GH78	1289	2	1.11		
GH33	3469	9	1.86		
GH23	488	2	2.95		

Table 12. Observation results during nest visiting phase from artificial nests that were not used by hornbill in 2009.

Nest code	Observation duration (minutes)	Hornbill visiting frequency	Hornbill visiting frequency / 12 h (observed from 0600-1800 hours)	Mean	SD
3	784	0	0	0.20	0.46
4	420	0	0		
8	656	0	0		
16	5774	3	0.37		
17	893	1	0.8		
18	591	1	1.21		
19	316	0	0		
20	214	0	0		

Table 13. Observation results during nest visiting phase from artificial nests that were used in 2009.

Nest code	Observation duration (minutes)	Hornbill visiting frequency	Hornbill visiting frequency / 12 h (observed from 0600-1800 hours)	Mean	SD
2	433	0	0	2.16	1.27
6	487	2	2.95		
9	413	2	2.57		
13	344	1	2.09		
14	1577	7	3.19		

Table 14. Comparison of hornbill visiting frequency per 12 h (Sig. level ≤ .05) between samples.

	Mann-Whitney U-test Asymp. Sig. (two-tailed)
Between used artificial nests and used natural nests	.186
Between used artificial nests and unused artificial nests	.028*
Between used natural nests and unused artificial nests	.021*

Table 15. Range, mean, mode, and SD of nest visiting duration observed during the 2009 breeding season.

Nest type	From female finished to female emergence				From female emergence to chick emergence				Entire nesting period		
	Range (min)	Mean	Mode / Frequency (min / % of total visited)	SD	Range (min)	Mean	Mode / Frequency (min / % of total visited)	SD	Mean	Mode / Frequency (min / % of total visited)	SD
Artificial (n = 3)	1-35	6.13	6.0/25.5	4.16	2-58	9.01	5.0/31.8	9.76	7.21	5.0/27.4	6.95
Natural (n = 3)	1-65	8.29	5.0/20.8	7.45	1-56	7.69	5.0/36.8	6.65	8.09	5.0/26.3	7.19

Table 16. Normality test results of nest visiting data (Sig. level < .05).

Kolmogorov-Smirnov test	Visiting duration recorded from artificial nest	Visiting duration recorded from natural nest
Sig. (two-tailed)	.000	.000

Table 17. Comparison of nest visiting duration between artificial nests and natural nests (Sig. level < 0.5).

Mann-Whitney U-test	Comparison of nest visiting duration between artificial nests and natural nests
Sig.(two-tailed)	.584

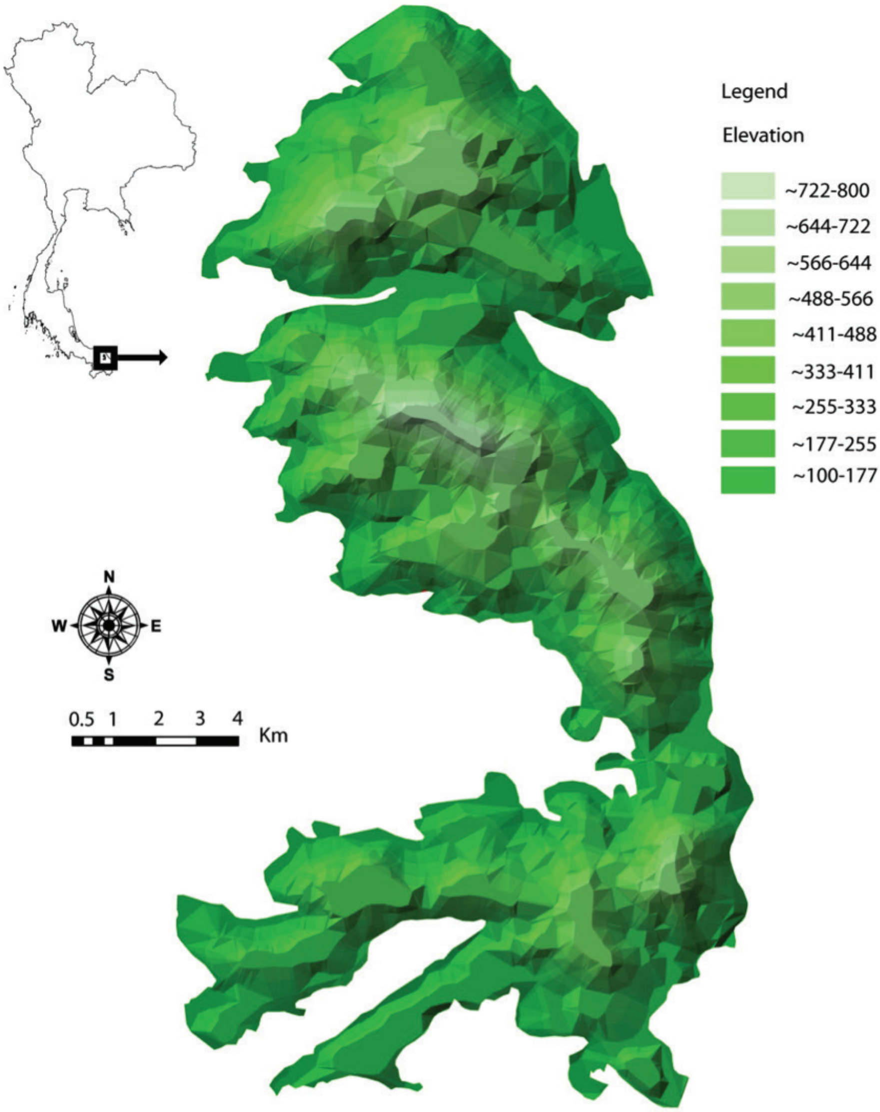
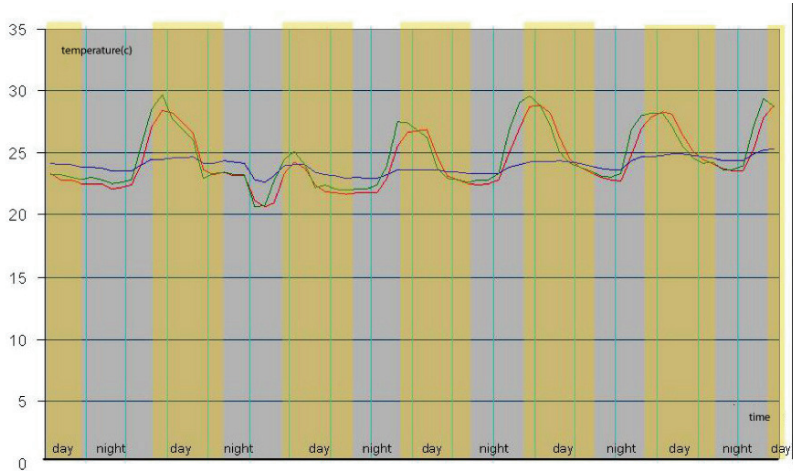


Figure 1. Budo Mountain Range.
[Source: Thailand Hornbill Project (2006) and land use data from Land Development Department, Ministry of Agriculture and Cooperatives, Thailand (2007)].

Figure 2. Artificial nest prototype 6.

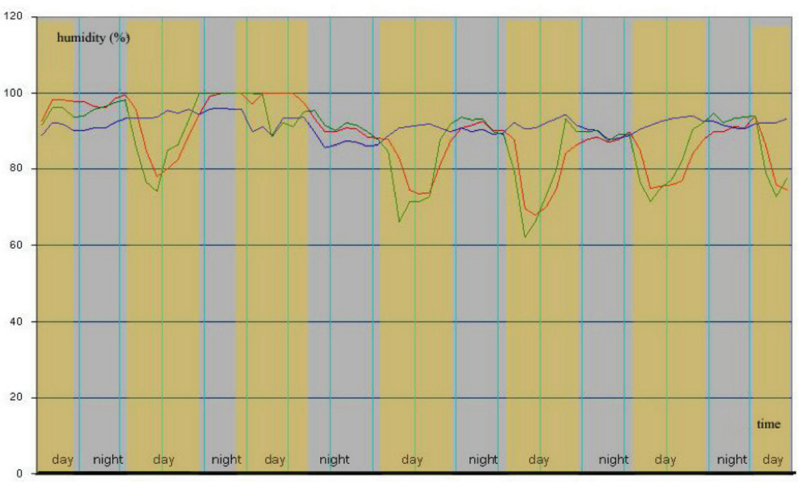
Figure 3. A male Great Hornbill at artificial nest No. 2.
(Photo credit: Ittipol Bauthong)



Legend

The temperature inside an artificial nest
Outside temperature
The temperature inside a natural nest

Figure 4. Temperature (^{o}C) recorded from three environments; (1) outside nest, (2) inside a natural nest and (3) inside an artificial nest.



Legend

The humidity inside an artificial nest
Outside humidity
The humidity inside a natural nest

Figure 5. The humidity (%) recorded from three environments; (1) outside, (2) inside a natural nest and (3) inside an artificial nest.