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Migration and Home Range of the Grey Heron (*Ardea cinerea*) in the Republic of Korea

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Abstract.—This study was conducted to determine the size of the breeding season home range and the migration pattern of Grey Heron (*Ardea cinerea*) using global positioning system telemetry in Daejeon, Republic of Korea. Four Grey Heron were successfully tracked between 15 March and 16 November 2016. The home range size for Grey Herons was estimated by minimum convex polygon (MCP) and kernel density estimation (KDE) of 90%, 70% and 50%. The mean home range size estimated by MCP varied among individuals, ranging from 14.3 to 1,372.1 km^2 (mean = 492.3 km^2). The mean home range size using the kernel density estimation, which is indicative of the core area of a home range, was 114.2 km^2 (range = 1.8-352.2 km^2). Of the four successfully tracked herons, two individuals stopped several times during their migration to the southern part of China. Further studies into habitat selection, seasonal patterns, and species-threatening factors would assist in the proper management of this species.
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Key words.—Grey Heron, home range, Republic of Korea, movement

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Radio and satellite tracking have been used to determine the breeding and wintering sites, habitat use pattern, distribution, and migration routes of many bird species (Higuchi and Pierre 2005, Kang *et al.* 2016). Such information has aided the conservation and management of various species and their habitats (Higuchi *et al.* 1998). Long-legged waterbirds such as herons and egrets are important components of the breeding bird populations observed in numerous wetlands and woodlands in the Republic of Korea (hereafter Korea). Of 72 egret and heron (Ardeidae) species recorded in the world, 19 species have been observed in Korea (Lee *et al.* 2014). Among them, the Grey Heron (*Ardea cinerea*) breeds in the summer in Korea. Some Grey Heron winter in Korea, but usually they occur from February to September and then migrate to India, Africa or the southern parts of the Eurasian continent for wintering (Park 2014).

Studies have been done on survival rates in winter (North 1979), feeding and breeding activities (Vessem and Draulans 1986; Marion 1989; Feunteun and Marion 1994; Jakubas and Mioduszewska 2005), resource partitioning (Moser 1984), and juvenile dispersal (Kim *et al.* 2015), but there is a lack of detailed information on national and international patterns of movement in Grey Heron. Also, there are few studies on the ecology of the Grey Heron, and most of the studies mainly focused on breeding ecology of the Grey Heron in Korea. Grey Heron is a useful biological indicator to assess the health of habitats, because the species is sensitive to environmental changes (National Institute of Environmental Research 2012).

In this study we obtained Grey Heron movement information from a Global Positioning System—Wideband Code Division Multiple Access (GPS–WCDMA) telemetry system. Herein, we report on the home range size and migration patterns of four adult Grey Herons captured in Daejeon, Republic of Korea. The information on move-

ment patterns and international migration of the Grey Heron could be helpful for conservation of the species and their habitats.

METHODS

Our study area was near the Yudeungcheon River, Daejeon, Republic of Korea (36° 21′ 13.41″ N, 127° 24' 12.18″ E). We used a cannon net baited with fish to capture four adult Grey Herons (body mass range: 1500 - 2000g) in March 2016. This area was 4.8 km from their breeding site and used as feeding and resting site for Grey Herons. Upon capture, each heron was fitted with a GPS–WCDMA transmitter (Model WT-200). GPS–WCDMA is a method of obtaining and storing GPS coordinates at a given time and transmitting them over a mobile communication system network, enabling researchers to access locations remotely on the internet. Each transmitter was attached to the back using a harness made of 10-mm Teflon ribbon (Ueta *et al.* 2000; Kang *et al.* 2016). The size of the WT-200 transmitter was 75 (L) × 40 (W) × 15 (H) mm, and weighed 27 g, less than 3% of the body mass of the individuals bearing the transmitters. We programmed the transmitters to acquire location data every 4 hours from 06:00 to 18:00 hr and obtained one additional location at midnight to elucidate if location changed at night. Marked birds were tracked from March 2016 until November 2016 or until signal was lost, presumably due to transmitter failure.

Data Analysis

We used the Animal Movement Tool Extension of Hawth's Analysis Tool on ArcGIS to analyze the movement of birds with default settings (Klaus *et al.* 2020). We evaluated the size of home range of the birds during breeding season in Korea using a minimum convex polygon method (MCP). Also, we used the kernel density estimation (KDE) of 90%, 70% and 50% to clarify a core area within their home range (Seaman *et al.* 1999; Kang *et al.* 2016).

RESULTS

Home range

In total, 2,950 GPS positions (range = 329-968 points per bird) for four individuals (ID 1501-1504) inside Korea during breeding season and 1,090 GPS positions (range = 454-636 points per bird) for two individuals migrating outside of Korea. These were used to analyze the size of the herons' home range and/or their movement distances and migratory route (Table 1). Tracking for two individuals ceased before migration began (Table 1), presumably due to transmitter failure.

The home range size of the four tracked herons estimated by MCP varied greatly and ranged from 14.3 km² to 1,372.1 km² (mean = 492.3 km²) during breeding season in Korea. The home range size of the four herons in breeding season based on 90% KDE, 70% KDE, and 50% KDE were 3.7 km² to 755.7 km² (mean = 246.0 km²), 1.8 km² to 352.2 km² (mean = 114.2 km²) and 1.1 km² to 194.2 km² (mean = 62.5 km²), respectively Table 2; online Appendix).

Migration

Two of the four tracked herons were successfully tracked to wintering sites. On 13 July 2016, one individual (ID: 1502) flew to the Saemangum area (Buangun, Jungranamdo, Korea) which is 7.5 km from the bird's breeding site (Gamsungri, Sejong, Korea). Later, on 13-14 July 2016, the individual flew to Rugaoshi, Nantong Province, China. On 15 July 2016, the heron was in Yangzhoushi, Jiangsu Province, China, and on 17 July 2016, the heron settled down in a reservoir and farmland area in Hefeishi, Anhui Province, China, which is about 980 km from the breeding site. This individual stayed around this area and the signal was lost on 28 November 2016 (Fig. 1).

The other individual (ID: 1503) flew to Rongchengshi, Shandong Province, China, which was 451.3 km from the bird's breed-

Table 1. Information on radio-tracked four Grey Herons (*Ardea cinerea*) in Daejeon, Republic of Korea (Korea).

ID No.	GPS Fixes times/day	Number of GPS Fixes (Korea)	Number of GPS Fixes (Non- Korea)	Tracking period (Korea)	Tracking period (Non-Korea)
1501	8	881	—	15 March - 8 July	
1502	6	772	636	15 March - 13 July	13 July - 5 November
1503	6	968	454	25 March - 2 September	2 September - 16 November
1504	6	329	—	25 March - 24 May	

Table 2. Home range estimates of Grey Herons (*Ardea cinerea*) by Minimum Convex Polygon (MCP) and Fixed Kernel Density Estimate (KDE) methods. mean ± S.E.

ID No.	MCP (km²)	90% KDE (km²)	70% KDE (km²)	50% KDE (km²)
1501	223.7	203.3	94.9	51.1
1502	1372.1	755.7	352.2	194.2
1503	359.0	21.3	8.1	3.8
1504	14.3	3.7	1.8	1.1
Mean	492.3 ± 301.7	246.0 ± 175.8	114.2 ± 82.1	62.5 ± 45.4

ing site (Gab-Cheon, Daejeon, Korea), on 2 September 2016. The individual moved to Pizhoushi, Jiangsu Province, China on 13 September 2016 and settled down in a reservoir and farmland area in Dangyangshi, Hubei Province, China on 14 September 2016, which is about 1,542 km from the breeding site. This individual stayed around this area and the signal was lost on 6 November 2016 (Fig. 2).

DISCUSSION

Egrets and herons are reported to feed within 10 km of their breeding site during the egg-laying and brooding periods (Gregory 1990, Hafner *et al.* 1993); however, the home range size and movement distances observed in this study were larger than this average. Compared to the other birds in our study, individual 1504 was observed to have a much smaller home range, although this could be due to the shorter duration of tracking and fewer total locations for this individual. The distances moved by individuals can be affected by the flight distance to foraging areas, by habitat type, and by habitat conditions or time of day (Choi 2008; Chen 2014; Kang *et al.* 2016).

The movement of two adult herons was successfully tracked to southern China. They moved along the coast from Shantung area, which was similar to a study of a radio-tracked juvenile Grey Heron (Kim 2015). During their migration, they stopped over at several locations for short periods, presum-

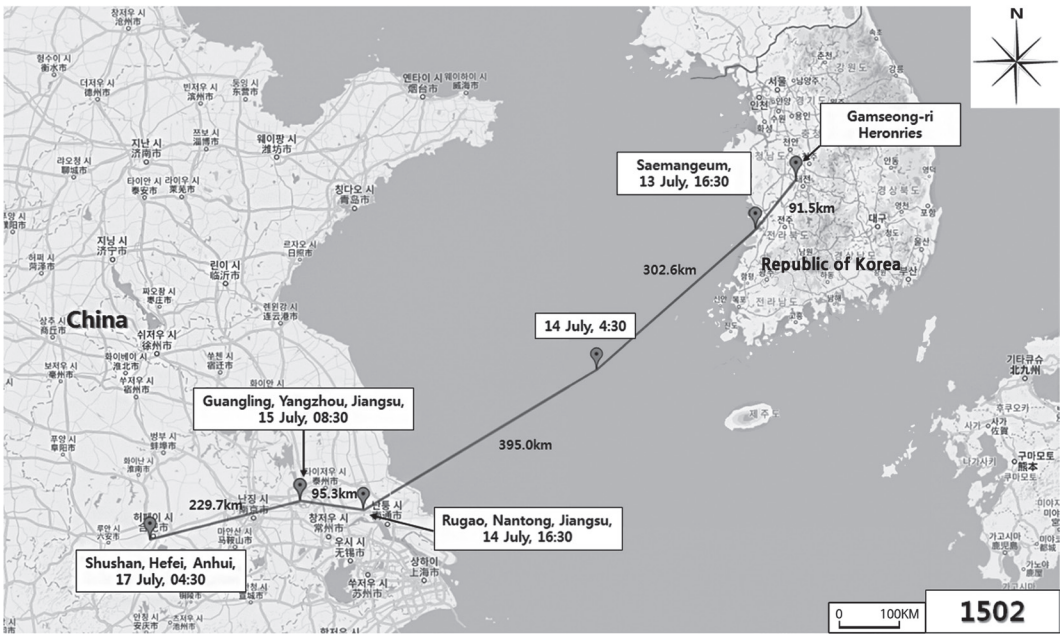

Figure 1. Fall migration of Grey Heron (*Ardea cinerea*) individual 1502 from breeding area in Republic of Korea to wintering area in China, 13 July – 5 November 2016.

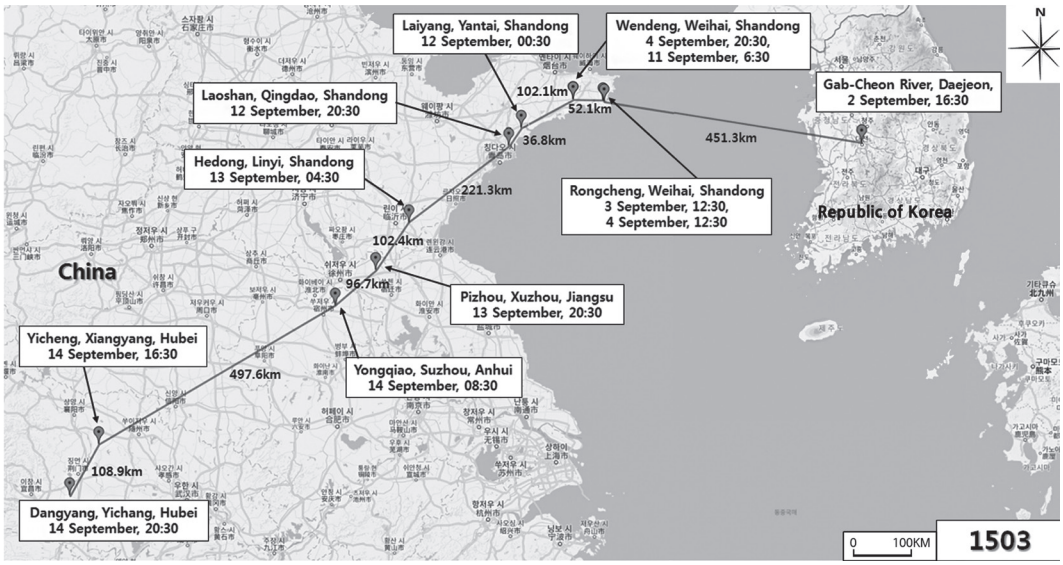

Figure 2. Fall migration of Grey Heron (*Ardea cinerea*) individual 1503 from breeding area in Republic of Korea to wintering area in China, 2 September – 16 November 2016.

ably to replenish energy reserves. A similar pattern was reported in a study of migration in Purple Heron (*A. purpurea*) (Van der Winden *et al.* 2010).

We report previously unknown domestic and international movement and home range of the Grey Heron breeding in Korea. Further studies into habitat selection, seasonal patterns, and species-threatening factors would assist in the proper management of this species across its breeding and migratory range.

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