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BREEDING OBSERVATIONS ON THE ORIENTAL PIED HORNBILL IN NEST CAVITIES AND IN ARTIFICIAL NESTS IN SINGAPORE, WITH EMPHASIS ON INFANTICIDE-CANNIBALISM

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***ABSTRACT.* –** Detailed video recordings were obtained for 14 breeding cycles of the Oriental Pied Hornbill *Anthracoceros albirostris convexus* over four years, from 2005–2006 to 2008–2009, from five nests (five pairs) in Pulau Ubin, an island off Singapore, and two breeding cycles of one pair (during one year, 2008–2009) in mainland Singapore. In the Jurong Bird Park, four cycles with chicks were observed in three nests over the same duration. The female sealed herself in the nest in P. Ubin mainly in January (between 4 January and 7 February), and from 9 January to 19 February in Jurong Bird Park. The average number of eggs laid in natural cavities in the wild was 3.4±0.5 (between 3 and 4), and in artificial nests in the wild was 3.3±0.4 (between 3 and 4); in captivity, 3.4±0.9 (between 2 and 4). The duration of incubation is quite consistent at between 25 and 29 days in the wild, and in captivity the average was between 26 and 33 days. The number of chicks hatched in the wild, in natural cavities, was 2.9±0.7 (between 1 and 4); and in artificial nests, was 3.1±0.5 (between 2 and 4); and in captivity, the number was significantly less, at 1.8±0.8 (between 1 and 3). Five cycles in the wild were observed to have cannibalism or cannibalism-infanticide, committed by two females: in three of the four cycles observed in one female, and in two of the four cycles observed in another female. Of the five cycles, cannibalism-infanticide (chick killed by mother and fed to other chicks or eaten by her) occurred in three cycles, all involving the fourth chick (in broods with four chicks): at 3d 13hr, 4d & 5d 10hr after hatching of the chick. Of the remaining two cycles, cannibalism occurred after the chick died: the victim being the second chick in a brood of three (3d 10hr after its hatching), and the third chick in a brood of three (3d 1hr after its hatching), respectively. These two phenomena were also observed in one captive female, both in captivity and after she was released into the wild. The average number of chicks fledged was 1.7±1.2 (0-3) from natural cavities, and 1.9±0.5 (0-3) from artificial nests in the wild. For captive birds, the average number of chicks fledged was 1.3±0.4 (0-2). Fledging success (from eggs laid) was slightly better in artificial nests in the wild compared to natural cavities (47.8% vs. 44.4%). However, it was poor in captive birds (20.8%). The average age of the chicks at fledging was between 41 and 64 days old. The female Oriental Pied Hornbill was confined in her nest for an average of 78.2±5.2 (between 66 and 89) days for natural cavities, but longer for artificial nests with an average of 86.0±3.0 (between 81 and 93) days in the wild. For captive birds, the average confinement duration was the longest with an average of 96.9±2.1 (between 95 and 100) days.

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.* –** Hornbill breeding, nest cavities, artificial nest, Singapore, infanticide-cannibalism.

INTRODUCTION

The Oriental Pied Hornbill, *Anthracoceros albirostris*, is found in many parts of Asia, including Southeast Asia. Its more southerly subspecies, *A. a. convexus*, occurs in the range from South Thailand (Pattani, Yala and Narathiwat provinces) to Peninsular Malaysia and Singapore; whilst *A. a. albirostris* is found in Thailand and north-east Peninsular

Malaysia (Kemp, 1995). From our studies, it is clear that the Oriental Pied Hornbill is now an established species with a good breeding population in Singapore. However, the subspecies identification is based on the amount of black on the tail (Frith & Frith, 1983), and in Singapore might not be clear-cut due to the possibility of some individuals having a hybrid origin (Wells, 1999). Natural habitats of the Oriental Pied Hornbill consist of forest edges, coastal mangroves, and forested islands (Kemp, 1995). These areas are able to provide an abundance of food.

All hornbills appear to be monogamous breeders, some additionally with helpers at the nest. The peculiarity of the nesting habits of hornbills has been the interest behind many studies performed on these birds. The breeding cycle begins with a courtship period, followed by the selection of a suitable nest, after which copulation takes place (Kemp, 1995). In the wild and in captivity, we observe courtship behavior, such as the provision of soil, nesting materials and food (large insects and lizards) to the nest, as a method for the male to convince the female to start the breeding cycle. Oriental Pied Hornbills usually use accessible natural tree cavities as nests. After selection, the female seals herself in the nest, using soil as the main sealant to reduce the nest entrance to a vertical slit just wide enough for the male hornbill to pass food items through. In this paper, we report the statistics of the successful and unsuccessful breeding events.

METHODS

From 2006 to 2009, a total of nine pairs of Oriental Pied Hornbills were surveyed with cameras during the breeding cycle, which typically runs from the month of December till May. Out of these nine pairs, four pairs were from the Jurong Bird Park, and five pairs from the offshore island of Pulau Ubin (Fig. 1).

The nests in natural cavities were found in *Durio zebithinus* trees, at an average height of 8.46±2.9 m (between 2.8 m and 12.14 m) above ground level, and with an estimated average volume of 90.14 litres (with the smallest cavity at 44.25 l and largest cavity at 175.77 l). Camera surveys revealed the following: in Pulau Ubin, 14 breeding cycles were recorded with cameras (over a period of four years, from 2005–2006 to 2008–2009) in five nests (involving five pairs) and two breeding cycles were observed in one nest (from 2008–2009 only) in southern Bukit Timah. In Jurong Bird Park, four cycles with chicks were observed in three nests (another three cycles in one pair were infertile, though that pair had successful fledglings in an earlier cycle). In situations resulting in equipment failure or damage, binoculars and field scopes were relied on for direct observations.

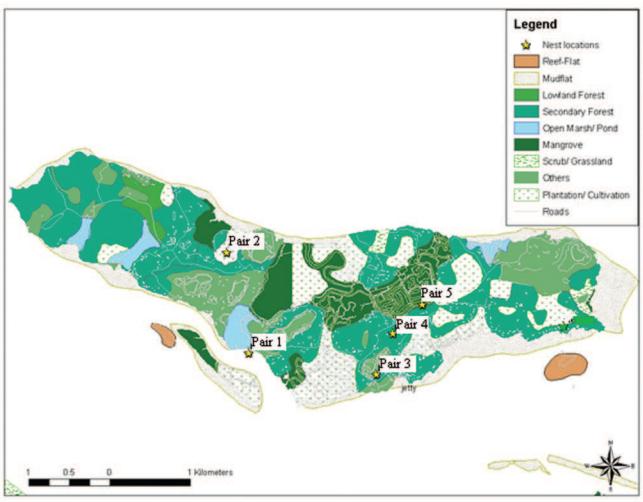

Fig. 1. Map of Pulau Ubin with approximate nesting locations of the birds surveyed (Map source: National Parks Board, National Biodiversity Centre). Yellow stars demarcate approximate nesting locations. Stars from left: Pair 2, Pair 1, Pair 3, Pair 4, Pair 5.

Camera surveillance system. **–** Observation of nests was possible for 24 hours daily with video recording into a digital video recorder (DVR) running the Telexper® software. The digital video recorder and cameras were fitted with lightning surge protection devices to protect against equipment damage and data loss. Recording system was powered by four 12V 150AH dry cell batteries that were recharged every three days. Each nesting location in the wild, regardless of natural or artificial cavities, was installed with at least two closed circuit television (CCTV) infra-red cameras, with internal cameras focusing on events within the nest box and external cameras capturing events at the entrance of the nest (Fig. 2). They are 1/3" day and night cameras with 440 TV lines resolution (built-in lens at f4.3 mm and f1.6).

Higher definition cameras were installed for Type 'b' and Type 'c' nests (described by Cremades et al., 2011). This is a 1/2" black and white camera with Exview HAD Technology, 600 TV lines resolution equipped with ten times optical zoom, and another high speed day and night dome camera with adjustable focal length (3.6 mm–82.8 mm), 480 TV lines resolution and 360 degrees high speed rotation. This allows better data collection, and clearer observation of the development of the chicks (Fig. 3).

In the Jurong Bird Park, the nests were installed with at least three infra-red cameras each, capturing the nest interior, nest entrance and the feeding dish. All data stored in the DVR had to be downloaded fortnightly and transferred to an external hard disk for storage and review.

Depending on the location, the recording system was powered (Fig. 4) by either four 12V 150AH batteries alone, or together with an uninterruptible power system (UPS); direct power supply; or a combination of batteries with solar panels.

RESULTS

Females sealed inside the nest. **–** Female Oriental Pied Hornbills sealed themselves in their nests in P. Ubin on a date between 4 January and 7 February, for both natural cavities and artificial nests. In the Jurong Bird Park, the females sealed themselves in the artificial nests on a date between 9 January and 19 February. In a captive pair that

was re-introduced into the wild, the female sealed herself in the artificial nest on 2 January, and then on 30 May in the same year, 56 days after she had emerged from the nest with two fledglings.

Egg laying. **–** The average number of eggs laid in natural cavities in the wild was 3.4±0.5, and in artificial nests in the wild was 3.3±0.4 (either three or four). In captivity, the number was 3.4±0.9 (between two and four). Eggs laid in the wild seem to be slightly earlier when the females are in artificial nests rather than when in natural cavities. The eggs were laid on average three days apart on Day 7, 10, 13, and 15 after sealing in natural cavities, whilst they were laid on Days 5, 8, 12, and 14 in artificial nests in the wild. Eggs laid in captive birds have a wider range, with an earlier average when compared with the Oriental Pied Hornbill in the wild. In captivity the eggs were laid on average on Days 9, 13 and 14.

Incubation. **–** The incubation lengths in the wild and in captivity are similar. In the wild, the duration of incubation is quite consistent at between 25 and 29 days, and in captivity the average was slightly longer between 26 and 33 days.

Hatching of chicks. **–** The number of chicks hatched in the wild, in natural cavities, was 2.9±0.7 (between one and four); and in artificial nests, was 3.1±0.5 (between two and four). In captivity, the number was significantly less, at 1.8±0.8 (between one and three). As it was not possible to access the overdue eggs, it was uncertain whether they were fertilized or not.

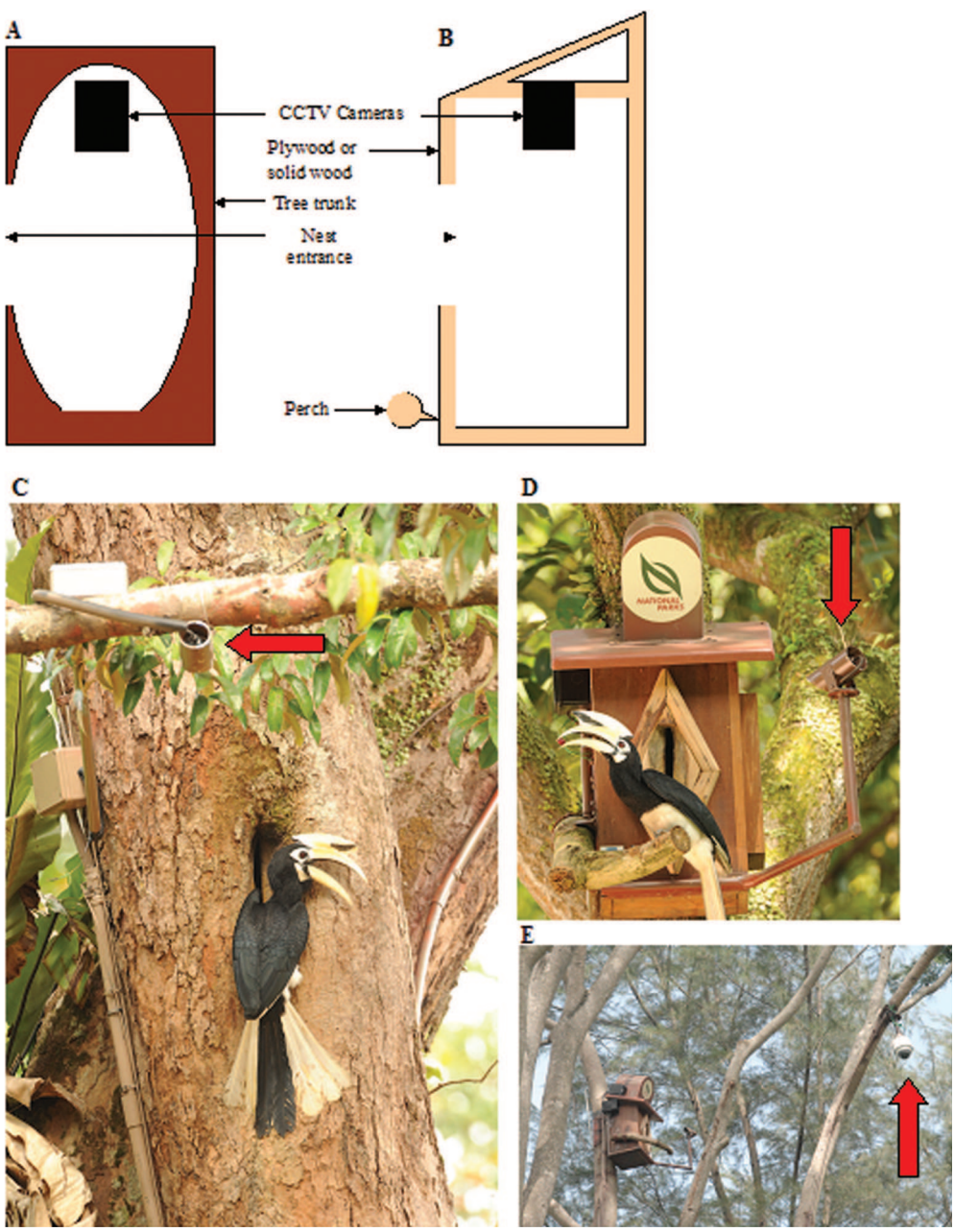

Fig. 2. Installation position for camera (A) within a natural nest cavity and (B) within a nest box. External camera positions (C) immediately outside a natural nest cavity, (D) immediately outside a nest box, and (E) at distance from a nest box.

***Cannibalism, infanticide-cannibalism and predation in the wild population.* –** An unusual phenomenon in which the adult female killed (infanticide) and then cannibalized the young was observed. Five cycles in the wild were observed to have cannibalism (Fig. 5A–B), committed by two females: three out of five cycles observed of one female, and two out of five cycles observed of another female. Of the five cycles that had cannibalism, three occurred in natural nests and two in artificial nests. Three out of the five cycles had cannibalism-infanticide (chick killed by mother and fed to other chicks or eaten by her, Fig. 5B–C), and all involved the fourth chick (in broods with four chicks): with the ages of the chicks at 3d 13hr, 4d & 5d 10hr old. Of the remaining two cycles, cannibalism occurred after the chick died, involving the second chick in a brood of three (at 3d 10hr old), and the third chick in a brood of three (at 3d 1hr old). Another observation of infanticide-cannibalism was observed in a pair that was re-introduced from captivity. This data is not included in our report; the details are given in Cremades et al. (2011).

In three other nests with two breeding cycles observed, there were no instances of cannibalism, though in one cycle two chicks in a brood of two were taken by a civet *Paradoxurus hermaphroditus*; in one cycle, three of the four chicks drowned; and in one cycle all three chicks died at 22d, 25d, & 31d old (one day apart starting from the youngest to the eldest chick), of unknown causes.

***Cannibalism or infanticide-cannibalism in the captive population.* –** In captivity, four cycles with chicks were observed in three nests (another four cycles in one pair were infertile, though that pair had successful fledglings in its earliest cycle prior to commencement of observations). Cannibalism-infanticide (Fig. 5C–D) occurred in one breeding cycle with three chicks—involving the second chick (at 3d 5hr old) and third chick (at 5d 1hr old) of the same brood; only one fledged. In the second cycle of that pair in the Jurong Bird Park, with three eggs laid, only one chick fledged. This same pair was re-introduced into the wild, and cannibalism-infanticide was observed in one of the two cycles in that calendar year (Cremades et al., 2011).

***Fledging success.* –** The average number of chicks fledged was 1.7±1.2 (range 0-3) from natural cavities, and 1.9±0.5 (range 0-3) from artificial nests in the wild. For captive birds, the average number of chicks fledged was 1.3±0.4 (range 0-2). Out of 23 fledglings, fledging success (from eggs laid) was slightly better in artificial nests in the wild compared to natural cavities (47.8% vs. 44.4%). However, it was poor

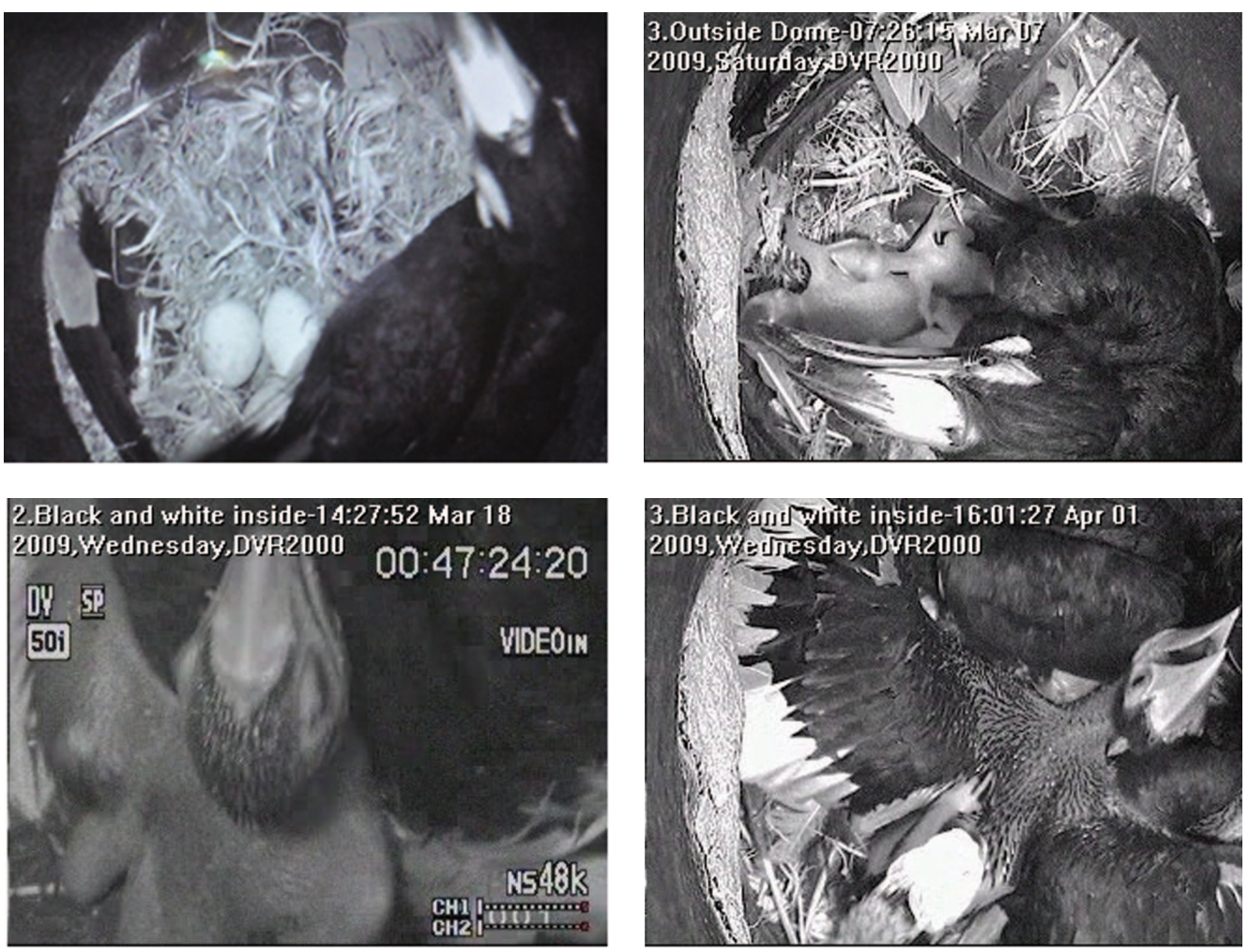

Fig. 3. (From left to right, top row) Nest interior showing female with at least 3 eggs; Newly hatched chick (few days older than 1 week); (From left to right, bottom row) Chicks at approximately 3 weeks old; Chicks at approximately 1 month old.

in captive birds (20.8%). If calculated per egg hatched, the figure for wild hornbills was only between 52.4% and 63.2% respectively and a high of 71.4% for captive hornbills, due to a large number of infertile eggs. The average age of the chicks at fledging was between 41 and 64 days old. Chick # 1 was the oldest at fledging.

Duration of female confinement. – The female Oriental Pied Hornbills were confined in their nests for an average of 78.2±5.2 days (between 66 and 89 days) for natural cavities, but longer for artificial nests with an average of 86.0±3.0 days (between 81 and 93 days) in the wild. For captive birds, the average confinement duration was the longest with an average

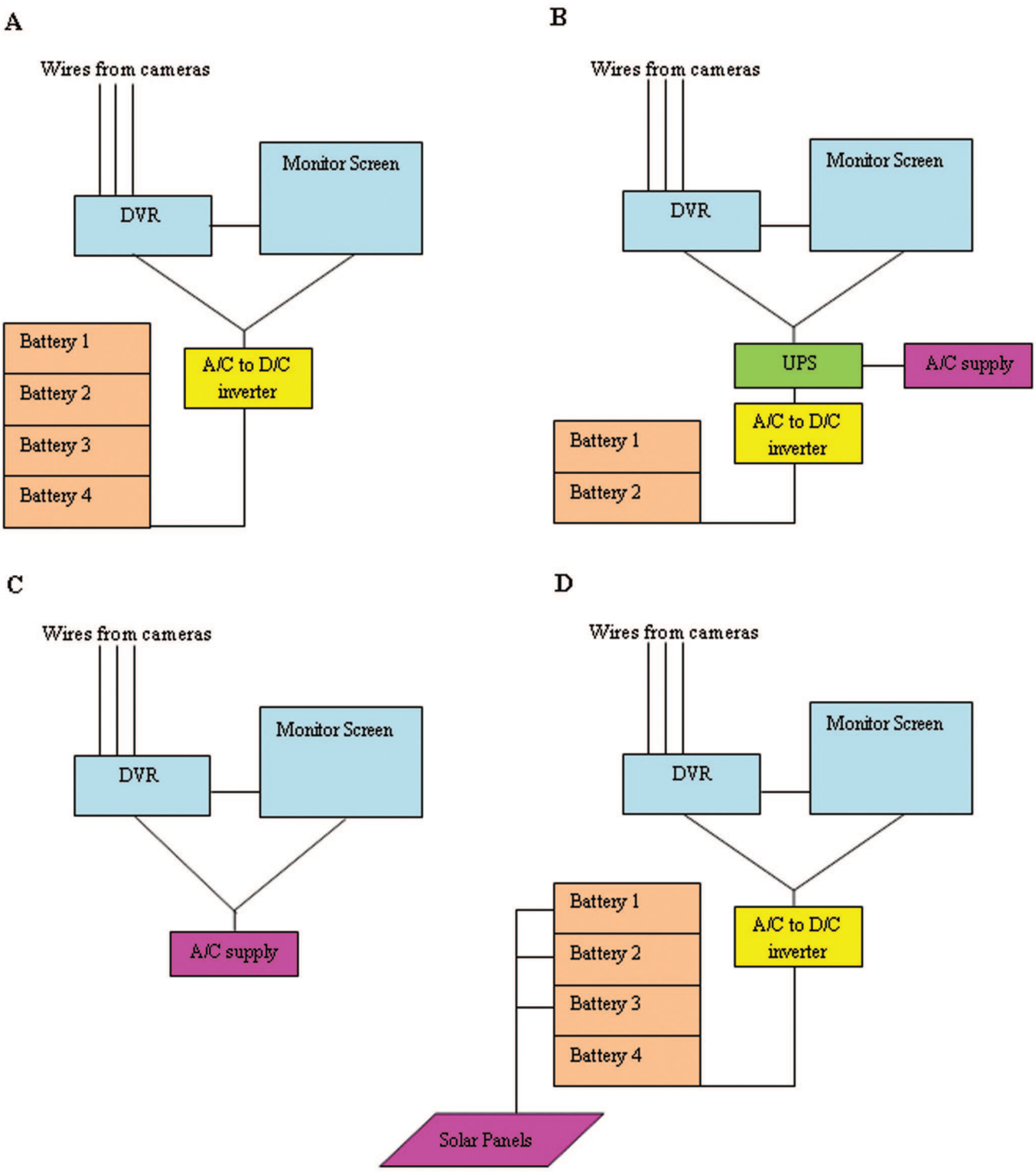

Fig. 4. Equipment set-up powered by 4 batteries, each of 12V and 150AH (**A**); or 2 batteries with uninterruptible power supply (**B**); or direct A/C power supply (**C**); or 4 batteries with solar panels (**D**).

Table 1: Average biostatistics for breeding cycles in the Oriental Pied Hornbill. Figures expressed as mean±SD (min–max).

#	Pulau Ubin		Jurong Bird Park	Released from Captivity
	Natural Cavity	Artificial Nest		
Day egg appeared, counted from day female sealed herself in				
Egg # 1	7.3±0.9 (6–10)	5.4±1.2 (4–7)	9.0±3.0 (5–16)	7.3±1.1 (6–8)
Egg # 2	10.6±0.9 (9–12)	8.3±0.7 (7–10)	13.0±4.7 (8–20)	10.5±0.1 (10)
Egg # 3	13.0±1.0 (12–15)	12.3±1.7 (10–16)	14.2±2.5 (11–20)	13.4±0.5 (13–14)
Egg # 4	15.7±0.3 (15–16)	14.0 (single)		
Incubation Period (days)				
Egg # 1	27.3±0.4 (27–28)	27.8±1.4 (25–30)	27.1±1.4 (26–30)	28.8±1.2 (27–30)
Egg # 2	26.9±0.8 (25–28)	28.0±0.6 (27–29)	28.2±1.8 (26–30)	28.1±0.9 (27–9)
Egg # 3	27.7±1.1 (27–29)	26.5±1.2 (25–28)	33.0 (single)	29.2 (single)
Egg # 4	26.9±0.9 (26–28)			
Age of chicks at fledging (days)				
Chick # 1	48.0±2.0 (44–52)	53.8±2.6 (49–58)	58.9±4.1 (53.6)	63.5 (single)
Chick # 2	44.8±3.3 (41–50)	51.5±2.8 (46–55)		60.0 (single)
Chick # 3	45.0±4.7 (38–51)	41.0 (single)		
Chick # 4		47.0 (single)		

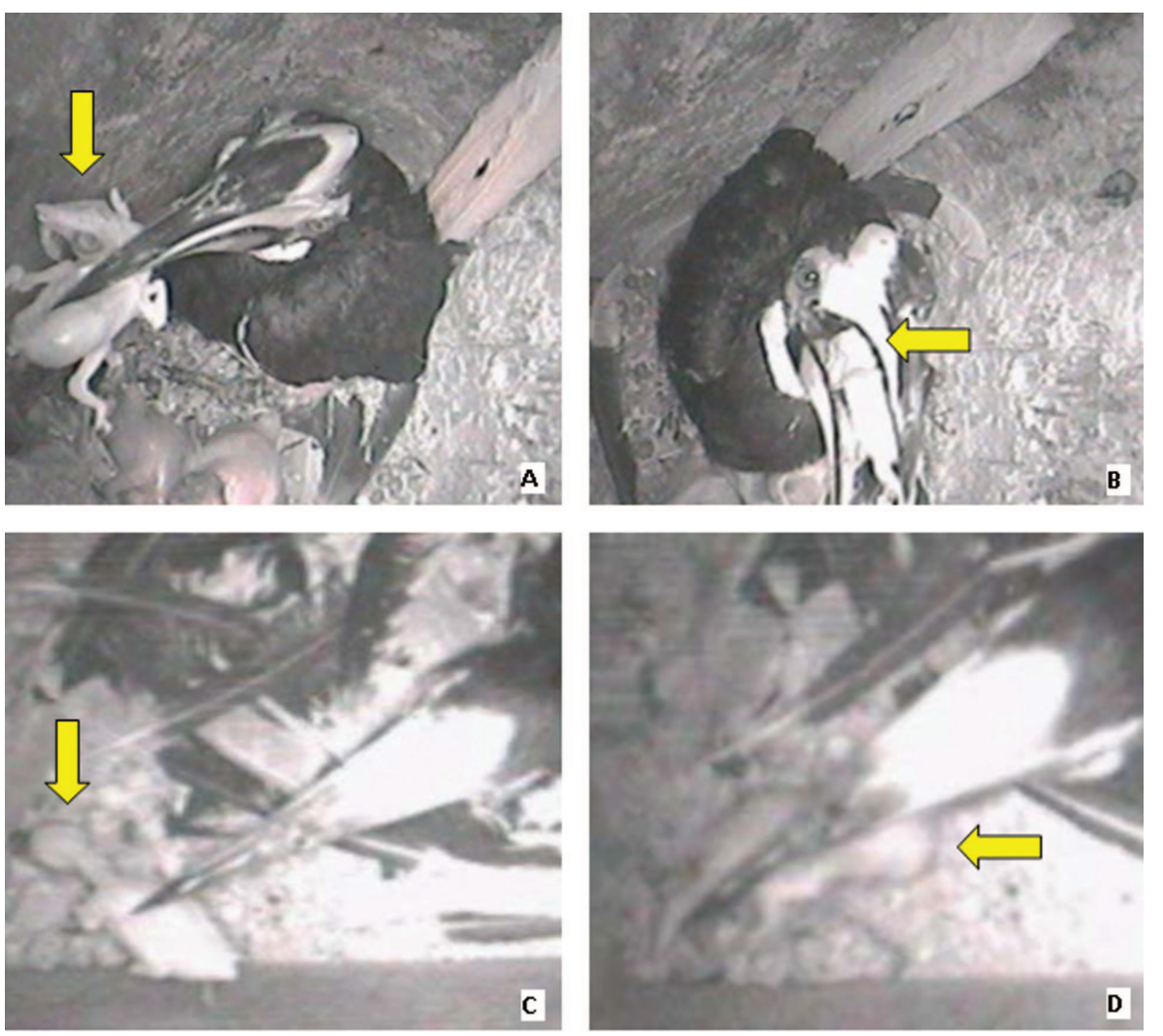

Fig. 5. **Cannibalism in natural cavity:** In a natural cavity, motionless chick, at 3 d 1 hr old, was crushed by female using her beak (**A**), this chick was swallowed whole by the female (**B**). **Infanticide-cannibalism in artificial nest, captivity:** Chick at 3 d 5hr old was crushed alive by female (**C**), this chick was swallowed whole by the female (**D**).

of 96.9±2.1 days (between 95 and 100 days). In most pairs observed, the female emerged from the nest on the same day as the chicks (Fig. 6), usually just before them. In one case, the third and youngest chick emerged three days after the female emerged; whilst in another case, the chick (only chick in the brood) emerged two hours before the female.

DISCUSSION

This report of observations of the breeding cycle of the Oriental Pied Hornbill *Anthracoceros albirostris convexus* in nest cavities and in artificial nests, in Pulau Ubin and the Jurong Bird Park, Singapore, is the most detailed so far. The observations show the potential of artificial nests as a supplementary conservation technique, where natural nest cavities are limiting. Artificial nests for wild hornbills are also being tested elsewhere (Pasuwan et al., 2011, James et al., 2011; Lee & Rombang, 2011), but without the advantage of camera and telemetry installations to give details about behaviour and physiology inside the nest. Hutchins (1976) used nest boxes for this species (reported as *A. malabaricus*) in captivity; our results are in broad agreement with his, but more numerous and detailed. While this species is not itself endangered, it provides an excellent model for testing techniques that may be adaptable to other hornbills that are endangered, as well as the opportunity for detailed studies of the reproductive cycle.

The subspecies *A. a convexus* has been documented to begin laying in January to March in Peninsular Malaysia (Kemp, 1995), and this is consistent with our observations. However, we recorded one pair with two breeding cycles with successful fledglings in a single calendar year (Cremades et al., 2011); this may be due to the optimal environmental conditions, with abundant food and lack of competition. The average points in the breeding cycle of the Oriental Pied Hornbill (*Anthracoceros albirostris convexus*) are summarized in Table 1.

Wells (1999) mentioned that the full clutch of this species is two eggs. However, our observations show that the mean number of eggs laid in the wild was 3.3 whilst the mean number of chicks fledged was half of that, at 1.8, thus giving an average fledging success of 55%.

The first observation of infanticide-cannibalism was reported by Chan et al. (2007). The present paper records more observations of this behavior. In total, there were ten recorded instances of cannibalism, of which seven were infanticides as well. In the wild, out of 16 cycles with chicks, there were six cycles (37.5%) where cannibalism occurred. Eight chicks (of a grand total of 51 chicks, i.e. 15.7%) were cannibalised, in five of which the female killed the chick (infanticide). In captivity, out of four cycles with chicks, only one cycle (25%) had two chicks (of a grand total of seven chicks, i.e. 28.6%) killed then cannibalized.

This phenomenon of brood size reduction by selective reduction of the weakest or smallest may be biologically innate in certain females, as it seems to occur only in two of five pairs in the wild; of these two pairs, cannibalism occurred in six out of eight cycles. In captive birds, cannibalism was seen in only one female out of three; this same female later committed cannibalism again in the second of the two breeding cycles when she was in the wild, after release (see Cremades et al., in press). We are unable to answer as to why this phenomenon occurred in these birds. We do not believe that lack of food or inadequate nesting space contributed to it, as it is observed in artificial nests and in captive birds that have ad libitum food supply. But it is clear that the female is able to identify the weakest chick; whether those chicks that were killed would have survived if they were not killed is uncertain.

The detailed treatment of artificial nest boxes will be published separately (Cremades et al., 2011). Observations on food brought in by the male and food intake by the female and individual chicks are being analysed and will be

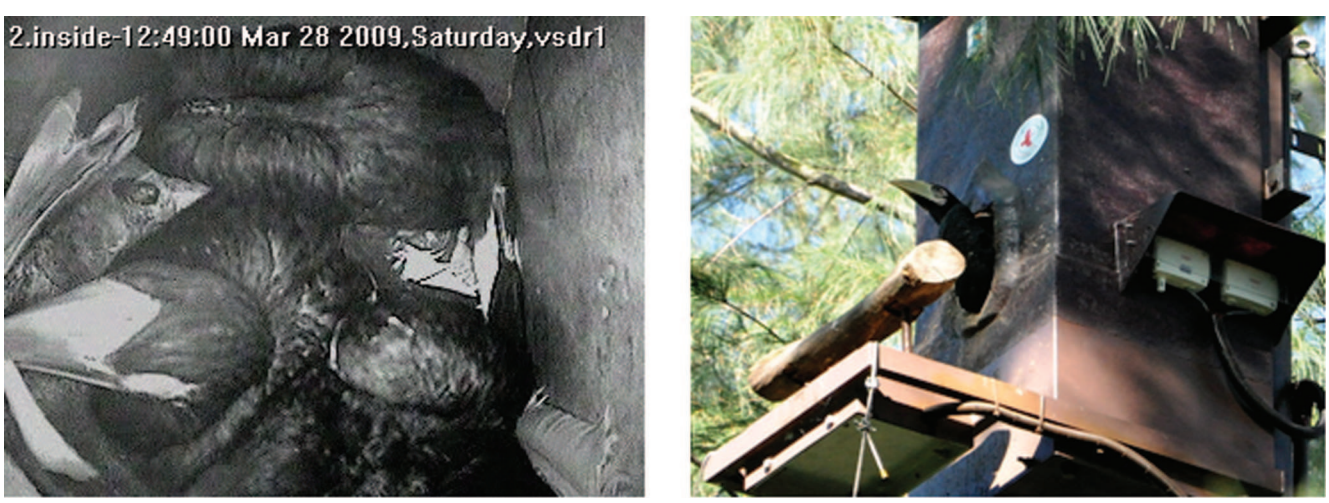

Fig. 6. Fledging of chicks (From left to right). Chicks at approximately 2 months old and ready to leave nest; emergence of chick after female broke open the entrance seal.

reported separately. Further work is on-going, especially in determining the geographical footprint of individual birds using GPS technology, and on the genetic characteristics of this subspecies.

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