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Using MaxEnt Model to Guide Marsh Conservation in the Nenjiang River Basin, Northeast China

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Abstract: Incorporating private and working lands into protected area networks could mitigate the isolation state of protected areas (PAs) and improve the efficiency of conservation. But how to select patches of land for conservation is still a troublesome issue. In this study, the MaxEnt model and irreplaceability index were applied to guide marsh conservation in the Nenjiang River Basin, Northeast China. According to the high accuracy of the MaxEnt model predictions (i.e., the average AUC value = 0.933), the Wuyuer River and Zhalong marshes in the downstream reaches of Wuyuer River are the optimal habitat for the Red-crowned crane and migratory waterfowls. There are 22 marsh patches selected by the patch irreplaceability index for conservation, of which 12 patches had been included in the current network of protected areas. The other 10 patches of marsh (amounting to 1096 km^2) far from human disturbances with high NDVI (up to 0.8) and close distance to water (less than 100 m), which are excluded from the existing network of PAs, should be implemented conservation easement programs to improve the protection efficiency of conservation. Specifically, the marshes at Taha, Tangchi, and Lamadian should be given priority for conservation and restoration to reintroduce migratory waterfowls, as this would lessen the current isolation state of the Zhalong National Nature Reserve.

Keywords: MaxEnt model; irreplaceability index; marsh conservation; Red-crowned crane (*Grus japonensis*); Nenjiang River Basin

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1 Introduction

Although the establishment of protected areas (PAs) has been globally regarded as an effective tool for biodiversity conservation at the landscape scale, the efficiency of this protection was still questioned and limited due to their isolated states (Beatty et al., 2014; Rodríguez-rodríguez and Martínezvega, 2018). Especially, in small PAs, species extinctions have increased greatly with its high levels of isolation state, where the surrounding landscape is not considered comprehensively in its original area design (Newmark, 2008; Calado et al., 2016).

To mitigate the isolation state of PAs, the governments of developed countries would invest large amounts of money to build conservation networks to preserve and connect the key habitats of species and the ecosystems, because such conservation networks could spatially distribute the risk of extinction and address the life-history needs of vagile species (Moore et al., 2011; Zisenis, 2017). In recent years, conservation easement programs, which incorporate private and working lands into networks of wetland PAs, have gained increasing

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attention from public conservation agencies and non-governmental organizations (NGOs) who wish to preserve biodiversity on privately owned lands (Parker and Thurman, 2013; Anderson and Padding, 2015; Bastian et al., 2017). The Wetland Reserve Easement (WRE) program created by United Sates Department of Agriculture (USDA) is one such effort (Evans-Peters et al*.*, 2012; Beatty et al*.*, 2014), of which the overarching goal is to restore the hydrology of a site as close as possible to pre-human development condition, in order to improve the wetland habitat for wildlife (Sonnier et al., 2018).

However, in China, which has experienced rapid economic development and urban expansion since the 1980s (Mao et al., 2018; Shi et al., 2018), many nature reserves were designated by expert knowledge as an emergency measure to preserve the degrading and disappearing biodiversity and terrestrial ecosystems. Although large numbers of PAs have been established for in situ biodiversity conservation (Zhang et al., 2016; Xu et al., 2018), many nature reserves were arbitrarily designed as large as possible, and sometimes they were zoned in the absence of detailed field surveys. For example, static functional zones of some wetland nature reserves were designed so impractically that they did not cover seasonally changing habitats of migratory waterfowls (Li and Fluharty, 2017; Zhang et al., 2017). Consequently, most spatially representative and complementary sites for biodiversity are poorly covered by PAs, resulting in low ecological representation of PAs network at the national scale (Xu et al., 2018). Thus, in December 2016, an institutional protection plan for wetland ecosystems was specifically enacted by the State Council of China to strengthen the conservation and restoration of the country's wetlands. A troublesome issue is: How to select wetland sites for conservation and restoration? And which patches of wetland should be designated as a priority for restoration?

Previous studies have relied on various factors, such as species richness, rarity, diversity, shape and other attributes, as indicators for conservation site selection, which is a major issue in conservation biology for decades (Memtsas, 2003; Dissanayake et al., 2011; Gjerde et al., 2018). However, this type of analysis was so complex that biologists had to use surrogate species (i.e., a flagship species or a biodiversity indicator) to solve these problems, e.g., red-listed species are frequently used as this kind of species for conservation, particularly at finer spatial scales (Schmeller et al., 2014; Gjerde et al., 2018). This is because a surrogate species may not only be used to proactively locate areas of high biodiversity, but also can act as an umbrella for sustaining the requirements of sympatric species (Senzaki et al., 2015; Fleishman et al., 2018), especially in the places that lack of fundamental data on species richness, abundances, and spatial distributions (Caro and O'Doherty, 1999; Jones et al., 2016). A case in point is the Red-crowned crane (*Grus japonensis*), an endangered species on the 2010 *IUCN* (*International Union for Conservation of Nature*) *Red List*, which is regarded as a wetland indicator species that has been proven effective for increasing public attention, conservation awareness, and funding for biodiversity protection (Lu et al., 2007).

Therefore, in this study, we used the Red-crowned crane as wetland indicator species to resolve the problem of conservation site selection in downstream marshes of the Nenjiang River Basin, Northeast China. Maximum entropy (MaxEnt) model outperforms other species distribution models and is able to produce reasonable and reliable quality models for many species with a relatively small number of records (Elith et al., 2006; Phillips et al., 2006; Na et al., 2018). In addition, the irreplaceability index, as an important term in systematic conservation planning, can help determine which patches are priorities for conservation. Therefore, by the combined use of the MaxEnt model and irreplaceability index, this paper aimed to: 1) select valuable patches of marsh for conservation, by predicting suitable habitat for the Red-crowned crane using the MaxEnt model; 2) assess the irreplaceability of these selected marsh patches; and 3) propose a rank ordering of patch prioritization for marsh conservation and restoration planning in the Nenjiang River Basin.

2 Materials and Methods

2.1 Study area

Enclosed by Da Hinggan Mountains to its west and the Xiao Hinggan Mountains to its north, the Nenjiang River Basin lies at the intersection of Heilongjiang, Jilin and Inner Mongolia of China, with a catchment area of 29.4×10^4 km^2 (Wang et al., 2015). Originating from the Yilehuli Mountain of the Da Hinggan Mountains, the Nenjiang River winds through a series of valleys and several tributaries, flowing down into the Songnen Plain, where numerous fresh or brackish shallow, reed-filled lakes and rivers occur among the flooded grasslands and meadows.

Since the early 1970s, more than 90 PAs have been established for biodiversity and ecosystem conservation in the Nenjiang River Basin (Wang, 2016), such as the Zhalong, Momoge, Xianghai, Chaganhu, Keerqin, Tumuji, Dabusu, Longfeng, Qiqihar, Halahai, and Gudahu nature reserves of marsh (Fig. 1). During the breeding season (April to June), the primary productivity of these marshes is so high, with abundant fish, frogs, mollusks and aquatic insects, that these sites served as ideal breeding refuges for waterfowl and rare endangered avian species, such as Red-crowned crane (*Grus japonensis*) and Chinese merganser (*Mergus squamatus*).

Unfortunately, during the past few decades, the primitive hydrological situation of these reserves had been changed by the agriculture development and infrastructure construction, resulting in the fragmentation of marsh and deterioration of the habitat quality (Na et al., 2018). So, marsh restoration and conservation must be strengthened in this region.

2.2 MaxEnt model building

MaxEnt model is a general-purpose method used to make predictions or inferences from incomplete information, and its origins lie in statistical mechanics (Jaynes, 1957). It can determine habitat suitability by presence-only data of species and related environmental and climatic variables (Phillips and Dudik, 2008). In this study, the MaxEnt model (version 3.4.1) was downloaded from the website (http://biodiversityinformatics.amnh.org/open_source/maxent/) to evaluate the habitat suitability of the Red-crowned crane in the Nenjiang River Basin.

2.2.1 *Input data*

Species occurrence data were obtained from available documents (Wang et al., 1999; He et al., 2004; Wu et al., 2016; Na et al., 2018), aerial survey reports (Feng and Li, 1985; Ma et al., 1987; Zhang and He, 2009; Qian et al., 2012), and the Global Biodiversity Information Facility website (http://www.gbif.org/species/2474944). For determining precise locations, only 24 occurrence records were collected (Fig. 1) and converted into a coma-separated value (.csv) datasheet with three columns, entitled species, longitude, and latitude.

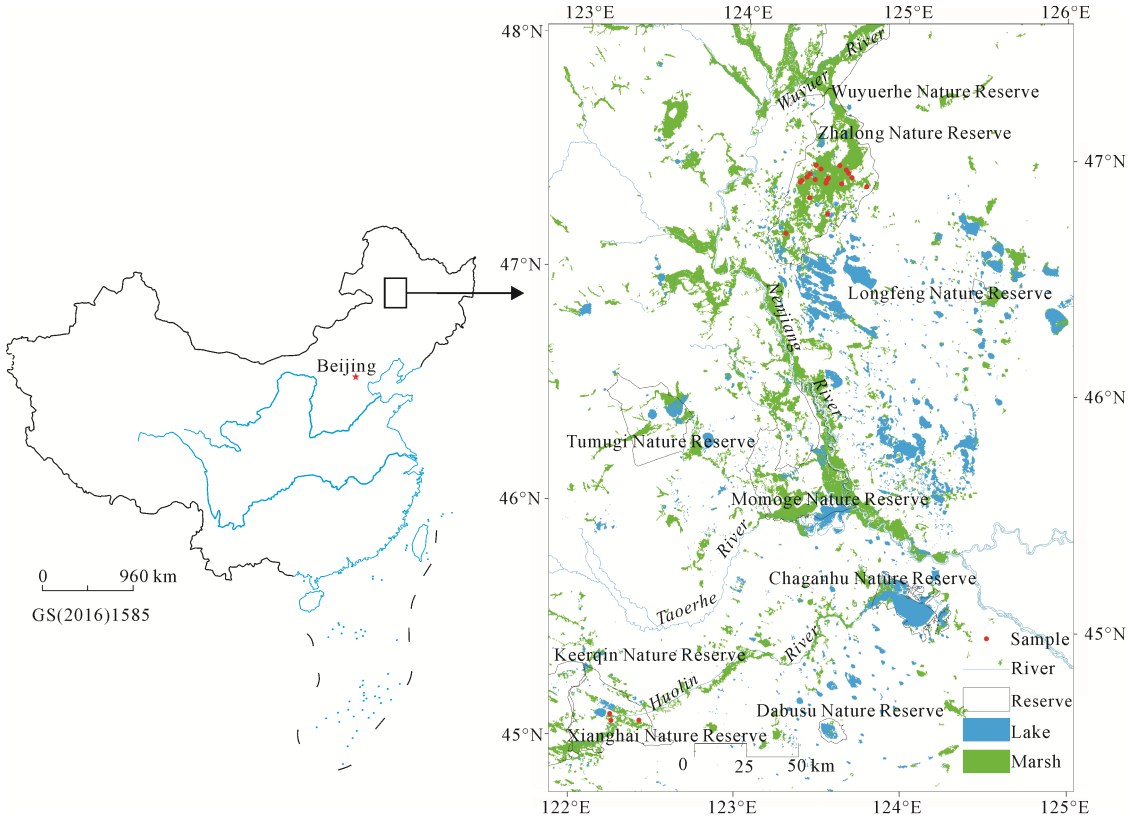


Fig. 1 Location of study area and sampling sites

Since the potential suitable habitat of the Red-crowned crane was the desired result for guiding marsh restoration, 10 landscape-scale predictor variables were ascertained as environmental layers:1) The normalized difference vegetation index (NDVI) average data (from 2000 to 2012) were obtained from the MOD13Q1 of Land Processes Distributed Active Archive Center (https://lpdaac.usgs.gov/); 2) The 30-m resolution DEM was obtained from 1 arc-second SRTM data of the Earth Resource Observation and Science Center (https://lta.cr.usgs.gov/SRTM1Arc); 3) Climatic data (mean annual temperature and mean annual precipitation from 2000 to 2012) were obtained from the National Meteorological Information Center (http://data.cma.cn/site/index.html); 4) The 2010 land-cover data, obtained from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (http://www.resdc.cn), was an essential environmental layer for the MaxEnt model. We reclassified its original classes of river, lake, reservoir, beach, and marsh into a single wetland category. Thus, this uniform category could be used as a bias file in the MaxEnt model; 5) The distance to water, roads, and residential area for each pixel were calculated in ArcGIS 10.0 with its spatial analysis tools. The residential area and water bodies were extracted from land cover data, while the roads were obtained from the National Catalogue Service for Geographic Information (http://www. webmap.cn/).

All the above datasets were re-projected to GCS_WGS_1984 and resampled to 250 m × 250 m grid of the same extent, using the raster calculator tools of ArcGIS 10.0. Then, they were all converted to the ASCII raster grid format required by the MaxEnt software, using the raster to ASCII conversion tool. Except the land cover data that was set as a categorical variable, all the other data layers were used as continuous variables.

2.2.2 MaxEnt settings

The value of 25 was entered for random test percentage, which meant that 75% of the occurrence data were randomly set aside for training the model, while the remaining 25% of the samples were reserved for testing the resulting models. The number of replicates was set to 10 for repeated subsampling and for cross-validation, wherein the occurrence data was randomly spilt into numbers of equal-sized groups. Compared with validation of a single training/test split, the cross-validation approach could make better use of small data sets for validation (Phillips et al., 2012). The other user-specified parameters were set as default values; for more technical details, please refer to the key reference publication (Phillips et al., 2006).

2.2.3 Model output

The Area Under the Curve (AUC) of the Receiver Operator Characteristic (ROC) plot was employed to examine the performance of the model, for which higher AUC values (> 0.75) indicate a model with better distinctive capacity, while lower AUC values (< 0.5) suggest the models cannot discriminate between preferred habitat and the environmental background. The jack-knife approach was used to evaluate the importance of predictive variables in the MaxEnt model, because it is recognized as a sound validation method for small sample sizes (Nazeri et al., 2012).

The logistic output map of MaxEnt is a continuous map, for which the grid cell value (range from 0 to 1) represents the occurrence probability of the species. For example, a presence site with a logistic output near 0.5 could be interpreted as having a 50% chance of the species being present there. Therefore, suitable habitat patches for Red-crowned crane were determined by overlaying wetland coverage and the output map of occurrence probabilities > 0.5. Next, the suitability level of each habitat patch was determined by the patch irreplaceability index.

2.3 Patch irreplaceability index

The term irreplaceability is one of the outcomes from systematic conservation planning (SCP) research (Margules and Pressey, 2000; Gardner et al., 2015), and an irreplaceability index was developed in response to the limitations of reserve selection algorithms. Irreplaceability index would identify a continuum of value (range from 0 to 1) for the areas within a region; those patches of restricted or endangered ecosystems typically attract the highest irreplaceability score, with values of 1, indicating they are completely irreplaceable patches and there are few alternative sites for the conservation targets of the ecosystems (Carwardine et al., 2007).

Because irreplaceability and vulnerability are the two principal measures of SCP (Kukkala and Moilanen, 2013; Buschke and Vanschoenwinkel, 2014), we incorporated the vulnerability criteria into the calculation of patch irreplaceability index, to produce a comprehensive patch irreplaceability index as a patch-based ranking method for conservation prioritization. The patch irreplaceability index (IR) was calculated as the sum of its probability by the MaxEnt model prediction and its protection level in the network of PAs, as follows:

$$IR_{\mathrm{p}}=IR_{\mathrm{mp}}+IR_{\mathrm{lp}}=\sum_{i=1}^{t}\left(\frac{1\times M_{\mathrm{mp}}}{N_{\mathrm{mp}}}\right)+\sum_{i=1}^{t}\left(\frac{1\times L_{\mathrm{lp}}}{N_{\mathrm{lp}}}\right) \quad (1)$$

where IR_{p} is the comprehensive irreplaceability index of the habitat patch; IR_{mp} is the irreplaceability index determined by patch probability obtained from the MaxEnt model, N_{mp} is the number of chosen patches by the model prediction, t is the number of pixels each patch contains, M_{mp} is the pixel value of each patch calculated by Equation (2); IR_{lp} is the irreplaceability index determined by the vulnerability criteria of patch protection level in the network of PAs, N_{lp} is the number of patches belonging to PAs and L_{lp} is the pixel value of each patch determined by Equation (3).

Overall, a higher irreplaceability index value indicates higher conservation significance for the selected patches.

$$M=\begin{cases}0, & \textit{the probability} < 0.5\\ 1, & 0.5 \le \textit{the probability} < 0.6\\ 2, & 0.6 \le \textit{the probability} < 0.7\\ 3, & 0.7 \le \textit{the probability} < 0.8\\ 4, & 0.8 \le \textit{the probability}\end{cases} \quad (2)$$

$$L=\begin{cases}0, & \textit{the patch is not in PAs}\\ 1, & \textit{the patch is in county level}\\ 2, & \textit{the patch is in provincial level}\\ 3, & \textit{the patch is in national level}\\ 4, & \textit{the patch is in international level}\end{cases} \quad (3)$$

3 Results

3.1 Performance of MaxEnt model

In our predictions, the average test AUC for the replicate runs was 0.933 (Fig. 2a), which exhibited a higher level of accuracy than the random prediction. The spatial distribution of the Red-crowned crane derived by MaxEnt model was a close approximation of real-world distribution probabilities, and its habitat suitability distribution was mapped.

Meanwhile, the jack-knife testing of variable importance (Fig. 2b) indicated that the variables DEM, mean annual temperature and mean annual precipitation (AUC > 0.85) were more important than the other seven variables. This means the Red-crowned crane might choose macroscale geographic or physical range characteristics as a first-order selection, which is consistent with findings of other bird habitat-selection studies (Johnson, 1980; Jones, 2001; Sánchez-Clavijo et al., 2016; Mcgarigal et al., 2016).

According to the response curves (Fig. 3), the Red-crowned crane would prefer marsh landscape at lower thresholds of elevation between 100 and 200 m a.s.l. (Fig. 3a), with a mean annual temperature in the range of 3℃ to 5℃ (Fig. 3b) and a mean annual precipitation in the range of 400 to 450 mm (Fig. 3c) in the Nenjiang River Basin. Its occurrence probability was rising with the increasing NDVI of marsh and decreasing with the distance to water (Figs. 3e and 3f); this indicated the species would choose contiguous marsh area with higher levels of vegetation cover (NDVI is up to 0.8) and closer distance to water (less than 100 m) as its optimal habitat. The influence of human disturbances is shown in Figs. 3g and 3h. The species occurrence probability would increase with the increasing distances to roads and residential areas, until further than 1200 m. This result indicated that the occurrence probability of Red-crowned crane was no longer influenced by the distances above 1200 m, and the Red-crowned cranes seemed to prefer marsh patches far from human disturbances (best distance is about 1200 m), which was coherence with the previous studies conducted by Wu (2005).

3.2 Field testing of the model

To assess the practicability of our MaxEnt model, it was tested by a field study that included both ground and aerial surveys of breeding populations of the Red-crowned cranes in the Songnen Plain; this field study was conducted simultaneously with a 5-year field survey of breeding waterfowl species under the support of the Siberian Crane Wetland Project from United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF) (Jiang and Piao, 2015).

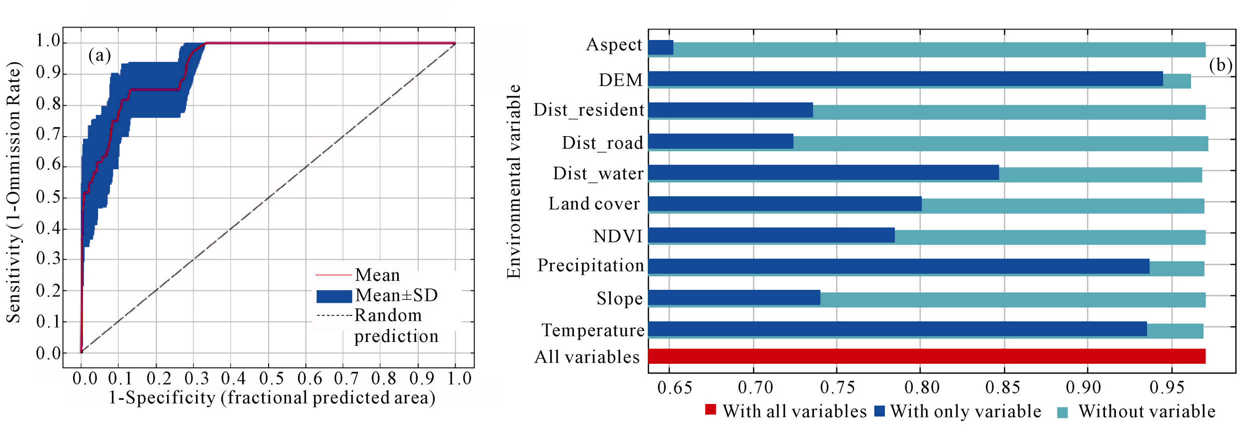
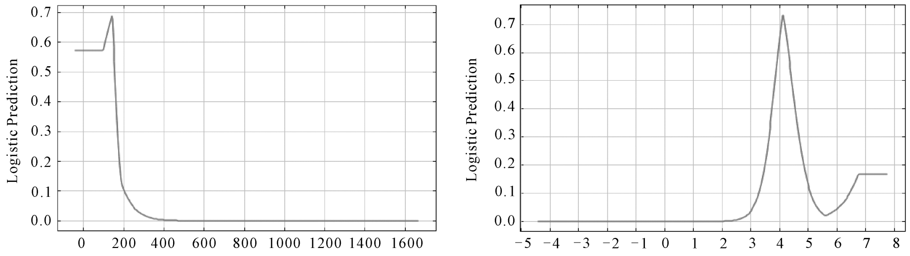
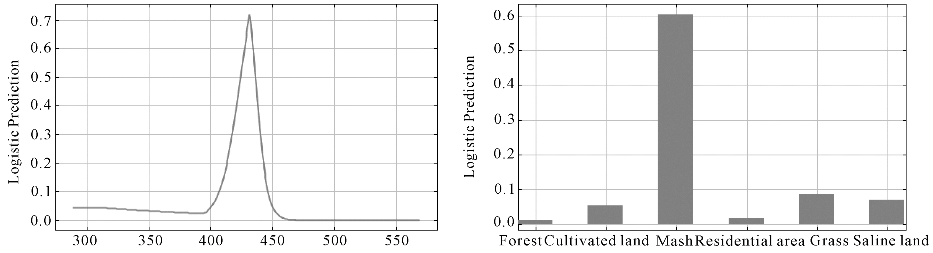


Fig. 2 The ROC curve (a) and jack-knife test of variable importance (b) in the MaxEnt model predictions for Red-crowned crane in the Nenjiang River Basin in 2010. SD is standard deviation



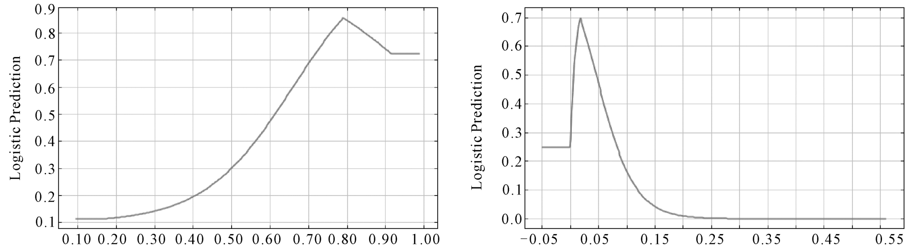
(a) DEM (m)

(b) Temperature (℃)



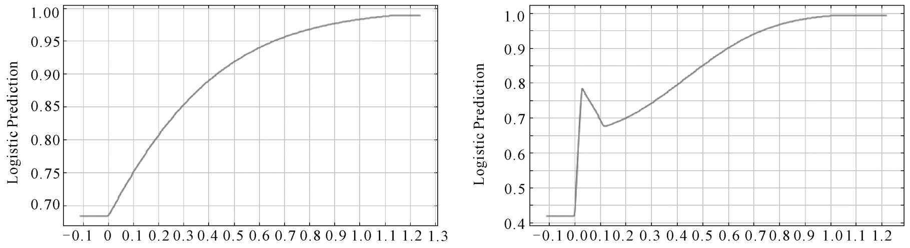
(c) Precipitation (mm)

(d) Land cover type



(e) NDVI

(f) Distance to water (km)



(g) Distance to residential area (km)

(h) Distance to road (km)

Fig. 3 Response curves of environmental variables for the occurrence probability of Red-crowned crane in the Nenjiang River Basin in 2010

Based on Fig. 4, the mean occurrence probability of the Red-crowned crane by MaxEnt prediction in Zhalong (mean probability = 0.8999) and Xianghai nature reserves (mean probability = 0.1120) were greater than that in the Momoge (mean probability = 0.0855) and Keerqin nature reserves (mean probability = 0.0696) and other patches of marsh, where the species was seldom detected and recorded (Table 1). The result is similar to the previous studies of this bird species (Wu et al., 2016; Na et al., 2018). Therefore, the prediction result was valuable and acceptable at the landscape scale.

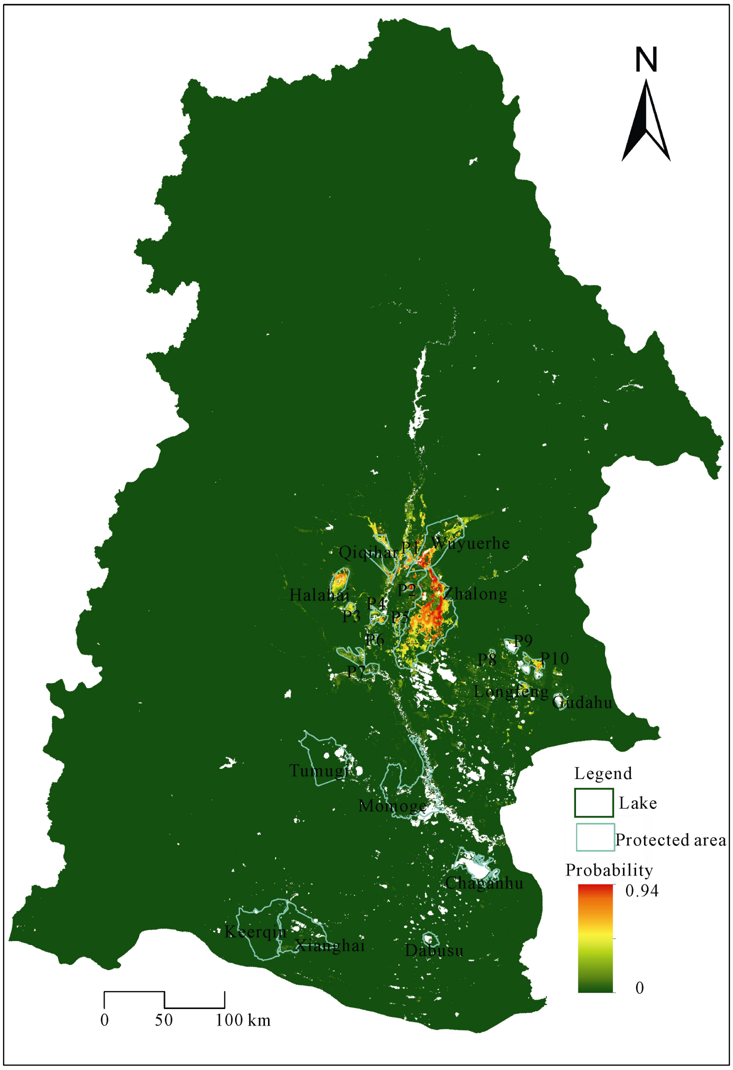


Fig. 4 The suitable habitat probability map for the Red-crowned crane and the patches chosen by the irreplaceability index. P1–P10: patches chosen for conservation and wetland restoration which are not protected area

Table 1 Field survey of Red-crowned cranes in national nature reserves

Location	2004 Ground survey		2005 Ground survey		2005 Air survey		2006 Ground survey		2007 Ground survey		2008 Ground survey		2008 Air survey	
	I	N	I	N	I	N	I	N	I	N	I	N	I	N
Zhalong	138	10	108	28	153	33	118	3	211	16	274	27	127	27
Xianghai	5	0	6	0	5	2	4	2	7	2	2	1	–	–
Momoge	0	0	0	0	0	0	8	1	4	1	0	0	–	–
Keerqin	0	0	0	0	0	0	0	0	0	0	0	0	–	–

Notes: I: individuals; N: nest

3.3 Distribution of predicted suitable habitat

According to the suitable habitat probability map of the Red-crowned crane based on the MaxEnt prediction (Fig. 4), there is a greater occurrence probability of the species in downstream marshes of the Nenjiang River Basin. Specifically, the optimal habitat for this species identified by the MaxEnt model are: 1) Zhalong and Wuyuer River marshes located in the downstream reaches of Wuyuer River, where have already been designated as national nature reserves in the network of PAs; and 2) marshes along the downstream reaches of Nenjiang River, where most sites remain unprotected in the current network of PAs.

3.4 Prioritization of marsh patches

In this paper, the patches of prediction probability greater than or equal to 0.5 and a coverage area greater than 20 km^2 could be considered as candidate marsh patches for conservation and restoration. In this way, there are 22 marsh patches chosen for conservation (Fig. 4), of which 12 sites were already legally included in the network of PAs, and the irreplaceability index of each patch was individually calculated by Eq. (1).

In considering the protection level of PAs ($\mathrm{IR}_{\mathrm{lp}}$), the comprehensive irreplaceability index (IR_{p}) of PAs exceeded those of the chosen patches (P1–P10; Table 2). The comprehensive irreplaceability index of the Zhalong Nature Reserve (IR_{p} = 0.2521) was the highest among the internationally important wetlands; the comprehensive irreplaceability index of Wuyuer River Nature Reserve (IR_{p} = 0.1565) was the highest among national wetlands; among the provincial wetland nature reserves, Longfeng Nature Reserve had the highest irreplaceability index (IR_{p} = 0.1351).

When the protection level of PAs was ignored (IR_{lp}), we ranked the comprehensive irreplaceability index of the chosen patches (P1–P10) based on the prediction results of MaxEnt model (IR_{mp}). Except for Zhalong Nature Reserve that had the highest irreplaceability index record (IR_{mp} = 0.0703), the comprehensive irreplaceability index of the national-scale nature reserves, such as Keerqin (IR_{mp} = 0.0001), Xianghai (IR_{mp} = 0.0001), Tumuji (IR_{mp} = 0.0001), Dabusu (IR_{mp} = 0.0001), Momoge (IR_{mp} = 0.0022), and Chaganhu (IR_{mp} = 0.0072) were lower than those of the smaller chosen patches. This result suggested that the abovementioned national-scale nature reserves might be designed so impractically that the area were too large to improve their irreplaceability index. So, there is an urgent necessity to redesign the area of nature reserves and the network of PAs in the Nenjiang River Basin.

Table 2 Irreplaceability index values of marsh patches chosen in the Nenjiang River Basin

Protected areas	Location	Area (km^2)	IR_{p}	IR_{mp}	Level	Rank	Patch	Location	Area (km^2)	IR_{p}	IR_{mp}	Level	Rank
Zhalong	Qiqihar	2224	0.2521	0.0703	I	1	P1	Qiqihar	55	0.0595	0.0595	Not	13
Momoge	Baicheng	1472	0.1840	0.0022	I	2	P6	Qiqihar	31	0.0549	0.0549	Not	14
Xianghai	Baicheng	1045	0.1818	0.0001	I	3	P8	Daqing	28	0.0515	0.0515	Not	15
Wuyuer River	Qiqihar	1025	0.1565	0.0201	N	4	P5	Qiqihar	81	0.0496	0.0496	Not	16
Chaganhu	Songyuan	503	0.1435	0.0072	N	5	P2	Qiqihar	44	0.0451	0.0451	Not	17
Keerqin	Xing’an	1244	0.1365	0.0001	N	6	P10	Daqing	198	0.0448	0.0448	Not	18
Tumuji	Xing’an	1023	0.1364	0.0001	N	7	P3	Qiqihar	65	0.0427	0.0427	Not	19
Dabusu	Songyuan	109	0.1364	0.0001	N	8	P4	Qiqihar	138	0.0251	0.0251	Not	20
Longfeng	Daqing	62	0.1351	0.0442	P	9	P9	Daqing	158	0.0163	0.0163	Not	21
Gudahu	Anda	100	0.1345	0.0436	P	10	P7	Qiqihar	298	0.0155	0.0155	Not	22
Qiqihar	Qiqihar	301	0.1286	0.0377	P	11	Sum		1096				
Halahai	Qiqihar	247	0.1252	0.0343	P	12							

Notes: I: internationally important wetland; N: national nature reserve; P: provincial nature reserve; Not: patches excluded from nature reserves; P1–P10: patches chosen for conservation and restoration; IR_{p} the comprehensive irreplaceability index, IR_{mp} is the irreplaceability index determined only by the MaxEnt model.

In summary, 10 patches of marshland totaling about 1096 km^2 outside the network of PAs in the Nenjiang River Basin were chosen eligibly for the implementation of conservation easement programs, and most of these patches are located in Qiqihar (712 km^2) and Daqing (384 km^2). As shown in Fig. 4, a patch's proximity to Zhalong National Nature Reserve increased, its irreplaceability level increased (Table 2). Specifically, the marshes at Taha (P1), Tangchi (P6), and Lamadian (P8) should be given priority for conservation and restoration to reintroduce migratory waterfowls. This recommendation is based on their higher irreplaceability index (≥ 0.05) and closer proximity to Zhalong National Nature Reserve.

4 Discussion

4.1 Prediction of MaxEnt model

The Red-crowned crane occurrence data were mainly collected from available documents, online databases, and aerial survey reports rather than from systematic planned surveys. Thus, this presence-only data may exhibit a type of sampling bias (also referred to as sample selection bias or survey bias) that would result in questionable conclusions from the MaxEnt model. In addition, biotic interactions (e.g., inter-specific competition, predation) along with geographic barriers and human influence could hinder the dispersal and colonization of a species, and these factors might prevent a species from inhabiting (or even encountering) the sites with the best ecological potential for it (Pulliam, 2000; Phillips et al., 2006). Therefore, the realized niche of a particular species may be narrower than its fundamental niche (or potential habitat), and our modeling prediction results may be doubted if they exaggerated the realized habitat extent of the Red-crowned crane due to an incomprehensive consideration of influential factors.

Nevertheless, the main objective of this paper was not to rediscover the populations of this bird species, but rather to identify those suitable marsh patches for migratory waterfowls at the landscape scale, presuming that suitable habitat for the Red-crowned crane is also favored by coexisting migratory waterfowls. Thus, the prediction results could be acceptable for the well performance of MaxEnt model, which predict the species occurrence probability under the verification of standard AUC measures and field testing.

4.2 Patch-based ranking method

In SCP, irreplaceability refers to the likelihood that an area will require protection to meet identified conservation targets. In the past two decades, several SCP methodologies have been designed to set site-specific quantitative and qualitative conservation targets in a local context for prioritizing conservation areas (Pressey et al., 2003; Rondinini and Chiozza, 2010; Brugière and Scholte, 2013; Fonseca and Venticinque, 2018). In this paper, a patch-based ranking method for conservation prioritization was proposed by incorporating the vulnerability criteria into the calculation of irreplaceability, and a priority order of patch for marsh restoration in the Nenjiang River Basin was put forward.

Superior to the conventional wetland restoration approaches, in which restoration sites are often chosen by the expert opinions made on presence-only datasets (Hunter et al., 2012). The MaxEnt-guided conservation site selection approach, which coupled with a patch-based ranking method as provided in this paper, could incorporate both abiotic (environmental data) and biotic (species data) information to identify potential marsh patches for conservation and restoration. Importantly, it is also an easy approach for conservation practitioners to implement, especially those who need to set watershed-scale (or larger) conservation and restoration priorities.

4.3 Implications for marsh conservation and restoration

In biodiversity conservation planning, comprehensive field surveys are not always feasible, but an evaluation prior to site visitations can improve conservation planning efficiency (Margules and Pressey, 2000; Hunter et al., 2012). According to our MaxEnt prediction results, the Red-crowned crane has a strong preference for marsh landscape in the downstream reaches that have higher values of NDVI (up to 0.8) and nearer distance to water (less than 100 m), but the distances from marshes to residential area and roads must be kept at least 1200 m away. These characteristics are important indicators for the establishment of a conservation and restoration plan for the Red-crowned crane and migratory waterfowls. Especially, for the marshes along the downstream reaches of Nenjiang River in Qiqihar and Daqing, where most sites remain unprotected in the current network of PAs, there is an urgent need to redesign the network of

PAs, or to incorporate privately owned lands into the networks.

5 Conclusions

In order to mitigate the isolation state of protected areas and improve the efficiency of conservation in the Nenjiang River Basin, Northeast China, the MaxEnt model coupled with irreplaceability index were chosen to guide marsh conservation. The MaxEnt model reveals that the Zhalong and Wuyuer River marshes in the downstream reaches of Wuyuer River are the optimal habitat for migratory birds, there are 22 patches chosen for restoration and conservation by the comprehensive irreplaceability index as the patch-based ranking method, of which 10 marsh patches are still excluded from the existing network of PAs. Especially, the marshes at Taha, Tangchi, and Lamadian should be given priority for conservation and restoration to reintroduce migratory waterfowls that would lessen the isolation state of Zhalong National Nature Reserve.

Superior the currently proceeding wetland restoration site selection method, the MaxEnt-guided method proposed in this study could combine abiotic and biotic information to guide marsh conservation and easy to implement for those who need to set watershed-scale conservation and restoration priorities.

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