Zoo Biology 31 : 683–693 (2012)

RESEARCH ARTICLE

Captive Breeding and Reintroduction of the Oriental Pied Hornbill (*Anthracoceros albirostris*) in Khao Kheow Open Zoo, Thailand

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This article discusses two related issues of the captive breeding and reintroduction of the Oriental pied hornbill (*Anthracoceros albirostris*) in order to increase its population in the natural habitats. Oriental pied hornbills were bred in Khao Kheow Open Zoo. Three pairs were separated and kept in breeding cages. Females occupied artificial nests between February and April 2005–2007. Eggs were laid and incubated between February and March each year from 2005 to 2007. Nestlings hatched in late March and left the nest in late April 2005–2007. Each breeding pair was fed with approximately 400 g of food each day. All three pairs reproduced resulting in mature offspring of seven in 2005, six in 2006, and five in 2007. Four of sixteen 3-year-old birds were randomly selected and equipped with a GPS receiver on their backs. Activities of the birds attached and unattached with GPS were not significantly different. The first two birds (one female, one male with GPS) were reintroduced on August 5, 2006, and another nine birds (four birds with GPS) were reintroduced on December 26, 2006. The average home range of these reintroduced birds was 0.13 km^2. Their foods

Grant sponsor: Budget Bureau of Thailand.

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Received 8 July 2011; Revised 26 September 2011; Accepted 6 October 2011

DOI 10.1002/zoo.20432
Published online 21 November 2011 in Wiley Online Library (wileyonlinelibrary.com).

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consisted of wild plants and animals in the home range. The first reintroduced pair was able to breed naturally by laying and hatching eggs in an artificial nest. Two juveniles left the nest in April 2008. These results indicate that both captive breeding and reintroduction are potentially important ways to increase the population of the Oriental pied hornbill in natural habitats. Zoo Biol 31:683–693, 2012. © 2011 Wiley Periodicals, Inc.

Keywords: captive breeding; reintroduction; hornbill conservation; Khao Kheow-Khao Chompu Wildlife Sanctuary; Khao Kheow Open Zoo; keystone species

INTRODUCTION

Hornbills (Family Bucerotidae) occur throughout subsaharan Africa, India, and Southeast Asia through to New Guinea. With the rapid loss of hornbill species worldwide, improving captive breeding has been a common approach to species conservation [Kemp, 1995; BirdLife International, 2000]. The major threats to hornbill populations are deforestation, habitat modification, and the vulnerability of island species with restricted ranges [Wilkinson, 2005; Styring et al., 2011]. On top of habitat loss, unsustainable hunting for the live bird trade and for food can severely endanger fragmented and isolated hornbill populations [Gonzalez, 1998; Trail, 2007; Sethi and Howe, 2009]. Hunted and logged sites have depleted populations of many species of hornbill, including the Oriental pied hornbill (*Anthracoceros albirostris*) [Datta, 1998]. The decreased number of hornbills will likely disrupt mutualisms between hornbills and some large-seeded food plants [French and Smith, 2005; Walker, 2007; Sethi and Howe, 2009] and decrease the opportunity of large-seeded food plants to move to special microsites favorable for establishment [Datta and Rawat, 2004] or to carry seeds to open habitats [Howe and Smallwood, 1982]. In Thailand, this phenomenon occurs throughout the country in all hornbill species, including the Oriental pied hornbill [Poonsawad and Kemp, 1993]. In nature, Oriental pied hornbills breed between January and May. During the breeding season, both males and females find cavities in trees to use as nests; most prefer their old nests [Kemp, 1995]. Average nest dimensions are 37 cm in width, 46 cm in length, and 150 cm in height. The average size of nest entrances is 10 cm in width and 25 cm in length. Usually, nests are made in living or dead trees, but sometimes holes in rocks may be used [Poonsawad and Kemp, 1993]. Birds use the female's feces mixed with fruit, wood, and mud to cover their nest. Average clutch size is two eggs and nestlings will hatch after 25 days [Tsuji, 1996]. Because of the specific need for nest trees and the low reproductive success of hornbills in nature, both in situ and ex situ conservation strategies are required. Studies of nesting biology in the wild that result in better understanding of nesting behavior may lead to improved captive production that may benefit the species [Worth and Sheppard, 1998]. Breeding in captivity is a recent strategy used to increase hornbill populations before reintroduction into natural habitat, but reproductive success is low world wide [Bárcena et al., 2005]. This species had previously been reported to have reproduced in many zoos [Vyas, 2002; Ng et al., 2011], but this research has confirmed the success in reintroduction for this species. This research aims to improve the potential of Oriental pied hornbill breeding in captivity and of reintroduction to the wild in order to improve the genetic diversity of native populations.

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METHODS

Study Area

The study was carried out in Khao Kheow-Khao Chompu Wildlife Sanctuary (KKWS) (101–102°N, 13–14°E, area: 144.7 km^2) and Khao Kheow Open Zoo (KKOZ) (total area: 8 km^2), which is located in KKWS in Maung and Sriracha Districts, Chonburi Province, Thailand (Fig. 1). Elevation from 220 to 550 m covers 49.5% of the total area (71.63 km^2). The average temperature is 29°C with average rainfall of 1,299 mm/year. The reintroduction was conducted in mixed deciduous forest in the foothills. The canopy comprised three layers, with the top canopy covering 90–95% of the total area. The dominant trees were 10–20 m high. The dominant species were *Pterocarpus macrocarpus* Kurz, *Xylia xylocarpa* Taub. var. *Kerrii* Nielsen, *Canarium subulatum* Guill, *Anogeissus acuminata* (Roxb. Ex DC.)

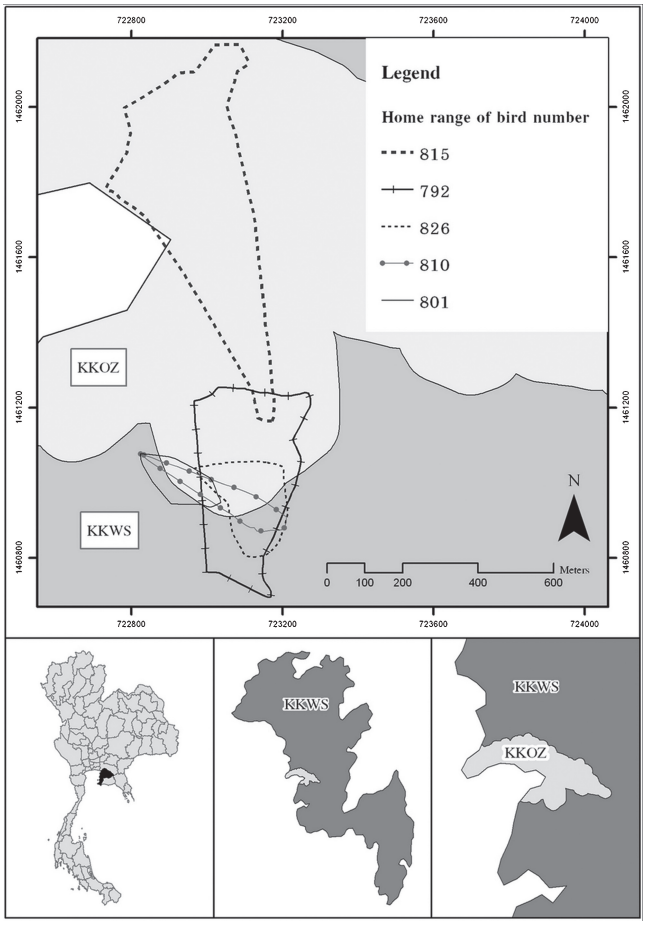

Fig. 1. Location of Khao Kheow-Khao Chompu Wildlife Sanctuary and Khao Kheow Open Zoo study area, Thailand, and the home ranges of Oriental pied hornbills after reintroduction.

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Guill. & Perr. var. *lanceolata* C.B. Clarke, *Garuga pinnata* Roxb., and *Schleichera oleosa* Merr. [The Royal Forest Department, 2002].

Captive Breeding of the Oriental Pied Hornbill

Oriental pied hornbills were bred in KKOZ. Selection of mates was made by the animals. After the Oriental pied hornbills selected their mates, three pairs were separated and each pair was kept in their own breeding cage (4 m in width, 8 m in length, and 3 m in height) between 2005 and 2007. Artificial nests made from iron tanks, 45 cm in diameter and 53 cm in height, with nest entrance of 11 cm in width and 17 cm in length, were placed in appropriate locations in the breeding cages. The artificial nest entrance was shorter in length when compared with the nest entrance of Oriental pied hornbills in their natural habitat in Khao Yai National Park [Poonswad, 1993]. Each breeding pair was provided with approximately 400 g of food per day. Percentage composition of the food mixture was bananas 28.64%; papayas 51%; grapes 6.48%; dog food 5.31%; pork 3.33%; rice with boiled chicken, egg, and corn 3.58%; laboratory mice 0.86%, and others 0.81%. This can be compared with the natural diet composition of the Oriental pied hornbill recorded in Khao Yai National Park, Thailand, which was figs 35.3%, non-figs 44.7%, and animals 20% [Poonswad et al., 1978]. This food mixture fulfilled the requirements of a diet that contained 10.8% crude protein with energy at 4.0 kcal/g dry matter for the hornbills to maintain their body mass [Foeken et al., 2008]. Nutritional values for each food item are shown in Table 1.

Training and Reintroduction of the Oriental Pied Hornbill

Sixteen, 3-year-old Oriental pied hornbills (eight males, eight females), all of which were bred in captivity at KKOZ, were released into a training cage of 800 m^2 in area and 12.5 m in height for 1 year. The training cage was situated at the reintroduction area in the forest and far from human activities to minimize behavioral imprinting of the Oriental pied hornbill to humans and had limited contact with humans or the public. The Oriental pied hornbills were trained to feed on natural foods and live prey. After training, the birds were kept in the release room, at 3 m in width, 3 m in length, and 2 m in height, inside the training cage for 1 day. After that, the release exit door 0.5 m in width and 0.5 m in length was open for birds to exit naturally. Natural trees were used to decorate the training cage. Native

TABLE 1. Nutritional Values of Major Items in the Daily Food of Caged Oriental Pied Hornbills in Khao Kheow Open Zoo, Thailand.

Food type	Moisture (%)	Lipid (%)	Protein (%)	Calcium (%)	Ash (%)
Banana	95.1	0.1	0.2	0.0	0.2
Papaya	70.9	0.1	0.8	0.0	0.9
Rice+boiled yolk+corn	70.8	1.5	2.9	0.0	0.5
Grape	90.3	0.2	0.4	0.0	0.5
Pork	76.8	2.0	20.0	0.0	1.4
Laboratory mice	79.8	5.6	10.3	0.5	2.0
Taro	79.1	0.2	1.5	0.0	0.9
Dog food	5.1	6.4	25.2	1.6	7.6
Squid mantle	–	–	–	31.4	85.4

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(bananas, figs, and others) and exotic fruits (grebes, papaya, and others) were hung on the tree canopy in the cage. The birds were trained for 6 months in predatory behavior by using laboratory mice before release into the wild. Six birds were equipped before release with GPS receivers, including data loggers in plastic backpacks (RC-Systems, JP7-T, FALCOM; Falcom Wireless Communications GmbH, Langewiesen, Germany, 433 MHz) with weight <3–5% of the birds' body weight on their backs [Tsuji, 1993]. In August 2006, the first pair was released to evaluate the GPS receiver following IUCN Council [1995] and Bryant [2002] guidelines. The other nine birds were released on December 26, 2006. GPS receivers were collected and downloaded 11 months after being attached to the birds. UTM points were employed to estimate the home range size of the birds after release.

Statistical Analysis

Analysis of variance (ANOVA) and Student's *t*-test were employed to test for associations of birds and their activities in different situations. Associations were determined to be significant based on the commonly accepted 0.05 significance level.

RESULTS AND DISCUSSION

Captive Breeding of the Oriental Pied Hornbill

After keeping the three pairs of Oriental pied hornbills in breeding cages, the female Oriental pied hornbills entered the artificial nests (iron tanks) and remained confined there from February to April each year from 2005 to 2007. This period was in the breeding season range (late February or early March and lasting until May) of the Oriental pied hornbill in Khao Yai National Park [Poonswad, 1993]. Eggs were laid and incubated between February and March each year from 2005 to 2007. Eggs hatched at the end of March and nestlings left the nest at the end of April each year during 2005–2007. Poonswad [1993] believes that drought triggers the breeding of the hornbills in Khao Yai National Park, whereas Kemp [1976] believes that the onset of the breeding cycle is linked to rainfall in some African hornbills. During the incubation period, feeding activities of male hornbills increased markedly and were highest in April. After females and nestlings left the nest, feeding activities of male hornbills decreased to normal levels. Seven, six, and five fledglings from the three mating pairs were produced in 2005, 2006, and 2007, respectively (Table 2). These numbers were close to data of Poonswad [1993] who reported the average number of

TABLE 2. Number of Fledglings From Each Pair of Oriental Pied Hornbills Bred in Captivity at Khao Kheow Open Zoo, Thailand, Between 2005 and 2007.

	Breeding pair number			
Year	1	2	3	Total
2005	2	2	3	7
2006	2	2	2	6
2007	2	1	2	5
Total	6	5	7	18
Average	2 ± 0	1.67 ± 0.58	2.33 ± 0.58	2 ± 0.5

$F = 1.50$; df = 8; $P = 0.20$ (95% confidence interval of the difference = 1.62–2.38).

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fledglings per pair of Oriental pied hornbills to be 1–2 fledglings/pair in the natural habitat of Thailand.

Reintroduction of the Oriental Pied Hornbill

All birds were screened by veterinarians of the KKOZ Hospital for any diseases, underwent general medical checkups, and were then kept in the training cage. All birds were trained to find and feed on natural food and live animals for 1 year. Human contact was avoided in order to minimize behavioral imprinting to humans. Four birds (two males and two females) had receivers attached on their back while still in the cage. The activities of these birds were observed for 5 months. The individual activities were not much significantly different (Fig. 2) compared with unattached birds.

Release and Adaptation After Release

The first pair of birds were released after 2 months of training of the male with a GPS receiver and fed on natural food. The two birds (one male with GPS receiver and one female without GPS receiver) were kept in the release cage for 24 hr and released on October 5, 2006. On December 26, 2006, the other nine birds (five birds with GPS) were released after the first two birds had adapted to the new environment.

During the 1st week after release, the keeper fed the hornbills every day near the cage, then reduced the feeding times to every 2 days in the 2nd week, only 2 days/week in the 3rd week, and did not feed in the 4th week. This practice of gradually reducing artificial feeding can help prevent the birds from starving and force them to find food in the natural habitat. Birds could find the natural food plants, such as *Musa acuminata*, *Maclura cochinchinensis*, *Muntingia calabura*, *Pseudodissochaeta septentrionalis*, *Ficus racemosa*, *Carica papaya*, *Brucea javanica*, *Caryota bacsonensis*, *Ficus benjamina*, and *Areca* sp., and animals, such as *Erionota thrax*, *Hemiplecta distincta*, spiders in the order Araneida, and insects in the order Coleoptera (Table 4). These food items were dominant in the reintroduction site, whereas Kitamura et al. [2004b] found *Cinnamomum subavenium* was dominant under the Oriental pied hornbill nesting trees in Khao Yai National Park. After 2 months of release, the birds' activities were not significantly different from their activities when kept in the training cage. At the beginning of release, the birds still waited for their food beside the cage until August 2006. After 11 months of release, in July 2007, each bird had distributed to a new food site, such as fig trees and the transition area between KKOZ and KKWS. The home range of the six birds with GPS receivers varied from 0.02 to 0.26 km^2 (0.13 ± 0.11 $km^2\,bird^{-1}$) (Table 3). Male Oriental pied hornbill number 801 had the smallest home range (0.02 km^2). Male number 810 was aggressive and disturbed visitors to the KKOZ, and so was caught on April 2, 2007, and kept in the breeding cage. The home range of this bird was 0.04 km^2. The home range of male number 826 was 0.09 km^2. The home range of female number 792 was 0.26 km^2. The home range of male number 815 was 0.22 km^2. Female number 770 was lost after 1 month of release. The average home range of the Oriental pied hornbill [weight 0.7–0.8 kg; Kitamura et al., 2004a] in this study was similar to the total range in the breeding season of the Oriental pied hornbill in Khao Yai National Park [Tsuji et al., 1987], but smaller than the average home ranges of the brown hornbill (*Ptilolaemus tickelli*), average weight the same as the Oriental pied hornbill (>0.5 kg) and average home range 4.3 km^2; the wreathed hornbill (*Rhyticeros*

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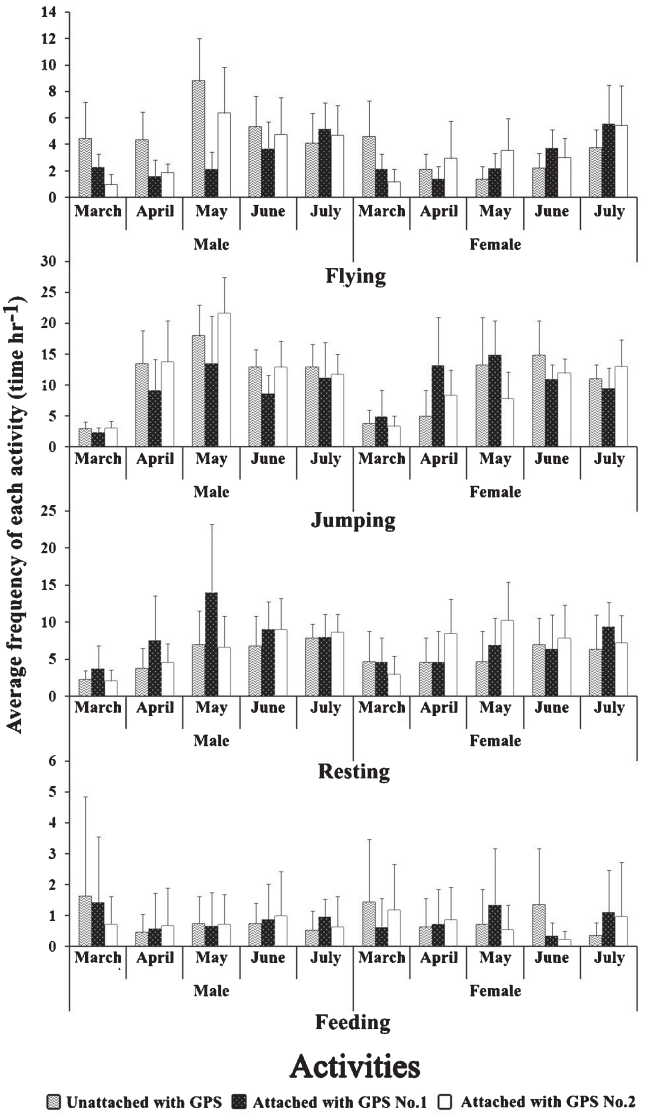

Fig. 2. Activities of Oriental pied hornbills after being attached with GPS receivers in training cages at Khao Kheow Open Zoo, Thailand.

undulates), weight 2–2.5 kg [Kitamura et al., 2004a] and average home range 10–28 km^2; and the great hornbill (*Buceros bicornis*), weight 2.2–3 kg [Kitamura et al., 2004a] and average home range 14.7 km^2. These home ranges vary depending on feeding and reproductive strategies [Poonswad and Tsuji, 1994]. Male number 826 showed courtship behavior with a wild bird for a year and then left this wild female and showed courtship behavior again with female number 792. Male number 815 paired with a wild bird, but breeding was not successful owing to the male being killed on May 2, 2007, in a mist net set by a farmer to protect the farm from bird and bat pests. This may be because bird number 801 was the male of the first mating pair

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TABLE 3. Home Ranges of Oriental Pied Hornbills 11 Months After Release in Khao Kheow Open Zoo, Thailand.

Bird number	Sex	Home range (km^2)
801	Male	0.02
810	Male	0.04
826	Male	0.09
815	Male	0.22
792	Female	0.26
Average ($\pm$SD)		0.13 ± 0.11

$t = 2.61$; df 4; $P = 0.06$ (95% confidence interval of the difference = −0.01–0.26).

TABLE 4. Major Foods of Oriental Pied Hornbills After Reintroduction in Khao Kheow Open Zoo, Thailand.

Food type	Order	Family	Scientific name	Habit	Utilization part
Plants	Arecales	Arecaceae	*Areca* sp.	P	Fruit
	Arecales	Arecaceae	*Caryota bacsonensis* Magalon	P	Fruit
	Caricales	Caricaceae	*Carica papaya* L.	ExST	Fruit
	Elaeocarpales	Elaeocarpaceae	*Muntingia calabura* L.	ExST	Fruit
	Myrtales	Malastomataceae	*Pseudodissochaeta septentrionalis* (W.W. Sm.)	ScanS	Fruit
	Rutales	Simaroubaceae	*Brucea javanica* (L.) Merr.	S	Fruit
	Urticales	Moraceae	*Ficus benjamina* L.	T	Fruit
	Urticales	Moraceae	*Ficus racemosa* L.	T	Fruit
	Urticales	Moraceae	*Maclura cochinchinensis* (Lour.) Corner	ST	Fruit
	Zingiberales	Musaaceae	*Musa acuminata* Colla	H	Fruit
Animals	Araneida	–	–	–	Whole body
	Coleoptera	–	–	–	Whole body
	Lepidoptera	Hesperiidae	*Erionota thrax* Linnaeus	–	Whole body
	Pulmonata	Ariophantidae	*Hemiplecta distincta* (Pfeiffer)	–	Soft parts

P, palm; ExST, exotic shrubby tree; ScanS, scandent shrub; S, shrub; T, tree; ST, shrubby tree; H, herb.

released to the wild. Unlike the other nine birds, the mating pair was established before release. This male surveyed for a nest site in December 2006 and lives close to the training cage. Consistent with the report of Poonswad and Tsuji [1994] that hornbills bred when trees were fruiting, so the ranges of hornbills in this study were reduced because they could find food close to their nest. Synchronization between

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fruiting and breeding periods could reduce the energy consumed and increase the breeding success in animals.

Breeding Success After Reintroduction

Of the three radio-tagged pairs, two were followed while the third pair lost its female. The male of the third pair later formed a pair with a wild female Oriental pied hornbill and did not successfully breed because the male accidentally died in a trap of a nearby farm outside the study area. The second pair was formed after release and was able to breed naturally by laying and hatching eggs in an artificial nest placed in a tree. Two juveniles left the nest in April 2008. This artificial nest, an iron tank, could provide a nest cavity for hornbills when natural nest cavities are few. Poonswad et al. [2005] suggested nest cavity modification as a strategy for hornbill conservation in Thailand.

CONCLUSIONS

A decrease in hornbills will disrupt forest tree diversity [Poonsawad and Kemp, 1993; Kinnaird, 1998; Whitney et al., 1998; Whitney and Smith, 1998; Holbrook and Smith, 2000; Poulsen et al., 2002; Kitamura et al., 2008], especially in tropical seasonal forest in Thailand [Kitamura et al., 2004c]. Increasing the numbers of Oriental pied hornbills by reintroduction can increase dispersal of large seeds and improve forest structure in natural habitats [French and Smith, 2005; Walker, 2007].

The Oriental pied hornbills in breeding cages entered the artificial nests from February to April. Eggs were laid and incubated between February and March and hatched at the end of March and nestlings left the nest at the end of April. The average number of fledglings per pair of Oriental pied hornbills is two fledglings/pair, which is similar to that found in natural habitat. The released birds can disperse to new food sites. The home range of the birds varied from 0.02 to 0.26 km^2. Of the three tracked pairs, one pair was able to breed naturally. The use of iron tanks as artificial nests demonstrates that this can be useful when the availability of natural cavities is reduced. In conclusion, captive breeding and reintroduction were shown to be important ways to improve the potential of hornbill conservation in both in and ex situ conservation and to ensure the short- and long-term survival of these interesting birds in Thailand.

ACKNOWLEDGMENTS

Thanks are extended to the Department of National Parks, Wildlife and Plants and to the Zoo Organization of Thailand for providing permission and assistance for data collection. Our appreciation and thanks to Assistant Professor Dr. John Milne, Department of Biology, Faculty of Science, Mahidol University, Thailand, for technical support and friendship.

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