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ORIGINAL ARTICLE

Breeding biology of the Oriental White Stork reintroduced in Central Japan

—Effects of artificial feeding and nest-tower arrangement upon breeding season and nesting success—

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Abstract Reintroduction of the Oriental White Stork *Ciconia boyciana* into Tajima District, Hyogo Prefecture started in 2005 and the population size is increasing with successful breeding in the wild. Our study on the reintroduced population composed of banded birds evidenced that the pair once formed continues to breed in a same place and the pair-bond continues over years. Eight pairs laid 29 clutches including 3 replacement ones in 5 years between 2007 and 2011. From information on the day of egg-laying, hatching, fledging of these clutches, it was concluded that incubation and nestling periods are 31–35 days and 63–74 days, respectively. Thus it takes about 100 days from egg-laying to fledging of young. Egg-laying started between early March and late April and fledging occurred from mid-June to late July excluding those by pairs that were fed enough artificially. They laid eggs and fledged young exceptionally early. Clutch-size was 3 or 4 in most cases, whereas clutch-size of 6 was available only from artificially well-fed pairs. Success rate of the first clutch of a year to fledge at least one young was 0.65 and the probability of an egg to fledge was 0.34. The average number of fledglings was 1.2 birds per first clutch of the year. Chicks were killed by predators and neighbouring territory owners, and parental infanticide occurred in three nests. The effects of artificial feeding and nest-tower arrangement on breeding are discussed.

Key words Breeding season, *Ciconia boyciana*, Clutch size, Infanticide, Pair-bond, Reintroduction

Introduction

A wild population of the Oriental White Stork *Ciconia boyciana* existed in Tajima District, northern part of Hyogo Prefecture until 1960's, but it was extinct in 1971. Just before extinction the small number of storks that survived in the wild was captured, and an attempt of captive breeding started in aviaries constructed in Toyo-oka City. The success was brought about in 1989 by a pair of storks transferred by Russian Government. Thereafter captive population size increased over 100, and reintroduction started in 2005. Seven birds being the van for the year, 27 birds in total were released into the wild by Hyogo Park of the Oriental White Stork (HPOWS), a prefectural institute specializing in reintroduction of the stork that was established in 1999 and taking over the aviaries. It was in 2006 that the first clutch was laid in the wild, and in 2007 the first chick fledged after 46 years from the last fledging in the wild in Japan and population size is increasing thereafter (HPOWS, 2011).

Pairs of the Oriental White Stork have territories throughout a year (HPOWS, 2011) and after reintroduction most of the pairs bred on artificial nest-towers built by various kinds of stakeholders including the Government of Hyogo Prefecture, the Government of Toyo-oka City, HPOWS and residents of the City. Some of the towers are built in the open space in paddy field area, different from the past wild population that nested on top of large pine trees on the hill-side facing paddy field (Iwasa, 1936a,b). And some of the pairs have raised their young depending on fish artificially supplied.

In this paper we report breeding biology of the Oriental White Stork reintroduced in Hyogo Prefecture, Japan based on data acquired for pairs that bred between 2007 and 2011, and discuss effects of artificial feeding and nest-tower arrangement. Scientific information on ecology and

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breeding biology of the past Japanese wild population is restricted to Yamashina (1941). Information on wild populations that breed in Russia and China, on the other hand, is mostly descriptive. Thus this paper probably is the first one that reports on breeding biology of this species with enough quantitative data.

Study area and methods

Toyo-oka City where the reintroduction project has been carried out is situated at the northernmost part of Hyogo Prefecture facing Japan Sea. River Maruyama flowing from south to north forms a large floodplain called Toyo-oka Basin surrounded by low-elevation hills, suitable for breeding of the Oriental White Stork in the wild.

Released birds are all colour-banded and are identifiable individually. Pairs nested in 9 rural areas of Toyo-oka City, namely Akaishi (initialed as A), Fukuda (F), Hinado (H), Izu (I), Nojo (N), Sho-unji (S), Toshima (T), Yuruji (Y) and Yamamoto (YM). Fig.1 shows distribution of the nest towers used by pairs with information on the location of HPOWS. It can be seen that some nest-towers are set back and located more than 1km from the main flow of River Maruyama like F, N, H, S and YM, whereas T, A, Y and I are located near that or near River Izushi that joins the main flow at the 15 km spot upstream from the river-mouth. Moreover Y is almost at the centre of an extensive open space of paddy field. Many of the pair members often fly to an open cage of HPOWS during the non-breeding season and forage that, where fish are supplied to storks displayed for public all the year round that are kept flightless by regular feather-cutting. Pair Y (meaning the pair that nested in area Y) that fledged the first chick in 2007 had been fed enough (1 kg of fish/day) by HPOWS all the year round in order to solicit their settlement in the first stage of reintroduction until it was completely stopped in 2012. Pair T has been regularly fed about 500 g of fish by a NPO managing the wetland including the nest-tower during winter and the breeding season until it was completely stopped in 2012. Pair N has been fed a little, irregularly and privately. Other pairs were not fed artificially within their territories. Other than on nest-towers, storks often tried to nest on telegraph poles that exist all over Toyo-oka Basin and on the cages

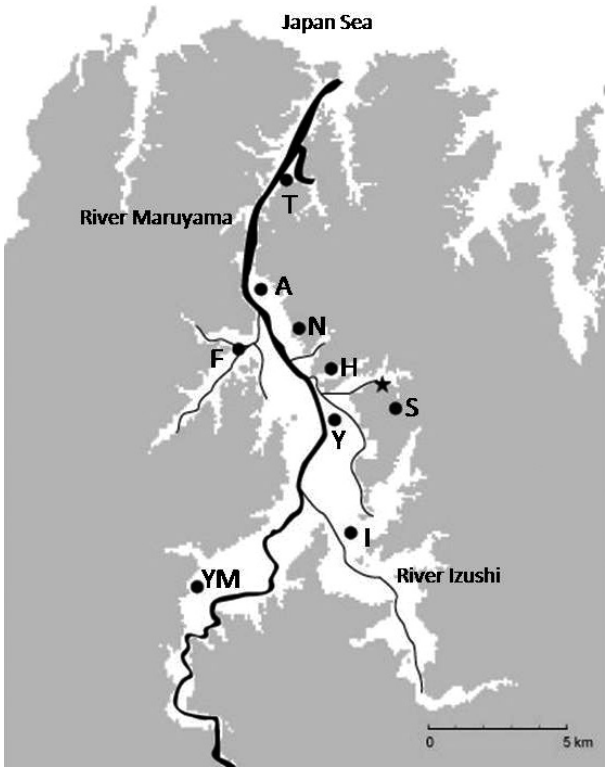

Fig. 1. Study area and distribution of nest-towers used by pairs of the Oriental White Stork. Hills higher than 20 m above sea level are shaded. Nest name is same with the area name, Akaishi (A), Fukuda (F), Hinado (H), Izu (I), Nojo (N), Sho-unji (S), Toshima (T), Yuruji (Y) and Yamamoto (YM). The nest-tower of H was not used and the pair nested on a telegraph pole nearby. A sign of star indicates the location of the main premise of HPOWS in Sho-unji area.

of captive storks within the two distinct premises of HPOWS, situated in Sho-unji (the main premise) and Nojo (the branch aviaries), respectively. The nesting on the pole and the cage has been artificially disturbed in order to avoid electric accidents and intra-specific infection of diseases from the wild to captive birds. Despite these disturbances some pairs laid clutches on nests put on the pole or on the cage. The examples are the clutch laid by pair N in 2008 that nested on a cage located in the branch aviaries of Nojo, pair N in 2009 that nested on a telegraph pole, pair S in 2009 that nested on a cage in the main premise of HPOWS in Sho-unji and pair H in 2010 that nested on a telegraph pole. Of them, pair S in 2009 gave up breeding but from other 3 clutches chicks fledged as shown in results. In this paper we name each pair by combining the year and area name (*e.g.* 2010S) and often by area name only.

Nest towers are 8.0–12.5 m high and it is not easy to confirm the nest content until chicks grow up and become

visible from the ground. But we made every effort to confirm the nest content throughout the nesting period by watching directly using 8x binoculars and 25x telescopes from higher places on the hill, sometimes from the top of a mobile elevation system, and indirectly by using video cameras. In these cases we could determine the exact date of first egg-laying and first hatching in a nest, and exact number of eggs and hatchlings. On the other hand, it was very easy to watch and confirm fledging of young birds directly.

Results

Pairs and their nesting

Number of pairs that laid eggs in Toyo-oka Basin was 2 in 2007, 5 in 2008, 6 in 2009, 7 in 2010 and 6 in 2011, totaling up to 26 in 5 years (Table 1). It can be seen that the pairs bred continuously every year with the same mate once they started breeding, except the cases where the males were dead in accidents at the start of the breeding season. Although the female of pair S between 2009 and 2011 was not banded, it is highly possible that it was the same individual throughout the study period, because she was the only non-banded adult female with no young feathers during the study period, probably a wild immigrant from the continent. Nesting places of a same pair were also the same in principle. The only exception was the pair between J0389 and J0384 that started on the nest-tower of A in 2007 but changed to the nest-tower of F in 2008 and returned to A in 2009. The youngest pair was 2007A, both the male and the female being born 3 years before the first breeding. And the male of 2008N was 2 years old when he joined the first breeding. It should be added that the age of a non-banded male of pair 2011YM is estimated to be 3, because non-banded fledglings at that time were restricted to those from pair I in 2008.

Breeding season and the length of nesting period

During the 5 years 26 pairs in total laid 29 clutches including 3 replacement ones after failure (Table 2). Of the 26 first clutches no eggs hatched from 6 clutches (code 2, 9, 13, 21, 25 26), resulting in 77% (20/26) of hatching success per clutch. The exact day of first egg-laying of the year is known for 9 pairs (code 10, 12, 13, 16, 17, 19, 20, 23, 25) and with a few days of estimation ranges for 4 clutches (code 1, 6, 18, 26). Of these 13 clutches, the ear-

Table 1. Nest site of storks that bred between 2007 and 2011 and their age of first breeding. Males and females occupying a same nesting site in a year is a pair. Banded birds have their own individual codes and NB indicate non-banded birds. Regarding the age of a non-banded male, refer to the text.

Individual code	Sex	Year of Birth	Nest site					Age of 1st breeding
			2007	2008	2009	2010	2011	
J0275	male	2000	Y	Y	Y	Y	Y	7
J0228	female	1998	Y	Y	Y	Y	Y	9
J0389	male	2004	A	F	A	A	†	3
J0384	female	2004	A	F	A	A		3
J0391	male	2004		T	T	T	T	4
J0294	female	2001		T	T	T	T	7
J0001	male	2006		N	N	N	N	2
J0362	female	2003		N	N	N	N	5
J0381	male	2004		I	I	I	I	5
J0296	female	2001		I	I	I	I	7
J0405	male	2006			S	S	S	3
NB	female	unknown			S	S	S	unknown
J0408	male	2006				H	†	4
J0002	female	2006				H		4
NB	male	2008					YM	3
J0399	female	2005					YM	6

Y: Yuruji; A: Akaishi; F: Fukuda; T: Toshima; N: Nojo; I: Izu; S: Sho-unji; H: Hinado; YM: Yamamoto

†: dead in accidents at the start of the breeding season

Table 2. Breeding season of the Oriental White Stork and length of incubation, nestling and nesting periods, the last meaning those from the day of first egg-laying to fledging of the first chick, for the first clutch of the year by each pair (a) and for replacement clutches after failure (b). The day of each event is not always exactly known and a sign "～" is used when the event occurred on or before the day. Code number is given for each of the 29 clutches. Pairs with asterisks nested on the telegraph pole or on the cage of captive storks.

a)

Code no.	Pair name	Start of			Days of		
		egg-laying	hatching	fledging	incubation	nestling	nesting
1	2007Y	14–18 April	19–20 May	31 July	31–36	72–73	103–109
2	2007A	～10 April					
3	2008Y	～4 March	～22 March	4 June		≧74	≧92
4	2008F	～26 March	～20 April	22 June		≧63	≧88
5	2008T		28 April	2 July		65	
6	2008N*	28–31 March	1 May	3 July	31–34	63	94–97
7	2008I	～31 March	～14 May	20 July		≧67	≧111
8	2009Y	～12 February	11 March	24 May	≧27	74	≧101
9	2009A	～21 April					
10	2009T	28 February	2 April	9 June	34	68	102
11	2009N*	～22 March	22 April	29 June	≧31	68	≧99
12	2009I	8 April	11 May	16 July	33	66	99
13	2009S*	16 March					
14	2010Y	～23 February	～27 March				
15	2010A		～11 April	14 June		≧64	
16	2010T	21 February	～28 March	8 June	≦36	≧72	108
17	2010N	21 April	26 May		35		
18	2010I	22–23 March	～28 April		≦36		
19	2010S	17 March	17 April	23 June	31	67	98
20	2010H*	16 March	19 April	30 June	34	72	106
21	2011Y	～21 April					
22	2011T	～2 March	～6 April	9 June		≧64	≧99
23	2011N	26 March	28 April	2 July	33	65	98
24	2011I		～12 May	17 July		66	
25	2011S	9 March					
26	2011YM	16–17 March					

b)

Code no.	Clutch name	Start of			Days of		
		egg-laying	hatching	fledging	incubation	nestling	nesting
27	2010Y	～1 June	～30 June	29 August		≧53	≧89
28	2011Y	～29 June	～18 July	21 September		≧65	≧84
29	2011S	14 April	17 May	20 July	33	64	97

liest egg-laying occurred in February for 2009T (code 10 on 28 Feb.) and 2010T (code 16 on 21 Feb.) that were fed regularly. And pair Y that were fed enough is known to have started egg-laying in February of 2009 and 2010 (code 8, 14), the former being the earliest of all clutches, although the exact day is not known (on or before 12 Feb.). Excluding the two regularly fed pairs, egg-laying started between early March and late April (9 March-21 April). The date of fledging of the earliest chick is known for all of the 17 first clutches that were successful. Here also, the earliest records are available in regularly fed pairs (code 3 and 8 in May or early June by pair Y, code 10 and 16 in early June both by pair T). Excluding them, fledging occurred from mid-June to late July (14 June to 31 July). In 3 replacement clutches egg-laying started in April or June and chicks fledged from July to September.

Incubation period (days between first egg-laying and first chick hatching) is exactly known for 6 first clutches

(code 10, 12, 17, 19, 20, 23), which is distributed in a range of 31–35 days. For other 2 clutches incubation periods with estimation ranges, being 31–36 days (code 1) and 31–34 days (code 6), consist with the result from exact data. Information on other 4 clutches (code 8, 11, 16, 18) does not contradict the conclusion of 31–35 days of incubation period. For nestling period, exact information is in a range of 63–74 days (code 6 the shortest, 8 the longest) and this range can explain all other first clutches. The nesting period, from first egg-laying to first young fledging, is in a range of 98–108 days for 6 clutches with exact data (code 10, 12, 16, 19, 20, 23). This range can explain all other clutches whose nesting period is not known exactly except code 7 whose nesting period is 111 days. We can conclude that about 100 days are required from egg-laying to fledging. Conclusions on incubation, nestling and nesting periods as being 31–35, 63–74 and about 100 days are consistent with the 3 replacement clutches.

Clutch size and breeding success

Seventeen of the 26 first clutches produced at least one fledgling, success rate per clutch being 0.65 (17/26). Nine unsuccessful clutches include 3 (code 2, 13, 26) by pairs that bred for the first time whose success rate is 0.63 (5/8), not different from 0.67 (12/18) by other pairs. The female of pair S when she bred first with the mate in 2009 (code 13) laid 10 eggs, because the male of 3 years old mishandled and destructed eggs by himself three times (1st to 3rd eggs) and crows depredated the other eggs on the day each egg was laid. This pair did not lay replacement clutch this year (Table 3). Video cameras were used to observe this clutch and the interval between each egg-laying is known as 2 days in three cases, 3 days in five cases and 4 days in one case. The interval of egg-laying is precisely known for clutch-code 19 by pair 2010S for which video cameras were used again. The female in this year laid 4 eggs and the interval between eggs were 2 days in every case.

For 25 clutches other than code 13 by pair 2009S, "concept of clutch-size" is applicable and the exact clutch-sizes are known for 15 first clutches, which is distributed in a range 2–6 and the average clutch-size is 3.9 (59/15). The largest clutch-size of 6 was recorded for clutch-code 8 and 14 both by pair Y that was artificially fed enough. Other pairs are not known to have laid 6 eggs. Of the 25 first clutches that completed clutches, breeding failed during incubation period in 5 nests (code 2, 9, 21, 25, 26). Mortality factor of these eggs is not known. Brood-size, the full number of hatchlings is exactly known for 15 broods including the 5 clutches that failed during incubation (brood-size: zero). The average brood-size is calculated as 1.7 (26/15). If we exclude the 5 clutches that failed during incubation, the average brood-size is calculated as 2.6 (26/10).

Chicks that fledged from 26 first clutches total up to 30 birds. Thus, the average breeding success is calculated as 1.2 birds per first clutch (30/26). Replacement clutches added 7 fledglings from 3 nests. The interval between fledging of different chicks in a nest is in a range of 0 (same day)-6 days between 1st and 2nd fledging, and 0–3 days between 2nd and 3rd fledging (there was an exceptional case of 22 days between 2nd and 3rd in clutch-code 12, whose 3rd chick was not well nourished) including replacement clutches (see Table 3).

Mortality factors during the nestling period are predation (one chick), parental infanticide (4 chicks) and intra-specific attack against nestlings (1 chick). The predation occurred in the nest of pair I (code 7) on 20 May 2008. A Black Kite *Milvus migrans* attacked the nest while the parents were absent and carried away one of the 3 nestlings. The age of the chick is estimated to be about a few days, if we count backward from the day of fledging assuming nestling period as being 70 days (see Table 2). Parental infanticide was recorded in 3 nests. On 30 April 2010 the female of pair S (code 19) took a nestling that hatched about 2 weeks before (see Table 2) and deserted it outside the nest. The other 2 nests are both by pair Y in replacement clutches (code 27, 28). On 5 July 2010 the male of pair Y tried to swallow 2 chicks that were the smallest of the 5 nestlings (about two weeks after hatching if we assume nestling period as being 70 days, see Table 2) but in failure, one of which being found dead thereafter. And 3 days later on 8 July, the male took the smallest of the surviving 4 chicks and deserted it outside the nest. On 28 July 2011 the same male took the smallest of the surviving 3 chicks from the nest of 2011Y and deserted that into a small pool on the ground near the nest site. The age of the chick is estimated to be about two weeks if we assume nestling period as being 70 days (see Table 2). Intra-specific attacks were observed at 2009T

Table 3. Breeding success of the Oriental White Stork for the first clutch of the yearof each pair (a) and for replacement clutches after failure (b). Number of eggs and nestlings are not always exactly known and signs of inequality are used in such cases indicating the minimum number. Mortality factors during egg stage are not known except for clutch-code 13, the details being described in the text.

a)

Code no.	Pair name	Number of			Fledging interval (days)		Chick mortality
		eggs	nestlings	fledglings	1st-2nd	2nd-3rd	factor
1	2007Y	≧3	≧2	1			
2	2007A	3	0	0			
3	2008Y	≧5	≧3	2	6		
4	2008F	3	≧1	1			
5	2008T	≧3	≧3	3	1	3	
6	2008N	≧4	≧1	1			
7	2008I	3	≧2	1			Predation
8	2009Y	6	≧4	1			
9	2009A	4	0	0			
10	2009T	4	4	3	2	0	Intra-specific attack
11	2009N	4	3	3	0	3	
12	2009I	4	3	3	1	22	
13	2009S	10	−	−			
14	2010Y	6	2	0			
15	2010A	≧1	≧1	1			
16	2010T	4	≧2	2	3		
17	2010N	≧4	1	0			
18	2010I	≧2	1	0			
19	2010S	4	3	2	2		Infanticide
20	2010H	4	2	1			
21	2011Y	2	0	0			
22	2011T	4	≧3	2	2		
23	2011N	4	4	1			
24	2011I	≧3	3	2	3		
25	2011S	≧4	0	0			
26	2011YM	≧2	0	0			

b)

Code no.	Pair name	Number of			Fledging interval (days)		
		eggs	nestlings	fledglings	1st-2nd	2nd-3rd	
27	2010Y	6	5	3	0	0	Infanticide
28	2011Y	≧6	≧5	2	3		Infanticide
29	2011S	4	4	2	0		

(code 10). On 6 and 15 May 2009 the male of pair A, the owner of the neighbouring territory that failed in breeding, flied to the nest while the parents were absent and violently attacked the 3 nestlings after a month of hatching (see Table 2). Although the death of one chick was confirmed later on 18 May, it is highly probable that these attacks caused its death.

We must be careful in calculating success rate per egg because exact information on clutch-size is available for 15 (code 2, 4, 7–12, 14, 16, 19–23) of the 26 first clutches. The eggs laid by them totaled up to 59 and 20 chicks fledged from these nests. Thus the probability of an egg to fledge is calculated as 0.34 (20/59).

Discussion

This is the first study that evidenced existence and continuity of the pair-bond over several years by identifying Oriental White Storks individually. In captive population storks usually start breeding when they are four years old

(Ogawa, 2011). In this study, however, a male of two years old succeeded in fledging a chick (clutch-code 6) and a pair formed between birds of 3 years old laid eggs (code 2), and males of three years old joined breeding (code 13, 26), although pairs other than the first one did not fledge any young.

Information on breeding biology of the past wild population is limited to Yamashina (1941). It describes clutch-size usually to be 3 or 4 and irregularly 2 or 6. Results of our study coincides completely to his description, although the fact that the largest clutch size was recorded from pairs regularly fed should be referred to later again. The upper limit of 5 eggs per clutch is common to descriptive notes by Russian and Chinese biologists (Fei 1991; Fei et al. 1991; Li et al. 1991; Roslyakov et al. 2000). Darman et al. (2000) who collected information using helicopters in Amur Region describes that average clutch-size in May 1998 was 3.4 for 25 nests that is exceeded by our result of 3.9 per first clutch. The same authors describes the average brood-size to be 2.5 in July which is almost the same with the result of this study 2.6, excluding clutches that failed during incubation. Information on number of fledglings is rare. Fei (1991) recorded number of eggs, hatchlings and fledglings, perhaps by a same pair for 10 years. According to his data, 9 chicks fledged from 10 nests, 0.9 per nest which is smaller than for our population of 1.2. Thus, as long as number of eggs, chicks and fledglings are concerned, our population is similar to the wild Japanese population in the past, and as successful as, or better than those breeding on the continent.

Concerning breeding season, egg-laying is described to start in March or April by Yamashina (1934), which coincides completely with this study if we exclude clutches laid by regularly fed pairs that started their clutches in February. On the continent also several authors describes that to be April (Fei 1991; Fei et al. 1991; Li et al. 1991; Roslyakov et al. 2000).

Here we should discuss the effect of artificial feeding on breeding biology of the Oriental White Stork. In this study egg-laying in February was recorded only in the 4 nests by two pairs that were fed regularly. The timing of egg-laying is greatly affected by physiological conditions of the female, because she requires much food to produce eggs (Daan *et al.* 1986). It is highly possible that the artificial feeding stimulated too early egg-laying of the two pairs, and it is possible that the artificial feeding is responsible also to the large clutch-size in their nests. These possibilities can be tested by experimental stops of artificial feeding.

This study suggests that predators on eggs and nestlings come only from air, like crows and kites. This is attributable to the location of the artificial nest-towers that are built in the open space having some, long or short distances from the hill. It is impossible for terrestrial predators to approach the nest, probably different from the past wild population that nested on a tree on the hill-side that is accessible for mammals and snakes.

As described in results, a pair male attacked his neighbouring nest and is supposed to have killed a chick. It is suggested that nests were invisible with each other in the past wild population due to their positioning in the hill-side (HPOWS 2011). The intra-specific attack occurred between nests near the main flow of River Maruyama, and hence the spatial relationship of them, visibility of nests could cause an easy attack.

This study will be the first one that reports the existence of parental infanticide in the Oriental White Stork just like the White Stork *Ciconia ciconia* (*e.g.* Jakubiec 1991, Tortosa and Rodondo 1992). Zielinski (2002) suggests that parental infanticide in this group of birds functions as an effective measure of brood reduction in years of relative food shortage. In this study, however, 3 of the 4 infanticide occurred in nests that were fed enough, contradicting the hypothesis of brood reduction. On the other hand, the pair concerned nested at the centre of an extensive open space of paddy field, completely different from the past wild population. The nest is visible from all the directions. The unnatural nest-site and food provisioning both brought about artificially must have made the state of affairs surrounding the pair very complicated. Hence this subject should be studied in near future under conditions with no artificial feeding after appropriate rearrangement of nest-towers.

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再導入されたコウノトリの繁殖期と繁殖成功，および給餌と人工巣塔の影響

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摘　要

兵庫県但馬地方でコウノトリの野生復帰が開始されたのは2005年のことであり，個体数は野外繁殖の成功とともに増加している．当該個体群は個体識別されており，コウノトリのペアはいったん繁殖すると同じ場所で相手を変えず繁殖し続けること，つまりつがいのきずなが続くことが証明された．2007年から2011年の５年間に８ペアが，失敗後のやり直しの３クラッチを含めて29クラッチを産んだので，これに対して定量的な解析を行なった．その結果，抱卵期と育雛期がそれぞれ31-35日と63-74日であり，産卵開始から最初のヒナが巣立つまでにおおよそ100日を要すると結論できる．また，産卵期は３月上旬から４月下旬，ヒナの巣立ち期は６月中旬から７月下旬の間であった．いっぽう十分な給餌を受けていたペアの産卵と巣立ちは例外的に早かった．クラッチサイズはほとんどが３もしくは４であり，例外的な卵数６は十分な給餌を受けていたペアのみで記録された．ヒナの死亡はトビによる捕食と隣接ペアによる襲撃によって起こったが，親による子殺しが３巣で見られ，これにより４ヒナが死亡した．給餌と人工巣塔上での営巣およびその配置はコウノトリの繁殖生態に大きな影響を与えており，十分な給餌を受けているペアで子殺しが多く起きたので，これに関与する要因は複雑であると考えられる．

キーワード　繁殖期，コウノトリ，クラッチサイズ，子殺し，つがいのきずな，野生復帰