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# Rectification of Abnormal Migration Recorded in Hand-reared Red-crowned Cranes (*Grus japonensis*)

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**Abstract.—**Understanding the complexities of avian migration is important for ecological and conservation biological studies. While much progress has been made in studying relatively small-sized birds, migratory behavior of large and long-lived species such as cranes is not fully understood and experimentation on such species is difficult. In December 2015, four hand-reared Red-crowned Crane (*Grus japonensis*) subadults were found in northeast China, which is not the normal wintering ground for this species. Using GPS-GSM transmitters, migration performance of four hand-reared and three wild Red-crowned Cranes was monitored between 2015 and 2018. Wild individuals followed a north-south migration route along the east coast of China, while hand-reared cranes took an abnormal west-east migration route for the first two years. After reaching sexual maturity in 2017, one of the hand-reared individuals rectified its abnormal migration route and obtained a regular north-south migration route. Results indicate that it is critical to include experienced migrants in the releasing group to guarantee correct migration direction when implementing re-wilding projects in Red-crowned Cranes. *Received 26 March 2019, accepted 4 October 2019.*

**Key words.—**bird migration, hand-reared, migration route, migratory behavior, Red-crowned Crane, reintroduction, social learning, subadult

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Migration is a life-history strategy that animals evolved to explore distant areas with abundant but seasonal food resources (Dingle and Drake 2007). Studies have shown that successful bird migration depends on both genetic and social factors (reviewed in Newton 2008). However, it still remains unknown whether inherent navigation mechanisms or post-natal learning has greater influence on migratory behavior in different bird taxa (Alerstam 2006). Both laboratory and field studies have demonstrated that migratory behavior (e.g., timing, direction, duration of migration) of some nocturnal passerines (e.g., Eurasian Blackcap, *Sylvia atricapilla,* Berthold and Pulido 1994; Swainson's Thrush, *Catharus ustulatus,* Delmore *et al.* 2015) was primarily influenced by genetic factors (Berthold 2004). Using tracking technology, researchers further revealed the importance of non-genetic factors on the migratory behavior of some long-lived birds (e.g., White Stork, *Ciconia ciconia,* Chernetsov *et al.* 2004; Whooping Crane, *Grus americana,* Mueller *et al.* 2013).

Red-crowned Crane (*Grus japonensis*) is a long-lived waterbird that distributes in Northeast Asia (mainly China, Russia, Japan, North and South Korea). Due to threatened habitat and low population numbers (~3,050 individuals), it is classified as Endangered by the International Union for Conservation of Nature (IUCN 2019). Based on different migration habits, Red-crowned Cranes are divided into a migratory continental population (~1,580 individuals) and a sedentary island population in Hokkaido, Japan (~1,470 individuals) (BirdLife International 2018). The western migratory population mainly breeds in wetlands of Heilongjiang, Jilin, Liaoning and Inner Mongolia, and migrates to the Yellow River Delta and Yancheng in China during non-breeding seasons (Su and Zou 2012).

In December 2015, four Red-crowned Crane subadults were found in a village near Hulun Lake Nature Reserve in northeast China, which was not the species' normal wintering area. Three of them were fitted with unique identifiable color rings and were later proved to be hand-reared individuals released by Khingansky Nature Reserve on 21 April 2015, another one had an un-

known origin. We deployed GPS-GSM transmitters on them as well as on another three wild Red-crowned Cranes in 2015 and 2016 to assess migration routes of both hand-reared and wild Red-crowned Cranes, with the objectives of 1) comparing differences in migration routes between them; 2) determining whether and how migratory behavior of hand-reared individuals would change among years.

## METHODS

### Study Area

Hulun Lake Nature Reserve (49° 03′ 00″ N, 117° 30′ 36″ E; hereafter HNR) is located in Hulunbuir City, China, with average temperature of 0.3 °C annually and -18 ~ -35 °C in January. It is a breeding area for the Red-crowned Crane, with up to eight individuals recorded during 2004-2007 (Zhao 2008). Khingansky Nature Reserve (49° 13′ 48″ N, 129° 25′ 48″ E; hereafter KNR), located in Amur, Russia, is also a breeding area for the cranes (Higuchi *et al.* 2010).

### Animal Tagging

Staff at KNR have run a wild population restoration project to artificially hatch Red-crowned Crane eggs donated from breeding centers and zoos. Crane chicks were raised in a semi-wild environment and released into the wild at one-year-old with engraved color plastic rings (Smirenski *et al.* 2018). On 23 December 2015, four Red-crowned Cranes were found in a farmer's backyard near HNR, three of them were marked with color rings 1K7, 2K6, 3K1. For convenience, we will refer to these four subadult cranes as hand-reared individuals in the following context, despite one with unknown origin. They were caught and transported to HNR by staff of the local Forestry Bureau. We took these hand-reared individuals back into captivity and provided food and shelter for them through the winter. On 16 May 2016, we banded the individual with unknown origin as S43. Then we attached 40-g GPS-GSM transmitters (Model HQLG4021S, developed by Hunan Global Messenger Technology Co., Ltd, China) to the four individuals and released them at HNR. The transmitters were powered by a lithium battery and a solar-powered panel for satellite positioning via GPS. Positioning data was transmitted by GSM (Global System for Mobile Communication) and returned information back hourly. The accuracy of returned information was divided into five levels: A (within 5 m), B (within 10 m), C (within 20 m), D (within 100 m) and invalid. We lost connection with 1K7 immediately after release, and transmitters of 2K6, 3K1, S43 stopped working later in June 2016. On 20 November 2016, individuals 2K6, 3K1 and S43 were detected near HNR again in farmer's backyard. Using the same method as in 2015, we gave them necessary aids between November 2016 and April 2017. On 24 April 2017, we deployed 37-g backpack-type (Model HQBG5037S) GPS-GSM transmitters on the three individuals and released them at HNR.

In 2015, in addition to four hand-reared individuals, we also tracked ten wild Red-crowned Cranes. But migration routes were only successfully recorded in three individuals (namely, A14, A20 and A02), and we will only focus on them in the following context. These three wild Red-crowned Cranes were all found and released at Lindian (47° 12' 00" N, 124° 33' 36" E), Heilongjiang Province, China in April 2015. Individuals A14 and A20 were found poisoned on 7 and 8 April respectively, while A02 was found slightly injured after hitting a power line on 11 April 2015. After giving them necessary medical treatment, we attached 37-g backpack-typed (Model HQBG5037S) GPS-GSM transmitters to these three individuals and released them on 8, 9 and 25 April 2015, respectively. Before release, their free-movement abilities were carefully checked. Transmitters used in this study were about 0.3-0.7% the weight of the Red-crowned Cranes, and would not affect their normal activity, as maximum weight of transmitters should be <3% avian body weight (Ma 2009).

## RESULTS

As of September 2018, we received a total of 48,574 locations, of which 46,870 were valid. Six out of fourteen tracked individuals completed at least one migration to and from breeding areas (Table 1 and Fig. 1). For hand-reared individuals, we received 162 valid locations from the first set of transmitters. After release on 21 May 2016, transmitters on three (2K6, 3K1, S43) of four hand-reared cranes functioned well and showed their synchronous eastward migration back to hatching site at KNR. While the fourth crane, 1K7, had a failed transmitter, and we have not received any information from it since transmitter failure. Transmitters of 2K6, 3K1 and S43 lost signals on 14, 21 and 24 June 2016, respectively, at KNR before they could start autumn migration. With the second set of transmitters attached April 2017, a total of 728 valid locations were recorded. After release on 24 April 2017, 2K6, 3K1 and S43 did not move back to KNR synchronously. Individual 2K6 and S43 arrived at KNR on 1 and 15 May respectively, while 3K1 died in Hulunbuir City, Inner Mongolia (49° 27' 36" N, 125° 00' 00" E; ca. 615.33 km away from release

**Table 1. Detailed information on migratory performance of three wild and four hand-reared Red-crowned Cranes (*Grus japonensis*) tracked using GPS-GSM transmitters in north China between April 2015 and April 2018.**

| Band Number | Date of Transmitter Deployment | Migration Time | Total GPS Locations/Valid Locations Received | Migration Distance (km) | Notes |
|---|---|---|---|---|---|
| A14 | 8 April 2015 | 25-30 October 2015 | 131/131 | 2405.43 | Natural-born adult |
| | | 6-29 March 2016 | 545/545 | 2551.80 | |
| | | 23-29 October 2016 | 114/114 | 2392.46 | |
| | | 10 March-4 April 2017 | 591/589 | 2786.25 | |
| A20 | 9 April 2015 | 18-29 October 2015 | 268/268 | 1892.99 | Natural-born subadult |
| | | 12 March-21 April 2016 | 932/928 | 2221.51 | |
| | | 28 October-8 November 2016 | 275/268 | 2586.92 | |
| | | 3-16 March 2017 | 257/257 | 2053.27 | |
| A02 | 25 April 2015 | Transmitter failed | | | Natural-born juvenile |
| | | 19-26 March 2016 | 34/34 | 1186.87 | |
| S43 | 16 May 2016 | 21-24 May 2016 | 62/62 | 897.66 | Subadult with unknown origin |
| | 24 April 2017 | 26 April-15 May 2017 | 509/245 | 1340.44 | |
| 1K7 | 16 May 2016 | Transmitter failed | | | Hand-reared subadult |
| 2K6 | 16 May 2016 | 21-24 May 2016 | 51/51 | 895.25 | Hand-reared Subadult |
| | | 26 April-1 May 2017 | 119/119 | 790.22 | |
| | 24 April 2017 | 31 October-3 November 2017 | 19/19 | 1575.91 | |
| | | 16-19 April 2018 | 36/36 | 1643.65 | |
| 3K1 | 16 May 2016 | 21-24 May 2016 | 49/49 | 892.94 | Hand-reared Subadult, died on 9 May 2017 |
| | 24 April 2017 | 26 April-9 May 2017 | 309/309 | 615.53 | |

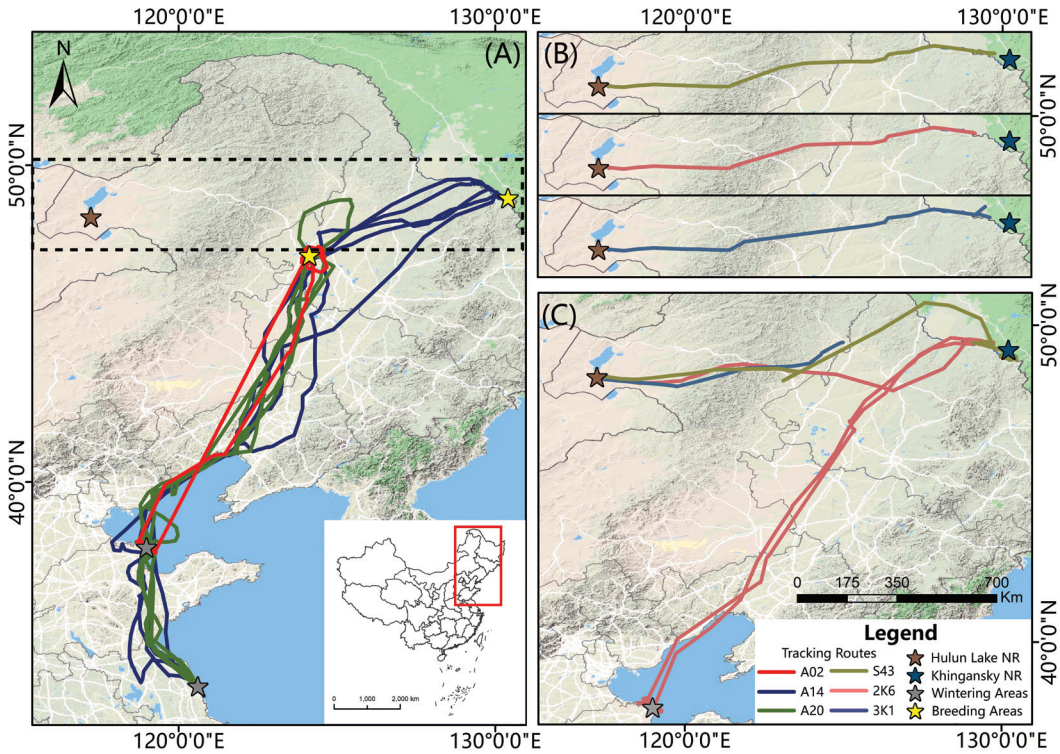


**Figure 1. Migration routes of six Red-crowned Cranes (*Grus japonensis*) tracked using GPS-GSM transmitters in north China between April 2015 and April 2018; (A) migration of three wild cranes (A02, A14, and A20) along regular migration routes used by the Red-crowned Crane western population between 2015 and 2017; (B) movements of three subadult cranes (2K6 and 3K1 were hand-reared individuals, S43 was with unknown origin) returning to Khingansky Nature Reserve in Russia after releasing on 16 May 2016 (dashed line rectangle in A shows area in B); (C) movements of 2K6, 3K1 and S43 returning to Khingansky Nature Reserve after releasing at Hulun Lake Nature Reserve on 24 April 2017, and subsequent corrected migrations of one hand-reared individual 2K6 in autumn 2017 and spring 2018.**

site) due to poisoning on 9 May 2017, on its way back to KNR. We lost signals from S43 on 24 June 2017 at KNR. On 31 October 2017, 2K6 started to follow the traditional migratory route of Red-crowned Cranes and wintered at Yellow River Delta and then successfully returned back to KNR in spring 2018 (Table 1; Fig. 1).

For three natural-born crane individuals (A14, A20, A02), nine migration routes with 3,134 valid locations were recorded between October 2015 and April 2017 (Table 1). After release in 2015, crane A14 migrated north to its breeding ground in China-Russia border, while the other two individuals stayed in Lindian until the breeding season in 2015. Individuals A14 and A20 wintered each year in Yancheng, Jiangsu Province, while A02 wintered in Yellow River Delta where hand-reared 2K6 also wintered after rectifying its migration from previous years (Table 1; Fig. 1).

## DISCUSSION

Using tracking technology, we tracked both hand-reared and wild Red-crowned Cranes in this study. While wild individuals used normal north-south migration route, three hand-reared subadults took an abnormal west-east route for the first two years. In the third year, hand-reared individual 2K6 rectified abnormal migration route and traveled to the species' regular wintering site. We speculate that 2K6 either migrated with other subadult groups or its mate after reaching sexual maturity in 2017 (Red-crowned Crane

reaches maturity at three to four years of age; Masatomi and Kitagawa 1974). Due to limited sample size, we cannot further explain the causes of their abnormal migratory behavior. However, it is certain that, in addition to promote understanding of bird migration, our findings bear important implications for the protection, re-wilding and reintroduction of cranes or other similar species.

The Red-crowned Crane western population now faces two major threats: high rates of individual loss (poisoning and loss of wild populations due to captivity) and habitat destruction (Wood *et al.* 2010; Su and Zou 2012; Zhou *et al.* 2016). Autopsy results showed that 3K1 died of eating seeds mixed with pesticide, which is a common form of poisoning reported (Zhou *et al.* 2014). The sedentary Red-crowned Crane population is stable but with low genetic variation (Harris and Mirande 2013; Akiyama *et al.* 2017). Researchers found that if migratory behavior was completely dominated by genetic factors, it was likely to persist, regardless of population size; however, for species relying mainly on learning for their first migration, small migratory populations may face strong "Allee effect (individual fitness tends to decline at low population density)", which will ultimately lead to loss of migratory behavior (Stephens and Sutherland. 1999; Fagan *et al.* 2012; Berdahl *et al.* 2016; Foss-Grant *et al.* 2018). There has been success in reestablishing migratory behavior of Whooping Cranes using ultralight aircraft, but the process was very costly and labor-intensive (Ellis *et al.* 2003).

Artificial interventions are encouraged in protecting endangered species with small population size (Wang *et al.* 2018). Inexperienced migrants of some bird taxa (e.g., passerines and raptors) may rely on inherent navigation system to find correct way to wintering area for their first migration (Berthold 2004; Thorup *et al.* 2007; Mellone *et al.* 2016). For birds migrating in flocks (e.g., storks, cranes and bustards), the importance of learning has been proved: inexperienced migrants follow their parents or other elder group members for their first migration, so that correct migration route can be passed on (Palacín *et al.* 2011). Studies on White Stork and Sandhill Crane (*Grus canadensis*) also found that if the young failed to migrate with their parents or other members in the first year, they will experience higher rate of mortality during migration (Chernetsov *et al.* 2004; Hayes 2015). According to our study, when re-wilding captive-bred or reintroducing individuals of some long-lived species, experienced individuals should be included in the group to ensure successful migration (Teitelbaum *et al.* 2016).

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