Captive Rearing and Breeding of the Crested Ibis, *Nipponia nippon*

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Only seven crested ibis (*Nipponia nippon*) were rediscovered in China in 1981, and the number of birds increased to more than 230 in both wild and captivity by the time of 2000. The following results were obtained in Shaanxi Crested Ibis Feeding and Breeding Center during 1995-2000 : (1) Nineteen breeding pairs laid 325 eggs in total, of which 96 eggs (ca.30%) were damaged in the nests, and 150 eggs (ca.66%) were fertile, from which 127 chicks (ca.88%) hatched and 95 birds (ca.77%) survived to the stage of post-fledging. (2) Considerably high hatchability (ca.99%) was obtained by combination of parental and artificial incubation. (3) Successful improvement of fertility, hatchability and survivability of the crested ibis were demonstrated by cross breeding between the offspring. (4) Sufficient development of human-hand-rearing system was also certified by using artificial diets. (5) Frequent appearance of a kind of physical disturbances was also observed. Collectively, these results show considerably higher rates of fertility, hatchability and survivability of the crested ibis in captivity, suggesting that such heavy inbreeding system as in this study might have not influenced serious damages to the propagation of this species.

Key words : captivity, rearing, breeding, the crested ibis

Introduction

The crested ibis (*Nipponia nippon*) has formerly been found throughout the Russian South Far East, Korea, and Japan to central China (Yamashina, 1975). The population size of this species has been declining dramatically since the early time of the 20th century. By the late 1970s, this species was extinct in Russia and Korea (Achibald and Lantis, 1981 ; Hankcock *et al.*, 1992). In Japan, the last five birds were captured for possible captive breeding in 1981 (Yamashina, 1983), and only a single Japanese crested ibis survived until one pair loaned from Chinese Government to Japanese Emperor was successfully bred at the Sado Ibis Conservation Center in 1999 (Chikatsuji, 1999 ; Fujihara and Xi, 2000).

In China, population size of the crested ibis had declined to only seven, including

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two breeding pairs and three nestlings, which were rediscovered in Yangxian, Shaanxi Province in 1981 (Liu, 1981). Since then, some conservation projects started from these seven birds, aiming at management of free-living crested ibis population and of some basic researches (Liu, 1981 ; Shi *et al.*, 1991 ; Lu, 1999 ; Xi and Fujihara, 2000a, b). Some of the scientific researches have been conducted using accidentally died birds (Fan *et al.*, 2000 ; Liu *et al.*, 1997).

On the other hand, captive breeding of this species has been reported to be quite difficult compared with other wild birds (Tan, 1989), but first successful breeding was achieved in Beijing Zoo in 1989, with two chicks which survived for only one week (Li, 1991). Another captive rearing and breeding started in Shaanxi Crested Ibis Breeding Center in 1990 by rescuing sick or injured chicks and some of the eggs which were deserted by parental birds in the wild (Xi *et al.*, 1995, 1997). Thereafter the crested ibis was successfully bred since 1995, and some progeny joined breeding in the center (Xi *et al.*, 1999).

So far, the most important thing for captive rearing and breeding of the species have been the release of the birds to the wild after the propagation, which may be much more useful to save species from extinction than the case of wild state (Fujihara, 1999 ; Scott and Carpenter, 1987). Concerning this topic, captive breeding of the endangered birds have already been succeeded in such bird as the whooping crane (*Grus americana*) (Cade and Temple, 1994), California condor (*Gymnogyps californianus*) (Kuehler and Witman, 1988), Hawaiian goose (*Branta sandvicensis*) (Black and Banko, 1993 ; Black, 1994) and bald eagle (*Haliaeetus leucocephalus*) (Simons *et al.*, 1988) in the United States, and the bald ibis (*Geronticus eremita*) in Turkey (Akçakaya, 1990). Especially, the Mauritius kestrel (*Falco punctatus*) in Mauritius has been increased from four birds in 1974 to more than 331 individuals by 1994 (Jones *et al.*, 1994), suggesting the possibility of rearing endangered birds by human being in captivity (Clout and Craig, 1994 ; Brownell, 2000).

Therefore, in the present studies, a special attention was paid to the points of captive rearing and breeding of the critical endangered crested ibis, focusing on the population size of individuals in the wild and captivity. These fundamental research data, therefore, may be useful process for providing very important factors to increase the crested ibis population in the wild state.

Materials and Methods

Captive Rearing

To keep the crested ibis, large flight aviaries and chicks-raising laboratories with good facilities for the breeding were established in Yangxian County. In April 1990, four nestlings less than one month old were rescued from wild nests, including one male and three females. Other two birds in 1991, four in 1992, one in 1994 and two more in 1997 were also taken into the captivity due to sick or injury (Xi *et al.*, 1995). Of these 13 birds, 3 birds were died and 4 suffered from several problems with eyes, wings, and legs. In addition to these birds, in 1993 and 1997, six eggs, which were deserted by parents, were collected from the wild nests. By artificial incubation, 4 chicks were

hatched and resulted in 12 birds in total, which were maintained in the Center (Xi *et al.*, 1997).

Captive Breeding

The adult birds reared in the Center were subjected to breeding program since 1995. Breeding systems were designed to be far from possible inbreeding, and the selection of the best couples was conducted according to a pairing test in the cages of the Center (7 m × 5 m), with TV monitoring systems for watching breeding activities of the birds.

Incubation

All eggs used for this study were recorded on laying date and laying time, measured for size, and weighed for further information. In the present studies, three kinds of method were used for incubating eggs : (1) Newly laid eggs were removed just after laying for artificial incubation to promote the birds relaying. (2) Eggs were kept in the nest for entire incubation period, referring to as parental incubation. (3) Eggs were retained in the nests for three weeks and subsequently transferred to an electric incubator until hatching. The incubator was maintained at 37.6 C under 60–70% relative humidity. The humidity was increased up to 70–80% around three days before hatching. The eggs were also cooled at interval of 4 hr per day by opening the door of the incubator.

Brooding

Newly hatched chicks were placed in an artificial nest in a preheated isolate incubator which was maintained at 36 C. After the chicks were 3–5 days old, the temperature was gradually reduced to 33–35 C. At around the 18th day, when the nestlings can move by themselves, the birds were transferred to a rectangular wooden box, in which an incandescent lamp was attached to keep the floor temperature around at 26 C. At 30 days old, the chicks were moved to an enclosure, adjacent to the room for keeping the nestlings inside in the case of raining.

The first feed was given between 10 and 12 hr after hatching, according to the recommended feeding schedule (Table 1), which was based on the diet of the wild

Table 1. Basal diet for the chick, young and adult* of the crested ibis

Age (Days)	Loach (%)	Yolk (%)	Mealworm (%)	Chicken (%)	Milk powder (%)	Apple (%)	Mixed food (%)	Feeding (times/day)
1– 5	40	5	5	6	40	4		6
6–10	46	5	10	15	20	4		6
11–15	68	3	8	9	12			6
16–20	72	3	7	8	10			5
21–30	72	3	5		10			4
31–42	72						28*	3

* Feed composition of mixed food for the adult are : 75% beef, 10% boiled eggs, 8% grain (26% corn, 34% wheat, 40% bean), 5% carrot, 1% milk powder, 1% yeast, calcium tablets, and digestive enzyme tablets.

crested ibis and the diet of the white ibis in Shanghai zoo (He, *et al.*, 1988 ; Shi *et al.*, 1991). The diets were supplemented with vitamins, diastase, pepsin and calcium. Daily feed intake and body weight were recorded until 44 days of post-hatching. After fledging, the birds were generally reared as adult birds.

Results

Egg laying

The egg laying period of the crested ibis lasted from early March to late June. Two or three clutches of 1–6 eggs were laid at intervals of 36–48 hr between eggs and 8–10 days between clutches. The laying time ranged at 06 : 00–08 : 00 (67%), 09 : 00–11 : 00 (5%), and 17 : 00–19 : 00 (28%). As a result, the rate of egg laying for one clutch varied from 6 eggs (3%), 5 eggs (9%), 4 eggs (43%), 3 eggs (39%), 2 eggs (3%) to 1 eggs (3%), respectively. The average clutch size was 3.6 eggs. A total number of 91 clutches with 325 eggs were recorded during the past 6 years (1995–2000). In this study, it was found that approximately 30% of the eggs were damaged by agitated birds flying in or out of the nest during the incubation. However, the fertility rate of remaining intact eggs in the nests was ca.66% on average during 6 years (Fig. 1).

Features of egg

The eggshell color of the crested ibis is blue-green with brown-strips. The followings are the figures on average. The egg weighed 79.11 g (SD=4.08, n=21). The length of the egg was 69.49 mm (SD=0.51, n=53) and the breadth was 46.17 mm (SD=0.42, n=53).

Hatchability and Survivability

Average incubation period of the crested ibis was calculated to be around 27 days (n=119). As for this species, two phases were estimated for embryonic development

Fig. 1. Egg production of the captive Crested Ibis during the past 6 years (1995–2000). Damaged eggs may include some of fertile eggs, since no determination was done for fertility due to the difficulty of candling eggs for this bird.

during the incubation period. The first phase was from day 1 to the piping time, around 25 days + 9 hr (SD = 12 hr, $n = 25$), and the second phase was from piping time to hatching, around 36 hr + 48 min (SD = 4 hr + 27 min, $n = 25$). In the second phase, most important thing was to be careful to peel off the shell by human hand only when self-hatching of the chicks was found to be difficult. For three ways of incubation, 2 chicks hatched from 12 eggs by the entirely parental incubation (natural incubation), resulting in average hatchability of 14% for total incubated eggs and 20% for fertile eggs (Table 2). Five chicks hatched from 16 eggs by entirely artificial incubation, having the hatchability of 20% for all eggs and 33% for fertile eggs (Table 2). On the contrary, 120 chicks hatched from 190 eggs by a combined method of artificial and parental incubation, leading to ca.63% of hatchability for total eggs and 99% for fertile eggs. (Table 2).

It was also found in this experiment that the efficiency of breeding of this species was significantly ($P < 0.05$) improved by cross breeding among the offspring ($F_1 \times F_1$, $F_1 \times F_2$ and $F_2 \times F_2$) (Table 3).

Fledging

The nestlings fledged at approximately 42 days of post-hatching. In the present studies, the birds aged 43–70 days old were classified to be juvenile and the birds from 71 days–2 years old were sub-adults. The birds at 70 days post-fledging start molting, leading to the feather color changed from ash-gray of young birds to pink-white, showing the body size close to the adult. Since this age, a kind of pseudo-copulation was observed in some of the individuals. One of the one-year old female laid two eggs, which were about 20 g smaller than normal eggs. Most of the birds sexually matured at the age of two years when they succeeded in breeding.

Mortality

A total number of 127 chicks hatched at the Center during 6 years (1995–2000), of which 97 individuals were raised by human hand rearing and only one bird by parental rearing. Subsequently, 36 birds of F_1 , 45 of F_2 and 16 of F_3 generations were obtained during 6 years. The mortality of nestlings was ca.18% for 1–10 day chicks, 10% for 11–42 day nestlings, 8% for 43–70 day fledglings, 9% for beyond 70-day birds and 37% for all individuals of the captive population, from the hatching to the adults (Table 4).

With regard to the death of birds, there are many causes : (1) Carelessness of agitated parental birds and (2) many kinds of diseases such as dyspepsia, diarrhea, pneumonia, eye diseases, dysgenopathy, paralysis and some other diseases. After the fledging, considerably high rate of mortality was observed though no clear explanation was provided in the present works (Table 4).

Growth pattern

Hatching weights varied among birds, with a mean of 55.5 g (SD = 0.8 g, $n = 96$), ranging from 44.8 g to 64.3 g. The chicks with hatching weights less than 48 g failed to thrive. Growth of the chicks was slow until about 10 days of post-hatching. After 20 days old, nestlings were provided fresh loach. This period of rapid growth was characterized by an increase in average weight gain from 20 g to 50 g per day. The growth pattern is $w = 1264.4/e^{3.0390 - 0.1394t}$ (Fig. 2). After 37 days of hatching,

Table 2. Comparison of incubation methods including parental,

Incubation Method	Year	1995	1996
Parental ¹⁾	No. of Eggs	2	2
	Fertile eggs	2 (100%)	1 (50%)
	Hatching	1 (50%) ⁴⁾ (50%) ⁵⁾	0
Artificial ²⁾	No. of Eggs	8	2
	Fertile eggs	5 (63%)	1 (50%)
	Hatching	0	0
Combined ³⁾	No. of Eggs	8	16
	Fertile eggs	4 (50%)	12 (75%)
	Hatching	4 (100%) (50%)	12 (100%) (75%)

¹⁾ Incubated by parents throughout the whole incubation period.

²⁾ Incubated by a commercial incubator throughout the whole incubation period.

³⁾ Incubated by parents till 3 weeks (21 days) and subsequently by a commercial

⁴⁾ Calculated by formula : Hatched eggs/fertile eggs $\times$ 100.

⁵⁾ Calculated by formula : Hatched eggs/total eggs incubated $\times$ 100.

Table 3. Comparison of breeding systems with several generations

Breeding System	W ¹⁾ $\times$ W	F ₁ ¹⁾ $\times$ W	F ₁ $\times$ F ₁	F ₁ $\times$ F ₂ ¹⁾	F ₂ $\times$ F ₂
No. birds used	3 ♀ $\times$ 3 ♂ ²⁾ (6ys) ²⁾	4 ♀ $\times$ 4 ♂ ²⁾ (3ys)	6 ♀ $\times$ 6 ♂ ²⁾ (2ys)	4 ♀ $\times$ 4 ♂ ²⁾ (1ys)	2 ♀ $\times$ 2 ♂ ²⁾ (1ys)
No. eggs used	137	66	81	31	10
Damaged eggs	50 (36%)	17 (28%)	14 (17%)	11 (35%)	4 (40%)
Viable Eggs	87 (64%)	49 (72%)	67 (83%)	20 (65%)	6 (60%)
Fertile Eggs	57 (66%)	29 (59%)	49 (73%)	10 (50%)	5 (83%)
Hatched eggs	45 (52%) ³⁾ (79%) ⁴⁾	24 (47%) (79%)	44 (66%) (90%)	9 (45%) (90%)	5 (83%) (100%)
Survived chicks ⁵⁾	34 (76%) ⁶⁾	18 (78%)	32 (73%)	7 (78%)	4 (80%)

¹⁾ W : wild, F₁ : first generation, F₂ : second generation.

²⁾ Breeding years which were combined for this system.

³⁾ Calculated for total eggs incubated.

⁴⁾ Calculated for fertile eggs.

⁵⁾ Chicks survived for 70 days of post-fledging.

⁶⁾ Calculated for hatched chicks.

food intake decreased until 42 days and body weight also declined after 39 days of post-hatching until fledging period (Fig. 3). This decreased body weight after 37 days coincided well to the time of fledging of wild nestlings (Shi, *et al.*, 1991).

artificial, and combination of parental and artificial incubation

1997	1998	1999	2000	Mean
	3	3	4	14
	2 (67%)	2 (67%)	3 (75%)	10 (72%)
	0	0	1 (33 %)	2 (20%)
			(25%)	(14%)
1	2	2	10	25
1 (100%)	2 (100%)	1 (50%)	6 (60%)	16 (71%)
1 (100%)	1 (50%)	0	3 (50%)	5 (33%)
(100%)	(50%)		(30%)	(20%)
9	32	44	81	190
5 (56%)	24 (75%)	29 (66%)	50 (62%)	124 (64%)
5 (100%)	24 (100%)	29 (100%)	46 (92%)	120 (99%)
(56%)	(75%)	(66%)	(57%)	(63%)

incubator.

Table 4. Survivability of the newly hatched Crested Ibis in captivity

Growing Stage*	1995			1996			1997			1998			1999			2000			Mean
(age in day)	l_x	d_x	q_x	l_x	d_x	q_x	l_x	d_x	q_x	l_x	d_x	q_x	l_x	d_x	q_x	l_x	d_x	q_x	Q_x
Hatchling (0-10)	5	2	40%	12	1	8%	6	2	33%	25	1	4%	29	1	3%	50	9	18%	18%
Nestling (11-42)	3	0	0	11	1	9%	4	1	25%	24	1	4%	28	2	7%	41	6	15%	10%
Fledgling (43-70)	3	1	33%	10	0	0	3	0	0	23	1	4%	26	2	4%	35	2	6%	8%
Young (71-Adults)	2	0	0	9	1	11%	3	1	33%	22	2	9%	25	0	0	33	0	0	9%
Total	5	3	60%	12	3	25%	6	4	67%	25	5	20%	29	4	14%	50	17	34%	37%

* Growing stages were classified as hatchling (0-10 days), nestling (11-42days), fledgling (fledged-70 days), and Young birds (70-adults). L_x : Number of hatched chicks, d_x : Number of dead birds, $q_x : d_x/q_x \times 100$, Q_x : Average mortality in six years (1995-2000).

Fig. 2. Growth curve of the crested ibis in captivity.
Vertical bars indicate the standard deviation (SD).

Fig. 3. Food intake for growing nestlings of the crested ibis.
Vertical bars indicate the standard deviation (SD).

Discussion

The crested ibis population has increased sufficiently both in the wild and captivity. A total number of 98 birds were produced in Shaanxi Crested Ibis Breeding Center during the past 6 years (1990–2000). In the wild state, about 100 birds were propagated during around 20 years (Lu *et al.*, 1999 ; Zhai *et al.*, 1999). Therefore, the present results suggest that the captive breeding of this species may also make a great contribution to the increment of population size of the birds. In this case, the release to the wild of captive-bred birds holds certainly the casting vote about the population size of this species in the wildstate.

Recent trends in the conservation of endangered species including birds are to restore these animals in captivity (Cade and Temple, 1994 ; Foose and Ballou, 1988 ; Fujihara, 2000b). These trials are considered to be also necessary for keeping biodiversity on the earth (Brownell *et al.*, 2000 ; Holt *et al.*, 1996). Some of them are the falcons, cranes, and goose, which are now going to be studied extensively (Cade and

Temple, 1994 ; Black, 1994). In this connection, captive breeding of endangered birds has been demonstrated elsewhere. It has also been suggested that these sorts of animals are becoming no common due in part to habitat destruction, and increased information about their care in captivity may help counteracting the decline of population size (Fujihara and Xi, 2000a, b ; Franklin, 1980).

Judging from the present experiments, the loach used as a main diet, which was especially preferred for the crested ibises, was considered to be an essential food material for egg laying of this species. This fish has already been reported to be full of nutrition for animals (Zhao, 1987). In particular, it may include some of nutritional resources required to form eggs, especially as materials for protein and calcium (Perrins, 1996), though further detailed studies will be needed to clarify nutritional mechanism of the loach. However, if this fish is exactly fundamental to keep the crested ibis in captivity, another important factor will occur. The fish must be provided constantly even if some of the environmental conditions are drastically changed on the earth. With regard to this point, some sufficient development of artificial diets for this species may be helpful for everlasting life of the crested ibis.

The percent fertility of the crested ibis during the past 6 years (1995–2000) ranged from 58% to 76% (ca.66% on an average), indicating no definite tendency toward the decrease of breeding rate of the bird. This figure is also very important for the propagation of the crested ibis in the future in the wild state. As for the increased hatchability obtained from the crossbreeding using offspring, the present study failed to clarify the reason for this occurrence, and then the further experiments may be required in the future.

The increased population size of the crested ibis in the present studies apparently suggests that not so severe genetic problems have been observed in the Center. Some evidence of inbreeding depression was shown by relatively high rate of damaged eggs during the incubation and some physical disturbances. In addition to this, in the process of captive breeding, several kinds of physical disturbances were observed, though the reason for that has not been clarified yet in the present works. It is also likely that very strictly limited population size of this species might be responsible for this phenomenon. Therefore, some kinds of defects from the inbreeding system should be checked carefully in case of the captive breeding of rare species of wild animals.

On the contrary, average values for fertility, hatchability and survivability of the crested ibis were 66%, 88% and 77%, respectively. These breeding rates were also similar or slightly higher compared with some other critical endangered birds such as the Mauritius kestrel for which comparable figures were 75%, 78%, and 78%, respectively (Jones *et al.*, 1994).

With regard to the combined method of incubation, in case of the captive-bred crested ibis, most of the male and female have a tendency to abandon their parental duties for brooding. Therefore, toward the end of parental incubation, a kind of help by human being will be needed to have successful results in the hatching. According to the preliminary experiments, better results were obtained when the incubating eggs were removed from the nests to the artificial incubator toward the third period (ca. 3

weeks) of the parental incubation in the wild state. As a result, the combined method of parental and artificial incubation was considered to be the best for this species at the present.

These data also show the possibility of genetic diversity of the crested ibis based on the viewpoint of DNA differences between individuals. The present finding, in which the crested ibis has been bred by inbreeding manner, may suggest that most of the endangered wild birds probably increase in population without receiving any serious problems due to the inbreeding system.

In conclusion, the previous reports on this species have been mainly focused on the points of natural observation, especially on some kinds of behaviors in the wild state. The present studies, on the contrary, might have verified many sorts of basic researches which may provide the first scientific data regarding the crested ibis throughout feeding and breeding in the captivity. These data also show the possibility of genetic diversity of the crested ibis via DNA distance between individuals, even if these wild birds started breeding by inbreeding system. Therefore, most of the endangered wild animals will increase population size probably without having so serious damages by inbreeding manner.

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