Opinion

A proposal for the habitat restoration of Hwanghae regions in North Korea through the reintroduction of Oriental Storks in the Korean Peninsula

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Abstract The Oriental Stork (*Ciconia boyciana*) was distributed in the Korean Peninsula in 1950s, and the resident population has disappeared since 1970s. Considering the reintroduction sites of captive storks in a broad scale in the Korean Peninsula, the first region includes Yesan-gun of Chungcheongnam-do with Jeonlabuk-do and Jeonlanam-do, and the second region contains Jincheon-gun of Chungcheongbuk-do, with Gyeongsangbuk-do and Gyeongsangnam-do, and the last region consists of Kanghwa-gun of Incheon-si in South Korea and Hwanghae-do in North Korea. Among these regions, as a new strategy that involves the reintroduction of Oriental Storks in North Korea, we plan to build a reintroduction facility in Kyodong Island of Kanghwa-gun. With soft release facilities in Kyodong Island, the installation of artificial nest towers in Hwanghae-do, the previous breeding grounds, plans for eco-friendly agriculture supports, and improvement of agricultural ecosystem will be achieved. Therefore, we suggest the possibility of establishing a peace regime for North Korea and South Korea through the reintroduction of storks to the wild in the near future.

Key words Korean Peninsula, Oriental Stork, Reintroduction

INTRODUCTION

The Oriental Stork (*Ciconia boyciana*), a large wetland bird belonging to the family of Ciconiidea, is internationally one of Endangered Species Class I (IUCN Red List of Threatened Species 2015) and designated as Natural Monument No. 199 protected in the Korean Peninsula. The storks bred commonly in the Korean Peninsula before the 1950s, but the number of the stork decreased rapidly due to loss of nesting trees during the Korean War in 1950 (Park et al. 2014). Moreover, the wild breeding population disappeared in 1971, and the major cause of decrease is known to be the overuse of pesticides resulting in food shortage for the storks (Park and Cheong 2002).

The breeding grounds of the storks were mainly located in Chungcheongnam-do, Chungcheongbuk-do, Gyeonggi-do in South Korea, and Hwanghae-do in North Korea. A number of nest trees for breeding were destroyed by the Korean War in 1950, and the remaining storks were almost disappeared presumably due to the overuse of pesticides and farm land establishment in 1960s to 1970s. In 1971, a pair of the last storks in the Korean Peninsula was found in Eumseong-gun, Chungcheongbuk-do, but the male was shot dead in three days after the discovery, and thereafter the unhealthy female solely lived in Seoul Zoo from 1983 to 1994. The Korea National University of Education imported 38 storks from Russia, Germany, and Japan from 1996 to 2010 (24 storks from Russia, eight storks from Japan, and six storks from Germany). The captive stork propagation was accelerated from the first chicks born in 2002 to 174 individuals by 2015 (Park and Cheong 2002; KIWR 2010). In June of 2014, the Yesan Oriental Stork Park was established in Yesan-gun of Chungcheongnam-do, and 60 storks raised at the Korean National University of Education were transferred to the park for future reintroduction. Since September 3, 2015, a total of 15 captive-born storks have been released to the wild environment of the Korean Peninsula.

In this paper, we propose a long-term strategy for the reintroduction of the storks by dividing the Korean Peninsula into three regions, using some available data on the status of the released storks in the Korean Peninsula.

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Movements of Oriental Storks reintroduced in South Korea

The reintroduction of Oriental Storks was started in September of 2015, 44 years after disappearance of the wild storks breeding in the Korean Peninsula. The Yesan Oriental Stork Park collaborated with the Korea National University of Education released a total of 15 captive storks to the wild in 2015 and 2016. The six adult individuals (three males and three females: A01, A02, A27, A30, A04, and A05 in leg bands) were released by a hard releasing method, and the nine individuals (juveniles: B01, B02, A33, A35, and A37; two male adults: A89 and A99, and two female adults: A08 and B88) were released by a soft releasing method. Some storks mainly inhabited in Chungcheongnam-do and, the others stayed in the southern region mainly in Jeonlanam-do and Jeonlabuk-do (Fig. 1). The soft releasing method was used continuously every year in Yesan-gun. This preliminary result suggests the suitable release method for the stork reintroduction (Park et al. 2010).

A reintroduction strategy for Oriental Storks in the Korean Peninsula

The perspective strategy of the stork reintroduction in the Korean peninsula is categorized by three regions as follows (Fig. 2). The first region for conserving Oriental

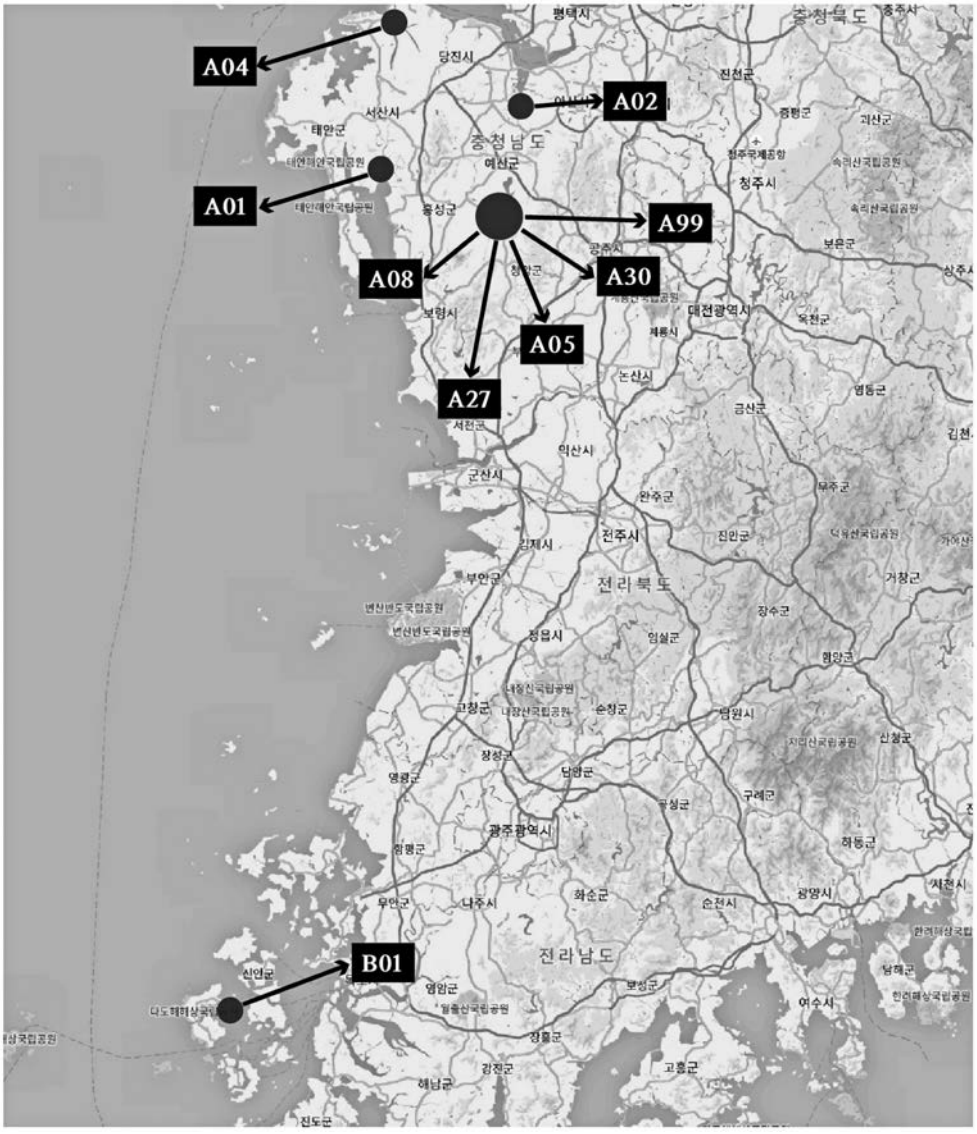

Fig. 1. The release sites of nine Oriental Storks released until June, 2016: Seosan-si in Chungcheongnam-do (A01; stork ID), Dangjin-si in Chungcheongnam-do (A02 and A04), Yesan-gun in Chungcheongnam-do (A05, A30, A27, A99, and A08), and Sinan-gun in Jeonlanam-do (B01) (Google Map).

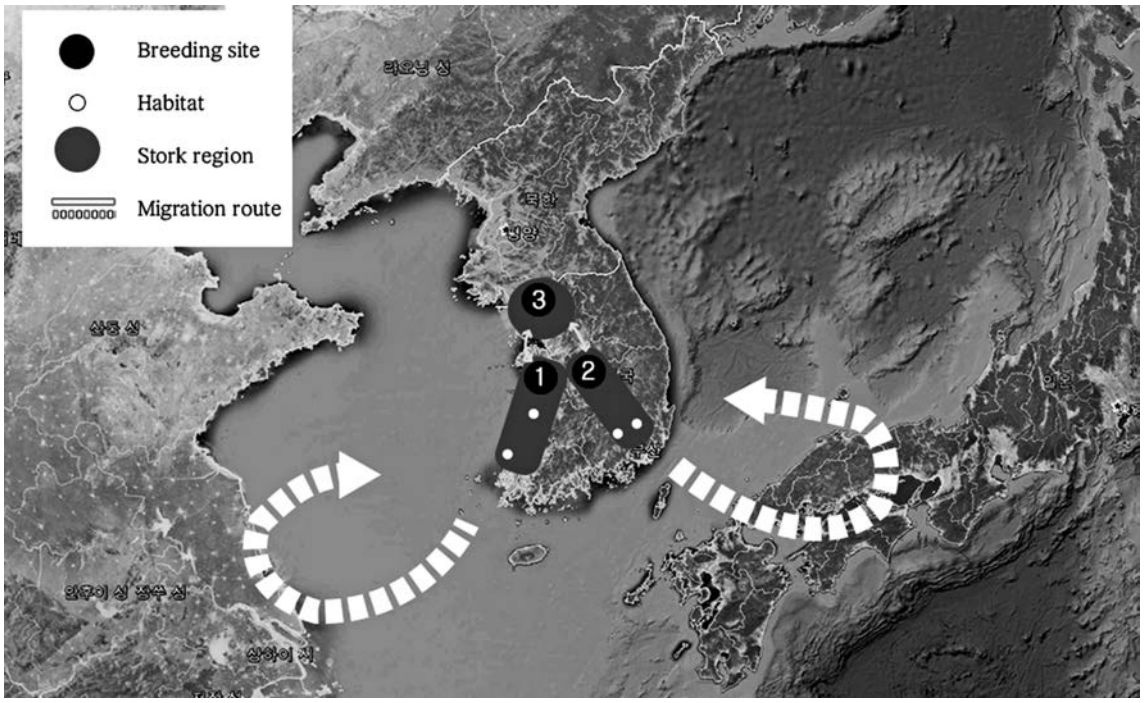

Fig. 2. The proposed areas based on the reintroduction strategy of the Oriental Stork in the Korean Peninsula: the first region is Jeonlabuk-do to Jeonlanam-do region based on Yesan-gun in Chungcheongnam-do (1); the second region is Gyeongsangbuk-do to Gyeongsangnam-do region based on Jincheon-gun in Chungcheongbuk-do (2); and the third region is Hwanghae-do to DMZ region based on Kanghwa-gun in Incheon-si (3) (Google Earth).

Storks consists of Chungcheongnam-do (Yesan-gun), Jeonlabuk-do, and Jeonlanam-do. Currently, the center of Chungcheongnam-do toward Jeonlabuk-do and Jeonlanam-do is bound by the distribution pattern of the stork individuals that were released in Yesan-gun in Chungcheongnam-do. In the Korean Peninsula, the storks separately were predicted to use the breeding and wintering sites in the past, thus the individuals released in the Yesan-gun presumably left there in the fall, and they might go to Jeonlanam-do's coasts or Jeju Island in the winter, and then they were likely to come back to the release area, that means Yesan-gun in Chungcheongnam-do and its surroundings. Of course, the possibility cannot be excluded that the storks descending to Jeju Island can go to the southern part of China presumably due to the food shortage in the winter.

The second region of restoration for Oriental Storks includes Chungcheongbuk-do (Jincheon-gun), Gyeongsangnam-do, and Gyeongsangbuk-do. The region was categorized based on the fact that one individual (female: B49) which accidently escaped from the Korea National University of Education, utilized the past breeding grounds, Jincheon-gun in Chungcheongbuk-do, for two months. As a result of Jincheon's ecological and environmental investigation, this area seems to have a very high biodiversity if agricultural residents reduce pesticide usage, or do farming using environment-friendly farming methods. It is also planned to establish another stork village after the settlement of the Yesan Oriental Stork Park and surrounding stork villages (Upper Stork Village Construction Project; Eco-institute for Oriental Stork, 2015). The second region includes the sites where the storks bred until 1971, Eumseong-gun, in addition to Jincheon-gun. Gwanseong-ri (Saenggeuk-myeon, Eumseong-gun, Chungcheongbuk-do) is the area where the last pair of storks was found a breeding event in South Korea (Park and Chung 2002). It is likely that the storks will migrate to Gyeongsangbuk-do and Gyeongsangnam-do regions in the winter when the storks are released here. Furthermore, the distance from the coast of Gyeongsangnam-do to Fukuoka in Japan is only about 200 km, if the winter temperature of the Korean peninsula lasts below -10 °C (inland temperatures on the Korean peninsula are 10-20 °C before the 1970s), the storks can migrate to Fukuoka.

The third region for the restoration of Oriental Storks

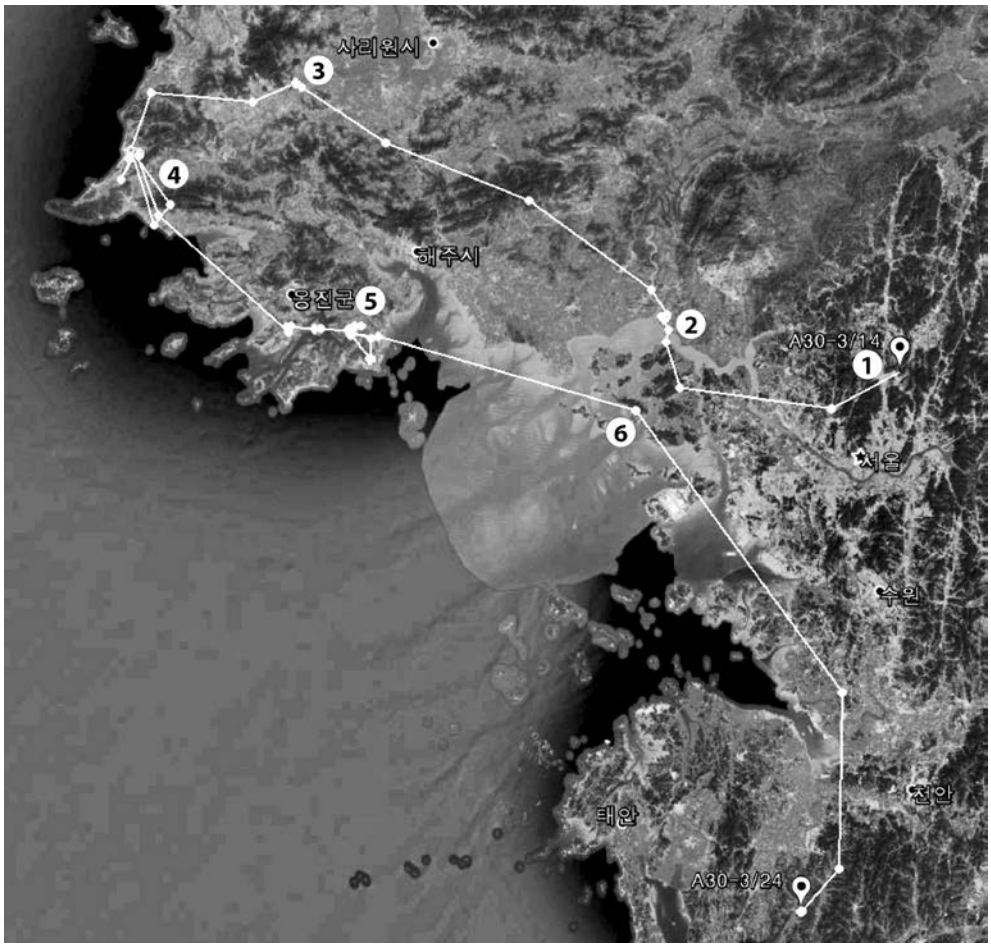

Fig. 3. A movement of the released Oriental Stork (A30) within North Korea: Uijeongbu-si, Gyeonggi-do (site 1; March 14th, 2016) → Gaepung-gun (site 2; 15th, stream-farmland) → Sincheon-eup (site 3;16th, farmland) → Jangyeon-gun in Hwanghaenam-do (site 4;16th to 20th, coastal wetland and farmland) →Ongjin-gun in Hwanghaenam-do (site 5; 20th to 23th, coastal wetland and farmland) → Kanghwa-gun in Incheon (site 6; 23rd) → Yesan-gun in Chungcheongnam-do (last site; 24th) (Google Earth).

consists of Incheon-si (Kanghwa-gun), Hwanghaenam-do, and Hwanghaebuk-do. The region includes Hwanghaenam-do with Hwanghaebuk-do in North Korea and Kanghwa-gun in South Korea. Baecheon-gun in Hwanghaenam-do and Pyeongsan-gun in Hwanghaebuk-do are the areas where the storks bred in the past (Chosun Encyclopedia 2001). Yeonbaek plains, the third largest plains in the Korean Peninsula, is located in this region. It has been investigated that the characteristics of the past breeding grounds of the storks prove them suitable for foraging sites in the flood plain area (Kim et al. 2009). The farmland in the flood plain has much higher biodiversity than other farmlands, which is same as Yesan-gun in Chungcheongnam-do, where the storks used to breed in the past. It is expected that the third region can be the best places for the storks to live, as estimated that the storks bred in the flood plain area with high wetland biomass from March to August in the past. One stork (female, A30) recently released in Yesan-gun stayed near the Yesan Oriental Stork Park and visited Hwanghae-do in North Korea (Fig. 3). The stork returned to the Yesan Oriental Stork Park after a week of stay in a paddy field-river wetland and a coastal wetland in Hwanghae area, suggesting the possibility of linking to the third region (inhabitation in North Korea after reintroduction).

However, the evidence that the ecological environments are not maintained enough to allow the storks to live in North Korea's Hwanghae-do, can be seen from the fact that the storks has completely disappeared here since 1970s. As a result of the GIS analyses using the satellite images, it was found that some of the rivers were changed due to the straight strengthening process compared to the past river types (Lee et al. 2005), but it is not yet clear whether there is enough food for inhabiting.

As rice paddy farming depends on chemical fertilizers and pesticides in North Korea, if organic agriculture is implemented through eco-friendly farming and material supports, it is expected to become breeding sites of the Oriental Stork as well as the past.

Yeonbaek plain, the second largest plain in North Korea, is located in the coastal area of Yeonan-gun, Baecheon-gun and Chungdan-gun in Hwanghaenam-do, and covers an area of 1,150 km^2. There are no large rivers, as there is Myeoraksanmaek (mountain range) adjacent to coast with same direction with the shoreline and Yesung River, relatively large river in the east supplies with many tidal types of sediment. It is located in the northeast of Gyeonggi-bay and has a coastal line with the east-west direction and located in the estuary of Han River, Imjin River, and Yesung River; thus the tideland is developed widely and only 2.3 km^2 away from Kyodong Island in Kanghwa-gun, South Korea. It is a warm temperature region in North Korea, and the annual precipitation is about 1,100 mm, which is quite enough for inhabitation of the storks. There are a few streams that flow inside the Yeonbaek plain, such as Uhsa-cheon, Hwayang-cheon, Myeoncheon-cheon, and Najinpo-cheon, since they are generally small in size, and there is a limit to supply water to the wide farmland of Yeonbaek plain; thus relatively large reservoirs are built such as Guam Reservoir in the upper stream of Hwayang-cheon and Hangyo-choen to supply agricultural water. In view of the changes of the coastline along the Yeonbaek plain, the coastline seemed to be enlarged and simplified to the sea as the reclamation project proceeded in most areas between 1916 and 1981 (Lee et al. 2005). There is no significant change between 1981 and 2002. The sea in front of Yeonbaek plain is an estuary of Han River and Yesung River which flows into the Gyeonggi Bay, which is a place where large scale suspended sediments supplied from the land are accumulated and tideland was widely developed since the past. Judging from the data of 1916, 1981 and 2002 (Lee et al. 2005), the tideland is changing in almost all areas, especially in the offshore of Haenam-ri, Honam-ri and Moonsan-ri.

The tideland of the sea in front of Haenam-ri show the greatest change between 1916 and 1981 (Lee et al. 2005), and while the expansion of the tideland is prominent in the southwestern direction of Haenam-ri after forming of salt pans in 1981, the reduction of the tidelands is prominent in the southeastern sea. In other words, the tideland in front of Haenam-ri was relatively eroded in the east and the sedimentation was active in the west. It is considered that the flow of seawater and the coastal terrain caused the change of sediment transport route and sedimentation environment. In the estuary of Najinpo-cheon, the tidelands along the coastline have almost disappeared and a large area of alluvial island type of tidelands has been developed in the east-west direction with Kyodong Island. In 2002, as the sedimentation became active along the coast around Yeonbaek Plains, the tideland, which took the shape of a long alluvial island to the east and west direction, was developed to a width of 1.5km along the coast to the north and the development of the tidelands was very poor in the center of sea. It appears similar to the aspect of Najinpo-cheon in the off the coast of in Moonsan-ri and Bongha-ri.

Changes in the flow of rivers due to the agricultural land reformation, improvement activity of the rivers and the reclamation of the coasts have been observed. Since the Myungcheon-choen, Najinpo-cheon, and Hankyo-choen are all small streams of less than 50 km in length of main stream, large-scale changes of river channels do not occur, but in the middle and downstream of each river, simplified river flows are easily identified. Myungcheon-choen is formed by river linearization. Downstream of Myungcheon-choen became a land in the reclamation project. The cut off past stream channel and tidal channel still retains its shape and serves as a reservoir space. In Najinpo-cheon, river linearization of the mainstreams and tributaries is also clearly identified. There was a large wetland called Namdaeji (reservoir) in the south-east of Yeonan-eup in 1916, but the wetland disappeared and only the agricultural land was confirmed in the topography of the region of 1981. The satellite image of 2002 was also expressed farmland as a black, which means vestige of the former wetland.

Baecheon-gun in Hwanghaenam-do and Pyeongsan-gun in Hwanghaebuk-do are the areas where the storks have bred in the past (Chosun Encyclopedia 2001). Yeonbaek Plain, the third largest plains in the Korean Peninsula is located in this region. It has been investigated that the

habitat of breeding grounds of the storks in the past is a suitable feeding site in the flood plain area (Kim 2009). The farmland in the flood plain might have a much higher biodiversity than farmland, which is common with the Chungcheongnam-do's Yesan-gun, where Oriental Storks used to breed in the past (Chosun Encyclopedia 2001). It is expected that the Yeonbaek plain can be the best places for the storks to live, as it is estimated that the storks have bred in the flood plain area with high wetland biomass during the breeding season from March to August in the past. However, the evidence that the ecological environment is not maintained enough to allow the storks to live in Hwanghae-do can be seen from the fact that the storks has completely disappeared here since 1970s. However, it is not yet clear whether there are enough food organisms for the storks. However, if North Korea does not rice paddy farming depending upon chemical fertilizers and pesticides, and organic agriculture is implemented through eco-friendly farming and material supports, it is expected to become a stork breeding place enough as the past.

The third area where an ecological belt may be created for breeding habitat of the storks connecting Kanghwa-gun in South Korea and the DMZ, including the stork breeding area in North Korea (Fig. 4). Of course, it is expected that the storks in this area will join with the storks after moving down to south from the first and second regions in the fall season. Considering the breeding habitat of the storks, the place to which the storks went down will become breeding grounds, and as a result that the third area becomes the agricultural area of the whole North Korea as eco-friendly farming area, and it is expected to influence the stork habitats of Rimungbul in Gimchaek-si of Hamkyungbuk-do (North Korea Natural Monument No. 303), where the storks bred in the past (Chosun Encyclopedia 2001).

We propose the following two strategies for the establishment of the reintroduced stork population in North Korea. First, a strategy of Oriental Stork habitat improvement can be applied to Hwanghae-do in North Korea. For preparation for the stork reintroduction in North Korea, Kanghwa Island with a wide paddy field, as a stork habitat, should set up the storks releasing site around the closest area to North Korea. Kyodong-myeon

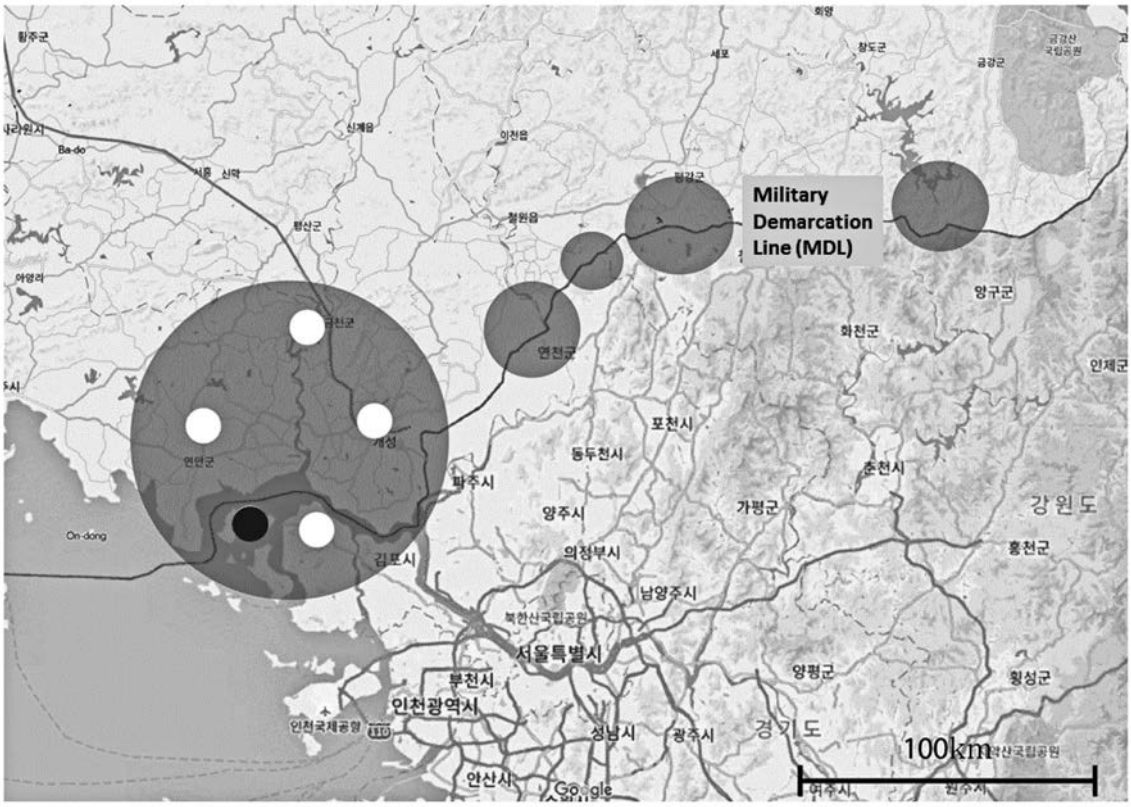

Fig. 4.The area of the third region (white circles) for reintroduction of the Oriental Stork in the Korean Peninsula and construction of the DMZ ecological pathway (gray circles) including the restoration center of the Kyodong Island Stork Restoration Center in Kanghwa-gun, Incheon-si (a black circle) (Google Map).

is the closest to the coastline of Yeonbaek plain, only 3−4 km away. Also, the distance from Baecheon-gun, which was a breeding site of the storks in the past, is 10−20 km away, so the released individuals from Kyodong-myeon will immediately move to Baecheon-gun's farmland. Given that the distance is 60 km to Pyeongsan-gun, and the storks may fly about 300 km to Jindo Island in Jeonlanam-do released from Yesan County, all of Hwanghaenam-do as well as Hwanghaebuk-do could be the habitat for storks. We are currently preparing a soft release site, artificial nest tower, artificial breeding ground including wetland, and research and educational facilities for storks within an area of about 3,000 m^2 in Kyodong-myeon. The name of this facility is tentatively called 'Kanghwa Stork Restoration Center'. The front of the center is composed of ecological rice paddy fields. Stork Ecological Agriculture (Eco-institute for Oriental Stork 2014) will be implemented in the field of 1,400 ha of rice paddies, with the aim of enhancing biodiversity in agricultural lands without using pesticides for creating ecological villages where storks live. It plans to activate tourism business through cultivating the safe agricultural products for consumers. Toyooka City, Hyogo Prefecture, Japan, where the storks are reintroduced to the wild since 2005, will become a best practice (Park et al. 2014). The average number of visitors to the Hyogo Park of Oriental White Stork is 300,000 people per year, and the 'White Stork Friendly Rice' produced there is sold at a price 1.7 to 3 times higher than that of ordinary rice (M. Nakagai, personal communication). From 2017, the Kanghwa Stork Restoration Center plans to release four to six storks each year by hard and soft release techniques. Satellite-based solar locator (Model 65 GPS, North Star ST LLC.) will be attached to all the released individuals; when it informs us of their location in North Korea in real time, we will carry out joint researches with North Korea's researchers.

Second, habitat restoration for the storks is prospected in North Korea. The storks will be released in the central areas of each region of the Korean Peninsula's storks (Yesan-gun of Chungcheongnam-do, Jincheon-gun of Chungcheongbuk-do, and Kanghwa-gun of Incheon-si), and in the beginning the storks as floaters wander inside of each area for 1−3 years, and thereafter, it is expected that breeding grounds will be established when stork pairs are formed within the each region.

The number of storks in the Korean Peninsula before 1970s is not known precisely. According to an investigation by Kim (2009), 27 breeding places in South Korea have been confirmed. However, North Korea has not been investigated yet, so there are no records except Kimchaek-si in Hamkyungbuk-do, Pyeongsan-gun in Hwanghaebuk-do, and Baecheon-gun and Yeonbaek-gun in Hwanghaenam-do (Ministry of Education 1959), and the breeding grounds in the Korean Peninsula could be 31 places so far, but it is estimated that there would be much more breeding grounds if we do the investigation in North Korea. Therefore, in the restoration project of the Korean Peninsula's storks, we aim to establish 50 breeding grounds for each region.

For the ecological stabilization of the storks, the storks' genetic diversity is very important (Price 2010). There are currently 174 individuals in total (including the Yesan Oriental Stork Park) and among them, captive breeding pairs are 17 and a close relative individual has not been produced so far; but with this breeding population alone, we cannot rule out the possibility of a large number of inbreeding pairs. In order to solve this problem, we are considering the transfer of genetically related individuals to Russia as well as introduction of populations from China, where storks have not introduced so far. However, unless long-term artificial introduction is solved, it is necessary to look forward to the storks that come to the Korean Peninsula in the winter, which has breeding grounds in the Amur River basin.

By the early 1900s, worldwide population of the Oriental Stork had been composed of Russian and Chinese Amur's, Korean Peninsula's, and Japanese populations, suggesting that genetic exchange among these populations was active (Park et al. 2014). In 2006, a single wild stork immigrated to Toyooka City, Hyogo Prefecture, Japan from the continent, thereafter the stork mated with a released individual to breed (Ohsako 2011), suggesting that there is a high possibility that the individuals coming to the Korean Peninsula could breed with the released individuals in the Korean Peninsula. In this way, it is expected that natural gene exchange can be achieved between individuals released both in the Korean

Peninsula and Japan.

For the stork reintroduction project, it is very important to establish international ties among the researchers in the Korean Peninsula (Table 1). Especially, it is a big obstacle that South and North Korea cannot build a relationship between researchers in the reality of division. In addition, this study poses a politically sensitive problem that cannot be realized by the researchers of North Korea and South Korea. In the North Limit Line in front of Kyodong-myeon, Kanghwa-gun, North Korea and South Korea are militarily confronted, and it seems unlikely that ecological investigations by researchers will take place immediately. Therefore, this study aims to prepare a base area for storks in South Korea and find ways to improve the relationship between North Korea and South Korea by releasing storks with expecting the improvement of future inter-Korean relations (Fig. 4).

When the storks are released in South Korea, if North Korea does not show any responses, this study will likely be delayed for a considerable period. However, since North Korea has already conducted a similar research project, we expect them to participate in this project more positively. North Korea has carried out a project to restore the Anbeon's habitat of Red-crowned Cranes with the support of the Turner Foundation from 2008 to 2013. Anbeon, Gangwon-do in North Korea was the major wintering spot for cranes until 1980. Due to North Korea's shortage of food resulting in loss of down grain of rice, the Red-crowned Cranes no longer used this area as a wintering spot. Thus, the International Crane Foundation (ICF), headquartered in Wisconsin, USA, sent a habitat restoration expert to North Korea and then the wintering spot was restored through education for organic farming without using chemical fertilizer, and for cultivation by agricultural machines (Healy, 2007; G. Archibald, personal communication; Table 1). Therefore, it is very important for the public to participate in this project, which is aimed at restoring the stork habitat in North Korea (Temple 1978). And with maintaining the political and military tensions between the South and the North, the understanding and cooperation of the endangered species restoration experts and politicians of the South and the North are required. Finally, in the sole current situation on the planet as division of the South and North, it is expected that the "Stork Reintroduction Project in the Korean Peninsula" will be of interest not only to both South Koreans and North Koreans but also to people all over the world.

Table 1. Establishment of international ties among the North and South Korea's researchers in the Korean Peninsula.

Fields	Detailed directions
Ecology and Agriculture	- Researchers from both countries will collaborate and manage stork habitat restoration - Stork's nest tree seedlings support and afforestation in the forests of the area where it is expected that the storks breed in Baecheon-gun and Pyeongsan-gun - Formation of artificial nest towers to induce stork breeding - Supports of organic materials, agricultural machinery, and agricultural technology to Baecheon-gun and Pyeongsan-gun paddy fields where storks breed in the past - In some paddy fields, construction of artificial wetlands without planting rice seedlings to create and manage stork feeding habitat. - Supports of food from South Korea due to reduced crop yields of ecological agriculture products
Ecological education	- Establishment of a professional graduate school, restoration center for Kanghwa's storks, and a research educational institution - Activation of natural resource education in which students from both countries reside - Human resource development project to revitalize ecotourism of local natural resources - Development of agricultural training and education programs to enhance biodiversity
Ecological tourism	- Creation of a stork eco-road that leads to Kyodong - Yeonbaek - Baecheon - Pyeongsan - Gaeseong - DMZ - Kanghwa - Establishment of a stork peace zone in the certain area by the two countries jointly, which is listed as a World Heritage Site ※ In Germany, 3,540 km^2 of the stork village along Elbe River: the landscape was designated as a World Heritage by UNESCO in 1979 (www.unesco.de).

Remarks

The Oriental Stork (Natural Monument No. 199) was a common bird that bred in the Korean Peninsula until 1950s, but the native stork population has been extinct in the 1970s. In this paper, after 2015, the Korean Peninsula is divided into three regions, and a long-term strategy for reintroduction of the storks is proposed. The first region is located in Jeonlabuk-do to Jeonlanam-do areas centered on the present Yesan-gun, and the second and third regions are necessary to implement the long-term plan with a new strategy. Especially, the proposed region from Hwanghae-do in North Korea to Kanghwa-gun in South Korea is a new, indirect, strategy for stork restoration in North Korea, which has a great meaning in restoring the past breeding grounds of the storks including their paddy-river ecosystems in North Korea. We suggest the possibility of establishing breeding population both in North Korea and South Korea through the reintroduction of the storks in the future.

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