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Habitat use, preference and utilization distribution of two crane species (Genus: *Grus*) in Huize National Nature Reserve, Yunnan-Guizhou Plateau, China

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Understanding habitat use and spatial distribution of wildlife could help conservationists determine high-priority areas and enhance conservation efforts. In this study, we studied habitat use, preference and utilization distribution of two Gruidae species (Black-necked Cranes *Grus nigricollis* and Eurasian Cranes *G. grus*) in Huize National Natural Reserve, Yunnan-Guizhou Plateau, SW China. Line transect method indicated that the anthropogenic habitat of farmland was utilized the most by these two species (>90% of flocks observed for both). But Black-necked Cranes preferred marsh to farmland and grassland while Eurasian Cranes favored grassland in our study. Nearly all the Black-necked Cranes (99.30% of the flocks observed) utilized habitats in the core area of the reserve, covering an area of 283.84 ha close to the common roost. Eurasian Cranes were mostly (55.39% of the flocks observed) distributed in the buffer zone with higher elevation and further distance to the roost, covering an area of 558.73 ha. We believe that our findings could help guide habitat management, functional zoning planning and adjustment in the future. According to our results, we recommended restoration of more wetlands, retain large areas of farmland, and protect the areas that cranes use most frequently.

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Abstract: Understanding habitat use and spatial distribution of wildlife could help conservationists determine high-priority areas and enhance conservation efforts. In this study, we studied habitat use, preference and utilization distribution of two Gruidae species (Black-necked Cranes *Grus nigricollis* and Eurasian Cranes *G. grus*) in Huize National Natural Reserve, Yunnan-Guizhou Plateau, SW China. Line transect method indicated that the anthropogenic habitat of farmland was utilized the most by these two species (>90% of flocks observed for both). But Black-necked Cranes preferred marsh to farmland and grassland while Eurasian Cranes favored grassland in our study. Nearly all the Black-necked Cranes (99.30% of the flocks observed) utilized habitats in the core area of the reserve, covering an area of 283.84 ha close to the common roost. Eurasian Cranes were mostly (55.39% of the flocks observed) distributed in the buffer zone with higher elevation and further distance to the roost, covering an area of 558.73 ha. We believe that our findings could help guide habitat management, functional zoning planning and adjustment in the future. According to our results, we recommended restoration of more wetlands, retain large areas of farmland, and protect the areas that cranes use most frequently.

Keywords: *Grus nigricollis*; *Grus grus*; habitat use; spatial distribution; threatened species; coexistence

Introduction

Understanding the habitat use and spatial distribution of wildlife is important for conservation and management (Morris, 2003; Nina et al., 2008). Conservation planning should be drawn up more carefully for protected area managers when more than one species are taken into consideration. And things are going to be more complicated when the area is surrounded by human beings and anthropogenic habitats (e.g. farmland) are utilized by wildlife (Fujioka et al., 2010; Li et al., 2013), such as wintering crane species.

Black-necked (*Grus nigricollis*, Przevalski, 1876) and Eurasian Cranes (*G. grus*, Linnaeus, 1758) are two large Gruidae waders. Black-necked Cranes were Vulnerable (Vu) species on the IUCN Red List of Threatened Species (BLI, 2016) and Biodiversity Red List of China, while Eurasian Cranes were recognized as Least Concern (LC) and Near Threatened (NT) species on the Red List of Threatened Species of IUCN and China, respectively.

Both of the species are typical migrators. Eurasian Cranes are vastly distributed across Eurasia. Their breeding range extends from northern and western Europe across Eurasia to northern Mongolia, northern China, and eastern Siberia; and the winter range includes the Mediterranean region of northern Africa, the Persian Gulf, the India Peninsula, as well as southern China to northern Indo-China, Myanmar and Assam (Johnsgard, 1983; Meine and Archibald, 1996). The Black-necked Crane mainly inhabits the alpine wetlands of the Qinghai-Tibet and Yunnan-Guizhou Plateaus of China with a population of 10,000–10,200 individuals (Li and Li, 2005; Li, 2014). Nearly all the Black-necked Crane breeding populations are distributed on the Qinghai-

Tibet Plateau, China, except for a small number of pairs (maximum 139 birds) in adjacent Ladakh, India (Chandan et al., 2014). The wintering area of Black-necked Cranes includes lower elevations of the Qinghai-Tibet and Yunnan-Guizhou Plateaus of China, Bhutan, with occasional records in Nepal, Myanmar, Vietnam and Kashmir region (Li, 2014; Chandan et al., 2014). These two crane species have a clearly divided breeding range overlapping their wintering grounds mainly on the Yunnan-Guizhou Plateau, SW China (Wang and Wang, 2004).

The lake and lakeshore area on the Yunnan-Guizhou Plateau has been regarded as an important wintering place for waterbirds, e.g. geese, ducks, gulls, storks and cranes (Chen, 1998). As a typical mountain area, the majority of lakes on the Yunnan-Guizhou Plateau were formed by faulting (Wang and Dou, 1998) and the lakeside wetland ecosystem are fragile due to its narrow distribution and frequent disturbance by human activities, such as farming, fishery and tourism (Tian et al., 2004; An et al., 2007). The Black-necked Crane and Eurasian Crane are two flagship species of the wetland ecosystem on the Yunnan-Guizhou Plateau. Different from the breeding site, in winter cranes are distributed in the human-dominated area and mainly forage in anthropogenic habitats (Li, 2014). In order to put forward more rational and effective habitat management measurements and promote sustainable development of the plateau wetland system, we studied the habitat use, preference and utilization distribution (UD, or space use pattern) of two wetland flagship species (Black-necked Cranes & Eurasian Cranes) in the Huize National Nature Reserve (HNNR) on the Yunnan-Guizhou Plateau.

Materials & Methods

Study area

This study was conducted between November 2010 and March 2011 in the HNNR, north-eastern Yunnan Province (Fig. 1). The reserve was first established in 1990 as a county level reserve and upgraded to a national reserve in 2006 to protect wintering waterfowl and their habitats (Qiou, 2012). Black-necked Cranes and Eurasian Cranes were known as the flagship species of this plateau wetland ecosystem. There were 64 water bird species wintering at HNNR including about 400 Black-necked Cranes and 350 Eurasian Cranes (Yang and Zhang, 2014). The elevation of HNNR, which is located on the Yunnan-Guizhou Plateau, is 2,470–3,092 m above the sea level (Qiou, 2012).

HNNR has two discrete sites about 30 km apart named the Daqiao and Zhehai. Our study was conducted in the Daqiao site, which covers an area of 9076.28 ha (N26°38'00"–26°44'24", E103°12'06"–103°22'02") (Fig. 1). Daqiao site contains 470.50 ha of reservoir named Yuejin, 149.36 ha of marsh, 3966.53 ha of farmland, 178.19 ha of grassland, 302.11 ha of residential areas, and 4009.58 ha of woodlands (Qiou, 2012). The Yuejin Reservoir supplies shallow water roosting and foraging habitat for wading birds, as well as marsh, farmland and grassland, which serve as foraging habitats for the cranes, and woodland, which is considered unsuitable habitat for cranes (Kong et al., 2011). As a typical anthropogenic habitat, farmlands have more human activities during the harvest (from October to November) and planting season

(from February to March). Food grown by farmers, including grains and potatoes, is primarily consumed by cranes in winter (Dong et al., 2016). During the course of our study, there were about 340 Eurasian and 80 Black-necked Cranes in the Daqiao site, as well as several thousands of other waterfowl, such as Bar-headed Goose *Anser indicu*, Ruddy Shelduck *Tadorna ferruginea*, Grey Heron *Ardea cinerea*, and many other species. Wildlife in HNNR is facing intensive human disturbance due to the 12250 people residing in the study area. The mean annual temperature at Daqiao is 9.6°C, and there are 40 days of snowfall, 50 days with snow on the ground, and 45 days of frozen ice annually (Qiou, 2012).

Field surveys

Wintering cranes are gregarious and share communal roosting sites; they departed for foraging during the morning (06:30–08:00) and returned at night (18:00–20:00) (Kong et al., 2008). The line transects survey method was used to record bird distributions and habitat use while they fed on clear days (no rain, snow or fog) during 08:00–18:00. In general, three spatial relatively separated areas comprising villages of Yangmeishan-Bajiacun-Lijiawan (YBL), Maanshan (MAS) and Daqiao-Dideka (DD) were included along the line transect (Fig.1). The line transects covered 16.6 km and could be fully inspected in two days. Every day of field studies, we started off from the protecting station located in Yangmeishan village. The end point along the line transect of the previous day was used as the start point of the second day. The continuous two days' survey was considered as a whole survey or one independent sampling and we switched direction of travel in the next whole survey. In consideration of relatively constant activity area for cranes in a short time (Qian et al 2009); little probability existed for recording a flock repeatedly during one sampling period (two days). Therefore we considered the 12 whole surveys conducted during the study period as 12 independent replicate. Crane flocks could be easily detected along the transect with 10×42 binoculars; nearly 100% of the Black-necked Crane population (mean=78, n=12) and about 80% of the Eurasian Crane population (mean=263, n=12) could be sighted during each whole survey. We defined flocks as being discrete if they were 500m apart. Each flock was considered a sample unit and one GPS point was recorded for every flock due to non-independence of individuals in a flock (Thomas and Taylor 1990). For each crane flock, we recorded detailed information including date, time, habitat type, GPS location, elevation, distance to roost (DTR), flock size and flock composition. DTR was defined as the distance from the location of each flock to the communal roosting site (N26°42'05.6", E103°16'00.6") and was calculated in ArcGIS 10.2 software.

We divided the foraging habitat into three categories of farmland, marsh and grassland. Farmland included plowed and unplowed lands used for crops, including *Solanum tuberosum*, *Rassica campestris*, and *Zea mays*. Marsh was near the reservoir where the ground was covered with shallow water (≤50 cm) throughout the winter. The most dominant vegetation in the marsh was *Ranunculus japonicus*, *Juncus effuses* and *Poa annua*. Grassland included meadows without water covered during winter, and predominately occupied by *Leontopodium andersonii*, *Prinula*

malacoides and *Trifolium repens*. All of these habitats were scattered around the Yuejin Reservoir.

Habitat use and preference

Jones (2001) reviewed that habitat use refers to the way in which an individual or species uses habitats to meet its life history needs, while habitat preference that takes into account habitat availability, resulting in the disproportional use of some resources over others (Krausman, 1999). Both habitat use and preference are consequences of habitat selection, which refers to a hierarchical process of behavioral responses that may result in the disproportionate use of habitats (Block and Brennan, 1993)

Habitat use was calculated by the number of crane flocks occurring in each habitat type as the percentage of all crane flocks observed. Compositional analysis was used to determine habitat preference rank of the birds by considering the relative magnitude between utilization and availability of every two habitat categories. Log-transformed ratio value of habitat was used instead of the absolute value for avoiding the unit-sum constraint of available habitat types (only the farmland, marsh and grassland were regarded as available foraging habitat as mentioned above) (Bingham and Brennan, 2004). The equation of $d_{ij} = \ln(\chi_{Ui} / \chi_{Uj}) - \ln(\chi_{Ai} / \chi_{Aj})$ were used to construct a ranking matrix of habitat preference, where i and j means the i th and j th habitat type and $i \neq j$; χ_U and χ_A are habitat proportion utilized and available, respectively (Aebischer et al., 1993). If $d_{ij} > 0$ habitat i is utilized more than expected relative to habitat j , otherwise habitat i is utilized less than expected.

Utilization distribution

The utilization distribution (UD) provides a useful global representation of space use pattern of animals by defining the relative frequency of occurrence of animals (Benhamou and Riotte-Lambert, 2012). We calculated utilization distributions using the nonparametric kernel method called the “LoCoH” local convex hull method to assess space use by the cranes (Getz and Wilmers, 2004; Getz et al., 2007). This method is more appropriate than a parametric kernel method for constructing UD and can capture hard boundaries (e.g., rivers and cliff edges) and process a large sample size (Getz et al., 2007). This method is also very powerful in processing aggregated and clustered data (Getz and Wilmers, 2004) on population level (Liu et al., 2010). We constructed kernels with the r -LoCoH method (available at <http://locoh.cnr.berkeley.edu>), using data of flock locations within a fixed radius of 500 m, which was sufficient to distinguish two crane flocks. Shapefiles obtained from this implementation was imported to ArcGIS 10.2 to construct the UD map. We considered the 90%, 70% and 50% UD isopleths of cranes in our study in order to determining areas with high conservation priority. We considered the 90% isopleths instead of 100% isopleths as the overall distribution range of the cranes by omitting outlying points representing exploratory animal movement rather than those necessary for survival. And the 90% UD isopleths could reflect actual spatial distribution pattern of animals faithfully (Luca et al., 2006).

Statistical analysis

We used parametric and non-parametric tests, as appropriate after the *Kolmogorov–Smirnov* test was conducted for each data set. For comparing mean of flock size, elevation and distance to the roost of two crane species, the nonparametric test of Mann-Whitney U was selected as the normality violation of our data. Statistical analysis were completed with IBM SPSS Statistics 19.0 and the difference between two variables was considered statistically significant when the two-sided *p*-values of significant probability < 0.05 .

Results

Habitat use and preference

We observed 287 and 399 flocks for Black-necked Cranes (BNC) and Eurasian Cranes (CC), respectively during the 12 whole surveys. In winter, both of the two crane species showed similar habitat use pattern with the most utilized proportion of farmland (BNC: 90.94%; CC: 93.73%). For the other two habitat types, more Black-necked Cranes utilized marsh and more Eurasian Cranes selected grassland (Table 1).

Mann-Whitney U test indicated that Eurasian Cranes usually selected habitat with higher elevations ($Z_{686} = -12.046$, $P = 0.000$), further distance to the roost ($Z_{686} = -14.164$, $P = 0.000$) and aggregated in bigger flock ($Z_{686} = -9.913$, $P = 0.000$) than Black-necked Cranes (Table 2, Fig. 2). Eurasian Cranes utilized habitat at higher elevations than that of Black-necked Cranes at the areas of YBL ($Z_{262} = -5.556$, $P = 0.000$) and DD ($Z_{262} = -2.141$, $P = 0.032$). Moreover, Eurasian Cranes distributed further away from the roost than those of Black-necked Cranes in the area of YBL ($Z_{262} = -4.616$, $P = 0.000$) and MAS ($Z_{201} = -2.008$, $P = 0.045$) (Fig. 2).

Compositional analysis indicated that these two species had different habitat preferences. The habitat preference rank of Black-necked Cranes was Marsh $>$ Farmland $>$ Grassland, while Eurasian Cranes preferred Grassland to Farmland and Marsh (Table 3).

Utilization distribution

Nearly all Black-necked Cranes (99.30%) were distributed in the core area close to the roosting sites encompassing YBL and MAS, whereas Eurasian Cranes scattered in the whole region with over half of flocks (55.39%) in the peripheral area of DD (Fig. 1, Table 2). For Eurasian Cranes, the utilization distribution covered larger area of 558.73 ha (90% isopleths of the UD, or UD₉₀) than that of Black-necked Cranes (UD₉₀ = 283.84 ha). UD₇₀ of Eurasian Cranes scattered in three discrete areas occupying 380.46 ha, whereas Black-necked Cranes concentrated in the area near the roost covering 165.58 ha. The UD₅₀ of Black-necked Cranes was rather small (92.89 ha) at YBL area, but the UD₅₀ of Eurasian Cranes was situated in YBL and DD with an area of 224.81 ha (Fig. 3).

Discussion

As two large wader species of Gruidae, Black-necked Cranes and Eurasian Cranes were

recognized as the flagship species of wetlands on the Yunnan-Guizhou Plateau. Due to their close phylogenetic relationship and similar morphologies, the birds have quite a similar wintering ecology. We found wintering crane species exhibited extremely high dependency on the anthropogenic habitat of farmland in winter, which was understandable, considering that farmland was the predominant available habitat (92.37%) in our study area. Wintering Black-necked Cranes usually forage in cultivated lands and marshes not only at two other wintering sites like Dashanbao National Nature Reserve (Kong et al., 2011) and Yongshan County (Lu and Yang, 2014) on the Yunnan-Guizhou Plateau, but also in the Lhasa river valley Tibet on the Qinghai-Tibet Plateau (Tsamchu and Bishop, 2005), possibly due to plenty of food storage in farmland than other habitats. For example, the residue potato *Solanum tuberosu* and grains like oat *Avena sativa*, buckwheat *Fagopyrum tataricum*, and corn *Zea mays* on the farmland supplied over 80% wintering food for Black-necked Cranes (Li et al 2009; Dong et al 2016). During the whole winter, marsh and farmland rather than grassland were favored by Black-necked Cranes in Huize reserve. Other studies conducted on the Yunnan-Guizhou Plateau also indicated that Black-necked Cranes preferred marsh to other habitats (Li, 1999; Kong et al., 2011). Habitat use is the results of the behavioral response of animals to the local environment (Block and Brennan, 1993; Jones, 2001), while habitat preference reflects the biological characteristics of animals (Hall et al., 1997). In our study area, farmland occupies an extremely high proportion of the available habitat, e.g., about 26 times more than marsh in size. Although Black-necked Cranes prefer marsh, the limited area of marsh cannot support all the birds, which may explain the significant difference between habitat use and preference observed in our study.

The Eurasian Crane are found in farmland both in our study and other studies from Asia to Europe (Avilés et al., 2003; Zhan et al., 2007). Eurasian Cranes mainly prefer grassland in this study, whereas farmland and marsh are favored habitats for Eurasian Cranes in Yeyahu wetland, Beijing (Zhan et al, 2007) and Spain (Avilés et al., 2003), where Black-necked Cranes are absent. Although habitat preference reflects the biological characteristics determined by a series of innate and learned behavioral decisions (Hall et al., 1997), this is not invariable. When wintering with Black-necked Cranes in sympatric area in our study, Eurasian Cranes preferred grassland to farmland and marsh. We inferred that this may be caused by the presence of Black-necked Cranes whose larger body size gives them an advantage in competing for resources (Smith and Brown, 1986), and as a result they exclude the smaller Eurasian Cranes from their favored habitats. Thus, the difference in habitat preference between this study and the others may be partly explained by the inter-species competition.

In consideration of the same habitat use pattern of these two cranes, inter-specific competition could be expected. However, coexistence has occurred for similar species when niche divergence is present (Schoener, 1974), although we found that the two crane species seem to avoid inter-species competition by moderately segregating of habitat preference as mentioned above. At the same time, we found significant segregating in spatial distribution between these two species. The two crane species seemed to avoid foraging together during the winter by distributing in different areas. Nearly all of black-necked cranes (99.3%) located in the area of YBL and MAS while over half of Eurasian Cranes (55.39%) distributed in the buffer zone of DD. That is why

less than 3% of mixed flocks were recorded in our study. Previous empirical observations also indicated that Black-necked and Eurasian Cranes share roosts, although they forage at different sites (Yang et al., 1992) and often compete for foraging sites when wintering in sympatry (Li and Li, 2005).

Our result showed that Black-necked Cranes concentrated for foraging in the central area near the common roost, while Eurasian Cranes scattered throughout the region on a wider scale. This could explain that larger populations of Eurasian Cranes occupy more expansive areas. We found that Eurasian Cranes usually selected habitats 2.55 km farther away from the roost and 55 m higher along the elevation than the Black-necked Cranes. Earlier studies pointed out that foraging near the roost is a strategy of reducing energy expenditures for the cranes (Alonso et al., 1992; Kong et al., 2011), and undoubtedly only the dominate species could occupy the optimal habitat, e.g. close to the roost or with plenty of food. Although we occasionally detected the larger Black-necked Cranes repelling smaller Eurasian Cranes from their foraging farmland habitat, we do not have strong evidence demonstrating that it is the inter-species competition resulting in spatial separation of these two crane species in our study, in spite of a similar distribution pattern documented by Yang et al. (1992). An observation carried out in the Caohai National Nature Reserve of Guizhou Province on the Yunnan-Guizhou Plateau, reported that Black-necked Cranes mostly forage in places near their roosting site, whereas smaller Eurasian Cranes forage in peripheral areas 10–20 km away on the hill (Yang et al., 1992).

Taking into consideration our and earlier habitat studies, we inferred that cranes use different habitats in different ways (Kong et al., 2011; Dong et al 2016). Marsh could be recognized as the optimal foraging habitat for cranes because of the highest amount of food resources (including underground tubers and insect larvae), the softest ground surface for cranes to dig the food and the difficult access for humans (Li et al. 2009; Kong et al., 2011). Farmland is considered as the suboptimal habitat with the largest amounts of underground tubers and medium amounts of insects, but with higher human disturbance (Li et al., 2009). On the other hand, farmland is utilized the most by cranes (especially for Black-necked Cranes) across the Yunnan-Guizhou Plateau to Qianghai-Tibet Plateau (Tsamchu and Bishop, 2005; Kong et al., 2011; Lu and Yang, 2014), and could be regarded as the vital foraging habitat for wintering cranes. Grassland with scarcest food resources and hardest ground surface represent the worst habitat quality (Li et al., 2009).

Although this case study was carried out in one reserve, our study could also shed light on the mountain area on the Yunnan-Guizhou Plateau and suggest habitat conservation and management lessons for the other protected areas. Our results indicated that effective and sustainable conservation measures, such as maintaining plenty of farmland, restoring wetlands, and prohibiting humans and livestock entering the core area inhabited by cranes, could benefit the wintering crane species. We believe the conservation of flagship crane species could also enhance conservation efforts of other waterbirds in the wetland system.

Conclusions

As two close related species, Black-necked and Eurasian Cranes showed high similarity in habitat use patterns. However, they were inclined to utilize habitats in different areas, and Black-necked Cranes kept to the core area while Eurasian Cranes inhabited larger areas. We argue that spatial separation could mitigate interspecies competition and facilitate coexistence. We recommended protection of the farmlands utilized the most by cranes, and restore more wetlands.

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References

- Aebischer NJ, Robertson PA, Kenward RE. (1993) Compositional analysis of habitat use from animal radio-tracking data. *Ecology*, 74: 1313-1325.
- Alonso JC., Alonso JA., Alonso JC. (1992) Daily activity and intake rate patterns of wintering Eurasian Crane Eurasian Cranes (*Grus grus*). *Ardea*, 80, 343–351.
- An SQ, Li HB, Guan BH, Zhou CF, Wang ZS, Deng ZF, Zhi YB, Liu YH, Xu C, Fang SB, Jiang JH, Li HL. (2007) China's natural wetlands: past problems, current status, and future challenges. *AMBIO: A Journal of the Human Environment* 36(4): 335-342.
- Avilés JM. (2003) Time budget and habitat use of the Eurasian Crane wintering in dehesas of southwestern Spain. *Canadian Journal of Zoology* 81: 1233-1238.
- Benhamou S, Riotte-Lambert L. (2012) Beyond the utilization distribution: identifying home range areas that are intensively exploited or repeatedly visited. *Ecological Modelling* 227: 112-116.
- Bingham R., Brennan L.A. (2004) Comparison of type I error rates for statistical analyses of resource selection. *Journal of Wildlife Management* 68: 206-212.
- Blcock WM, Brennan LA. (1993) The habitat concept in ornithology: Theory and applications. *Current Ornithology*, 11:35–91.
- BLI [BirdLife International]. (2016) IUCN Red List for birds.
- Chandan P, Khan A, Takpa J, Hussain SA, Medi K, Jamwal PS, Rattan R, Khatoon N, Rigzin T, Ababd A, Dutta PK, Ahmad T, Ghose PS, Shrestha P, Theengh LT. (2014) Status and distribution of black-necked Crane (*Grus nigricollis*) in India. *Zoological Research* 52(S1) :567-576.
- Chen KL. (1998) Wetlands and waterbirds of China. *Bulletin of Biology*, 33:2–4.
- Dong HY, Lu GY, Zhong XY, Yang XJ. (2016) Winter diet and food selection of the Black-necked Crane *Grus nigricollis* in Dashanbao, Yunnan, China. *PeerJ* 4:e1968; DOI 10.7717/peerj.1968.
- Fujioka M., Lee SD, Kurechi M, Yoshida H. (2010) Bird use of rice fields in Korea and Japan. *Waterbirds* 33(sp1): 8-29.

- 328 Getz WM, Fortmann-Roe S, Cross PC, Lyons AJ, Ryan SJ, Wilmers CC. (2007) LoCoH: Nonparametric
329 kernel methods for constructing home ranges and utilization distributions. *PLoS ONE* 2(2): e207.
330 doi:10.1371/journal.pone.0000207
- 331 Getz WM, Wilmers CC. (2004) A local nearest-neighbor convex-hull construction of home ranges and
332 utilization distributions. *Ecography* 27: 489-505.
- 333 Hall LS, Krausman PR, Morrison ML. (1997) The habitat concept and a plea for standard terminology.
334 *Wildlife Society Bulletin* 25(1): 173-182.
- 335 Johnsgard PA. (1983). *Cranes of the world*. Bloomington: Indiana University Press.
- 336 Jones J. (2001). Habitat selection studies in avian ecology: a critical review. *The Auk* 118(2): 557-562.
- 337 Kong DJ, Yang XJ, Liu Q, Zhong XY, Yang JX. (2008) Diurnal time budget and behavior rhythm of wintering
338 black-necked crane at Dashanbao in Yunnan. *Zoological Research*, 29, 195–202.
- 339 Kong DJ, Yang XJ, Liu Q, Zhong XY, Yang JX. (2011) Winter habitat selection by the vulnerable black-
340 necked crane *Grus nigricollis* in Yunnan, China: implications for determining effective conservation
341 actions. *Oryx* 45(02): 258-264.
- 342 Krausman PR. (1999) Some basic principles of habitat use. In: Launchbaugh KL, Sander KD, Mosley JC.
343 *Grazing behavior of livestock and wildlife*. University of Idaho, Moscow. pp85-90.
- 344 Li DL, Chen SH, Lloyd H, Zhu SY, Shan K, Zhang ZW. (2013) The importance of artificial habitats to
345 migratory waterbirds within a natural/artificial wetland mosaic, Yellow River Delta, China. *Bird*
346 *Conservation International* 23(2): 184-198.
- 347 Li FS. (1999) Foraging habitat selection of the wintering black-necked cranes in Caohai, Guizhou, China [in
348 Chinese with English abstract]. *Chinese Biodiversity* 7: 257-262.
- 349 Li FS. (2014) IUCN Black-necked Crane (*Grus nigricollis*) conservation plan [in Chinese with English
350 abstract]. *Zoological Research*, 35(S1): 3-9.
- 351 Li WJ, Zhang KX, Wu ZL, Jiang P. (2009) A study on the available food for the wintering Black-necked
352 Crane (*Grus nigricollis*) in Huize Nature Reserve, Yunnan [in Chinese with English abstract]. *Journal of*
353 *Yunnan University*, 31(6): 644-648.
- 354 Li ZM, Li FS. (2005) *Black-Necked Crane Study*. Shanghai Technological and Educational Press, Shanghai,
355 People's Republic of China.
- 356 Liu Q, Yang JX, Yang XJ, Zhao JL, Yu HZ. (2010) Foraging habitats and utilization distributions of Black-
357 necked Cranes at the Napahai Wetland, China. *Journal of Field Ornithology*, 81(1):21-30.
- 358 Lu GY, Yang XJ. (2014) Black-necked cranes wintering in Yongshan County, Yunnan and their conservation
359 [in Chinese with English abstract]. *Zoological Research* 35(S1): 143-150.
- 360 Luca B, Novella F, Giampiero DM, Alberto G, Fiora M, Andrea M, Sandro L, Tim C. (2006) Effects of
361 sampling regime on the mean and variance of home range size estimates. *Journal of Animal Ecology* 75:
362 1393–1405.
- 363 Meine CD, Archibald GW. (1996) *The cranes: status survey and conservation action plan*. Gland, Switzerland:
364 IUCN.
- 365 Morris DW. (2003) How can we apply theories of habitat selection to wildlife conservation and management?
366 *Wildlife Research* 30(4): 303-319.
- 367 Nina K, Fernández N, Kramer-Schadt S, Herrmann M, Trinzen M, Büttner I, Niemitz C. 2008. Habitat
368 selection models for European wildcat conservation. *Biological Conservation* 141(1): 308-319.

- 369 Qian FW, Wu HQ, Gao LB, Zhang HG, Li FS, Zhong XY, Yang XJ, Zheng GM. (2009) Migration routes and
370 stopover sites of black-necked cranes determined by satellite tracking. *Journal of field ornithology* 80(1):
371 19-26.
- 372 Qiou GX. (2012) General introduction. In: Qiou GX, Yang XJ, editors. *Yunnan Huize National Nature reserve*
373 *of black-necked crane*. Yunnan Science and Technological Press House: Kunming. pp1-5.
- 374 Schoener TW. (1974) Resource partitioning in ecological communities. *Science*, 185(4145): 27.
- 375 Smith JM, Brown RLW. (1986) Competition and body size. *Theoretical population biology* 30(2): 166-179.
- 376 Tian K, Mo JF, Lu M, Chang FL, Yang YX. (2004) Human disturbances on the ecological environment
377 degradation of Napahai wetland in the upstream of Yangtze River. *Resources and Environment in the*
378 *Yangtze Basin* 13:292-295.
- 379 Tsamchu D, Bishop MA. (2005) Population and habitat use by Black-necked Cranes wintering in Tibet. In:
380 Wang QS, Li FS(Chief Editors). Crane Research in China [in Chinese with English abstract]. Kunming:
381 Yunnan Educational Publishing House, 44-48.
- 382 Wang SM, Dou HS. (1998) Chinese lakes of China. *Science Press*, Beijing.
- 383 Wang YH, Wang H. (2004) Advance in study of Eurasian Crane and its present status in China [in Chinese].
384 *Guizhou Science* 22 (3): 65-71.
- 385 Yang F, Zhang YP. (2014) Quantities and distribution of the Black-necked cranes and other large waterfowl on
386 the Yunnan and Guizhou Plateau. *Zoological Research* 35(S1): 80-84.
- 387 Yang TL, Huang HX, and Guan YH. (1992) Ecological behavior of black-necked Crane and Eurasian Crane
388 wintering at Caohai [in Chinese with English abstract]. *Environmental Protection and Technology* 2: 44-
389 49.
- 390 Zhan YJ, Chen W, Hu D, Wu XS, Zhang JG. (2007) Food selection of wintering Eurasian Crane *Grus grus* in
391 the wetland of Beijing [in Chinese with English abstract]. *Wetland Science* 5(1): 46-50.

Table 1(on next page)

Habitat use and availability of Black-necked and Eurasian Cranes

Table 1. Habitat use and availability of Black-necked and Eurasian Cranes in Huize National Nature Reserve, NE Yunnan, China. (Habitat use was calculated by the number of crane flocks occurring in each habitat type as the percentage of all crane flocks observed. Habitat availability was calculated as the percentage of each habitat to the total area.)

		Habitat types			Total
		Farmland	Marsh	Grassland	
Black-necked cranes	Area (ha)	3966.53	149.36	178.19	4294.08
	Habitat availability %	92.37	3.48	4.15	100.00
	No. of flock observed	261	25	1	287
	Habitat use (%)	90.94	8.71	0.35	100.00
Eurasian Cranes	No. of flock observed	374	3	22	399
	Habitat use (%)	93.73	0.75	5.51	100.00

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Table 2 (on next page)

Spatial distribution of Black-necked and Eurasian Cranes

Table 2. Spatial distribution of Black-necked and Eurasian Cranes in Huize National Nature Reserve, NE Yunnan, China. (YBL is an area comprised of three villages of Yangmeishan, Bajiacun, and Lijiawan. MAS is in the Ma'anshan area. DD is the area from Daqiao to Dideka. *N* – sample size of the crane flocks.)

		YBL (Core zone)	MAS (Core zone)	DD (Buffer zone)	Sum / Mean
Black-necked Cranes	Elevation / m	2488.37 ± 39.85	2512.35 ± 19.51	2486.50 ± 3.54	2497.97 ± 25.06
	Distance to the roost / m	0.84 ± 0.47	3.35 ± 0.76	5.38 ± 0.08	1.88 ± 1.40
	Flock size	8.75 ± 13.66	2.91 ± 1.28	2 ± 0	6.36 ± 10.92
	<i>N</i>	170 (59.23%)	115 (40.07%)	2 (0.70%)	287 (100%)
Eurasian Cranes	Elevation / m	2514.09 ± 30.01	2512.43 ± 17.89	2584.20 ± 62.80	2552.57 ± 60.83
	Distance to the roost / m	1.13 ± 0.39	3.49 ± 0.70	6.18 ± 0.89	4.43 ± 2.23
	Flock size	7.50 ± 8.57	6.08 ± 7.66	9.98 ± 12.41	8.57 ± 10.83
	<i>N</i>	92 (23.06%)	86 (21.55%)	221 (55.39%)	399 (100%)

Table 3(on next page)

Habitat preferences of Black-necked and Eurasian Cranes

1 Table 3. Habitat preferences of Black-necked and Eurasian Cranes in Huize National Nature
2 Reserve, NE Yunnan, China. (Log-transformed ratio of every two habitat category components
3 were used in constructing ranking matrix based on utilization and availability of habitats. Rank
4 was determined by the number of positive values in each row, and the larger number means
5 preference.)

	Habitat types (numerator)	Habitat types (denominator)			Rank
		Farmland	Marsh	Grassland	
Black-necked Cranes	Farmland	—	-0.934	2.462	1
	Marsh	0.934	—	3.395	2
	Grassland	-2.462	-3.395	—	0
Eurasian Cranes	Farmland	—	1.546	-0.270	1
	Marsh	-1.546	—	-1.816	0
	Grassland	0.270	1.816	—	2

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Figure 1(on next page)

Habitat use and spatial distributions of Black-necked and Eurasian Cranes

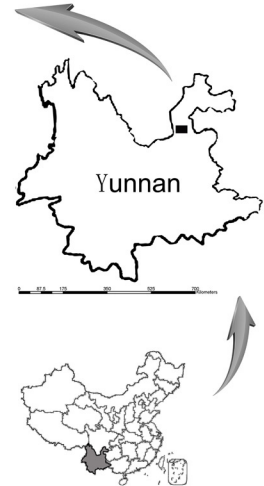
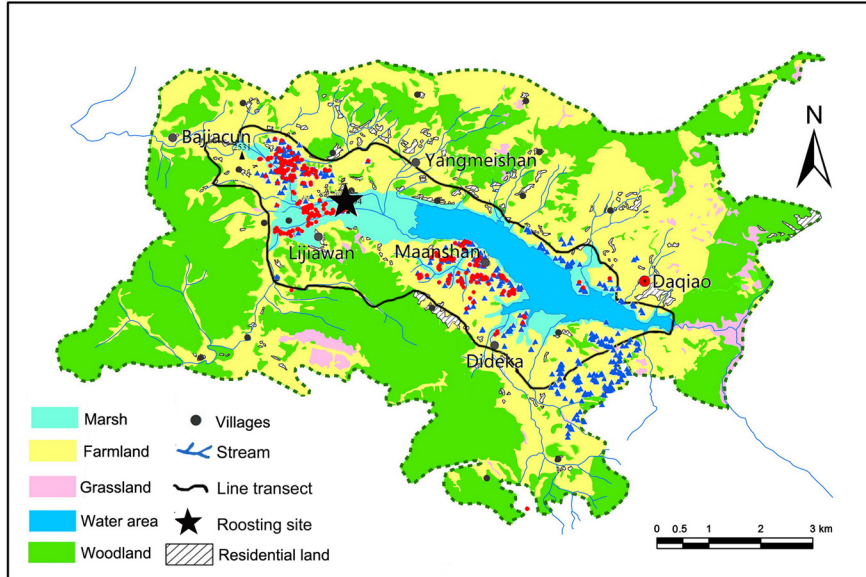


Figure 2(on next page)

Habitat selection of Black-necked and Eurasian Cranes

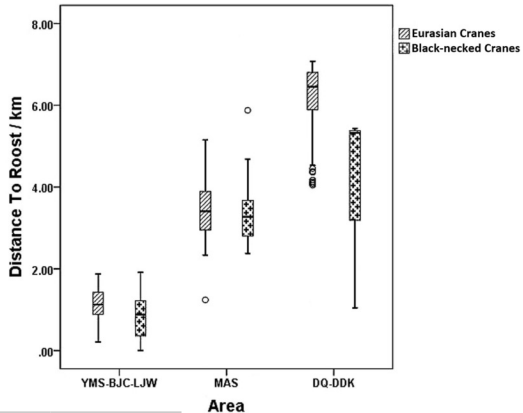
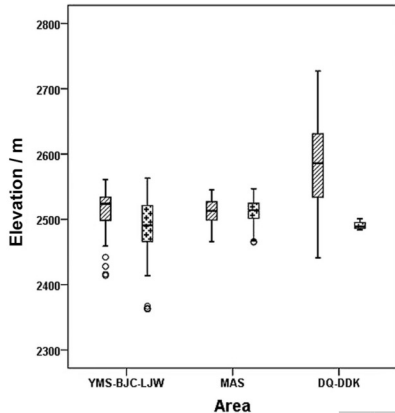


Figure 3(on next page)

Utilization distributions of Black-necked and Eurasian Cranes

