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A Case Study of the Breeding Biology of the Oriental White Stork (*Ciconia boyciana*) in Captivity

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ABSTRACT: The captive breeding biology of the Oriental white stork (*Ciconia boyciana*) was studied over 3 breeding periods. Both the male and female participated in nest building, but the male started to build the nest earlier and spent much time. Time used to build the nest was steadily increased to the egg laying. The copulations were observed 30 ± 10.53 (n = 3) times in a breeding period. Both male and female incubated their eggs but the female spent more time than the male did. The chicks were hatched 32 ± 1.29 (n = 6) days after egg laying. Not only the male but also the female took part in the rearing chicks. The male spent more time than the female as chicks grew. The results of this study are useful to assess the ecological soundness of the breeding pair and facilitate the breeding environment in captive breeding of the Oriental white stork.

Key words: Captive breeding biology, *Ciconia boyciana*, Endangered species, Oriental white stork

INTRODUCTION

The Oriental white stork (*Ciconia boyciana*) is an endangered species listed in the Red data Book and remains about 2500 individuals in the world. For the conservation of the Oriental white stork, many efforts have been made to protect individuals and their breeding and wintering habitats as well as to propagate in captivity for reintroduction (Collar et al. 2001).

The first captive propagation of the Oriental white stork was made at Shanghai zoological park in China in 1984 (Fulin 1991, Baoqing and Yunshuang 1998), successively, at Vogelpark in Germany in 1987 (King 1992) and at Tama Zoo in Japan in 1988 (Komain and Sugita 1990). The Moscow Zoo in Russia tried to propagate but failed (Rozdina et al. 1991). In Korea, The breeding attempt in captivity has started since 1996 and a breeding pair was made and successfully bred in 2002 (Park and Cheong 2002).

To understand the captive breeding behaviors for successful reintroduction, it is important to make the subject species sustain the nature in field (Erickson 1980). Therefore, the breeding behaviors of the subject species have to be observed and recorded continuously on the bases of the fieldwork. In addition, the data from the captive breeding biology could be useful to compare with those from the fieldwork: First, we can assess ecological soundness of the breeding birds and their chicks in captivity. Second, we can prepare for the similar environmental conditions in field for successful reintroduction in captivity. Third, the conditions and techniques used for captive breeding could be continuously fed back by the comparisons of the data (Erickson 1980). As few studies have been made about the breeding biology of the Oriental white stork in field, the study of the captive breeding biology is still more important.

The Oriental white stork is a monogamous species, and starts to breed when it becomes 4 years old in nature (Collar et al. 2001). In captivity, it is very difficult to make breeding pairs because males of the Oriental white storks are so aggressive (King 1995). Therefore, there are few captive breeding pairs in the world (Saegusa 2003), and the data on the breeding of the Oriental white stork is not enough to understand its breeding biology.

We studied breeding biology of one pair of Oriental white storks as a case study. It was the first breeding pair in captivity in Korea. With this study, we purposed to accumulate the data of the breeding biology of the Oriental white stork in captivity, and apply them to facilitation of captive breeding environment for newly breeding pairs.

MATERIALS AND METHODS

We conducted this study in Korea Institute of Oriental White Stork Rehabilitation Research, Cheongwon, Chungbuk from 2002 to 2004. The male of the breeding pair hatched in 1991 and the female hatched in 1999. They formed a pair in 2000 and started to breed in 2002. In 2002, although they hatched three chicks successfully for the first time, they failed to rear the chicks. The abandoned

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Table 1. Time table of breeding processes in a Oriental white stork pair over three years (*: chick death)

Year	Nest building	Copulation	Egg laying	Number of eggs	Hatching	Number of nestling	Rearing
2002	10 Jan.-	27 Feb.-	12 Mar.-	4	9 Apr.-	3 (1*)	Hand
2003	25 Dec.-	4 Feb.-	27 Feb.-	4		0	
		7 Apr.-	25 Apr.-	4	3 Jun.-	1	Parents
2004	20 Dec.-	8 Jan.-	13 Feb.-	5		0	
		19 Mar.-	6 Apr.-	3	9 May-	3 (2*)	Parents/Hand

chicks were reared by human. In 2003 and 2004, we applied the double clutching method. We removed the first full clutches from the nest and incubated artificially. The pair incubated the second clutches and completed all the breeding procedures to chick rearing successfully. They reared one chick in 2003 and three chicks in 2004 (Table 1).

The breeding cage was surrounded with wire nets and covered with fabric nets, where a long panel shaded sunlight on the part of the roof. We made a water pond (1.5 × 1 × 0.45 m) in the center of the breeding cage. In addition, we set up a nest platform (1.8 × 1.8 m) on a 1.5 m pole in the breeding cage to help to develop pair bonds and to build nests. For nest building materials, we provided enough branches of 20~70 cm length and dry straws for the pair before the breeding started. We provided loach (*Misgurnus anguillicaudatus*) as food in the breeding periods and controlled the size of loaches as the chicks were growing (Table 2). We restricted visitors from approaching to their nest in order to minimize any potential stress from them.

We observed and recorded all the breeding behaviors, such as nest building, copulation, incubation and chick rearing, of the pair in a breeding cage (5 × 5 × 4.3 m) with a remote camera connected to close circuit television monitors from 0900 to 1800.

We set the first day of nest building when the individuals brought a nest material to the nest. We recorded the frequency of bringing nest materials and time spent for nest building as sex. We judged the success of copulation by whether the cloacae of male and female were contacted or not. We also recorded the frequency and duration of copulations.

Table 2. The Information on the food length and weight of food (loach) controlled in breeding period

Chick's age	Length (cm, N=50)	Weight (g, N=50)
0~2 days	3.5 ± 0.8	2.86 ± 0.28
3~7 days	7.9 ± 1.4	5.32 ± 0.57
No chicks, 8 days	13.1 ± 1.4	18.46 ± 2.29

The wild Oriental white stork delay egg incubation before the full clutch is fulfilled (Fei et al. 1991), however the breeding pair subjected started to incubate eggs right after laying the first egg. Therefore the incubation frequency and duration was recorded as sex from the first egg laying until the first nestling hatching. For the chick rearing behavior, we recorded the frequency of feeding of male and female.

Because the data obtained were distributed normally with Shaprio-Wilk normality test, we applied parametric statistical methods. We used independent samples of t-test to analyze the sexual and annual differences of the breeding behaviors. We analyzed the seasonal tendency of breeding behaviors with curve estimation. Numerical data in the text were presented as mean ± SD.

RESULTS

Nest Building and Copulation

The nest building behavior was observed in 2004. The behavior started about 50 days before laying eggs, in which the time used for the nest building increased steadily (Fig. 1, regression equation, $y = 105.53x + 1361.23$, $F = 4.83$, df = 23, $P < 0.001$).

Although the nest building behavior was observed from both male and female of the pair, the male started the nest building behavior earlier and spent much time than the female in total (male 2,994.54 ± 324.43 sec./d; female 1,541.25 ± 349.93 sec./d; $t = 3.05$, df = 46, $P < 0.01$). However, the female suddenly spent much time in building the nest from 22 days before laying eggs. When we consider the nest building period in two phases on the bases of 22 days before laying eggs, the time spent for nest building between the male and the female during the phase 1 differed significantly

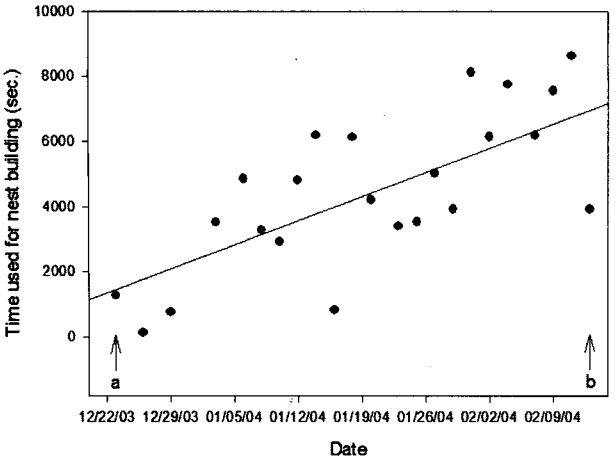

Fig. 1. The relationship between time spent in nest building by a breeding pair from the first day of observation (a) to the first day of egg laying (b). The regression equation is $y = 105.53x + 1361.23$ ($F = 4.83$, df = 23, $P < 0.001$).

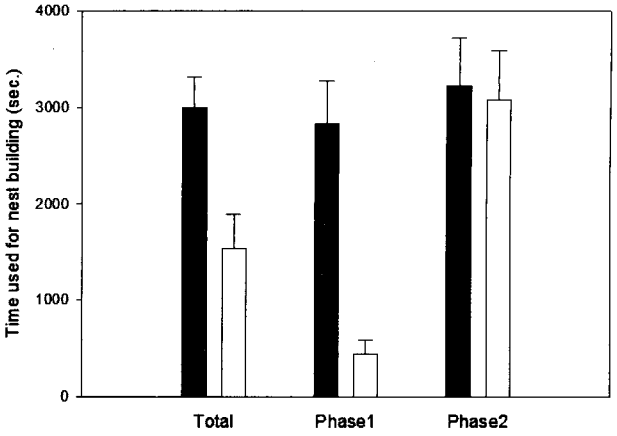

Fig. 2. The comparison of the time used for nest building between male and female. Total: total days from 54 days to before the first day of egg laying, phase 1: 54~23 days, phase 2: 22 days before the first egg laying (■: male, □: female).

(male, 2,829.36 ± 440.78 sec./d; female, 446.57 ± 139.65 sec./d; $t = 5.15$, df = 26, $P < 0.001$), but during the phase 2 did not differ (Fig. 2, male, 3,225.80 ± 492.41 sec./d; female, 3,073.80 ± 514.04 sec./d; $t = 0.21$, df = 18, $P = 0.833$). In phase 2, the male added the new materials to their nest significantly more (14.50 ± 2.52 times / day; $n = 24$) than the female did (1.50 ± 0.41 times / day; $n = 24$; $t = 5.09$, df = 46, $P < 0.001$).

We observed the copulation behavior 20 times in 2002, 29 times in 2003 and 41 times in 2004. The pair started to copulate about one month before laying eggs, in which we observed the behavior one to five times per day.

They did not always succeeded to complete copulation. The copulation success rate was 50.0 % in 2002, 78.6 % in 2003, and 80.0 % in 2004. The duration of the copulation was 15.21 ± 0.90 sec. ($n = 28$) in 2003 and 17.28 ± 0.72 sec. ($n = 25$) in 2004. There was no statistical difference in the duration of the copulation between the two years ($t = 1.77$, df = 51, $P = 0.83$).

Incubation and Hatching Eggs

We observed a crouching behavior of male and female on the nest without any egg regardless of incubation. The behavior appeared 6 days before laying eggs for males and two days before laying eggs for females in 2004 breeding period. This behavior was continued 7~20 min. per day.

The female always laid eggs from 7 to 10 am. The male as well as the female incubated the eggs, but the female spent much time in incubation for three years ($\chi^2 = 1,494.18$, $P < 0.001$). In 2002, the male spent 2,666 min (42.2 %) and the female spent 3,657 min (57.8 %) of total 6,323 min observed time. In 2003, the male spent 3,115 min (32.3 %) and the female spent 6,552 min (67.7 %). In 2004, the male incubated for 4,226 min (44.1 %) and the female incubated for 5,361 min (55.9 %, Fig. 3). The incubating duration per one event was longer in the female (34.81 ± 17.25 min, $n = 166$) than in the male (26.08 ± 11.09 min, $n = 151$; $t = 5.302$, df = 251.55, $P < 0.001$).

We frequently observed the off-duty individual pricked the rump of the incubating individual several times with its bill while members of the pair exchange the duty of incubation. Then, the incubating individual mostly stopped incubating and stood up to shift the incubation duty.

We also observed that the incubating individuals often rotated the eggs or arranged the nest while incubation. The duration ex-

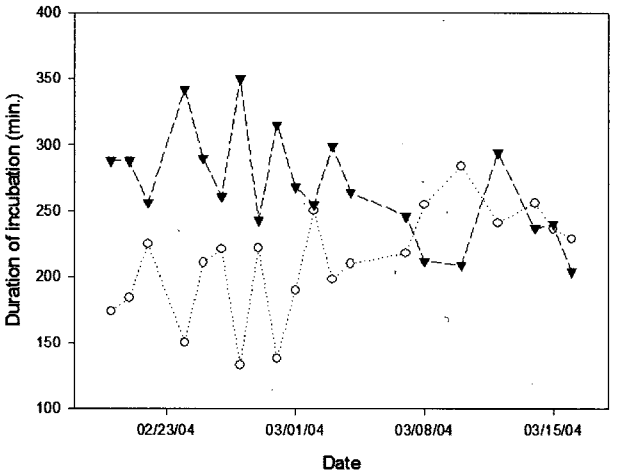

Fig. 3. The duration of incubation according to dates in 2004 breeding season. Female spent more time for incubation than male(○: male, ▲: female).

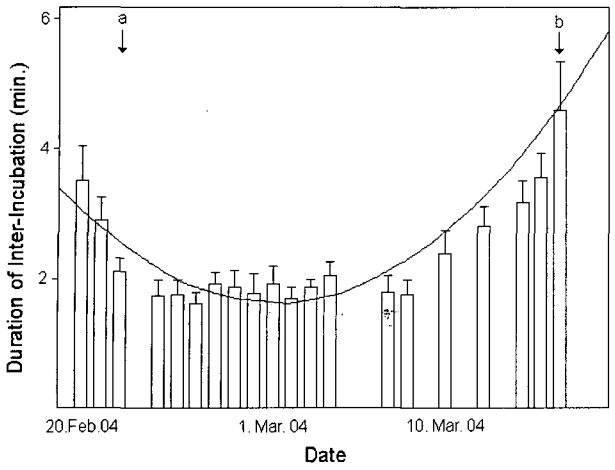

Fig. 4. The seasonal change of inter-incubation duration. The duration across the incubation period fits for a quadratic regression model; $y = 3.3755 - 0.2985x + 0.0126x^2$, $F = 50.70$, df = 322, $P < 0.001$ (a: final day of laying eggs, b: first day of hatching the eggs).

posed to the air without incubation (inter-incubation duration), which occurs when exchanging incubation duty, rotating eggs, and arranging the nest, was 2.40 ± 1.56 min (n = 325). The inter-incubation duration steadily decreased from the first egg towards completing the full clutch. Then, it was stable for about 20 days and increased from 10 days before hatching the eggs (Fig. 4, quadratic regression equation, $y = 3.3755 - 0.2985x + 0.0126x^2$, F = 50.70, df = 322, $P < 0.001$).

The incubation period was 32 ± 1.29 days (n = 6). In 2002, the first and second eggs of the clutch hatched after 32 days and the third after 31 days in 2002 while the first egg after 34 days the second after 32 days, and the third after 30 days.

Rearing Chicks

The parents started to feed chicks several hours after hatching. The chicks did not eat food and just move around in the nest right after egg hatching. The parents vomited food for the chicks 2~3 times a day, and they ate again or removed the left overs from the nest. The chicks tend to eat food one day after hatching. The amount of food chicks ate was sharply increased after initiating to eat food with increase of feeding frequency of the parents until 10 days after egg hatching. After that, the feeding frequency slowly decreased was 2~3 times a day after 30 hatching days (Fig. 5).

The feeding frequency was different depending on the number ofchicks in the nest. The feeding frequency was 7.38 ± 2.75 times (n = 24) with two chicks and 5.21 ± 2.35 times in a day with one chick in the nest (Fig. 5).

Both male and female fed their chicks with vomited food, but

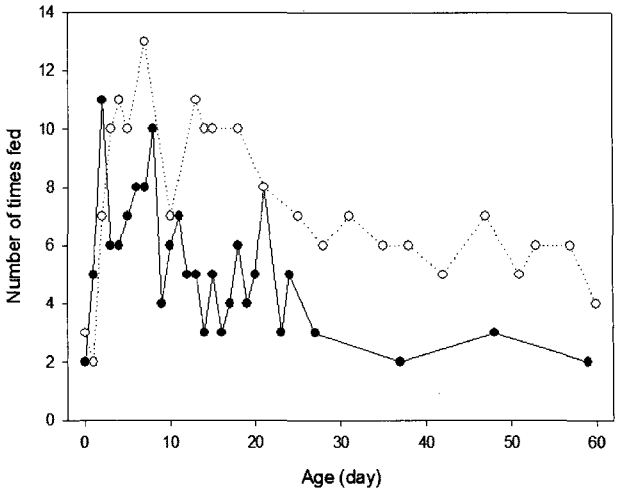

Fig. 5. The number of times fed chicks in 2003 (solid line, n = 1) and 2004 (dashed line, n = 2) breeding season.

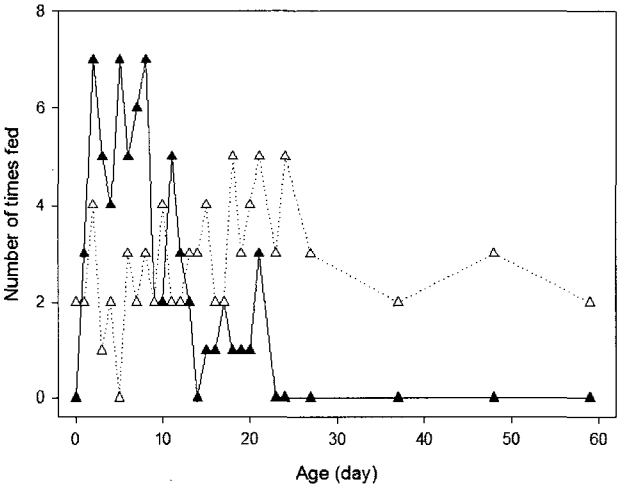

Fig. 6. The frequency of feeding chicks by male (dashed line) and by female (solid line) in 2003.

the frequency between them changed as the chicks grew. In 2003, the female mainly fed the chicks during the first 10 days after hatching, but the male mainly fed after that. Moreover, the female did not feed chicks after 20 days of hatching (Fig. 6). Similarly, the female did not feed the chicks after 20 days of hatching in 2004.

We also observed special parental behaviors such as making the shade, vomiting water, cleaning off the nest, and defending the nest.

DISCUSSION

Minimizing potential stresses of breeding pair from human activities, noise, or traffic is critical in artificial rearing of captive birds (Gill 2001). In addition, the Oriental white storks abandoned

feeding chicks and failed to rear chicks by stress (Sato 2005, personal communication).

This study showed that both members of the pair participated in building and repairing their nest. The frequency of nest building increased with the time of close egg laying. The result was the same to the previous researches (Komain and Sugita 1990, King 1992). The male started breeding behavior earlier than the female, which was suggested that the nest building behavior of the male induce the physiological preparation and elaboration for initiating the female breeding behavior (Mendoza and Mason 1991).

The frequency of adding new materials to the nest differed between the male and female while the time consumed for the nest building did not differ. Some altricial birds showed such difference in nest building (Torikai 1997, Alworth and Scheiber 2000). Smith (1978) suggested the division of labor decreases the consumption of unnecessary energy to ensure the efficient energy investment for successful reproduction. This behavior may adjust sex roles to increase breeding success as males transport the materials and females arrange the nest. Breeding readiness of individuals may be appeared as the crouching behavior. The behavior was observed from an unpaired male as well as a paired female two or three days just before laying eggs. Archibald (1991) suggested the behavior of males to be sexually matured and ready to breed. However, there was no reported in the wild Oriental white stork.

The time spent in incubation was significantly longer for the female than for the male. Similar result was reported for the birds in the field, but captive females spent only 47 % of 107.25 hours observation, less than male, in Vogelpark, German (King 1992). Rather than how much male and female invest time for incubation, whether the both male and female actively take part in incubation play a role in the captive Oriental white stork management.

The inter-incubation duration was relatively longer in the early and late period of incubation. It seems a kind of strategy to induce synchronous egg hatching. The duration may be changed depending on the microbial circumstances of the nest to control the time of hatching eggs (Drent 1975). Such a strategy is essential to breeding success. The synchronously hatched eggs diminish any additional energy and raise the survival rate of chicks (Welty 1982, Wiebe et al. 1998).

This is a case study of the successful breeds of the Oriental white storks in captivity. Even though the detailed breeding techniques of the pair maybe changed slightly year by year (Welty 1982), the data of this study could provide useful information for facilitating ideal breeding environment and inducing prefer breeding conditions for further management plans.

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