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AN ASSESSMENT ON ARTIFICIAL NEST CONSTRUCTION FOR HORNBILLS IN BUDO SU-NGAI PADI NATIONAL PARK, THAILAND

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***ABSTRACT.* –** The aim of this pilot study was to explore the feasibility of using artificial nests for hornbill conservation as well as to develop techniques for their practical usage. The project was divided into three components:

1. To design and implement artificial nests for hornbills by using biological data on hornbills as criteria for design;
2. To assess the suitability of the artificial nests for hornbills by comparing them with natural nests, using hornbill nesting behavior as a criterion;
3. To study the correlations between some environmental factors and the hornbills' selection of nest cavities.

This paper covers the first part of the project and includes some preliminary results from work during the period 2003 to 2009. The design of artificial nest in this study covers not only hornbill requirements, but also various practical issues related to this design, i.e., production feasibility, transportation to the sites, and installation. The anticipated outcome of this study is the ready-made nest that can serve both hornbill requirements and installation process. Nineteen artificial nests were permanently installed at Budo-Su-Ngai Padi National Park, Southern Thailand in the year 2005 and observation of artificial nests during the breeding season has been conducted since then. The first pair of hornbills entered an artificial nest in 2006. Since then, the use of artificial nests by hornbills has been increasing steadily. The data obtained from this long-term observation will be used to assess the suitability of the artificial nest and to develop future artificial nest designs.

This paper was presented at the 5th International Hornbill Conference jointly organised by the National Parks Board (Singapore) and the Hornbill Research Foundation (Thailand), in Singapore on 22nd–25th March 2009.

***KEY WORDS*. –** Hornbills, nest boxes, artificial nests, conservation, Thailand.

INTRODUCTION

Hornbills are large tropical forest birds; the largest species may reach about 1.5 m long and has a wingspan of about 2 m. They include some 57 living species, about 12 of them native to Thailand. Hornbills are well known for their unique nesting habits. Even though hornbills nest in cavities, usually in large trees, they cannot excavate their own nest holes. They must use existing cavity 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 hornbills' nesting holes 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 this pilot study was to explore the feasibility of using artificial nests as a means for hornbill conservation as well as to develop a technique of using artificial nest for practical use.

METHODS

This study is a field research with quasi-experimental design method. The aim of the first part of this study was to design the artificial nest based on information provided by hornbill researchers.

Study area

The study was carried out in Budo Su-Ngai Padi National Park located in Narathiwat Province, southern Thailand (Fig. 1). The park has an area of 341 km^2 and covers parts of Narathiwat, Yala and Pattani provinces. It comprises the Budo mountain range and Su-Ngai Padi mountain range, 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 terrain of the study site is steep, 56% of the area having about 30% slope, and with an altitude range from 100 to 1,182 m a.s.l (Royal Thai Survey Department, 1981). Budo mountain range supports six species of hornbills: Great Hornbill (*Buceros bicornis*), Wreathed Hornbill (*Rhyticeros undulatus*), Rhinoceros Hornbill (*Buceros rhinoceros*), Helmeted Hornbill (*Rhinoplax vigil*), White-crowned Hornbill (*Berenicornis comatus*) and Bushy-crested Hornbill (*Anorrhinus galeritus*) (Poonswad, 2005).

Design process

The design process starts with determining and setting up of design requirements and criteria. These are used as guidelines in determining the design specifications. The design requirements and criteria are based on information obtained from reviewing related literature, surveys of the study site, and investigating similar design solutions in the field and related topics.

Design Requirements

From the literature review, three factors contribute to the design requirements. These can be presented in decreasing order of importance as follows.

1. Hornbill nesting behavior and function of various elements of the nest;
2. Transportation to the installation site and installation of the artificial nest;
3. Material and production process selection compatible with the above.

Design criteria

From the literature review, design criteria can be set up as follows.

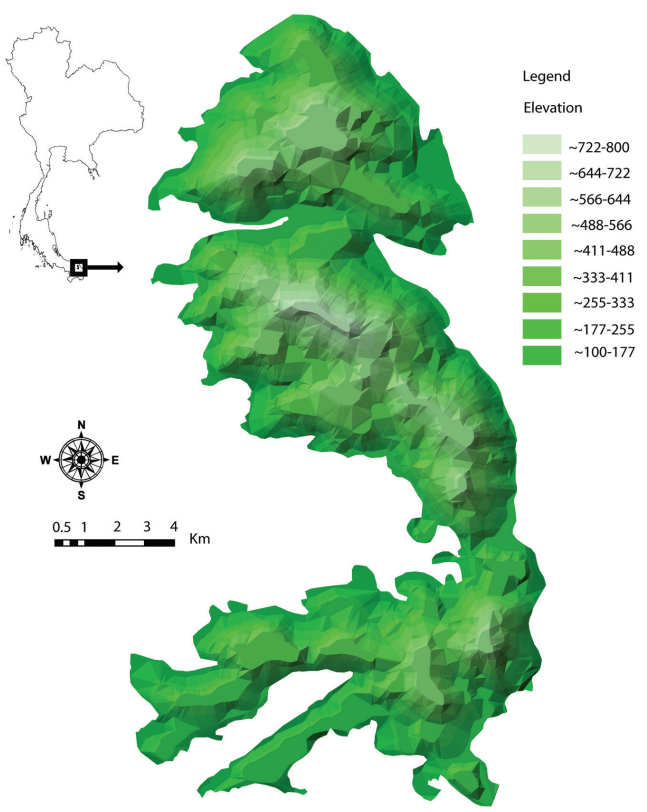

Fig. 1. Location and terrain map of Budo mountain range, Thailand. (Created by Thailand Hornbill Project).

Function of various elements of the nest and their dimensions

- Nest entrance: The entrance should be oval in shape, about 22–25 cm high, about 10–15 cm wide, and about 10 cm thick (Poonswad, 1987; 1993). Wood is considered to be the most suitable material for making the nest entrance.
- Nest interior dimensions: About 45×50×50 cm at the base, the level of the nest floor about 0–10 cm below the lower edge of the nest entrance 0–10 cm, and the whole structure at least 100 cm in height (Poonswad, 1987; 1993).
- Perching place: A perching place should be available at the front of the nest. It should not be placed directly in front of the nest entrance because hornbills usually squirt their faeces through the cavity opening and their faeces can pile up on a perching place.
- Nest floor: Soil and rotten wood should be put on the nest floor for both nest sealing and bedding material.
- Insulation material: From reviewing related literature, a suitable nest should have capability of temperature and humidity control. So in designing of an artificial nest, insulation material should be considered as a criterion.
- Other factors: Other factors that should be considered in designing of an artificial nest include a water drainage system and air ventilation system.

Transportation to the installation site

- The survey of the study site showed that there is no road into the area and most of the area is of steeply sloping terrain. Carrying by man is the only way to transport an artificial nest to the site. So every part of an artificial nest should be design to fit a human's carrying requirements as follows.
- Because both size and weight of an entire artificial nest are not efficient to transport by carrying, modular design approach should be considered in order to divide an artificial nest into smaller parts that can be independently carried.
- Weight of each part must not exceed the average weight that a human could carry.
- Size of each part must not exceed an average size that a human could carry.

Installation of an artificial nest

- From a survey of study site, we determined the installation criteria as follows.
- Safety measures for installers must be carefully considered because they need to work high above the ground.
- Installation process should be simple and there should be as few steps as possible in order to reduce the risk to installers who need to work high above the ground.
- Because there is no electricity in the area, it is better to avoid using any electrical tools in the installation process.
- Because both the orientation and angle between branches and tree trunk vary, any holding equipment (that will be used for holding an artificial nest) must be adjustable to any angle and orientation.

Selection of artificial nest site

- Criteria for the selection of an artificial nest site are as follows.
- An artificial nest should be installed at least about 20 meters above the ground (Poonswad, 1995).
- Trees of the family Dipterocarpaceae are the first choice for installing an artificial nest but some other tall and large trees may be considered depending on the conditions at each location (Poonswad, 1995).
- The distance between an artificial nest site and nearest natural nest should be about 400–500 m (Poonsawad, 1999).

Material and production criteria

- Material criteria: Exterior surface of an artificial nest requires a material that has the ability to resist weathering. Beside this, nest boxes also require lightweight material because they need to be carried.
- Production process criteria: In this project, production volumes seem to be the important constraint for selection of production process. Because about 20-30 artificial nests are required per production lot, the production volume is too low to manufacture by any industrial process, so they have to be custom made. Moreover, the design of parts should allow some dimensional tolerance to allow assembly, as custom-made production often results in small variations. All installed artificial nests are monitored during the breeding seasons between February and May of each year.

RESULTS

Product analysis

Product analysis was conducted under five main topics: installation, transportation, design for assembly, product components and part design, and material specifications.

Installation

In order to determine the appropriate installation method for an artificial nest, there are two main questions that must be answered: where is the most suitable place to install an artificial nest on the tree and how to secure the nest box up there.

How to secure the nest box

The principle of securing a nest box is that both installation method and equipments must support a nest box from weight of a nest box plus the other environmental loads such as imposed by wind. This means a nest box must be locked in two planes, vertical and horizontal. For this reason, it seems that the suitable places for installation are in the crotch of

trees because, in this place, a nest box can be locked from both vertical and horizontal direction.

Where is the most suitable place to install an artificial nest on the trees?

This question can be answered by considering the physical form and external structure of trees. There are four possible places to install an artificial nest on the trees as follows:

- Over the crotch of a big branch (Fig. 2.1);
- Hanging underneath a branch (Fig. 2.2);
- On a big branch within a tree crown (Fig. 2.3);
- On the tree trunk (Fig. 2.4).

Among these four possible installation positions, each is different in both character and working situation that may also require different installation methods. This difference of working situations has a lot of influence on design decisions and solutions. So, in order to understand the real working situations and be able to determine the most suitable place to install, the installation tests by using full scale mock-up need to be conducted.

Installation tests by using mock-up

A full scale mock-up was made from card board to get an idea of shape and size and for using in installation tests. The testing results indicated that the orientation and angle between each branch and tree trunks vary a lot. Moreover, most of them have angles of more than 90 degrees which are considered to be unsuitable to install a nest box especially when placing a nest box on a branch.

So hanging a nest box underneath the big branch is the most suitable method because a nest box can be installed on almost any branch that is big enough, and a nest box is secure enough when installed by this method and the installation is not difficult.

The method for install an artificial nest underneath the crotch is by using wire rope to hang a nest box with the crotch and also encircle tightly with the tree trunk (Fig. 3).

Transportation

In order to determine the carrying method, there are two questions to answer: how to carry it, and what is the appropriate size and weight of the object.

How to carry it

In this study, three manual carrying methods were tested in study area by using full scale mock-up and prototype as a load. These tests focus on carrying object by using shoulder or back to support the load and each load was carried by one or two persons.

Transportation test indicated that the most suitable method to transport nest box parts is one man carrying with back-pack carrying method (Fig. 4). This method seems to have the most maneuverability while walking along the trail.

Theoretically, carriage in back-pack style has some biomechanical advantage. Because the load is very close to carrier's center of gravity, it requires less energy than a shoulder load carriage (Legg et al., 1992). Moreover, carrying object in this method does not interfere with carrier's line of sight. It also allows carrier's two hands to remain free so that carrier can use their hands for balancing while walking on the slope. Although this method has a lot of advantagous features, however, carrying object by this method requires the appropriate size, shape and weight of the object.

In conclusion, the back-pack carrying method seems to be more efficient than multi man carrying and one man carrying using a yoke. However, the size of the whole artificial nest

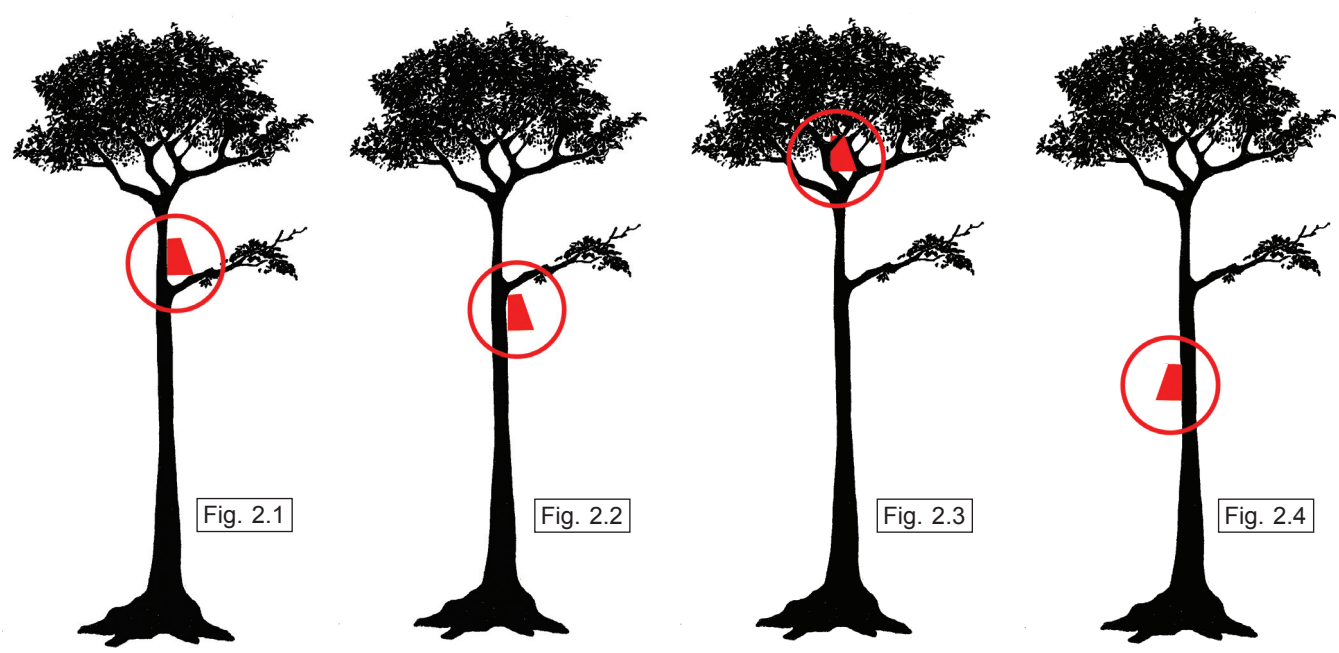

Fig. 2. Various possible positions for nest-box installation. (Drawn by Chakorn Pasuwan).

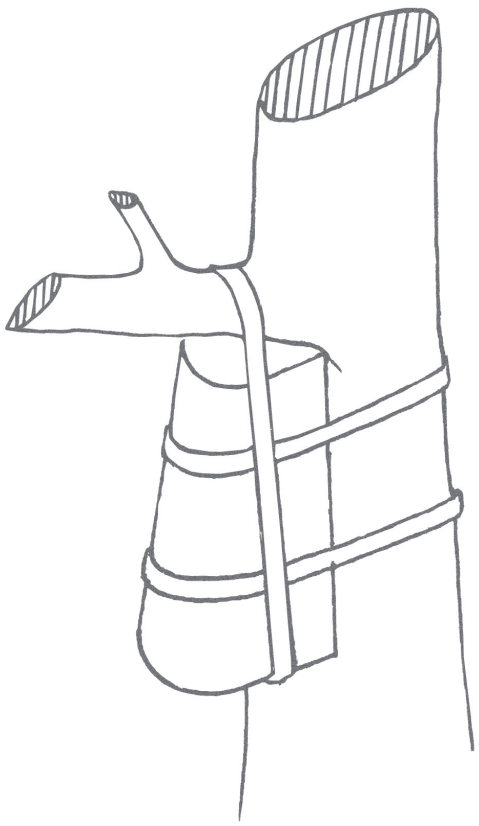

Fig. 3. Installation method for a nest-box showing straps to hold it against the tree-trunk and beneath a strong bough. (Drawn by Chakorn Pasuwan).

Fig. 4. Carrying a nest-box component using the back-pack method. (Photo by Chakorn Pasuwan).

box is obviously too large to be carried by this method, so there is a need to be divided into smaller parts.

What is the appropriate size and weight of the carried object?

Weight: Cook & Neumann (1987) determined that the weight of load while carrying by back-pack style should be about 10–20% of the carrier's body weight. The average weight of Thai men aged between16–60 is 68.9 kg (NECTEC, Thailand, 2008). So the average weight that could be carried on the back is about 6.89–13.78 kg.

Size and shape of the carried object: The terrain in the study area is very steep and there is a lot of undergrowth along the trail. So the size of carried objects should not exceed the size of the carrier's body in order to maneuver along the trail to avoid obstacles. The carried objects should not wider than the carrier's shoulders and not longer than the length from shoulder to hip or thigh. The average shoulder width of Thai men is about 54 cm and their average length from neck to hip or thigh is about 80–90 cm (School of Management Technology (MT), Thammasart University, Thailand, 2009). The shape of the carried object should be as flat as possible so that the load will lie close to the carrier's body.

In order to carry objects on the back more efficient, a carrying device is necessary. In this project, the metal structure of the military back pack was used as a carrying aid (Fig. 5). This metal structure is lightweight and it fits very well to a carrier's back. It is also useful as a frame on which to strap down a carried object.

For reasons stated above, the nest box needs to be divided into smaller parts for transportation purpose. Moreover, when they reach to the installation location, each parts need to be reassembled back to become a nest box again. So design for assembly is considered to be one of this project design criteria.

Fig. 5. Frame of back-pack for carrying the artificial nest-box to the installation site in the forest. (Photo by Chakorn Pasuwan).

Design for assembly

The dividing of form and the arrangement of parts for artificial nest design is based on the following context and criterions:

- A nest box should be divided in the way that every part will interlock each other. Moreover, when they are put together, they should create the interlock structure to stabilize the entire form;
- Each part of a nest box body must fit to the transportation criterion;
- When all parts are assembled to become a nest box, a nest box must perform its required function well.

A nest box was divided into three sections; top, middle, and bottom. A top section consists of one part. A middle section consists of four parts and a bottom section consists of one part (Fig. 6). When all parts were put together, the top and bottom parts will act as frame structures. These frames will lock all four middle parts from both ends while all four middle parts will lock each other. This interlocking structure will keep all parts in place and prevent them from moving in both along vertical and horizontal axis. This will increase the stability and also prevent a nest box from swaying.

Product components and part design

An artificial nest consists of six parts. Each part and its function can be described as follows.

Front part. **–** Some important functions which are required or related to a front part including a nest box wall, a nest entrance, a perching place, and installation requirements.

Nest entrance. **–** The hornbill's requirements determine that the dimension of nest entrance is estimated about 22–25 cm long, 10–15 cm wide and 10 cm thick and material is supposed to be of natural wood.

Perching place. **–** A perching place could possibly be designed as an extension of the front part.

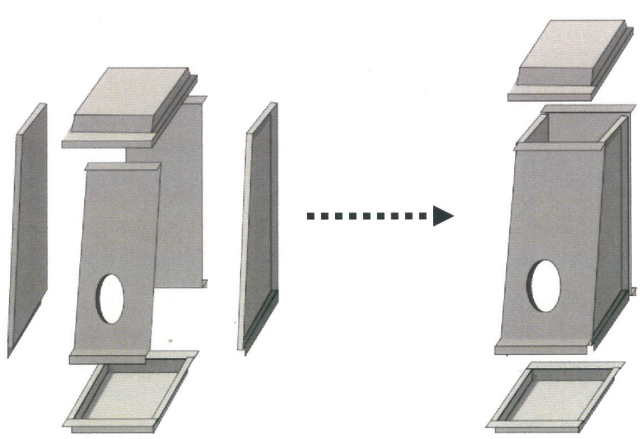

Fig. 6. Diagram showing the fabrication and the arrangement of parts for the artificial nest-box design. (Drawn by Monthon Chiemprabha).

Installation requirement. **–** An artificial nest will be secured on the tree with four wire rods; two rods for hanging and two rods for encircling tightly with a tree trunk. So these rods must be secured to the nest box by cable clamps in order to prevent both the nest box and wire rods from sliding out of each other.

Visual requirement. **–** Because this part is at the front side of a nest box and hornbill will see the front part first, it is considered to be the most important part in visual aspect. So this part needs to be surfaced to resemble tree bark. Anyway, the surfacing or texturing could not cover the entire part because the flat plane is required along the edge for assembly operation. So only the middle area of part need be surfaced.

Total length of the front part is about 70–80 cm.

Left and right side parts. **–** Left and right side parts are function as side walls of a nest box. However they need to be designed to meet the installation and transportation requirements.

Back part. **–** One of the important functions of a back part is to help stabilize a nest box and prevent it from swaying by live loads from wind or other natural causes. In designing of a nest box, the curve of the back part determines to be equal to average diameter of suitable trees which is about 60 cm.

Bottom part. **–** Main function of bottom part is a nest floor. Because the hornbill nest requires soil for bedding material, this part needs to be filled with soil for at least 20 cm thick. This means that this part must be designed to become a bowl shape.

Top part. **–** The main function of top part is both as a roof and ceiling of a nest box. So it should act as a normal roof which protects the occupant(s) from rain and sunlight and also allows rainwater to drain away rapidly. As a ceiling, it should allow hot air to get out of nest interior.

Material specifications

Suitable materials were selected based on all requirements of each part and also the production possibility. So each part may require different material.

Nest box body parts. **–** The required properties of material to make the nest box parts include high strength at low weight, and weather resistant property.

Light weight and strong materials. **–** Fiber reinforced plastic is selected as material for making nest box parts. This material provides a means of achieving high strength at low weight because they exploit very strong fiber in light weight matrix. Fiber reinforced plastic is also suitable for custom made production.

***Weathering resistance.* –** Commercial epoxy resins used in glass fiber-reinforced plastics are fairly durable (Somjai et al., 2002). Water immersion does not have much effect on its mechanical properties. Although the mechanical properties of glass/epoxy composites are reduced when temperature increases, the critical temperature of about 60ºC (Mehmet & Ramazan, 2008) is higher than normal working temperature in this study. Polymeric materials including glass fiber-reinforced plastics are generally not vulnerable to microbial attack under normal conditions (Campo, 2008).

***Insulation materials.* –** The selected insulation material is polyurethane foam. Its thermal conductivity is about 0.02 W/m°C (McMullan, 1983). About 5–7 cm thickness of this material will be put in between two layers of fiber reinforced wall. This sandwich cross section wall will have thermal transmittance value of about 0.5–0.3 W/m^2 ºC.

***Nest entrance.* –** The most suitable material for the nest entrance is natural wood.

***Other fixtures and equipment.* –** In this study, fixture and equipment will be selected from what available in the market. Galvanized wire rope 7×7 with 1/8 inches diameter was selected as holding rope for a nest box. This rope has minimum break strength about 700–800 kg.

***Final design of the artificial nest.* –** Many designs of the nest box had been developed and tested in this study. The final design of the artificial nest is prototype 6 (Fig. 7). The design direction for prototype 6 aims to balance between design criteria and production capability in combination with previous experiment results in order to get the best possible result.

Prototype 6 had been made from fiber reinforced plastic. Its dimensions are 50×50 cm at base and 120 cm height. A perching place is located at the left side of the nest entrance. Prototype 6 consists of six parts. All nest box parts will be assembled by proceeding vertically with other parts, added on top and lock all parts together with bolts. A total of 19 artificial nests had been installed at the study site during 2005–2006.

***Hornbill visits and use of artificial nests.* –** Five years of monitoring data area available so far. Only one pair of hornbills was observed to visit artificial nests during the first year after installation of artificial nests; however, in the second year after installation, the number of nests visited by hornbills steadily increased. When calculated by period of installation, visiting percentage started at 5% of total nest boxes in the first year, increasing to 20% in the second year, and 36.84% in the third year until the fourth year when the rate decreased slightly to 33.33%.

When calculated from each breeding season, visiting percentage started at 10% of total nest boxes in 2004, 30% in 2005, 10.5% in 2006, 22.22% in 2007, 35.29% in 2008, and 17.64% in 2009 (Table 1). It should be noted that in 2006, some more nest boxes were installed in the study area, so the total numbers of nest boxes were more than in the previous year. This causes a decrease in the visiting rate calculation. And in 2009 some nest boxes that had been visited by hornbills in the previous year, were used as breeding nests in this year. So the visiting rate also decreased.

Most of the reports of hornbills visiting from the first year till the third year after installation of the nest boxes were by Rhinoceros Hornbills, which began visiting boxes first. Only one pair of Great Hornbills visited a nest box in the second year; however this pair was first observed while chasing a Rhinoceros Hornbill that had previously visited the nest.

No artificial nest was used by hornbills during the first year after installation. The first nest box that was reported being used by hornbill was in the second year (Fig. 8). The Great Hornbill has been the first and only species that uses the

Fig. 7. Hornbill nest-box Prototype 6 (Photo by Chakorn Pasuwan).

Fig. 8. Great Hornbill using an artificial nest in the 2007 breeding season. (Photo by Thailand Hornbill Project).

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

artificial nest up till now while the Rhinoceros Hornbills keep visiting nest boxes but never used them. The number of nest boxes that have been used by Great Hornbills has steadily increased since then. When calculated by period of installation, usage started at 5% of total nests in the second year to 15.78% in the third year, and 16.66% in the fourth year. When calculated from each breeding season, usage started at 5.2 % of total nests in 2006 to 5.5% in 2007, 17.64% in 2008, and 29.91% in 2009 (Table 1).

In this study, the comparison between number and rate of nesting using natural nests versus artificial nests used by the Great Hornbill in the sample area can be conducted only in two breeding seasons, during 2008–2009 and 2009–2010, because availability and suitability of natural nests had not been surveyed prior to this. The comparison shows that percentage of nesting in natural nests was higher than in artificial nests in 2008, but lower than artificial nests in 2009. 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 by Great Hornbills. It should be noted that in late 2008, some unsuitable natural nests had been modified by Thailand Hornbill project teams, so the total number of suitable natural nests in 2009 were more than in 2008 breeding season. This caused the percentage use in 2009 to decrease slightly. If natural nests that had been modified are not included in calculation, the percentage use in 2009 is about 27.77%. So rate of nest use from 2008–2009 decreased about 5.56%–9.53% for natural nests while the rate of nest use for artificial nests increased about 12.27%.

DISCUSSION

Results of this study seem to show that it is possible to increase the breeding chance of wild hornbills by using artificial nests. However artificial nests need to be installed for at least one year before hornbills start using them. From monitoring results, the rate of visiting artificial nests by hornbills starts to decline in this year and most of nest boxes that had previously been visited by hornbill had by then been occupied. This seems to indicate that artificial nest use rate may be close to its highest point. Further study is required for both designing of artificial nests and hornbill habitat in study area.

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