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Predicted effects of Chinese national park policy on wildlife habitat provisioning: Experience from a plateau wetland ecosystem

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A R T I C L E I N F O

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A B S T R A C T

Understanding the ecological consequences of conservation policies on wildlife is critical for species conservation and policy implementation. China began to call for establishing a national park system in 2013 and used national parks as the predominant feature for its system of protected areas in 2019. Payment for ecosystem services (PES) and relocation constitute two important management strategies in new Chinese national parks and protected area system. To better understand the potential outcomes of such programs, we studied the winter foraging distribution of the threatened Black-necked Crane (*Grus nigricollis*), a flagship species of plateau wetlands, in Dashanbao Protected Area, SW China. Field survey data were combined with environmental variables and land use maps to model winter foraging habitat with respect to human settlements subject to PES and relocation. High suitability for foraging was mapped in the core zone around crane roosting sites, villages, and far from disturbance (e.g. main roads). Aiming at converting farmland to wetland, the payment for ecosystem services programs increased probability of occurrence of cranes by changing land cover in appropriate areas relative to crane roosts and other spatially distributed variables. Surprisingly, areas within 1 km of villages were recognized as highly suitable foraging habitats for cranes, which depend on waste grain in farmland in winter, revealing the potential risk of relocation-induced food shortage for wintering cranes. We argue that as an effective strategy in improving wildlife habitat, PES should be encouraged and relocation programs that change the existing long-term established human-wildlife interactions should be implemented only under full understanding of these relationships. As a pioneer study of the effects of conservation policy on wetland ecosystems in China, this study could shed light on conservation management for such ecosystem and species showing high dependence on a human modified environment. Future work should also focus on the social effects of these conservation strategies, especially relocation, during national park planning in China.

1. Introduction

Establishing Protected Areas (PAs) is considered an effective action to safeguard against habitat destruction, biodiversity decline, and ecosystem services degradation (Xu et al., 2017). Approximately 15.00% of the world's terrestrial area and 7.91% of marine areas are established PAs (UNEP-WCMC and IUCN, 2016, 2019). Seventy percent of the world's protected areas, however, are inhabited by increasing human populations (Wang et al., 2013), which makes it impossible to avoid anthropogenic disturbances, such as human settlements

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(Behdarvand et al., 2014), agriculture, and ecotourism (Ellenberg et al., 2006). These increasing anthropogenic pressures in PAs have exacerbated the conflict between wildlife conservation and human activity (Bennett et al., 2017; McShane et al., 2011).

Between establishment of the first nature reserve in 1956 and 2018, China designated 2750 nature reserves that cover more than 14.86% of its terrestrial area. These reserves have played a crucial role in slowing biodiversity loss (MEE, 2019). China has, however, the world's largest human population living in PAs (W. H. Xu et al., 2016; W. G. Xu et al., 2016), and more than 21.4% of vertebrates are threatened (MEE, 2017), partly due to ineffective governance by different administrative authorities, increasing anthropogenic disturbance, and habitat destruction (Huang et al., 2019; Wang, 2019; W. H. Xu et al., 2016; W. G. Xu et al., 2016). To improve conservation effectiveness, establishment of national parks as a central feature of the Chinese natural PA system has been initiated by creating new large national parks and reclassifying outstanding natural reserves as national parks to unify an administrative structure to manage and protect natural beauty, ecological integrity, and biodiversity.

In 2017, the document "Overall Plan for Establishing National Park System of China" (the Overall Plan) and in 2019 "Guidelines on the establishment of Chinese protected area system using national parks as the predominant feature" were released (China State Council and CCCPC, 2017, 2019). The plan established "ecological protection first" and "strictest protection" principles in national park planning. To meet these principles, managers proposed to eliminate human activities by resettling residents outside the core area of parks (ecological relocation programs), and to unify management of collective and private land by financially compensating local land holders (payment for ecosystem services programs, PES) across the planning national parks. Ecological relocation together with PES would result in the world's largest ecological resettlement program and substantial conservation expending increase in the coming decades. The social and ecological consequences of this program to both human and wildlife are still not well studied (Su, 2019; Torri, 2011; Tuanmu et al., 2016). In this study, we investigated the ecological consequences (e.g. habitat provision) of these policies on a globally threatened species, Black-necked Crane (*Grus nigricollis*; IUCN, 2019) in Dashanbao Protected Area ("Dashanbao"), SW China. Dashanbao has already implemented a pilot payment for wetland ecosystem service (PWES) program and has plans for a large-scale relocation project in the coming years. We ask: (a) did the PWES program have positive effect on foraging habitat of the bird (e.g. increase occurrence possibility) and (b) if so, how was this achieved, and (c) what were the potential effects of the conducted PWES and coming relocation program on wintering Black-necked Crane.

2. Methods

2.1. Study area

The study was conducted in the Dashanbao Protected Area (103°14′55″–103°23′49″E, 27°18′ 38″–2°29′15″N), northeastern Yunnan province, China (Fig. 1). Covering 19200 ha, Dashanbao was established in 1990 to protect Black-necked Crane and its wintering habitats (Zhong and Dao, 2005), and it was listed as a Ramsar Wetland of International Importance in 2004 (Ramsa, 2018). In 2016, the site was designated as a pilot Chinese National Park by the Yunnan provincial government.

The Black-necked Crane is notable as a flagship species of the plateau wetland ecosystem (Harris and Mirande, 2013; Song et al., 2014) and is endemic to Qinghai-Tibet Plateau and Yunnan-Guizhou Plateau in China, supporting ~96% of the world population of ~10,000 birds (Li, 2014; Pankaj et al., 2014). Dashanbao is the most important stopover and staging site (Kong et al., 2014), and the biggest wintering grounds (with the maximum population exceeding 1600 individuals) of wintering Black-necked Crane along the eastern migration route (Li and Yang, 2003; Yang and Zhang, 2014). Every year, the cranes arrive at Dashanbao at the end of October or in early November in the first year; and leave at the end of February or in early March (Kong et al., 2014). Dashanbao provides an abundance of marsh and swamp habitat and four reservoirs supplying shallow water habitat for Black-necked Crane roosting. The surrounding wetlands, farmlands and grasslands serve as foraging habitats for the birds (Kong et al., 2008).

As one of the two pilot sites of the PWES program in Yunnan Province, Dashanbao implemented a 4-year (2015–2018) wetland compensation program costing 20 million YUAN for improving wetland ecosystem services and habitat quality for Black-necked Crane. One of the most important actions was compensation for local farmers with governmental funds to prohibit them farming and grazing on PWES areas and to restore wetland habitat for cranes by paying land holders economic incentives (260 YUAN/mu; mu is Chinese unit of area, fifteen mu equals one hectare) in the first 4-year round. This program began in March 2015, and six separate areas of about 350 ha farmland had been converted to wetland at the end of 2016 (Fig. 1). A large-scale ecological relocation program, combined with a poverty alleviation resettlement program, has been planned for 2020, in which more than 10,000 local residents would be moved out of Dashanbao. The core zone has been proposed as the targeted relocation area by managers. In 2017, 10,129 people lived in the core zone, which encompasses 45.2% of the reserve (Fig. 1).

2.2. Black-necked Crane occurrence data

In winter, cranes usually forage in groups in the daytime and roost at common sites at night (Johnsgard, 1983). Four nocturnal roosting sites in shallow water of three reservoirs were recorded in the study area. With the line transect method, we recorded daily occurrence sites of Black-necked Crane between 09:00 and 18:00 (Kong et al., 2008, 2011). We located every flock within the field of vision of 8 × 42 binoculars from high points with a good view along the line transects. All line transects were located in the core zone of the Dashanbao reserve, covering 96 km (Fig. 1), and encompassing the known foraging habitats of the species. The width of the transects varied with visibility (Kong et al., 2018). We checked the line transects with a 4 × 4 vehicle. Field studies were conducted before PWES program implementation in the middle of two wintering periods (December and the following January 2013–2014 and 2014–2015), in consideration of population stability during this timeframe (Kong et al., 2014). We recorded one location for each flock, given the non-independence of each bird in the flock (Thomas and Taylor, 1990). All crane locations were marked in Google Earth on a mobile phone. Each location was considered as a foraging site because foraging behavior takes up 60–80% of the daily time budget of the species in winter (Kong et al., 2008). In total, 114 foraging locations were recorded Table 1.

2.3. Environmental and anthropogenic variables

Environmental and anthropogenic variables were selected based on their potential influence on the foraging distribution of wintering Black-necked Crane, which are influenced by climate, physical environment, and human disturbance (Kong et al., 2011; Han et al., 2017). Climate data were downloaded from the WorldClim database Version 2 (Fick and Hijmans, 2017). Six climatic variables were considered (Appendix Table 1). The physical environment was characterized by topographic factors, land cover, and natural resources related to Black-necked Crane foraging (e.g. roosts and water). Seven topographic variables were evaluated as the potential candidate variables. A 30-m resolution digital elevation model (DEM) was downloaded from ASTER Global DEM (USGS, 2018), from which we extracted or computed elevation (ELE), slope (Slope), Topographic Position Index (TPI), Terrain Ruggedness Index (TRI), Ruggedness (Rug), Standard Deviation of Elevation (SDE), and Slope Variability (SV). Eight land cover (LC) types of farmland (FL),

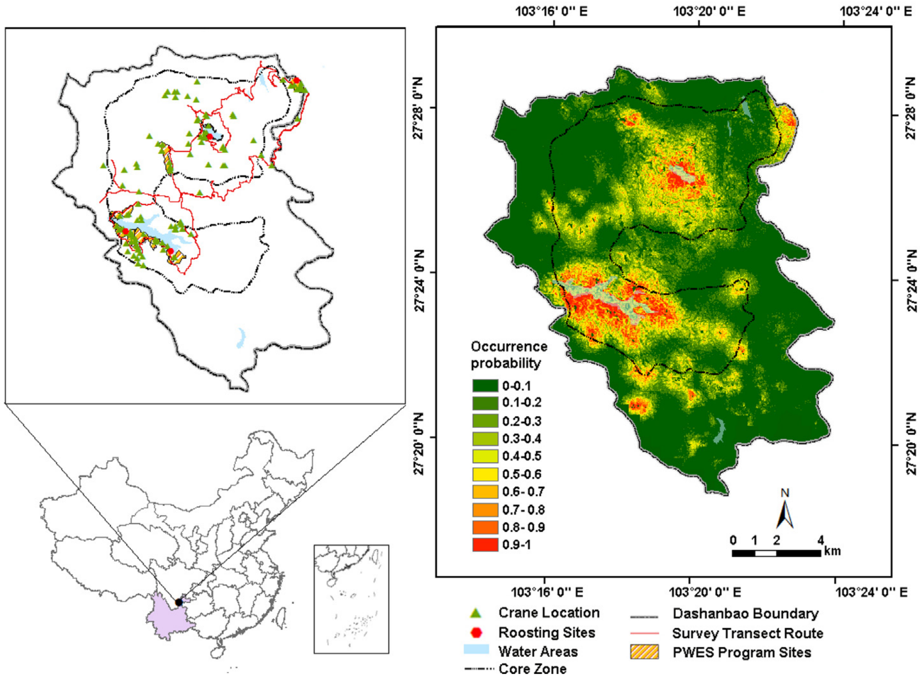

Fig. 1. Predicted distribution (occurrence probability) of wintering Black-necked Crane in 2013 (right map) in Dashanbao Protected Area (left upper map) and its location in China (left bottom). The Core Zone has been proposed as the targeted relocation program area.

Table 1
Percent contribution and permutation importance for the predictive variables of wintering Black-necked Cranes distribution model.

Variables	Permutation importance	Percent contribution
R_{dis}	46.1	39.5
VIL_{dis}	13.4	10.1
MR_{dis}	8.6	4
Tavg	7.8	3.4
W_{dis}	6.6	3.2
Slope	5.9	4.4
Wind	3.3	10.3
SR_{dis}	2.7	2.1
SDE	2.3	3.1
LC	2	15.4
TPI	1.3	4.4

Rdis refers to euclidean distance to roosting sites; VILdis refers to euclidean distance to villages; MRdis refers to euclidean distance to main road; Tavg refers to mean of monthly average temperature in December and January; Wdis refers to euclidean distance to water area; Wind refers to mean of monthly wind in December and January; SRdis refers to euclidean distance to secondary road; SDE refers to Standard deviation of elevation; LC refers to land cover; TPI refers to Topographic Position Index.

forest (FO), marsh (MA), grassland (GL), water area (WA), woodland (WL), and buildings and developed land (BD) were extracted from the land use map of 2013 and 2017 from Yunnan Service Center, Chinese National Survey and Planning Administration. We used three variables to measure anthropogenic pressure: distance from main road (MR_{dis}), distance from secondary road (SR_{dis}), and the distance from villages (VIL_{dis}). We also measured the distance of each crane flock to the roosting sites (R_{dis}) and the nearest water resource (W_{dis}). All distance data were generated using Euclidean distance. Buildings and developed land were considered as unavailable habitat for the Black-necked Crane in winter as previous studies documented (Kong et al., 2018, 2011). All variable layers were converted into 30 m^2 grid cells according to their original resolution (Appendix Table 1). We used ArcGIS v. 10.5 (ESRI, 2016) to prepare spatial data and do raster analyses.

2.4. Model selection and evaluation

By combining georeferenced species occurrence data and environmental conditions, species distribution models (SDM) have been used widely as a numerical tool for understanding environmental determinants of species presence across space and time to assess changes in habitat provision (Liu et al., 2017; Na et al., 2018; Phillips and Dudik, 2008). MaxEnt, by applying a machine-learning technique that implements maximum entropy modeling of species niches and distributions, is a favorably performing SDM model (Elith et al., 2006; Torabian et al., 2018). It has been widely used in studies from modeling potential spatial distribution (Behdarvand et al., 2014; Jiao et al., 2016) to evaluating project effects on habitat provisioning for species (Liu et al., 2017; Zhang et al., 2018).

We used Maxent version 3.4.1 (Phillips et al., 2017) to predict potential effect of PWES and ecological relocation on Black-necked Crane by modeling occurrence probability of the bird under different scenarios. Pairwise Pearson's correlation coefficients (r) were used for all candidate variables to quantify collinearity. Any two sets of variables were delimitated in model construction when their correlation was over 0.7 to avoid adverse effects of collinearity (see Appendix Table 2 for details; Nüchel et al., 2018). The area under the ROC curve (AUC) was used to measure the quality of ranking of sites by using the rank-based statistics (Fielding and Bell, 1997). Models with an AUC value above 0.75 are considered potentially useful (Elith et al., 2006; Phillips and Dudik, 2008). We also ran the jackknife test the relative importance of variables for model performance (Phillips et al., 2006), as AUC may weigh omission and commission errors equally, and be highly influenced by the geographical extent to which models are carried out (Lu et al., 2012).

2.5. Data analysis and habitat mapping

For understanding the effect of relocation of human populations on suitable habitat, we examined the relationship between Black-necked Crane foraging habitats and distance to villages. To explore the effect of the PWES program on habitat provisioning for Black-necked Crane, we predicted occurrence probability (OP) before (in 2013) and after (in

2017) program implementation. We ran predictive models for 2017 (scenario 2017), which used the habitat quality relationships defined by the 2013 model and substituted the 2017 land cover as changed by the PWES program for the 2013 land cover. We categorized habitat suitability for Black-necked Crane, as defined by occurrence probability, into four classes: (1) highly suitable, OP ≧ 90%; (2) moderately suitable, 66% ≦ OP < 90%; (3) marginally suitable, 33% ≦ OP < 66%; and (4) unsuitable, OP < 33% (Zheng et al., 2016).

To avoid overfitting or incorrect predictions caused by a biased sampling scheme, we split the study area into a training area and a projection area (Kassara et al., 2014). Considering that environmental and anthropogenic variables buffer effect on bird, the input area was delimited by the survey area, measured as a 2000-m buffer outside the Black-necked Crane occurrence points and the survey transect route to approximate visibility of the birds across the landscape (Kong et al., 2011). Models developed within this survey area were then projected to the whole study area. To derive suitability and predictive maps, the final models were run 10 times with cross-validate as the replicated run type.

3. Results

3.1. Foraging distribution

With a high AUC value of 0.827, our model indicated that Black-necked Crane mainly distributed in two conjunctive areas around reservoirs where roosts were located in the central of the reserve and in several small separate patches around villages. Moreover, most of these distribution areas were located in the core zone (see Section 3.4 for details, Fig. 1).

3.2. Factors affecting spatial distribution

The distance to roosts (46.1% of permutation importance) and to villages (13.4% of permutation importance) were the top two variables affecting foraging distribution of wintering Black-necked Crane (Table 1). Cranes showed a high occurrence probability (≧60%) in the 500 m areas around villages (Fig. 2), and nearly all (98%) highly suitable habitat (OP ≧ 90%) of the birds distributed within 1 km of villages. The distance to main roads, temperature and water played relatively uniform roles in shaping the foraging distribution of cranes, with more cranes occurring in moderate areas away from disturbance (main road) and near water (Fig. 2).

Distance to roost (39.5%) and land cover (15.4%) contributed the most to model construction, and cranes were detected with higher probability in marsh habitat and lower wind speed areas (Fig. 2).

3.3. PWES effects on habitat provision

We found increased OP for Black-necked Crane both in the whole study area and in the program implementation areas following PWES implementation. For the entire protected area, we detected a slight increase in OP from 0.18 in 2013 to 0.19 after the PWES program in 2017.

As to the six areas where the PWES program was conducted, a slight OP increase (from 0.67 to 0.69) was discovered after the PWES program in 2017 (Fig. 3; Appendix Table 3). PWES resulted in moderately suitable habitat (66% ≦ OP < 90%) increasing by 31.7 ha and unsuitable habitat (< 33%) decreasing by 158.6 ha at the end of 2017 (Fig. 3; Appendix Table 4).

3.4. Potential effects of ecological relocation program on habitat provision

Relocation of human populations would dramatically reduce agricultural land use. Our models indicated that in the core zone, the targeted area for the planned ecological relocation program, contains 80.4% of all suitable foraging habitat (OP ≧ 33%) for Black-necked Crane, including 83.6% of highly suitable and 64.3% of moderately suitable habitats in the reserve (Fig. 3). For these suitable foraging habitats in the core zone, 26.9% are farmland (2340 ha), constituting 25.2% of highly suitable area in the reserve.

4. Discussion

We explored the ecological effects of two national park planning policies, PES and ecological relocation on habitat provision for the vulnerable Black-necked Crane with a species distribution model. This is the first spatially explicit prediction on wildlife habitat provisioning based on landscape change of the recently implemented PWES program in China. The results can help predict the ecological consequences of ongoing and forthcoming large-scale national park planning on wildlife habitat. With the use of model calibration through splitting data (Merow et al., 2013) and collinearity tests (Renner et al., 2015) to avoid overfitting and reducing uncertainty, our models performed well with high AUC values and were consistent with our field observation of the Black-necked Crane in recent years in Dashanbao. Habitat modeling indicated that the Dashanbao PWES program increased the quality and quantity of available habitat but revealed a risk of relocating residents from the PAs.

4.1. PWES effects on Black-necked Crane habitat

Our result indicates that probability of winter occupancy by Black-necked Crane increased slightly throughout Dashanbao as a whole after the PWES program, although the effectiveness of this program seemed limited due to an extremely low percentage for the whole study area (< 0.02%). Since PWES program was implemented, agricultural cultivation or grazing activities began to be prohibited on PWES sites. This led to an increase of wetland, which is the most preferred habitat for wintering Black-necked cranes (Kong et al., 2011). Surveys not included in this study showed that the population of Black-necked Crane increased from 1131 in 2013 to 1433 in 2017, which is consistent with our models and could be the combined results of the habitat restoration of the PWES program and other conservation measurements, e.g. entrance limitation of tourists. Our research is limited by a lack of foraging distribution data on Black-necked Crane occurrence after the PWES program. Nevertheless, the habitat modeling approach is available for conservation managers to predict the outcomes of policy choices before program implementation and to bridge scientific research and decision-making (Xu et al., 2014).

4.2. Potential effects of ecological relocation

In contrast to prevailing wisdom that wildlife avoids human settlements, the occurrence probability of wintering Black-necked Crane increased near villages. The positive association with villages is likely a result of a benefit associated from available food resources (Bishop and Li, 2002; Dong et al., 2016). Cranes benefit from the open spaces created across subsistence agricultural landscapes as well as the bountiful waste grain left after harvest (Austin et al., 2018). Moreover, a previous behavioral study also showed that Black-necked Crane spent more time feeding in farmland than other habitats (e.g. marsh, grassland and water area; Kong et al., 2011). In contrast with intensified human-wildlife conflict caused by large carnivores, species like Black-necked Crane and Crested Ibis (*Nipponia nippon*) that rely heavily on anthropogenically produced habitat are more likely to coexist with humans (Namgay and Wangchuk, 2016; Zheng et al., 2018). Many species rely heavily on humans for survival (Lenda et al., 2012), especially in winter when the food resource is limited (Namgay and Wangchuk, 2016). Relocation of human settlements may threaten protected wildlife food resources through cropland abandonment, and even exacerbate ecological and conservation problems by breaking existing human-wildlife

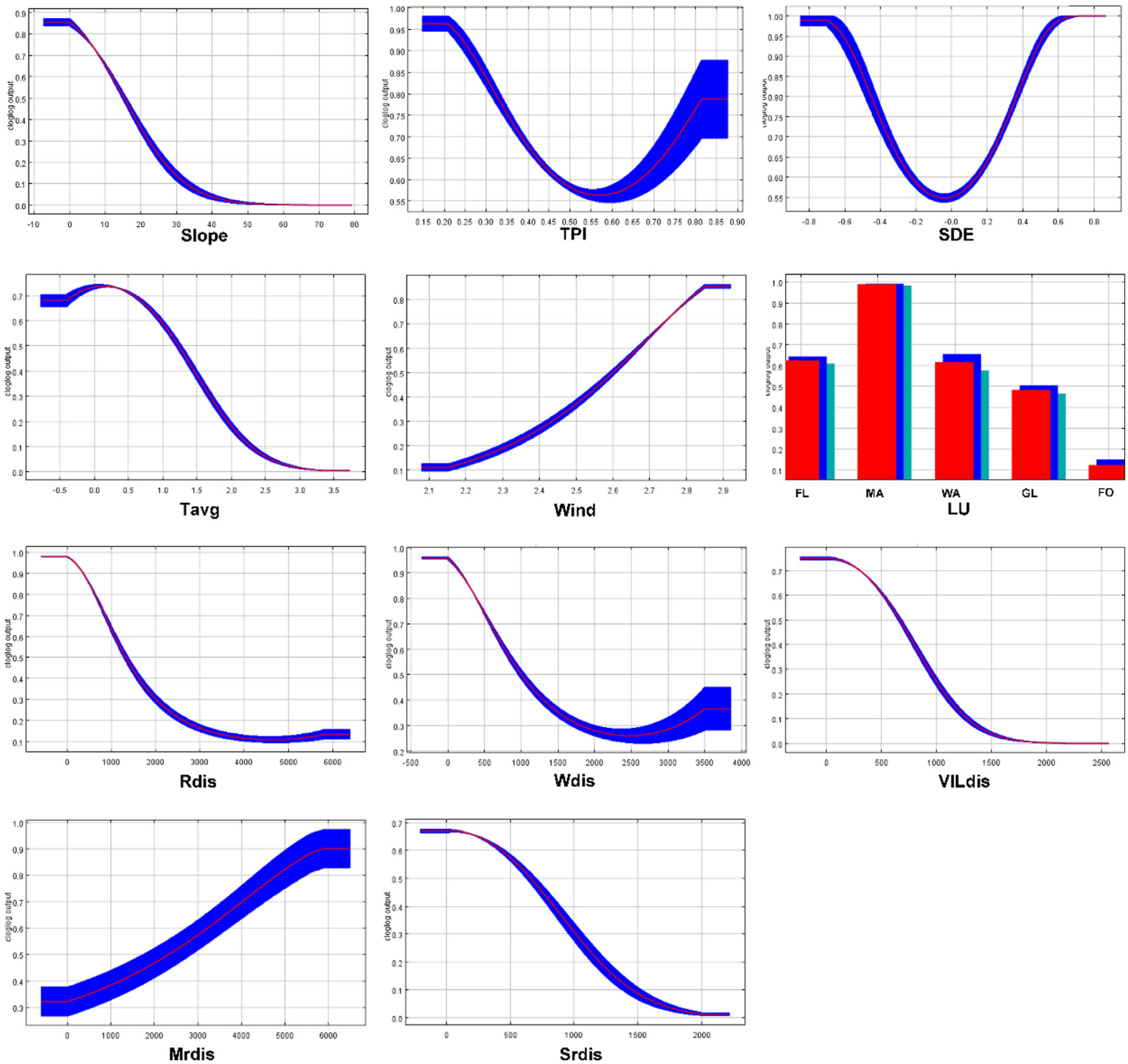

Fig. 2. Response curves of environmental variables to occurrence probability of wintering Black-necked Crane in 2013. The curves show the mean (red line) with one standard deviation (blue areas) generated by the cross-validated models with 10 replicate runs. Red histograms with blue and cyan shades indicate mean ± one standard deviation for categorical variables of land cover: farmland (FL), marsh (MA), water (WA), grassland (GL), and forest (FO).

coexistence relationships (Fan et al., 2015; Schwartz et al., 2012; Su, 2019). Considering the majority (80.4%) suitable foraging habitat in the targeted relocation areas in our study, without steps to replace the habitat value provided by farmland for foraging cranes, the relocation program would reduce overall available habitat for Black-necked Crane. Case studies in other contexts have demonstrated that resettlement programs can fail to achieve conservation goals and even pose new threats to threatened species (Colchester, 1997; Lashorchix and Koshari, 2009).

4.3. Variables affecting crane foraging distribution

Distance to roosts was identified as the most important environmental variable in the model, with wintering Black-necked Crane showing a foraging distribution within 2 km areas centered around roosting sites. The result mirrors Kong's (2011) finding that 73% of the wintering birds scattered in areas within 2 km from the roosts, and nearly all birds (99%) could be detected within 2 km from roosts in another reserve in Huize, NE Yunnan, China (Kong et al., 2018). Foraging near the communal roosts is an energy saving strategy for crane species (Alonso and Alonso, 1992). Another explanation for the close proximity to the roost of Black-necked Crane is that there is plenty of preferred marsh habitat (Kong et al., 2011, 2018; Liu et al., 2010).

Black-necked Crane mostly prefer shallow marsh, followed by farmland due to food availability and physiological demand, as supported by previous studies (Kong et al., 2011). Shallow marsh areas are used for social behavior and for providing invertebrate food sources, while farmland is the most important upland habitat for Black-necked Crane obtaining waste grains for over 80% of its diet (Dong et al., 2016). Similarly, in Tibet and Bhutan, farmland provides a large amount of food for wintering Black-necked Crane (Bishop and Li, 2002; Namgay and Wangchuk, 2016). Other habitats, like forest and woodland were likely to be less important for Black-necked Crane foraging because they lack appropriate food resources and have limited open space for flying (Kong et al., 2011).

Our results suggest that Black-necked Crane foraging habitat distribution is influenced by anthropogenic disturbance, and the response varies by different anthropogenic elements. The probability of occupancy increased with distance from main roads but decreased with distance from villages. Na et al. (2018) similarly found that Red-

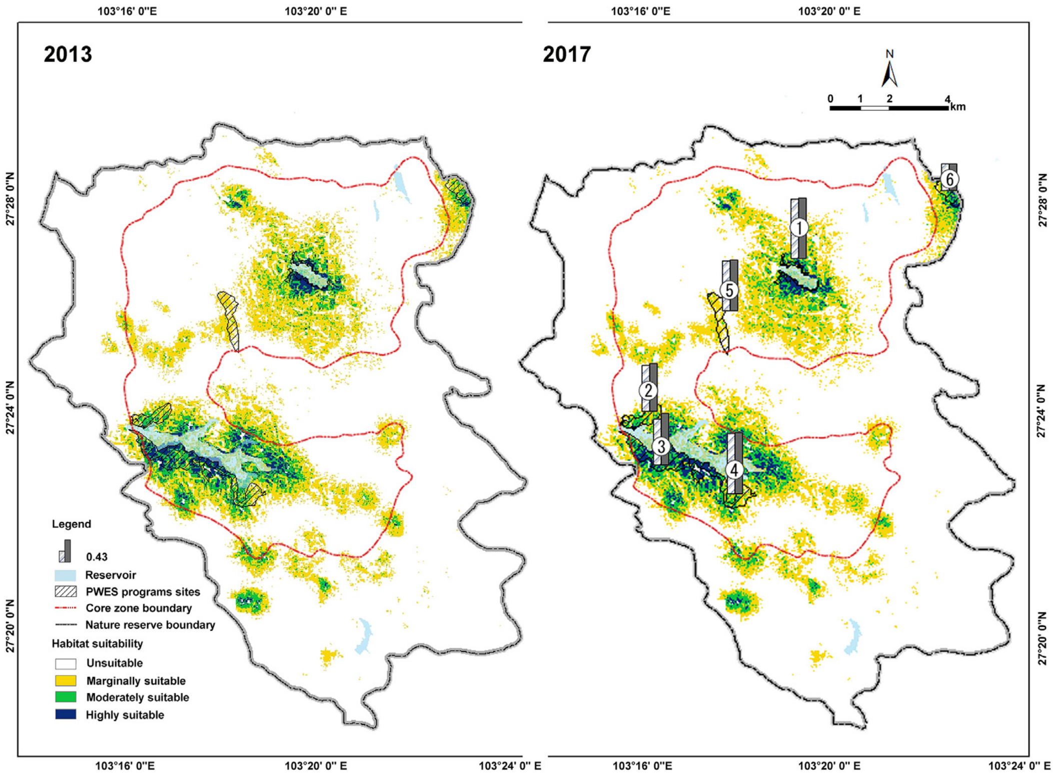

Fig. 3. Habitat suitability of Black-necked Cranes in 2013 (left) and in 2017 (right) after payment for wetland ecosystem service (PWES). Light grey with oblique lines and dark grey bars in the map of 2017 show the occurrence probability of wintering black-necked crane in 2013 and 2017, respectively, for each of the six specific areas conducting the PWES program. The Core Zone has been proposed as the targeted relocation program area.

crowned Cranes (*Grus japonensis*) had a negative association with distance to roads, consistent with roads constituting a primary anthropogenic disturbance in PAs (Harmsen et al., 2010).

5. Conclusions and implications

Our study demonstrated that PES can be a preferable conservation strategy for species conservation and should thus be encouraged. Relocating all inhabitants outside the core zone in PAs to avoid human activities, however, should not be the default position. Relocation of long-standing human communities has been criticized among conservationists and managers in the national park system dating back to Yellowstone, USA (Brüggemann et al., 1997; Hutton et al., 2005). Instead, any relocation effort should be informed by a careful understanding of specific species responses to human activities to avoid unintended consequences.

Future work should also focus on the social dimensions of conservation strategies for China's national parks e.g. research on how ecological relocation and ecological compensation affect local people's livelihood and welfare.

CRediT authorship contribution statement

Wanting Peng: Conceptualization, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. **Dejun Kong:** Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing - original draft, Writing - review & editing. **Chengzhao Wu:** Conceptualization, Methodology, Funding acquisition, Project administration, Resources, Supervision, Writing - review & editing. **Anders Pape Møller:** Writing - review & editing. **Travis Longcore:** Conceptualization, Formal analysis, Methodology, Software, Supervision, Validation, Visualization, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2020.106346. These data include Google maps of the most important areas described in this article.

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