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Localized Habitat Use of Endangered Oriental Storks (*Ciconia boyciana*) Recently Reintroduced into South Korea

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ABSTRACT

The oriental stork (*Ciconia boyciana*) is listed as an endangered species internationally. Its resident population has been extirpated in South Korea since 1971. Its predicted historical habitat included forests (54%), rice paddy fields (28%), grasslands (17%), river-streams (less than 1%), and villages (less than 1%) based on pre-extirpation records in a previous study. However, habitat attributes of recently reintroduced oriental storks since 2015 remain unknown. To examine habitat use patterns and home ranges of recently reintroduced oriental storks, 2015-2017 tracking data of 17 individuals were used to analyze their spatial attributes with a Kernel Density Estimate method and breeding status. Their habitat use patterns from peripheral to core areas were highly associated with increasing rice paddy fields (26%) and decreasing forested areas (55%). Scale-dependent home ranges were 51% smaller for breeders than for non-breeders on average. Our study results highlight that the habitat use pattern of reintroduced oriental storks seems to be comparable to the historical pattern where the used area is likely to be more centralized for breeders than for non-breeders in South Korea. Furthermore, the direction of habitat management for oriental storks should focus on biodiversity improvement of rice paddy fields with chemical free cultivation and irrigation.

Keywords: *Ciconia boyciana*, Conservation, Habitat use, Localization, Reintroduction

Introduction

The oriental stork (*Ciconia boyciana*) is listed as an endangered species internationally due to its habitat loss and overhunting in the past (BirdLife International, 2021; Elliot *et al*., 2020). To date, this species has been managed in breeding facilities for captive propagation and released into reintroduction sites of Yesan County, South Korea, since 2015. In general, oriental storks forage extensively in cultivation areas, especially rice paddy fields. They breed in nearby woods in Japan and South Korea (Kim *et al*., 2008; Naito & Ikeda, 2007; Yamada *et al*., 2018; Yoon *et al*., 2012). Rice paddy fields have been historically man-managed for cultivation. They might provide oriental storks with suitable foraging habitats as alternative wetlands for prey sources (e.g., fish, amphibians, aquatic invertebrates) in South Korea (Yoon *et al*., 2012). In general, rice farming involves rice cultivation irrigation (Feb. to Mar.), rice planting (Apr. to May), and drainage-harvesting (Sep. to Oct.) in South Korea. The breeding schedule of oriental storks has been observed to include egg-laying (Feb. to Mar.), incubation (Mar.), post-hatching care (Apr. to May), and fledging (Jun.) in captivity and wildness (see also Yoon *et al*., 2012; 2015). However, it is necessary to examine if recently reintroduced oriental storks show habitat attributes similar to those known from historical records.

The present study aims to investigate patterns of habitat use and home ranges related to beha vioral traits of recently reintroduced oriental storks since the extirpation in South Korea in 1971. To date, 38 captive individuals imported from Russian wildness, Japanese zoos, and German zoos have been propagated and released into the wild of South

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Korea since 2015 in order to restore the extirpated resident population. However, little scientific information is available to understand differences between current and past situations with respect to their habitat use pattern after reintroduction. Here, we used the first two-year tracking data of reintroduced oriental storks linked to some life-history related traits such as breeding status (i.e., breeders versus non-breeders) to understand the adaptiveness of recently reintroduced oriental storks as residents in the current environment of South Korea.

Materials and Methods

There are 118 captive oriental storks managed in breeding facilities of South Korea. Of them, 86 storks have been released into recovery sites of Yesan County (36°36′32″N, 126°48′05″ E) since 2015. Captive storks have managed in two breeding facilities: Ecological Institute for Oriental Stork, Korea National University of Education (36°36′15″N, 127°21′33″ E) and Yesan Oriental Stork Park (36°32′32″N, 126°48′42″ E) in South Korea. The main function of these two facilities is to pursue captive propagation, reintroduction, and habitat management towards eco-friendly rice paddy fields with artificial nest platforms since 1996 (Park & Cheong , 2002; Park *et al*., 2011). We collected point data from 17 oriental storks during the two-year tracking period (Sep. 2015 to Sep. 2017). Trackers (WT-300, KoEco, South Korea) were attached to the back of each released individual. These trackers weighed 62 g (less than 3% of the body weight). We used an average of 4,391-point data for each individual depending on the tracker's condition and individual mortality (Table 1).

To document characteristics of habitat use and home ranges of recently reintroduced oriental storks, tracking data were analyzed to control each individual. We pre-selected seven land cover types known to be related to the occupancy of oriental storks based on several literature surveys (Ezaki & Sagara, 2014; Kim, 2009) and our observations of rice paddy fields, riversides, reservoirs, coastal areas, forests, residential areas, and roads in land cover maps (National Geographic Information Institute, South Korea). We managed and analyzed positioning and raster data using ArcGIS ver. 10.1 (ESRI) with the extension of Hawth's Tools. Averaged land cover attributes within home ranges by each Kernel's volume contour (i.e., from 90% in the most periphery to 10% in the most core) were calculated using a Zonal Analysis tool in ArcGIS, resulting in the production of seven raster data (30 m x 30 m in cell size) in the geological extent of South Korea. Here, scaling factors of Kernel's parameter were set to have a value of 10 with a smoothing factor (h = 0.5) in Hawth's tools. Habitat use (i.e., percent land cover) was examined as functions of

Table 1. Tracking list of 17 oriental storks *Ciconia boyciana* reintroduced into South Korea

ID	Sex	Hatch year	Released (mm/yy)	Breeding status*	Tracking period (mm/yy to mm/yy)	Number of data points
A01	Male	2013	09/15	N	09/15 to 09/17	9,044
A02	Female	2013	09/15	N→B	09/15 to 04/17	7,468
A04	Female	2013	09/15	N→B	10/15 to 09/17	4,706
A27	Male	2013	09/15	N →B	09/15 to 09/17	9,104
A33	Female	2016	07/16	N	08/16 to 12/16	2,210
A35	Male	2016	07/16	N	08/16 to 02/17	2,701
A37	Female	2016	07/16	N	08/16 to 07/17	4,671
A81	Female	2017	05/17	N	07/17 to 09/17	1,237
A83	Male	2017	05/17	N	08/17 to 09/17	873
A85	Female	2017	05/17	N	08/17 to 09/17	934
A89	Male	2007	07/16	N→B	08/16 to 09/17	5,398
A99	Male	1996	05/16	N	06/16 to 03/17	3,924
B01	Male	2015	09/15	N	09/15 to 08/17	8,902
B02	Male	2015	09/15	N	09/15 to 11/15	1,005
A05	Male	2013	09/15	N→B	09/15 to 05/17	6,980
A08	Female	1999	05/16	N	06/16 to 07/16	768
A30	Female	2013	09/15	N→B	09/15 to 09/16	4,728

* Breeding status indicates non-breeding (N) or breeding (B) status of an individual. Arrow (N→B) represents the transition from a non-breeding status to a breeding status during the tracking period.

habitat type, Kernel's volume contour, and two-way interaction. Home range size (ha) was inspected as functions of reproductive status (breeding versus non breeding), Kernel's volume contour, and two-way interaction. Here, we examined changes in habitat attributes and home range sizes with respect to decreasing spatial scales instead of an arbitrary fixation of Kernel's volume contour. All statistical analyses were performed with SPSS ver. 16 (SPSS Inc., Chicago, IL, USA). We did not need to transform any variables to meet model assumptions.

Results

Reintroduced oriental storks exhibited a significant pattern of habitat use (mixed model: $_{HABITAT}F_{6,\ 805} = 81.53$, $P < 0.001$; $_{KERNEL}F_{1,\ 805} < 0.001$, P = 1.00; $_{HABITAT\ X\ KERNEL}F_{6,\ 805} = 3.99$, $P < 0.01$; Fig. 1). Specifically, habitat use of orienting core areas (10%) from peripheral areas (90%) (i.e., decreasing Kernel's volume contour) was highly associated with increasing rice paddy fields (overall 25.5%; slope estimate = 0.14 ± 0.05, $P < 0.01$) and decreasing forested areas (54.8%; slope estimate = -0.09 ± 0.05, $P = 0.09$). However, it was not associated with river (7.1%), coastal area (i.e., mudflats; 6.9%), reservoir (2.2%), residential area (2.2%), or road (1.2%). Home ranges of oriental storks were likely to depend on breeding status (Fig . 1 and 2). The area of home range by Kernel's volume contour was relatively smaller for breeding individuals than for non-breeding individuals (mixed model: $_{KERNEL}F_{1,102} = 108$, $P < 0.001$; $_{BREED}F_{1,66.8} = 4.13$, $P = 0.05$; $_{KERNEL\ X\ BREED}F_{1,102} = 19.26$, $P < 0.001$). Calculated home range decreased with Kernel's volume contour (%) at a lower rate for breeding individuals (slope estimate = 248.28 ± 21.08) than for non-breeding ones (slope estimate = 611.20 ± 74.36). The former (8,120.81 ± 2,197.71 ha) was approximately 51% smaller than the latter (15,889.39 ± 2,034.68 ha; see Fig. 2).

Discussion

The present study used the first two-year tracking data to determine spatial patterns of habitat use and home range of oriental storks recently reintroduced to the past breeding environment of South Korea presumably perceived as a new wildness. Our results indicated that habitat use was likely to be centralized to rice paddy fields (Fig. 1) where breeders appeared to be more localized than non -breeders (Fig. 2). Here, we would like to discuss about which degrees of historical and reintroduced oriental storks have a potential to possess some characteristics of comparable habitat use between extirpated and reintroduced ones in South Korea.

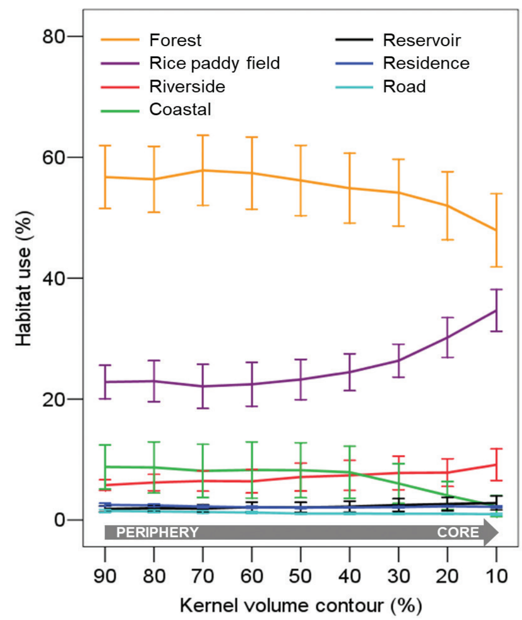

Fig. 1. Changes in percent of land cover types (forest, rice paddy field, riverside, coastal, reservoir, residence, and road) as a function of Kernel's volume contour (90 to 10 %) used by 16 reintroduced oriental storks (*Ciconia boyciana*).

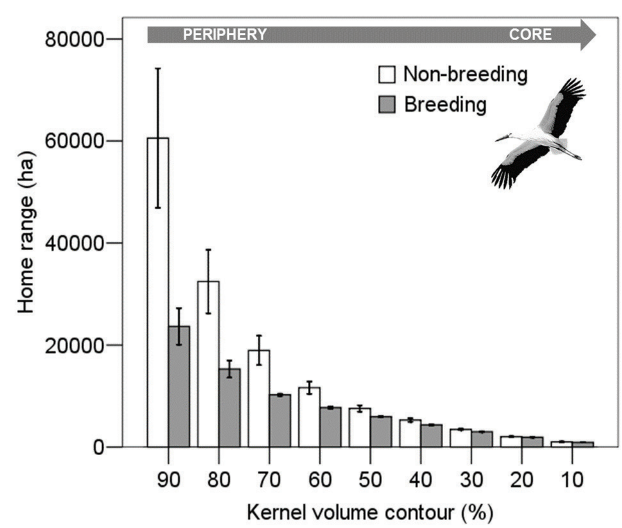

Fig. 2. Differences in home ranges (ha) of reintroduced oriental storks as a function of Kernel's volume contour (90 to 10 %) with breeding status (i.e., breeding versus non -breeding). Here, six individuals out of 13 shifted their status from non-breeding to breeding during the tracking period.

Kim *et al*. (2008) have produced basic data for developing habitat suitab ility in relation to historical breeding sites (i.e., Gyeonggi and Chungcheong Counties in 1970s) of oriental storks, emphasizing the portion of rice paddy fields as foraging sites. In the past, breeding sites were approximated to rice paddy fields (*ca*. 30 m apart), river-streams (1 km), reservoirs (55 m), and villages (144 m) where they included some nesting trees for breeding. Specifically, habitat attributes of breeding oriental storks showed a mixture of forests (54%), rice paddy fields (28%), and others. A significant difference was found between ten breeding sites and 93 randomly selected sites. Our results showed habitat attributes of forest (55%), rice paddy fields (26%), and other land covers, comparable to results of the previous work.

In general, rice paddy fields play a more important role in providing foraging habitat than other land covers for reintroduced oriental storks in South Korea and Japan (Kim *et al*., 2008; Naito & Ikeda, 2007; Yamada *et al*., 2018; Yoon *et al*., 2012). Oriental storks are also globally known to use marsh habitats with scattered clumps of trees, wet grassland, and/or riverbanks in surrounding woodlands (Elliott *et al*., 2020). They tend to forage in various natural wetlands such as reed swamps and open water areas with water depth of 20-30 cm (Zhou *et al*., 2013). Some evidence also suggests that oriental storks can adapt to more anthropogenic areas with management in Russia (see also Elliott *et al*., 2020). Regarding the habitat use of breeding oriental storks in 1970s, the surrounding environment of their nests (i.e., within a radius of 5 km close to 8,000 ha) included mixed land covers of forest (54%), rice paddy fields (28%), grassland (17%), river (< 1%), and village (< 1%) (Kim *et al*., 2008), comparable to our findings for recently released oriental storks. In the present study, we examined changes in habitat attributes as a function of Kernel's volume contours (i.e., 90 to 10%) with respect to decreasing spatial scales instead of an arbitrary fixation. This method might allow us to clarify which spatial attributes are more centralized than others (e.g., increasing rice paddy fields versus decreasing forested areas; low percentages of other spatial attributes lacking variations; see Fig. 1). The alternative approach using scaledependent Kernel's volume contours might provide better resolution for understanding their key habitat requirements (i.e., rice paddy fields). However, it is worth noting that the habitat of oriental storks includes more forested areas than rice paddy fields in both past and present observations, which should be clarified for their habitat management. Forested areas (54%) surrounding rice paddy fields (28%) are usually patched and islet typed hills in South Korea, which might have also played a role in their perching, roosting, and nesting in the past. Nevertheless, artificial nest towers, utility poles, and/or power-line tower for vigilance, roosting, and nesting purposes may now work as substitutes for tall trees in pre-extirpation habitats of oriental storks.

The reproductive status (i.e., breeding versus non-breeding) of oriental storks appeared to be related to home range size. Breeders might be more localized than non-breeding ones (Fig. 2). This pattern is potentially linked to the case that breeding storks require remaining in fixed localities to incubate eggs and provide post-hatching chicks until fledging, resulting in smaller home ranges with lower movements with some territoriality than non breeders (Newton, 2011). That is, seasonal variation in space use appears to match with the schedule of rice farming. This means that reintroduced oriental storks in reproduction are likely to depend on rice cultivation areas. Future direction of habitat management for oriental stork conservation should focus on biodiversity improvement within eco-friendly rice paddy fields through chemical-free cultivation and four-season irrigation.

Conflict of Interest

The authors declare that they have no competing interests.

Acknowledgments

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