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# Foraging habitat selection of overwintering Black-necked Cranes in the farming area surrounding the Caohai Wetland, Guizhou Province, China

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## Abstract

**Background:** Understanding how overwintering birds choose foraging habitats is very important for conservation management. The overwintering Black-necked Crane (*Grus nigricollis*) feeds on crop remains in farmlands; thus, reasonable conservation management of this type of farmland that surrounds wetlands is critical for the overwintering populations of the Black-necked Crane; however, it is not clear how the Black-necked Crane chooses the foraging land in the farmland.

**Methods:** A thorough field positioning survey of all foraging sites in farmland areas around the Caohai Wetland and a sampling analysis of habitat selection by the Black-necked Crane were conducted during the winters from 2016–2017 and 2017–2018.

**Results:** Multiple factors contributed to the selection of foraging habitat in farmlands, i.e., food factors (crop remains and tillage methods) > human disturbance factors (distance to road and settlement) > topography factors (slope aspect), listed according to the strength of influence. Additionally, Black-necked Cranes tend to choose farmland sites where there was no machine tillage, the crop remains were > 500 g/m<sup>2</sup>, the distance to residences ranged from 100 to 500 m, the distance to roads ranged from 50 to 100 m, and the slopes exhibited western or eastern aspects. As the winters progressed, the volume of the edible crop remains declined, and the influences of the other main factors also changed, i.e., the factors of human disturbance (distance to road and settlement) became less important, while the effect of the food factor (crop remains) was strengthened. Thus, the foraging sites near the road became more important.

**Conclusion:** The farming area surrounding the Caohai Wetland is very important for the overwintering Black-necked Crane. Food factors and human disturbance factors are the main factors that influence the choice of feeding ground.

**Keywords:** Black-necked Crane, Caohai wetland in Guizhou, Farmland around the wetland, Foraging habitat selection, Overwintering period

## Background

Foraging habitat selection by birds is defined as a non-random choice by avian individuals of certain feeding sites, which is a connotation of understanding complex behavioral and environmental processes, and it is a decision-making process that researchers need to make an attempt to describe how the observed patterns reflect

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individual choice (Jones 2001; Beest et al. 2010). Thus, an understanding of how birds choose foraging sites is very important for the conservation management of winter migratory birds and their overwintering habitats (Goss-Custard et al. 2002; Davis et al. 2014; Kaminski and Elmerberg 2014). The Black-necked Crane (*Grus nigricollis*) is the only crane species that lives on the Qinghai-Tibet Plateau throughout its lifetime, and it is also the crane species that was most recently identified and recorded by humans among the 15 species of cranes throughout the world (Qian et al. 2009; Che et al. 2018; Sun et al. 2018). The Black-necked Crane is mainly distributed in the Qinghai-Tibet Plateau and Yunnan-Guizhou Plateau of China. Its breeding area is in the northern and western Qinghai-Tibet Plateau, while its wintering area is mainly in the middle of the Yarlung Zangbo River Valley, the south slope of the Himalayas and some parts of the Yunnan-Guizhou Plateau (Qian 2009). The Black-necked Crane is considered Vulnerable (VU) according to the IUCN Red List and is a nationally protected species in China (Category I).

In the early 20th century, the research on waterfowl mainly focused on breeding areas; however, since the end of the 20th century, more and more research on waterfowl began to shift to the non-breeding season, including habitat selection and utilization, especially in migratory waterfowl (Davis et al. 2014; Kaminski and Elmerberg 2014). In addition to the lakeshore, some previous studies have revealed that Black-necked Cranes strongly depend on crop remains in the farming areas around wetlands as food for survival while overwintering (Tsamchue et al. 2008). Black-necked Cranes prefer the tuberous of Cyperaceae plants on lakeshores and potatoes (*Solanum tuberosum*) and maize (*Zea mays*) in cultivated lands (Bishop and Li 2002). However, in most of the studies of Black-necked Crane in relation to Caohai and other overwintering wetlands, it is still not so clear what and how they forage in the farming areas. According to Wiens' classification method (Wiens 1973), some researchers divided the habitat selection of Black-necked Crane into three levels (Li 1999; Sun et al. 2018). It was concluded that Black-necked Crane would prefer to choose the sedge meadow around Caohai Lake, and the selection of agricultural land was relatively low (Li 1999). Its foraging was mainly based on the roots of sedge plants, and the selection of crops was less (Li and Nie 1997; Li 1999; Li and Li 2005). According to the latest research and investigations, each day during winter, most Black-necked Cranes fly to the outer area to forage in the farmlands in the mornings and fly back to fixed points of the inner area to roost in the evening (Bishop and Li 2002; Sun et al. 2018). Bird foraging will be affected by food, water and concealment (Yang et al. 2011). But, for the Black-necked Crane

of Caohai Waterland, the factors affecting the selection of foraging habitat by Black-necked Cranes in the farming area are still poorly understood.

Based on the field investigation and analysis, this paper aims to answer the following two questions: (1) what are the factors influencing the selection of foraging land in the farming area? (2) what are the main influencing factors in different overwintering periods? By answering these questions, we hope to provide reference for local conservation of this crane species.

## Methods

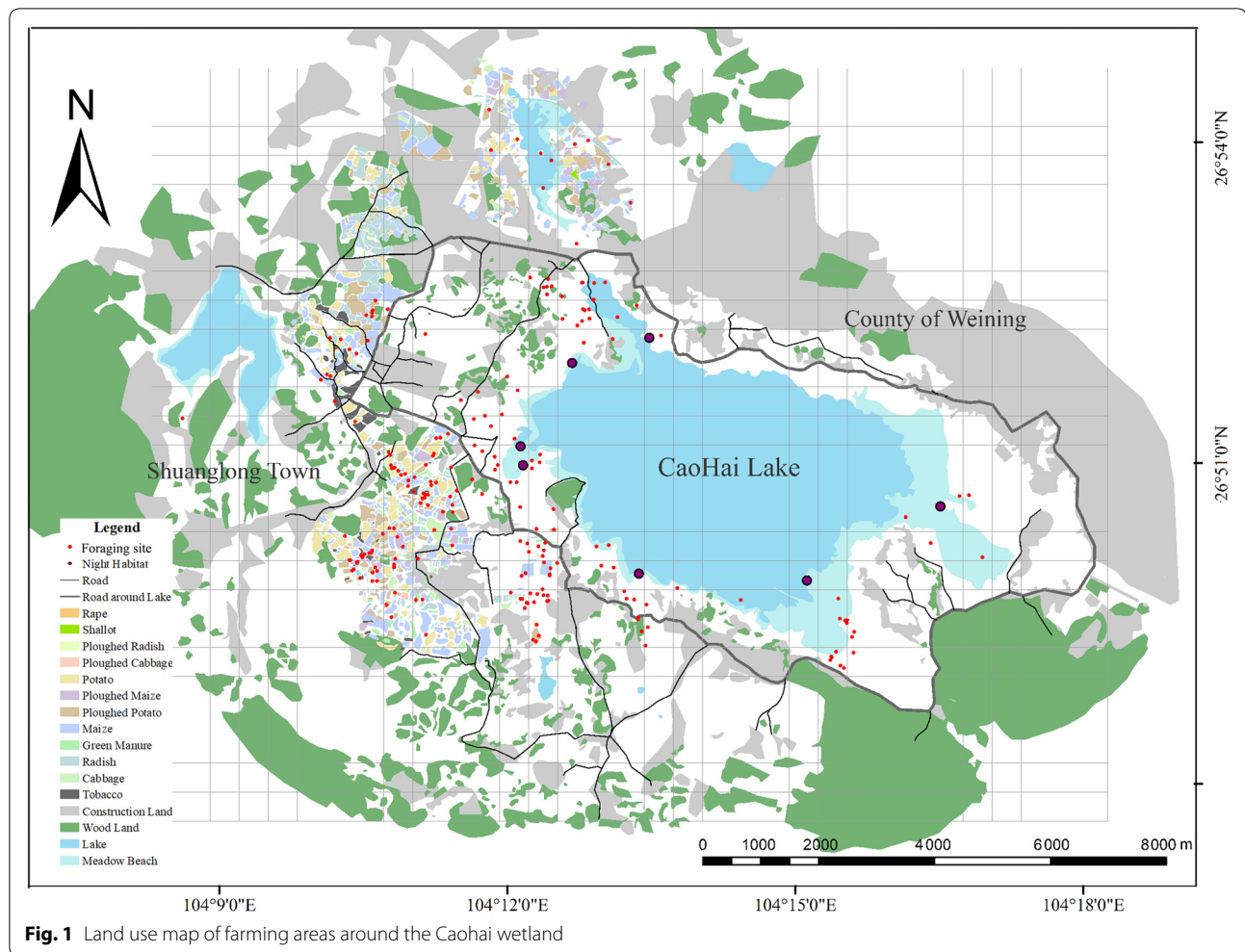
### Study area

The Caohai Wetland (with the main body of the Caohai National Nature Reserve, 26°47'–26°52'N, 104°10'–104°20'E), is located in the Guizhou Plateau, southwestern China, next to Weining County, Guizhou Province. This wetland is the largest natural freshwater lake in Guizhou, is regarded as a typical wetland ecosystem of the subtropical plateau in China due to its relatively integrated structure and function, and is an important site for the overwintering and stopover of migratory birds in southwestern China (Ran et al. 2017). The total area of Caohai is 120 km<sup>2</sup> with 25 km<sup>2</sup> of water. The elevation of the normal water level is 2171.7 m, and the maximum water depth is 5.0 m. Caohai belongs to the subtropical plateau monsoon climate, with the yearly average temperature of 10.9 °C and the coldest monthly average (January) temperature of 2.1 °C. Every winter, more than 80 species of waterbirds and 80,000 individual birds live in Caohai Wetland (Zhang et al. 2014).

Because the Caohai Wetland is close to Caohai County, the competition for living space between human beings and birds is more intense than other wintering areas. In recent years, construction for urban expansion plus a reduction in traditional tillage and increases in human activities have decreased the amount of farmland, especially after the construction of a 29.5 km road circling the lake in 2014, Caohai is divided into two parts by this road, i.e., the inner lakeshore area and the outer residential and farming area (see Fig. 1). This has led to a more prominent situation.

### Field survey

The field survey was conducted in two winter periods of 2016–2017 and 2017–2018. According to the duration of Black-necked Crane overwintering and local meteorological conditions, we divided each winter into three stages, namely, early winter (11th of November to 31st of December, EW), mid-winter (1st of January to 20th of February, MW) and late winter (21st of February to 31st of March, LW). We surveyed from 08:00–17:00 every day in sunny, windless weather conditions, for at least 15 days



in each stage. This pattern was repeated for both winters. To locate all foraging sites of Black-necked Cranes in farmland around the wetland, we used ArcGIS (version 10.3.0) software to define a 500 m × 500 m grid to investigate each grid square (see Fig. 1). In one grid, we tried to stay in the highlands to observe the Black-necked Crane foraging behavior using a monocular telescope (Magnification 20–60 ×) without disturbing the birds. If the site has foraging behavior without interference and is continuously foraged for more than 15 min, we located and recorded this site as a foraging site, and recorded the landuse type here.

To study habitat selection, we sampled the foraging points for the investigation of habitat environmental factors. After the Black-necked Crane left here to forage elsewhere, we set up a large quadrat (5 m × 10 m) in the center of each crop patch where a foraging point was located and 5 small quadrats (1 m × 1 m) at the center and the 4 corners of the patch. See Table 1 for a list of all variables investigated. A total of 98 large quadrats were

defined during the study periods (early winter: 23; mid-winter: 32; late winter: 43).

#### Type of land use

Using the Landsat OLI dataset from 2017, the data were corrected with the error control at 0.5 pixels. Additionally, using SPOT digital orthophoto images as references, we used ERDAS (ver.10.0) software for mask extraction to obtain the qualified images of our study area using the 1954 Beijing Projection Coordinate System. Finally, ArcGIS10.3.0 is used to map land use types. During the mapping process, the data were corrected according to the classification of land use status (GB/t201010-2017) and the environmental conditions of field investigation. We classified the study area into five classes: farmland, woodland, water, construction land, and natural grasslands. Additionally, farmland was divided into different patches: corn, potato, radish, cabbage, rape, shallot, green manure, tobacco, machine-plowed or non-machine-plowed (Fig. 1).

**Table 1 Sampling variables for the selection of foraging habitats**

Category	Variables	Description
Topographic factors	Slope degree (°)	Large quadrat: < 10° = 1, 10°–20° = 2, 20°–30° = 3, > 30° = 4
	Slope aspect	Large quadrat: shady slope = 1 (–67.5° to 67.5°), sunny slope = 2 (112.5°–247.5°), semi-sunny slope = 3 (67.5°–112.5°, 247.5°–292.5°)
	Slope position	Large quadrat: upper = 1, middle = 2, lower = 3
Human disturbance factors	Distance to water (m)	Straight-line distance (m) between the center of a large quadrat and the nearest water (ditch, canal, brook, or pool)
	Distance to settlement (m)	Straight-line distance (m) between the center of a large quadrat and the nearest residence
	Distance to road (m)	Straight-line distance (m) between the center of a large quadrat and a road
	Distance to tillagers (m)	Straight-line distance (m) between the center of a large quadrat and the nearest farmer working at a site
Food factors	Types of food	Type of crop: corn, potato, radish, cabbage, rape, shallot, green manure, tobacco
	Food richness	If more than two kinds of crops were in a large quadrat: yes = 1, no = 0
	Crop remains (g/m <sup>2</sup> )	The crop remains (g/m <sup>2</sup> ): the average of 5 small quadrats, measured by an electronic balance
	Tillage methods	Whether the crop patch was plowed by machine: yes = 1, no = 0

### Data analysis and statistics

We used the principal component analysis to reveal the main factors (slope degree, slope aspects, slope position, distance to water, distance to settlement, distance to road, distance to tillagers, food richness, crop remains, tillage methods) influencing the foraging habitat selection by Black-necked Crane in farmland. We retained the principal components with eigenvalues greater than or equal to 1.0 and determined the main factors that contributed the most to habitat selection.

We also used selectivity coefficients ( $W_i$ ) and the selectivity index ( $E_i$ ) (Vanderploeg and Scavia 1979) to determine how Black-necked Cranes chose foraging patches under the influences of the main factors. The formulas are as follows:

$$E_i = (W_i - 1/n) / (W_i + 1/n) \quad (1)$$

$$W_i = (r_i/p_i) / \sum (r_i/p_i) \quad (2)$$

where  $i$  is the level of a feature of the eco-factor (variables);  $n$  is the number of levels;  $p_i$  is the proportion of samples with feature level  $i$  in all samples in the whole study areas;  $r_i$  is the proportion of samples with feature level  $i$  in all samples in the foraging land of the overwintering Black-necked Cranes.  $E_i = -1$  represents no choice, expressed as NP;  $-1 < E_i < 0$  represents a tendency to avoid, expressed as NP;  $E_i = 0$  or approaching 0 represents a random choice, expressed as R;  $0 < E_i < 1$  represents a positive choice, expressed as S; and  $E_i = 1$  represents a highly positive choice, expressed as SP (Wei et al. 1996).

To analyze the influencing patterns of the main factors that varied during the different stages in winter,

one-way ANOVA and LSD multi-comparisons were used for the continuous variables, while a Chi square test was applied to discrete variables. In the analysis,  $P < 0.01$  means an extremely significant difference;  $0.01 < P < 0.05$  means a significant difference; and  $P \geq 0.05$  represents no significant difference.

All statistical analyses were conducted by using R 3.6 (R Core Development Team 2019) and SPSS software.

### Results

#### Foraging habitat selection

Four components (eigenvalue > 1.0) were determined to have a 65.83% cumulative contribution explaining the PCA results, reflecting the main factors influencing the selection of foraging habitats by Black-necked Crane. According to the scores of the load factors, we focused on the variables with significantly high scores and renamed them. In the first principal component (PC), tillage methods (–0.875) and crop remains (0.771) were renamed as the food factor; in the second and third PCs, the distance to residences (0.678), distance to tillagers (0.631), and distance to roads (0.698) were renamed as the distance factor; and in the fourth PC, the slope (0.639) was renamed as the topographic factor (see Table 2).

The selectivity coefficients ( $W_i$ ) and selectivity indexes ( $E_i$ ) showed that Black-necked Crane preferred to choose farmland patches as foraging sites, and these patches were located on semi-sunny slopes, with distances to roads ranging from 50–100 m, distances to a residence within 100–500 m, and crop remains of greater than 500 g/m<sup>2</sup>, and the preferred patches were not machine-plowed (see Table 3).

**Table 2 Contributions of habitat factors to the principal components in foraging areas in the farming areas**

Factors	PC-1 (27.525)	PC-2 (42.899)	PC-3 (55.785)	PC-4 (65.827)
Slope aspect	-0.259	0.484	-0.214	0.639
Slope degree (°)	-0.680	0.254	-0.008	-0.286
Slope position	0.351	-0.463	-0.221	-0.007
Distance to road (m)	0.092	0.388	0.698	0.016
Distance to water (m)	0.661	-0.053	0.175	-0.232
Distance to tillagers (m)	0.426	0.189	0.631	0.240
Distance to settlement (m)	0.187	0.678	-0.433	-0.048
Tillage methods	-0.875	0.130	0.170	-0.064
Crop remains (g/m <sup>2</sup> )	0.771	0.283	-0.235	0.188
Food richness	-0.281	-0.527	0.075	0.600

**Table 3 Selective parameters of major habitat factors for foraging habitats**

Factors	<i>I</i>	<i>P<sub>i</sub></i>	<i>R<sub>i</sub></i>	<i>W<sub>i</sub></i>	<i>E<sub>i</sub></i>	Preference
Slope aspect	Shady slope	0.400	0.347	0.867	-0.106	R
	Sunny slope	0.360	0.265	0.737	-0.186	R
	Semi-sunny slope	0.240	0.388	1.616	0.202	S
Distance to road (m)	<50	0.389	0.388	0.998	-0.002	R
	50–100	0.303	0.347	1.145	0.067	S
	>100	0.309	0.265	0.860	-0.076	R
Distance to settlement (m)	<100	0.263	0.031	0.116	-0.773	NP
	100–500	0.389	0.592	1.523	0.253	S
	>500	0.349	0.378	1.083	0.088	R
Tillage methods	Yes	0.657	0.531	0.807	-0.148	R
	No	0.343	0.469	1.369	0.114	S
Crop remains (g/m <sup>2</sup> )	<100	0.486	0.306	0.630	-0.299	NP
	100–500	0.366	0.449	1.228	0.025	R
	>500	0.149	0.245	1.648	0.170	S

R random choice, S normal choice, SP highly positive choice, NP tending to avoid

### Influencing patterns of the main factors during different stages of winter

We analyzed the results of the Chi square test and LSD multi-comparison tests that compare the main factors of the crop remains, distance to roads and distance to residences during different stages of winter. These three main factors showed extremely significant differences in late winter ( $P < 0.01$ ) compared to those in mid- and late winter, but there was no significant difference between those in mid- and early winter. Crop remains were greater than 500 g/m<sup>2</sup> in early winter but decreased to less than 200 g/m<sup>2</sup> in late winter (see Tables 4 and 5).

The 3D scatter plot (see Fig. 2) shows that due to the changes in crop remains, the foraging sites were evenly distributed in terms of the main factors of the distance to roads and the distance to residences in early winter. However, in mid-winter, all foraging sites were close to roads (the average was 63.19 m), and some sites with

relatively high crop remains were close to residences, but some were far from residences due to low crop remains (the average was 523.44 m). During late winter, when the crop remains were approaching their lowest levels, more foraging sites were close to both roads and residences, without any grouping.

## Discussion

### Selection of foraging habitats

Factors contributing to the first principal component in the PCA were named the food factor, which is also the first factor that influenced when Black-necked Cranes chose a crop patch as a foraging site, as shown in our study. Researchers have previously mentioned that food is the most important factor contributing to habitat selection for animals, especially the nutrition obtained from food resources (Langvatn and Hanley 1993; Storch 1993). The feeding efficiency of Black-necked Cranes

**Table 4** LSD multiple comparisons for the main influencing factors between different stages

Factors	Stages of time (I)	Stages of time (II)	Mean difference (I–II)	Standard error	P	Mean ± SD		
						EW	MW	LW
Crop remains (g/m <sup>2</sup> )	EW	MW	75.25	81.27	0.357			
		LW	354.68	76.80	0.000**	512.04 ± 359.56	436.79 ± 400.18	157.36 ± 118.33
	MW	LW	279.43	69.41	0.000**			
Distance to road (m)	EW	MW	88.33	19.71	0.000**			
		LW	76.94	18.63	0.000**	151.52 ± 89.86	63.19 ± 66.80	74.58 ± 65.08
	MW	LW	− 11.39	16.83	0.500			
Distance to settlement (m)	EW	MW	− 169.05	49.65	0.001**			
		LW	− 44.7	46.92	0.343	354.39 ± 163.77	523.44 ± 156.48	399.09 ± 206.16
	MW	LW	124.34	42.41	0.004**			

EW early winter, MW mid-winter, LW late winter

\*\**P* < 0.01**Table 5** Chi square tests for the main influencing factors between different stages

Type	Stages of time (I)	Stages of time (II)	P
Tillage methods (df = 1)	EW	MW	0.023*
		LW	0.000**
	MW	LW	0.008**
Slope aspect (df = 2)	EW	MW	0.473
		LW	0.561
	MW	LW	0.004**

EW early winter, MW mid-winter, LW late winter

\*\**P* < 0.01\**P* < 0.05

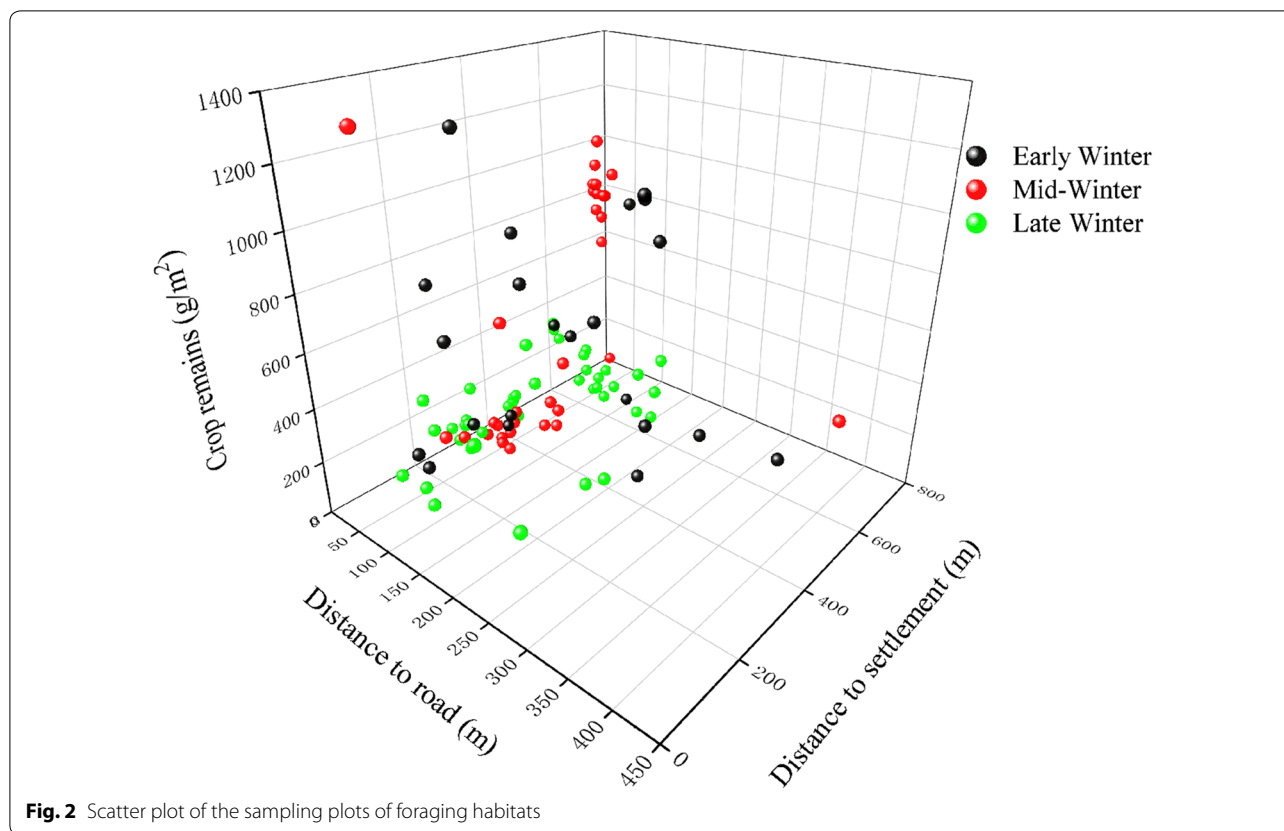
often depends to some extent on the soil density of the cultivated farmland of foraging sites, because cranes can use only their beaks and claws when searching for food (Jia et al. 2013). Overwintering Black-necked Cranes in the Huizhe Wetland, Yunnan Province, preferred to forage in plowed land because of the lower soil density and shallowly buried food (Li et al. 2009). Nonetheless, we obtained the opposite result, and Black-necked Cranes in Caohai tended to feed in non-plowed and food-abundant farmlands, although the soil density was higher than that of plowed locations. In recent years, local mechanized tillage has become more popular and will eventually completely replace traditional tillage methods. We found that the crop remains in farmlands plowed by machines were lower than those of patches plowed by traditional methods (*P* < 0.01); therefore, Black-necked Cranes perhaps preferred non-plowed land over plowed land because of the more abundant food they were able to obtain. Some cases concerning Red-crowned Crane (*Grus japonensis*) and White-naped Crane (*Grus vipio*) were reported in

farmlands near the Demilitarized Zone dividing North and South Korea, where many cranes foraged in non-machine-plowed farmland because machine-plowing resulted in few crop remains (Li et al. 2009).

The disturbance factor was also a main influencing factor that contributed to habitat selection by Black-necked Cranes (Jiang et al. 2017; Zhang et al. 2017). Many types of human activities in the farming areas around Caohai depend on roads (Sun et al. 2018). The local government has constructed many roads (especially hard-packed tractor roads between farmlands) to facilitate the agricultural industry, which has shaped a network covering the farming area. Black-necked Crane alert behavior is reliant on the positions of Black-necked Crane individuals (Kuang et al. 2014). Obviously, areas that are farther from roads and residences are more beneficial to foraging Black-necked Cranes due to reduced human disturbance. However, according to the results of the selectivity coefficients ( $W_i$ ), most of the foraging sites are located within 50–100 m to the road, rather than farther away from the road, because the farmland in Caohai is divided into small blocks by the road network, and the straight-line distance between most of the roads is within 100 m, which makes the foraging sites distributed near the roads without other options. The distance to water was not a significant influencing factor for Black-necked Cranes in our study, which indicated that Black-necked Cranes do not depend on the water when foraging in the farmland areas.

#### Influencing patterns of the main factors varied during the different stages of winter

Environmental conditions affecting wildlife survival often gradually vary with time during the winter. During the overwintering period in Caohai, foraging choice



of Black-necked Crane also varied with changes in the environmental conditions of the foraging habitats during the three different stages of winter (Wu and Li 1985). The main factor, crop food remains, declined sharply over time in winter in Caohai, especially in late winter, when it was only one-third of that available in early winter (mean: 512  $\text{g/m}^2$  in early winter, 157  $\text{g/m}^2$  in late winter). Due to the changes in food factors, influences from disturbance factors also changed. With the arrival of Black-necked Cranes in early winter, they often showed more alert behaviors because they had to adapt to the relatively new environment (Wu and Li 1985) and preferred to choose crop patches that were far from roads and residences. Upon the onset of mid-winter, weather conditions were more severe, and Black-necked Cranes needed more energy from food, but the crop remains decreased; therefore, the influences of disturbance factors, especially the distance to roads, began to weaken. Black-necked Cranes began to choose crop patches with abundant food remains that were far from residences (the average distance to residences was 500 m in mid-winter) as foraging sites. Black-necked Cranes have difficulty avoiding disturbances from roads because of the developed road networks in farmland areas. We found that foraging sites in this stage were comprised of two

groups, as demonstrated on the scatter plot (see Fig. 2). One group of sites was not far from roads but had low crop remains and was used mainly by families of Black-necked Cranes, with a family often consisting of parents and one or two juveniles, meaning that they needed less food than non-family Black-necked Crane groups (Kuang et al. 2014; Zhang et al. 2017) and show more territorial behavior and loyalty to their used foraging sites (Yang et al. 2016; Che et al. 2018). Another group of sites was farther from roads but had higher crop remains and was occupied mainly by non-family Black-necked Crane groups who needed large crop patches to meet their food demands. In late winter, after the last 10 days of February, crop remains decreased to their lowest level. When preparing to fly back to breeding sites, the cranes had to complete fat accumulation and migration excitation, which demands more energy than usual (Zheng 2012; Sun et al. 2018). Therefore, during this stage, influences of disturbance factors, especially those from residences, decreased further, and many foraging sites were distributed close to residences. In early March, local farmers begin spring sowing in Caohai, thus it seems that Black-necked Cranes would obtain more food. However, in contrast, Black-necked Crane foraging sites provide less food at this time because farmers do not allow cranes

to damage their cultivated land, and crop patches are reduced due to spring sowing. In the meantime, some Black-necked Cranes have begun to gradually migrate from the Caohai Wetland.

## Conclusions

It is critical for migratory birds to have foraging habitats of sufficient quality for overwintering survival (Davis et al. 2014; Wood et al. 2019). Presently, there are severe conflicts between birds and humans and an ecological imbalance of the wetland system in Caohai (Ran et al. 2017). These can also lead to conflicts between groups of people over how such issues should be managed (Redpath et al. 2015). As a result of the shrinkage of the lakeshore, including the farmlands within it, Black-necked Cranes are becoming more dependent on the outer farmlands surrounding the wetland; hence, protecting and managing the farmlands is critical to Black-necked Crane conservation. It is of great concern that the farmlands relied on by Black-necked Cranes are vanishing for the following reasons: more agricultural development projects are occurring, more areas of farmland reduction are arising, road construction and car owners are becoming more common, the plastic house culture is prevalent, machine tillage is becoming popular, and the traditional crop compositions are being altered. Therefore, we suggest that local authorities control the expansion of construction in farmland areas; partly recover and retain traditional agricultural production, for example, traditional tillage methods and sufficient cultivation of potatoes and buckwheat; and reduce disturbances from human activities to meet the demands by Black-necked Cranes for foraging habitats of sufficient quality for successful overwintering.

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## Authors' contributions

DW conceived the study, collected and analysed the data, and wrote the manuscript. HS supervised the research and provided multiple revisions of the writing. CH conducted research method guidance for the article. MZ and ZL implemented the field surveys and collected the data. All authors read and approved the final manuscript.

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## Availability of data and materials

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

## Ethics approval and consent to participate

The investigations comply with the current laws of China, where they were performed.

## Consent for publication

Not applicable.

## Competing interests

The authors declare that they have no competing interests.

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