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Analyzing Stopover and Wintering Habitats of Hooded Cranes (*Grus monacha*): Implications for Conservation and Species Dispersion in the East Asia

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Key words
***Grus monacha*, Stopover, Hooded crane, Bird conservation, Species dispersion, MaxEnt.**

ABSTRACT

The hooded crane (*Grus monacha*) is a vulnerable species. However, its stopover habitat receives little attention and is not well known or protected even. Here, we present the spatial distribution of the stopover habitats for hooded cranes in the East Asia. A machine learning modeling algorithm of maximum entropy (MaxEnt) weas applied and evaluated with Stochastic Gradient Boosting and Random Forests based on 115 every year used occurrence points (1990-2013) and 14 environmental layers as predictors. Results show that the Songnen Plain and Korea Peninsula are the most important stopover habitats. Four other major areas are also suitable for stopover: (i) the coastal area of the Bohai Sea, (ii) the Three Rivers Plain-Amur River Basin, (iii) the Torey Lake Basin and the (iv) Zeya River-Heilongjiang River. The gap analysis revealed that existing nature reserves conserve merely 16.7% of the suitable habitat and 26.7% of the core habitat. However, much more suitable habitat is still located widely outside nature reserves. Based on our predictions, a total of 22 priority areas should be considered when developing new nature reserves or expanding the existing nature reserves. In addition, we suggest that seven regions located at the Korean Peninsula are also suitable for dispersing hooded cranes from Izumi, Japan. Artificial feeding, including setting up feeding stations with grain, artificial cranes (decoys) and artificial flowing water impoundments can be used to attract wintering hooded cranes at these seven sites. Theoretically, our models show that these habitats can accommodate approximately 3,713 wintering individuals (ca. 35% of the wintering population in Izumi).

INTRODUCTION

Many birds perform long-distance migratory movements twice a year for the purpose of survival or reproduction (Chernetsov, 2012; Rappole, 2013). Stopover habitats play an important role in some migrations because some migrants make multiple stopovers *en-route* during which they rest and refuel (Chernetsov, 2012). As key refueling stations, stopover habitat not only has an influence on the rate of mass gain and survival of migratory birds (Schaub *et al.*, 2008), but it also can affect the timing and success of reproduction (Drent *et al.*, 2003; Smith and Moore, 2003). It is therefore critical to make efforts to understand and protect stopover habitats (Belaire *et al.*, 2014). However, stopover habitat has received little attention by managers while making conservation plans for migratory species. In fact, it is not sufficient to make conservation plans for migratory birds by just concentrating on breeding or wintering grounds without an explicit consideration of known stopover habitats (Moore *et al.*, 1995).

The description of a species' geographical distribution is essential to manage a species effectively (Johnson *et al.*, 2004; Pearce and Boyce, 2006). An accurate distribution map not only allows future surveys to focus on the area where a species is likely to occur, but can also be used to prioritize conservation and management (Rabinowitz and Zeller, 2010; Viña *et al.*, 2010). However, meaningful distribution maps remain unavailable for such purposes, especially for endangered species with a wide distribution. Species distribution models (SDMs) provide high-efficiency quantitative predictions of species distribution, and they are increasingly applied to a wide range of wildlife management studies (Miller, 2010; Drew *et al.*,

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2011). With the development of powerful computers and an increasing availability of large quantities of occurrence and environmental data, SDM have been widely used in the biological conservation (Drew *et al.*, 2011).

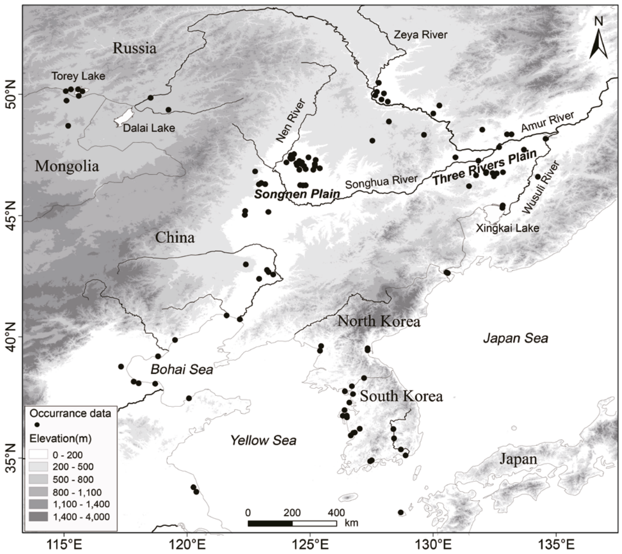

Fig. 1. Topographic map of the study area and species occurrence data used for modeling.

Here, we present a conservation planning model within the flyway of hooded cranes (*Grus monacha*) using SDMs. This species is endemic to the north East Asia (Meine and Archibald, 1996). The global population is estimated to be c.11,600 individuals, and it is already recognized as a vulnerable species in the International Union for Conservation of Nature (IUCN) red list (BirdLife International, 2012). It breeds in the Chinese Lesser Khingan Mountains up to south-eastern Siberia in taiga or other wetlands; it winters primarily at paddy fields in Izumi, Japan (Meine and Archibald, 1996; BirdLife International, 2012). However, there are also wintering in the South Korea and the lower Yangtze River in China. This species migrates twice a year between its breeding grounds and wintering grounds. Its stopover sites are scattered in the Korean Peninsula, the Songnen Plain and the Three Rivers Plain, as further evidenced by satellite tracking (Higuchi *et al*., 1992; Harris *et al*., 2000). Wintering hooded cranes are now highly concentrated at Izumi due to supplementary feeding. Such a large single concentration is at risk of a major population reduction from disease or other stochastic catastrophes (Meine and Archibald, 1996; Harris and Mirande, 2013).

In this study, we used the approach of maximum entropy (MaxEnt) (Phillips *et al*., 2006) to predict the stopover habitat of hooded cranes. However, beyond just producing a habitat prediction model, we also aimed to contribute in a robust fashion to a comprehensive conservation strategy within the migratory flyway. Our first goal was to identify significant stopover habitats and increase our understanding of stopover ecology in quantitative terms. Identifying and protecting important migration stopover habitat is regarded as one of the priority conservation measures for this species (Meine and Archibald, 1996). Our second goal was to conduct a gap analysis to evaluate the efficiency of the existing nature reserve system within the migratory flyway. To achieve this goal, we overlaid already existing nature reserve areas with the predicted stopover habitat map to find gaps and then identified potential conservation priorities. Finally, we tried to develop a more science-based plan to disperse the highly concentrated wintering flocks at Izumi, the dispersal of which is regarded as conservation priority to this species but received little attention (Meine and Archibald, 1996).

MATERIALS AND METHODS

Study area and species occurrence data

The study area is located in the East Asia and includes the entire flyway of hooded cranes between its wintering and breeding grounds (Fig. 1). We obtained species occurrence data that encompass the complete extent of its range from the published literatures or databases, our own field observations and satellite tracking (unpublished data). We have collected 115 occurrence points which span spring and fall migrations (Supplementary Table I). Although these occurrence points span more than 20 years (1990~2013), almost all these stopover sites are usually visited by migratory hooded cranes every year.

Environmental layers

To map the stopover habitats, we chose 14 environmental layers as predictors based on their availability to us and the migratory ecology of hooded cranes (Table I). Slope was derived from our global digital elevation model (DEM) using ArcGIS 10.1. The layers of distance to waterbody (DW), distance to coastline (DC) and land use were included as predictors because hooded cranes might select stopover habitat near waterbodies and cropland, and they have been observed foraging in cropland and roosting in wetland during migratory stopovers (Harris *et al*., 2000; Cai *et al*., 2014). DW and DC were rasterized based on vector layers in ArcGIS 10.1. Some studies have shown that climate variables can significantly affect bird migration. Climate variables, such as temperature and precipitation, can affect food availability at stopover sites and *en route* (Hüppop and Winkel, 2006; Gordo, 2007).

Table I.- Environmental layers used to develop model. Mean temperature of March (MTM), August (MTA), October (MTO) and November (MTN), mean precipitation of March (MPM), August (MPA), October (MPO) and November (MPN).

Predictor layer	Pixel	Resource	URL
Distance to waterbody (km)	-	Digital chart of the world	http://www.diva-gis.org/gdata
Distance to coastline (km)	-	Columbia University	http://sedac.ciesin.columbia.edu
Landuse	300m	European Space Agency	http://dup.esrin.esa.int/globcover
MTM, MTA, MTO and MTN (0.1°C)	1km	Worldclim	http://www.worldclim.org/current
MPM, MPA, MPO and MPN (mm)	1km	Worldclim	http://www.worldclim.org/current
Altitude (m)	1km	Worldclim	http://www.worldclim.org/current
Slope(°)	1km	Extracted from digital elevation model (DEM)	http://www.worldclim.org/current
Human influence index	1km	Columbia University	http://sedac.ciesin.columbia.edu

We used mean temperature and precipitation of March (MTM and MPM), April (MTA and MPA), October (MTO and MPO) and November (MTN and MPN) in the model because we have observed that hooded cranes mainly migrate in March and April during spring migration, and October and November during autumn migration. In addition, a human influence index (HII) was used in the model because human activities can also impact stopover habitat selection (Luo *et al*., 2012; Cai *et al*., 2014).

Model building

We mapped the stopover habitats using MaxEnt 3.3.3k (Phillips *et al*., 2006). MaxEnt is widely used as a machine learning algorithm (Drew *et al*., 2011). It is applied here because it has a high accuracy compared to other models (Elith *et al*., 2006) and is robust to low sample size (Wisz *et al*., 2008). In addition, MaxEnt is a presence-only modeling technique that is more convenient to use as software than traditional presence-absence models because species absence can be difficult to document with certainty.

In this study, we used all the occurrence points (n = 115) for modeling. The model used the default settings as follows: regularization multiplier = 1, maximum number of background points = 10,000 and convergence threshold = 10^{-5}. The model was run with 10 replicates, and the final results were the averaged results of the 10 models (Phillips *et al*., 2006). To allow adequate time for convergence, we used 5000 maximum iterations. Furthermore, to reduce the sampling bias, we developed a bias layer in which MaxEnt selected background or pseudo-absence data from countries where there were sample locations. This layer likely minimized sample bias because it made both the occurrence data and the background subject to the same type of bias (Phillips *et al*., 2009). The output format was set as logistic, which ranges from 0 to 1 and quantified the probability of suitable habitat in each grid cell (Phillips and Dudík, 2008).

Model evaluation

We used three methods to evaluate model performance of MaxEnt: the area under the curve (AUC) in receiver operating characteristic (ROC) analyses (Fielding and Bell, 1997), Cohen's Kappa (Cohen, 1960) and the True Skill Statistic (TSS) (Allouche *et al*., 2006). We evaluated model performance using the 115 occurrence points and 1000 pseudo-absence points randomly generated in the study area (Viña *et al*., 2010). We then extracted the habitat suitability index (HSI) using the Hawth's Tools Geospatial Modeling Environment (GME) (http://www.spatialecology.com/htools) and calculated AUC, Kappa and TSS values using the SDMTools package (Van Der Wal *et al*., 2011) in R 3.0.3. This package allows for an assessment of the model that is independent of the SDM software.

To verify the reliability of the results compared to other high performance machine learning methods, we used two additional high performance machine-learning approaches - Stochastic Gradient Boosting (SGB) (Friedman, 2002) and Random Forests (RF) (Breiman, 2001) - to calculate variable importance and generate alternative suitability maps. We used the same database used for MaxEnt, including the same occurrence points and environmental variables. To confirm the reliability of our model, we compared the similarity of the models visually and with Pearson's correlation of the predicted maps in R 3.0.3 based on the HSI of 10,000 random points followed the method of Belaire *et al*. (2014).

Gap analysis

Gap analysis is a generic method to identify conservation gaps and to present a quick overview of the conservation status based on the comprehensiveness of existing nature reserves (Scott *et al*., 1993). In our study, we merged the nature reserves that were obtained from the World Database on Protected Areas (WDPA) (http://www.wdpa.org/) and the Amur-Heilong River Basin Information

Center (http://amur-heilong.net/). However, those two maps are relatively coarse, and so we document-adjusted the range of some nature reserves and added 40 nature reserves to assure the accuracy and completeness of the map. We overlaid these nature reserves with the predicted distribution map to conduct a conservation assessment and to check for gaps (suitable areas not protected by nature reserves). The nature reserves layers are available from authors on request.

Setting conservation priorities

Although our models revealed the entire stopover habitats of hooded cranes, it is not feasible to conserve all suitable habitats in Asia at the same time due to resource and time limitations. These limitations forced us to prioritize conservation sites and efforts (Moilanen *et al*., 2009). In this study, we identified priorities based on core habitat (highly suitable habitat and the most suitable habitat) that is located outside of the existing nature reserves system. This well proven approach is regarded as a valid method to identify conservation priorities and has been used in some endangered species conservation cases (Viña *et al*., 2010; Luan *et al*., 2011).

Dispersing the concentrated wintering flocks at Izumi

Dense flocks of hooded cranes, representing approximately 85% of the population, winter on just a few hectares of artificially maintained rice paddies in Izumi, Japan (Harris and Mirande, 2013). The high flock density has high disease infection rates, putting the species at risk (Harris and Mirande, 2013). Moreover, the virus can infect and spread into poultry flocks or humans, causing a panzootic and posing a major challenge to human health (Guan *et al*., 2004). Diseases can travel both ways: from animals to humans and from humans to animals. That is a well-known issue in conservation and eco-tourism. Thus, carefully managed species dispersion is among the best options to reduce the threat to this species and public health.

Some references and our field observations found that hooded cranes winter at stopover habitat located near the major wintering ground, such as Suncheon Bay, Cheonsu Bay and Taegu in South Korea (Meine and Archibald, 1996; Collar *et al*., 2001; BirdLife International, 2012). Thus, some stopover habitat of hooded cranes in South Korea may be suitable for wintering. Based on this hypothesis, we identified potential wintering grounds that can be used to disperse the dense flocks at Izumi. Three aspects were taken into account when identifying potential wintering grounds: core stopover habitat, the historical wintering ground of the species (see Collar *et al*., 2001) and a zero-degree isotherm in January (Hijmans *et al*., 2005). We used the last criterion because the low temperature threshold can determine food and water availability (Carrascal *et al*., 2012), as well as population size (Xu *et al*., 2019).

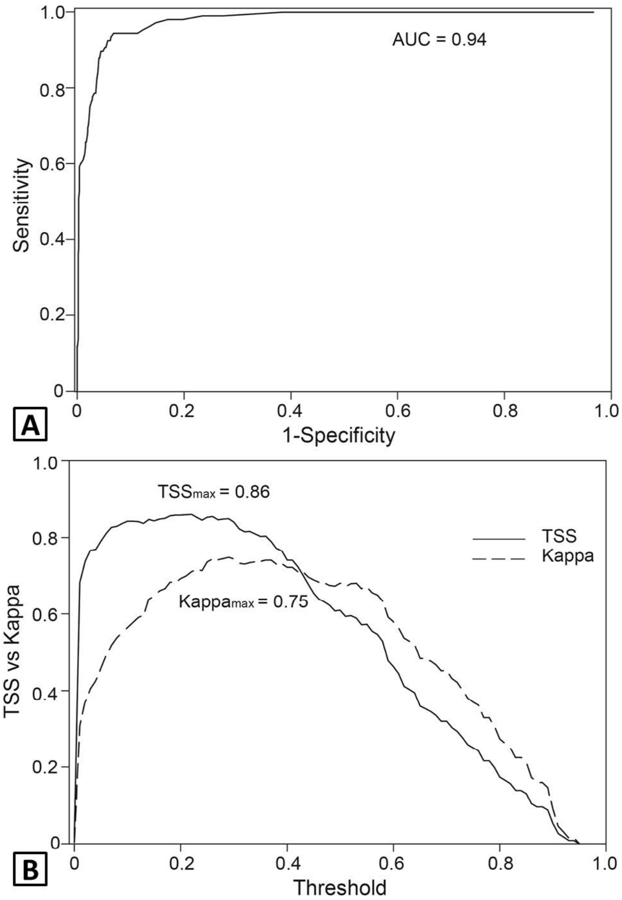

Fig. 2. Results of three methods to evaluate the model: **A**, the area under the receiver operating characterisitic curve (AUC); **B**, Cohen's Kappa and True Skill Statistic (TSS).

RESULTS

Model performance

The ROC analysis shows that the model had a much higher AUC value (0.93) than a random prediction (0.5). The maximum Kappa (0.75) and TSS values (0.86) of the model were equally high (Fig. 2). Based on the standards for judging model performance, these values show that the model is excellent (Cohen, 1960; Araújo *et al*., 2005). In addition, the habitat suitability maps generated by SGB and RF were visually similar to the map of our model, and the correlation analysis resulted in Pearson correlation coefficients of 0.86 ($P < 0.0001$) and 0.80 ($P < 0.0001$), respectively (Supplementary Fig. S1). Variable importance calculated by SGB and RF was also very similar to the result of MaxEnt (Supplementary Table II), and the models were supported by higher AUCs of 0.95 and 0.94. Thus, the predictive stopover habitat map was accurate and reliable and could be used for the following analyses.

Contributions of environmental variables

The jackknife test (Fig. 3) revealed that slope and altitude were the most important variables in the model when used individually, followed by DW, DC, MTA, MTM MTO and land use. MPA and MPM contribute little when used in isolation. Overall, temperature and precipitation in April and October were more important than in March and November. The model lost the most training gain when altitude was omitted from the full model (4.8% training grain lost), followed by slope (4.6% training grain lost) and land use (4.4% training grain lost). This result means that altitude, slope and land use were the important predictors for stopover habitat of hooded cranes.

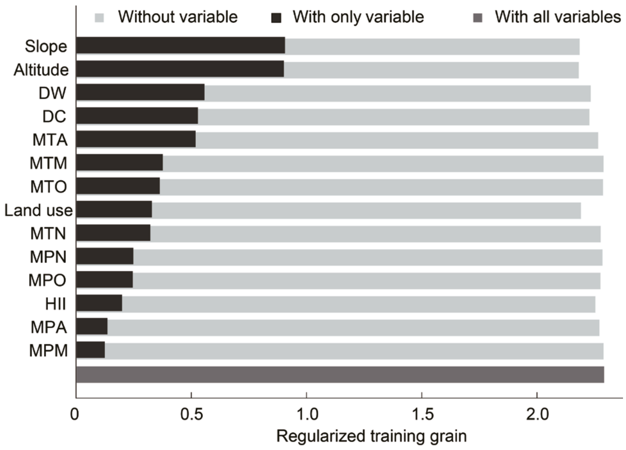

Fig. 3. Result of the jackknife test of environment variable importance. Black bars indicate the gain achieved when using that predictor only and excluding the remaining predictors; light gray bars show how the total gain is diminished without the given predictor. Distance to waterbody (DW), distance to coastline (DC), human influence index (HII), mean temperature of March (MTM), April (MTA), October (MTO) and November (MTN), mean precipitation of March (MPM), April (MPA), October (MPO) and November (MPN).

Potential stopover habitat map

Based on the sensitivity-specificity sum maximization approach (Liu *et al*., 2005), the map generated by MaxEnt could be separated into a binary 'not suitable' and 'suitable' map when using the optimal habitat suitability index (HSI) threshold of 0.22 (Fig. 2B). With this threshold, suitable habitat covers 329,953 km^2, corresponding to 9.5% of the study area (Table II). The core habitat covers 54,821 km^2, accounting for 16.6% of the suitable habitat. Suitable habitat is at lower altitude (below 160 m) and on flat land (slope < 1°) (Supplementary Fig. S2). This habitat is primarily located in six areas: the Songnen Plain (SP) (28.4%), the Three Rivers Plain-Amur River Basin (TRP-ARB) (24.8%), the coastal areas of Bohai Sea (CBS) (14.3%), the Korean Peninsula (KP) (10.7%), the Zeya River to Heilongjiang River (ZR-HR) (4.9%) and the Torey Lake Basin (TLB) (2.5%) (Fig. 4). TRP-ARB and SP have nearly equal areas of suitable habitat, but TRP-ARB has only 30% of the core habitat found in SP.

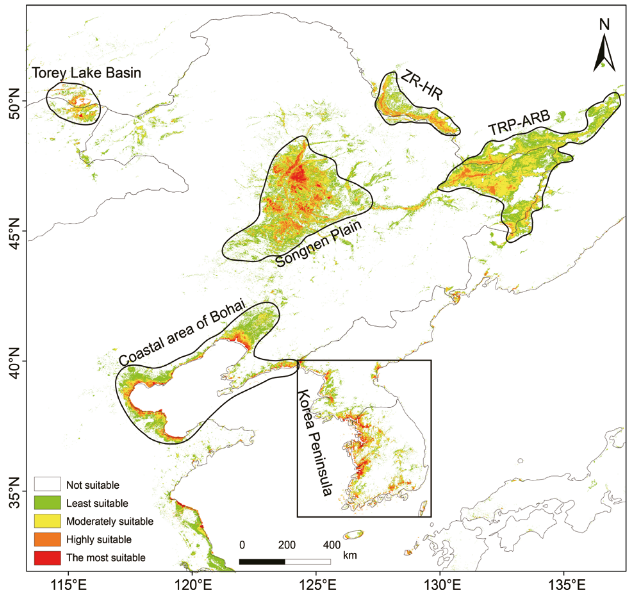

Fig. 4. Spatial distribution of the hooded crane habitat suitability index (HSI). Zeya river-Heilongjiang River (ZY-HR) and Three Rivers Plain-Amur River Basin (TRP-ARB).

Table II.- Suitability levels and their areas and proportions in the study area.

HSI	Suitability level	Area (km^2)	Proportion in study area (%)
0-0.22	Not suitable	3,135,669	90.5
0.22-0.4	Least suitable	176,173	5
0.4-0.6	Moderately suitable	98,959	2.9
0.6-0.8	Highly suitable	43,968	1.3
0.8-1.0	The most suitable	10,853	0.3

Gap analyses and conservation priority

A total of 194 nature reserves overlap with suitable habitats of hooded cranes. The gap analysis suggested that there are 54,963 km^2 (ca. 16.7%) of suitable habitat overlapping with existing nature reserves (Fig. 5). These nature reserves conserve 14,640 km^2 (ca. 26.7%) of the core habitat. The suitable habitats that are protected features 60.1% in TLB, 21.0% in ZR-HR, 20.6% in TRB-ARB, 16.9% in SP and 11.9% in CBS. However, only 1.3% of suitable habitats fall into existing nature reserves in KP. Based on the conservation gaps, we suggest that 22 areas (Fig. 5, A-V) should be considered priorities when expanding nature reserves or creating new nature reserves (Fig. 5).

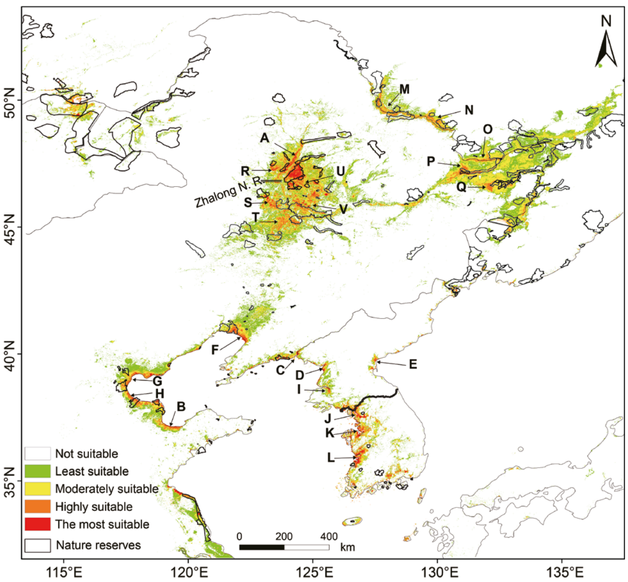

Fig. 5. Nature reserves in the study area and conservation priorities (arrows).

Planning to disperse the concentrated wintering flocks at Izumi

We defined seven stopover habitats in South Korea that could be suitable for dispersing hooded cranes from Izumi. Considering the freezing of water in the habitat, we classified these dispersion sites to two types: (I) not freezing habitat: the Nakdong River Plain, Nakdong Estuary and the seaside region in Sacheon and Mokpo, (II) freezing habitat: Gunsan, Asan Bay and Han estuary (Fig. 6). Habitat of type I is more important than type II because hooded cranes can live in habitat of type I throughout the winter.

Based on the species population (Bosselmann *et al.*, 2008; Li *et al.*, 2009) and the area of core habitat, Suncheon Bay could hold 330 individuals (88 km^2) in type I habitat and Cheonsu Bay could hold 14 individuals (120 km^2) in type II habitat in 2004-2009. These habitats could theoretically accommodate approximately 3,713 wintering individuals (Fig. 6). Therefore, seven dispersion sites could disperse ca. 35% of the wintering population from Izumi.

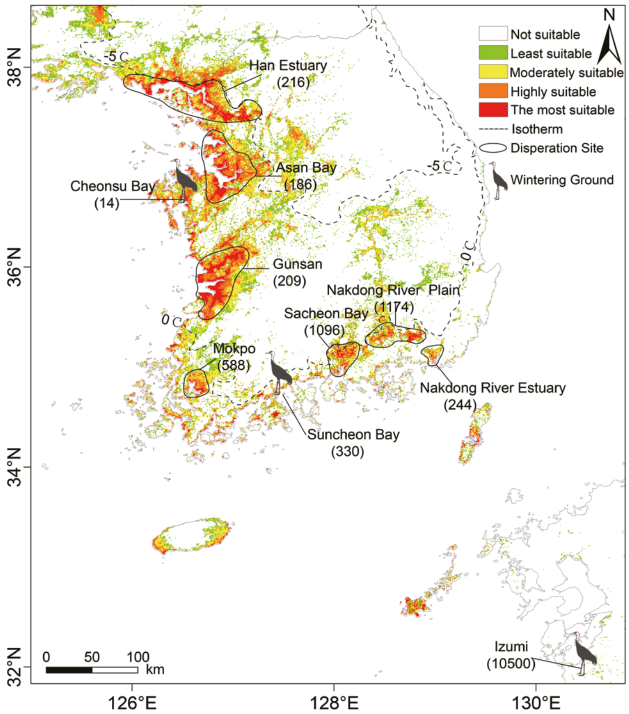

Fig. 6. Map showing species dispersion of hooded cranes from Izumi to South Korea.

DISCUSSION

Hooded crane stopover ecology and suitability habitat

Our study is the first to present a comprehensive science-based map of the stopover habitats for hooded crane in its migration corridor using best available data for the flyway. Our results showed that topographic variables (altitude and slope) effectively characterized suitable stopover habitats of hooded crane. These habitats are flat and low in altitude, and they are located near the coastline or waterbodies where cropland, tidal flat or wetlands occur (Fig. 1; Supplementary Fig. S2). This habitat preference may be due to a highly food availability in these areas, as harvested farmland has some grains, and tidal flats or wetlands carry an abundance of mollusks (Cai *et al.*, 2014). Food availability is regarded as an important factor influencing stopover strategies of migratory birds (Lindstrom and Alerstam, 1992). The model shows that climate variables (temperature and precipitation) had stronger influences in April and October than in March and November (Fig. 3). Thus, April and October are the most important migration times for hooded crane. This finding is in agreement with field observations, during which we observed more individuals at stopover sites in April and October.

The results show that six regions are very suitable for stopover: SP, CBS, KP, TRP-ARB, TLB and ZR-HR (Fig. 4). Among these regions, SP and KP are the most important stopover habitats for these migratory birds. SP has the largest area of suitable habitat (93,728 km^2, equivalent of 37.7% of SP), and over 4,000 hooded cranes (ca. 34% of the world population) stopover in this area during every migration season (Cai *et al*., 2014). In KP, only 35,168 km^2 (10.7%) of suitable habitat exists, but it has supported more than 85% of hooded cranes for stopover. All individuals wintering in Izumi stop over at KP during spring or autumn migration, mainly along the Nakdong River and on the west coast of South Korea (Higuchi *et al*., 1992; Meine and Archibald, 1996). Some areas, such as the Gimpo Plain, Shihwa Lake, Cheonsu Bay, Junam Reservoir, and Nakdong Estuary, are important for hooded crane stopover (Higuchi *et al*., 1992; Collar *et al*., 2001). Thus, these two important stopover habitats should receive more attentions when a conservation plan for this species is developed.

Conservation status and conservation planning

We used a compiled best-available set of 197 nature reserves for the gap analysis. We could not include all nature reserves due to the lack of data availability in some countries, such as North Korea. We could not obtain other nature reserves' data besides the data for the Korean Demilitarized Zone (KDZ), which is already regarded as a large nature reserve. The KDZ provides a sanctuary to endangered and threatened animals (Kim, 1997). Thus, nature reserves may conserve a little more than 16.7% of the suitable habitat.

Overall, existing nature reserves already protect some stopover habitat: 16.7% of suitable habitat and 26.7% of core habitat overlap with nature reserves. For example, the Zhalong Nature Reserve (Fig. 5), which protects 1996 km^2 (5.2%) of core habitat, plays an important role for crane conservation (Su and Zou, 2012; Cai *et al*., 2014). However, the development industry and agriculture seriously threaten nature reserves in China (Jiang *et al*., 2012; Ma *et al*., 2014). In the Three Rivers Plain, the marsh area has already decreased by 44.5% just from 1986 to 2005 alone due to the conversion of marsh into paddy fields and dry land (Jiang *et al*., 2012). In coastal wetlands, seawall construction, which covers already 60% of the total length of coastline along mainland China, has severely threatened biodiversity in coastal ecosystems, resulting in a rapid decline of waterbird populations in the East Asian-Australasian flyway (Ma *et al*., 2014). Clearly, hooded crane conservation efforts not only need to establish nature reserves but, equally, also need to enforce their protected status to ensure relevant, effective and meaningful long-term security (Davis, 1998).

The effective and well accepted method to conserve a species is the development of a systematic, science-based conservation management plan that ensures that all nature reserves conserve a species' distribution in a given geographic region and as planned (Margules and Pressey, 2000). In this study, our results showed that there is still a large area of hooded crane stopover habitats left widely outside the existing nature reserves. These areas need to be considered when developing new nature reserves or expanding the existing nature reserves (Fig. 5). Based on the core habitats located outside the existing nature reserves, we suggest that 22 priority areas (Fig. 5, A-V) should be included in the expansion of the hooded crane nature reserve system. The first five priority areas (Fig. 5, A-E) should be considered for the establishment of new nature reserves due to their flyway-scale importance as cranes stopover habitats, as revealed by our model. Future conservation efforts may concentrate on land-use planning. That's because field observations have found that hooded cranes prefer to stopover at croplands (Cai *et al*., 2014). However, it is difficult to create nature reserves within existing croplands because these areas receive human disturbance during agricultural activities. Considering that some priority areas are located in croplands (Fig. 5, F-L), we suggest that these areas create seasonal nature reserves that would strengthen hooded crane protection during the migration season. In addition, seven existing nature reserves should be expanded because they are close to some priority areas (Fig. 5, M-V). We believe that it is generally more appropriate and rewarding to identify high-priority places and habitat types than to focus purely on individual species (Mehlman *et al*., 2005). If the nature reserve system is completed and all priority areas are protected, the migratory birds can benefit from these conservation measures.

Planning to disperse the concentrated wintering flocks at Izumi

The single dense flock of wintering hooded cranes in Japan is a serious threat to this species because of the higher disease infection risk (Harris and Mirande, 2013). To date, efforts to disperse this species have had limited success due to the unique behavior of the hooded crane-subsidized and habituated hooded cranes do not move readily away from established habitat (Harris and Mirande, 2013).

Our results show that seven regions in South Korea are suitable for dispersing cranes from Izumi (Fig. 6). These regions could theoretically accommodate approximately

3713 wintering individuals. In fact, South Korea increasingly receives wintering hooded cranes, especially in the south. In Suncheon Bay, the wintering population has increased rapidly, from 75 individuals in 1996 to 687 individuals in 2014. Many studies have shown that birds have exhibited a poleward shift in wintering ranges in Asia and North America due to global climate change (Maclean *et al*., 2008; Hu *et al*., 2010). Thus, we propose that South Korea could be suitable wintering ground in the future.

Artificial feeding is viewed as a short-term emergency method of cranes conservation in spite of its negative effects in modifying crane behavior and increasing disease risk and human disturbance. However, it remains the best option to attract this species to wintering grounds (Davis, 1998). With ongoing artificial feeding of hooded cranes at Izumi since 1962, the population of hooded cranes increased from approximately 800 individuals in 1962-1963 to approximately 10,500 birds in 2012 (Ohsako, 1994; BirdLife International, 2012). Furthermore, the rate of population increase has a significant relationship with the availability of food in the wintering ground (Ohsako, 1994).

From a numerical perspective, therefore, we suggest that feeding stations with grains and artificial cranes (Davis, 1998) and artificial flowing water impoundments should be set to attract hooded cranes to wintering grounds at seven dispersion sites in the South Korea. In fact, these methods have been applied for several years at Cheonsu Bay and Suncheon Bay. The efforts, it seems, have received some success - Cheonsu Bay has been visited by wintering individuals and the wintering population has increased rapidly in recently years. However, domesticating such animals makes them less wild. Habitat protection to avoid domestication would be much better, when combined with textbook approaches to landscape and ecological service management (Forman, 1995). If successful, dispersion can reduce the disease risk of this species in Izumi and become a good example for species dispersion in the wild.

CONCLUSION

Our analyses of stopover habitats for hooded cranes have suggested two important regions: the Songnen Plain and Korea Peninsula. These two regions should receive more attentions when the new conservation plans are made, considering they are used by most individuals, to avoid habitat loss. South Korea also could be suitable for wintering birds of hooded cranes. It is however necessary to formulate a thorough conservation plan to attract wintering birds from Izumi.

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Supplementary material

There is supplementary material associated with this article. Access the material online at: http://dx.doi.org/10.17582/journal.pjz/2019.51.4.1323.1333

Statement of conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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