

Lessons learnt from the successful reintroduction of Crested Ibis *Nipponia nippon*

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Figure 1. One of the successfully reintroduced adult Crested Ibis *Nipponia nippon* on Sado Island. (Photo by Yuji Okahisa).

History of Crested Ibis in Japan

Crested Ibis *Nipponia nippon* (Figure 1), is widely known as one of the bird species that became extinct in Japan during the initial wildlife conservation efforts (Yamashina and Nakanishi 1983). Crested Ibis, however, is no longer extinct as it was successfully reintroduced.

Crested Ibis was distributed over a wide area of Far East Asia, from southeastern Russia, the Korean Peninsula, China, Taiwan, and western

Hokkaido, to Okinawa in Japan until the 19th century (Yamashina and Nakanishi 1983; Birdlife International 2001; Li *et al.* 2009; Park *et al.* 2010). Currently, wild populations are only in Yangxian, China. Reintroduction programs are ongoing at Sado Island in Japan, Changnyeong in South Korea, and six other locations in China (Su and Kawai 2015; Yoon and Choi 2018).

In Japan, Crested Ibis mainly bred in the eastern part of Japan and wintered over a wider area of Japan (Figure 2). In the past, records indicated that the ibises were captured for the use of their feathers and artificially introduced into western Japan in the late 1600s and early 1700s (Ishikawa Prefectural Museum of History 2010; Kaji 2018). Unfortunately, after the ban on hunting was lifted

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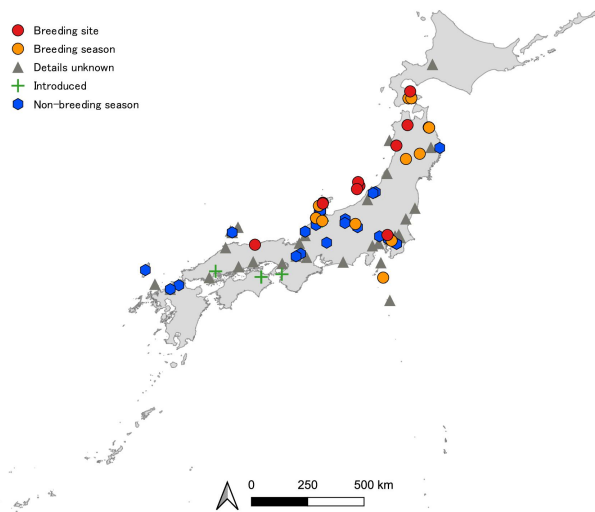


Figure 2. Records of Japanese Crested Ibis before extinction. (Breeding site: records of nests or breeding; Breeding season: records of ibis in the breeding season (from April to June); Non-breeding season: records of ibis in the non-breeding season (from July to March); Details unknown: no detailed information available of the sightings; Introduced: introduced in the Edo period. Data were collected from the following publications: Yamashina and Nakanishi 1983; Takahashi 1995; Birdlife International 2001; Ishikawa Prefectural Museum of History 2010; Kanto Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism 2010; Kaji 2018; Okamura 2019.)

in 1868, the ibis population declined rapidly (Yamashina and Nakanishi 1983). Large numbers of ibis were killed and exported to Europe where their feathers were used to make feather brooms, feather caps, etc. (Uchida 1915; 1933; Forestry Agency 1969). As a result of unsustainable hunting, the ibis was believed to have gone extinct around 1925 (Nakamura 1925). After that, small populations were found surviving on Sado Island and Noto Peninsula, and conservation efforts were initiated in the 1920s (Yamashina and Nakanishi 1983). However, conservation activities were interrupted and halted by the Pacific War and only resumed after the end of the war. Since 1946, feeding, restrictions on human access to nesting forests, construction of completely pesticide-free paddy fields to increase prey species, predator control, and rescue of injured individuals, have been implemented by both local residents and the national government (Niigata Prefectural Board of Education 1974; Niigata Prefecture 2000). In addition, the government bought and nationalized the nesting forest to make it a protected area (Niigata Prefectural Board of Education 1974; Niigata Prefecture 2000). In 1940s, Japan had no laws for the conservation of endangered wildlife. The Ministry of the Environment was established in 1971 whilst the Crested Ibis conservation project was underway. The conservation and propagation project attracted Japanese national attention as being the first modern endangered species conservation activity in Japan. However, the Japanese wild Crested Ibis population declined owing to breeding abandonment due to observation pressure by photographers and TV stations, accidental shots and capture by steel traps, predation by invasive Japanese Martens

Martes melampus, and agrochemicals (Niigata Prefecture 2000; Okahisa 2022). The population became extinct in the wild when all five birds living on Sado Island were captured for captive breeding in 1981 (Niigata Prefecture 2000). Unfortunately, initial attempts at captive breeding were unsuccessful, and the Japanese population became extinct in 2003 (Nagata and Yamagishi, 2013). The failure to protect the Crested Ibis demonstrated the difficulty of protecting endangered species and the fragility of nature.

Seven Crested Ibis were discovered in China in 1981. One of them was transported to Japan for captive breeding, which was the first exchange between the Japanese and Chinese captive populations (Liu 1981; Tan 1989; Niigata Prefecture 2000). Since 1999, Crested Ibises obtained from China were successfully bred in captivity on Sado Island, with the captive population growing steadily. Once the captive population reached 100, the reintroduction of Crested Ibis to areas within their known distribution range was started on Sado Island in 2008 (Nagata and Yamagishi 2013). To date, 26 releases have resulted in a total of 446 wild-living Crested Ibises.

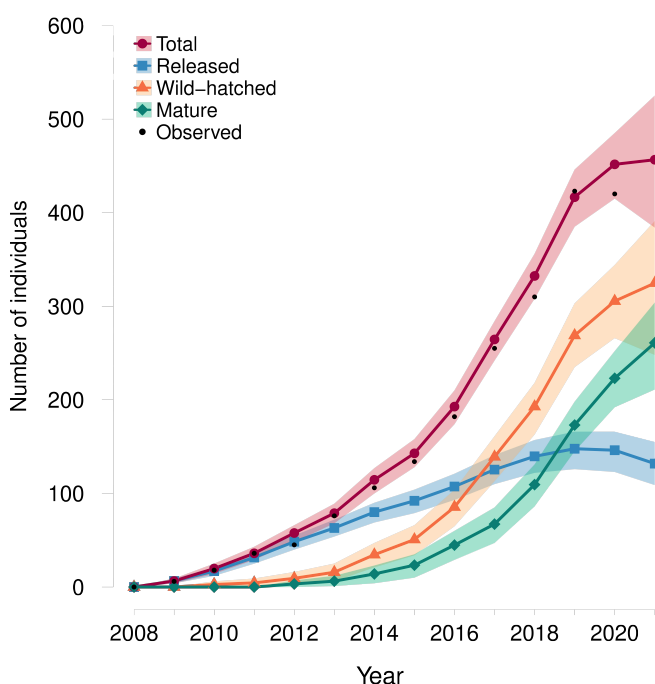
Status of the reintroduced population

Monitoring of the reintroduced ibis is being performed by 'Team Ibis', which comprises the Ministry of the Environment (Japan), Niigata University, and local volunteers. In addition, an integrated population model and population



viability analysis framework with roost count, mark-resight data, and reproductive performance was implemented to assess survival, reproductive success, population size, number of mature individuals, and population projection (Okahisa and Nagata 2022). The combination of close monitoring with the help of citizens and scientists, and a scientific approach that incorporated robust population modelling provided detailed information on the restoration project.

Our models detected that the released ibises had high annual survival rates (mean of 13 years: 0.566) during the first year after release, which improved after one year (0.865). The first successful breeding in the wild occurred in 2012, four years after the birds were released. Wild-hatched individuals had higher survival rates than released individuals (0.757 for juveniles and 0.899 for adults). Furthermore, the reproductive success rate of pairs including wild-hatched individuals was estimated to be higher than that of pairs of released individuals (released–released pair: 0.245; released–wild pair: 0.377; wild–wild pair: 0.350). The estimated reproductive success rate of the Sado Island population was lower than that of the wild populations in China (0.676; Ding 2004). The lower reproductive success rate observed was of concern, however, a high survival rate of successfully hatched ibises was recorded. The population size continued to increase over time through continuous release and breeding in the wild (Figure 3).



Although the population size of the ibis steadily increased, one challenge was to estimate the number of mature individuals, according to the IUCN definition. The IUCN states that “the number of mature individuals is the number of individuals capable of reproduction. Reintroduced individuals must have produced viable offspring before they are counted as mature individuals” (IUCN 2012). However, in an increasing population, the number of mature individuals in the field could not be counted. Thus, the number of mature individuals was estimated using an integrated population model. The results showed that in June 2021, the population reached 457 individuals with a total of 261 mature individuals (Okahisa and Nagata 2022).

The extinction probability for the next five generations was less than 0.01%, even if the release of birds was halted, indicating that the population had achieved self-sustaining viability. Our assessment led to the downgrading of the species from “Extinct in the Wild” to “Endangered” on the Red List of the Ministry of the Environment in January 2019 (Ministry of the Environment 2019). Thus, the conservation of the Crested Ibis, which has been ongoing since the 1920s, can be considered a success. Exceedingly few restoration programmes involving large waterbird population restoration have similarly undertaken robust statistical approaches to monitoring restored populations, and the Crested Ibis project’s learning can be of use to other

Figure 3. Population size from an integrated population model of the reintroduced Crested Ibis population on Sado Island, measured every June from 2008 to 2021. Posterior means and 95% Bayesian credible intervals are shown (from Okahisa and Nagata 2022).



projects as well.

Key factors of successful Crested Ibis reintroduction

There are two main factors behind the successful reintroduction of Crested Ibis. The first factor was the establishment of successful captive breeding techniques with trained scientists from within Japan and China. Various improvements in captive breeding were performed, especially regarding the establishment of chick-rearing techniques. In captivity, parent ibises exhibit abnormal behavior such as excessive stripping of the eggshell at the time of hatching (Xi *et al.* 2003; Ding 2004). Thus, temporary hand-rearing of chicks was carried out prior to and after hatching, in order to reduce embryo mortality (Okahisa *et al.* 2022). However, hand-rearing chicks for more than two days after hatching impacted their reproduction after release (Figure 4; Okahisa *et al.* 2022). Therefore, an appropriate rearing method was needed to mitigate malimprinting in captivity and to prevent the death of embryos caused by parental egg peeling. Thus, the offspring were hand-reared on the day of hatching and then the hand-reared nestlings were placed in the nests of their biological parents or foster parents so that they could be raised by them. To ensure the parents accepted the hand-reared nestlings, the eggs were replaced with dummy eggs made of clay or unfertilized eggs. After at least two weeks of incubation, the dummy eggs

were replaced with nestlings. This resulted in increased fostering rates by the parents and reduced the effects of hand rearing (Okahisa *et al.* 2022). These techniques are currently being implemented and incorporated in seven breeding facilities across the country (Niigata Prefecture and Ministry of the Environment 2018). These techniques are unique to the Crested Ibis and this restoration programme showed the very high value of developing suitable methods for each species independently with careful experimentation rather than imposing methods developed elsewhere on other species.

The second important factor was habitat restoration. Crested Ibis forages in wetlands and as there are few natural wetlands in Japan, rice paddies were utilized as their main foraging environment. On Sado Island, the local inhabitants promoted ibis-friendly agriculture (Usio *et al.* 2014). This initiative spread rapidly from 2008 onwards thanks to the cooperation of local residents, Japan Agricultural Cooperatives, and Sado city based on two aspects: the desire to support the reintroduction of Crested Ibis, and the brand strategy of Sado rice (Watanabe 2012). The initiative involved halving the use of pesticides and chemical fertilizers, installing paddy fishways, creating ditches and biotopes, and flooding paddy fields during the winter (Figure 5). The implementation of the conservation measures increased the number of organisms that ibises fed

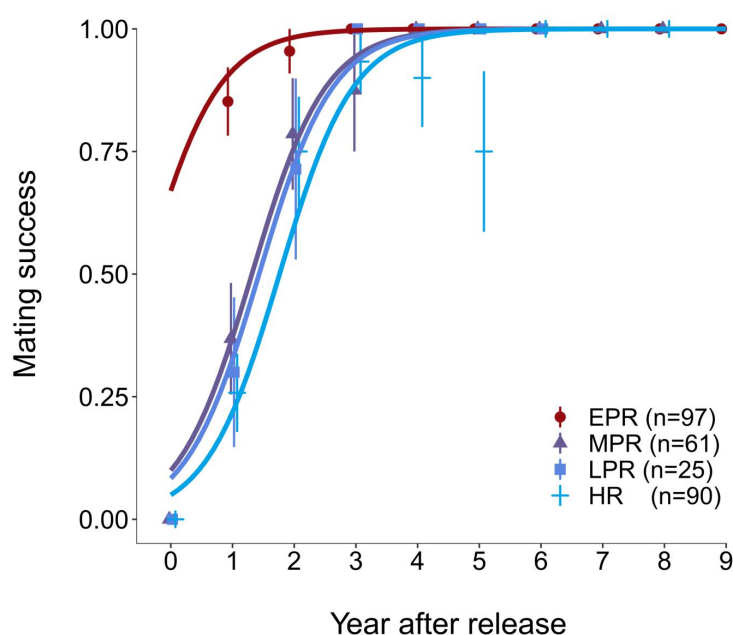


Figure 4. Pair formation rate of male Crested Ibis according to rearing methods. Dots and error bars show the observed mating success and standard error, respectively. (Regression curves were derived from the generalized linear mixed model. EPR: early parent-rearing (parent-rearing began before the chicks' eyes had opened); MPR: middle parent-rearing (parent-rearing began after the chicks' eyes had opened but before they were six days old when the eyesight is fully developed); LPR: late parent-rearing (parent-rearing began when the chicks were seven days old or older); HR: hand-rearing (no regular parent-rearing); from Okahisa *et al.* 2022).





Figure 5. Biodiversity-enhancing practices of the ibis friendly-rice farming (Toki to kurasu sato dukuri rice certification initiative) on the Sado Island. Fishway (top-left, photo by Yuji Okahisa), ibis feeding in the rice fields (top-right, photo by Yuji Okahisa), two ibises feeding in a diversion ditch (bottom-left, photo by Ministry of the Environment, Japan), and ibis benefitting from winter flooding (bottom-right, photo by Ministry of the Environment, Japan).

on, which is a major factor in promoting the high survival rate of Crested Ibis (Usio *et al.* 2014). An advantage for the farmers aiding the conservation was that growing 'Crested Ibis certified rice' could be sold at higher prices and the farmers received subsidies, thereby substantially increasing their income (Kuwabara 2015). These efforts are continuously improving, moving towards a stronger link for living in harmony with nature. The efforts included voluntary initiatives by residents, such as the ban on neonicotinoid pesticides in 2012 and the ban on herbicides in 2016. The reestablishment of the Crested Ibis through 100 years of continuous conservation programs has become a source of pride in the region (Honda 2015) and is a model that could be implemented globally. Thus, the successful reintroduction of Crested Ibis was driven by the cooperation of residents, researchers, and government officials, who all worked together to ensure successful captive breeding and habitat restoration.

Next steps for our programme

What should be the next steps since the reintroduction of Crested Ibis on Sado Island has been successful? Firstly, the lessons learnt from the history of ibis conservation must be evaluated. According to the IUCN guidelines (IUCN/SSC

2013), the main objectives of reintroductions are to improve the conservation status of the target species and to restore natural ecosystem functions or processes. Restoration of Crested Ibis population in Japan is a clear achievement for the conservation of this species. However, the knowledge on how the restoration of the ibis restored natural ecosystem functions or processes is limited. It is known that the Crested Ibis-specific mite, *Freyanopterolichus nipponiae*, was also conserved in our program (Waki and Shimano 2020). The symbiotic beetle, *Anthrachophora rusticola*, was found in nests of the ibis (Kishimoto-Yamada 2019), suggesting that this species is likely to increase in number with an increase in ibises. Other ecosystem functions that the ibis may influence include increasing nutrient dynamics, invertebrate control, and prey for raptors. Further research is needed to understand the significance of ecosystem restoration by the ibis.

In addition, social benefit such as the revitalizing local culture and communities, and the educational effects of using the ibis for environmental learning and awareness-raising should also be evaluated. For example, a questionnaire survey of tourists on Sado Island demonstrated that the success of the Japanese Crested Ibis increased tourism, bringing an annual economic profit of approximately 4.45 billion yen to the region (Okahisa 2022). These



economic benefits support local culture and communities. Furthermore, Crested Ibis is a symbol of nature conservation in Japan and stands as a global symbol for the utility of traditional farming such as Japanese rice farming as an important habitat for an endangered species. For this reason, it has featured in numerous textbooks, news items and various other media. This may have led to an increased awareness of nature conservation even among urban residents. The economic and educational effects of the Crested Ibis should also be evaluated from a broader perspective.

Secondly, the knowledge gained from this reintroduction project needs to be shared with other regions and could be applied to other endangered species. The Ministry of the Environment is currently working on a manual describing our efforts to restore the habitat of the ibis, will plans to expand its initiatives to mainland Japan. In the future, ibis-friendly farming may become more active even on the mainland and improve the environment so that Crested Ibises can disperse and settle there. Such an ibis-friendly environment is likely to be suitable for other endangered species, including Oriental White Stork *Ciconia boyciana*. There are other projects evaluating the comprehensive conservation of endangered species. For example, Japanese specialists, including myself, cooperated in the captive breeding and reinforcement program for the White-bellied Heron *Ardea insignis* in the Kingdom of Bhutan. I believe that our experience with the Crested Ibis reintroduction program will be helpful for successful conservation and restoration of many more species globally.

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