Winter diet and food selection of the Black-necked Crane *Grus nigricollis* in Dashanbao Yunnan, China

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Abstract

The Black-necked Crane *Grus nigricollis* is a globally vulnerable species, whose food selectivity is one of the most important factors determining its survival. Understanding the composition and seasonal variation of a bird's diet is fundamental to understanding its process of food selection. For this purpose, we used video recording to examine the dietary composition and temporal variation in food selection of Black-necked Cranes wintering in the Dashanbao National Nature Reserve, China. The composition of the birds' diets and their food selection were compared on a monthly basis. The corresponding data was analyzed using a SSpearman correlation coefficient to determine the correlation between environmental temperatures and the availability of key food items. The results revealed that the Black-necked Crane's diet consists primarily of domestic food crops (such grains 73.09%, potatoes 8.19%), and invertebrates 14.43%. A much smaller proportion of the diet was comprised of bastard speedwell and wild plant foods (leaves, stems, herbaceous plants, roots and tubers). In addition, there were obvious monthly variations in the Black-necked Crane's food selection. Monthly food preferences were partially related to the available amount of food. During winter months, the cranes preferred to eat domestic crops when they were ~~it was~~ available, whereas invertebrate animals were mainly selected in November and February because invertebrate organisms have been in short supply and their populations sharply decline in December and January due to the low temperature. In addition, grain consumption was negatively correlated with invertebrate consumption. In November, when invertebrate abundance peaked, and despite a concomitant peak in grain abundance, cranes exhibited a dietary proportionally ~~proportion~~ variation, indicating a preference for invertebrate, over

grains. We recommend that the protection administration supplement additional foods for cranes during icy periods.

Keywords: Black-necked Crane, *Grus nigricollis*, diet composition, food numbers, food selection; Dashanbao.

Introduction

The Black-necked Crane *Grus nigricollis* is a globally vulnerable species, whose food selectivity is one of the most important factors determining its survival. Wild populations of this bird are currently suffering due to significant habitat destruction resulting from grassland degeneration (Li & Li 2012) and conventional agricultural practices that have decreased the diversity of available food types for this species. Thus, understanding the Black-necked Crane's dietary habits, food preferences, and the associated factors will facilitate the development of effective conservation plans for the protection of this vulnerable species. Determining the dietary composition of wild birds is essential for understanding how the animals interact with their habitats and consequently identify their preferred food types (Baubet et al. 2004). Their late discovery and remote habits led to a late start in research pertaining to Black-necked Crane's feeding habits (Harris & Mirande 2013). To this point, research surrounding the Black-necked Crane's diet has included quantitative studies on various types of domestic and wild plant foods (Li & Nie 1997; Bishop & Li 2001; Liu et al. 2014a) and qualitative studies on animal-based foods (Han 1995; Hu et al. 2002; Li & Li 2005; Liu et al. 2014b). Nonetheless, there remains a lack of synthetic analyses or comparative data regarding the proportions of wild plants, domestic food crops, and animal-matter consumed by the Blacked-necked crane during the winter.

Until now, fecal microhistological analysis has been the only method used to identify plant material consumed by wintering Black-necked Cranes (Li & Nie 1997; Liu et al. 2014a). These studies did not mention the consumption of animal-based foods due to the need for alternative methods to collect this data (Liu et al. 2014b). Generally, fecal analysis can create a bias due to the high variability in digestibility of different food items (Redpath et al. 2001). Thus, we chose video recording as an alternative method to better understand the food selection of Black-necked Cranes. This method enabled a simple, minimally invasive manner to directly observe the feeding behavior of the threatened bird species in order to estimate their dietary composition (Newton 1967; Price 1987, Yoshikawa & Osada 2015).

Previous studies suggest that variations in temperature may impact food availability (Kushlan 1978; Stapanian et al. 1999). As mentioned by Alonso et al. (1994), low temperatures may decrease grain availability for Common Cranes by increasing foraging costs due to changes in soil properties. Likewise, temperature variations are the main correlates of insect activity, further affecting the invertebrate-feeding birds. Higher temperatures are associated with more frequent droughts and dry soils (Martin 1985), while lower temperature cause the soil to freeze. Thus, both affect the degree of insect activity (Mccolloc et al. 1927; Dowdy 1937; Zhou et al. 2015) and their availability for birds to feed on. Given this information, we considered that the temperature changes would influence the attributes of available foraging sites, and the bird' food selection, thus would limit the specific foods available for birds living on plateaus.

The goal of this research is to better understand factors influencing Black-necked Cranes selection of different feeding habitats during the winter. This information may facilitate the development of strategies to protect the Eastern Black-necked Crane, whose largest population winters in their most important stopover sites in the Dashanbao National Nature Reserve on the Yunnan–Guizhou Plateau (Li & Yang 2002; Qian et al. 2009). In this report, we provide a quantitative and comprehensive assessment of the cranes' wintering diet, which includes wild plants, domestic food crops, and animal-based foods. We synthetically analyzed the cranes' food selection, the composition of their diet, and any correlation between environmental factors, food availability, and food selection.

Methods

Ethics statement Our research on Black-necked Crane in Dashanbao National Nature Reserve was approved by the Chinese Wildlife Management Authority and conducted under Law of the People's Republic of China on the Protection of Wildlife (August 28, 2004).

Field Permit

The Administration of ZhaoTong Forestry Bureau approved our study on behavior observation and sampling collection in the research plot in Dashanbao National Nature Reserve (IDZTL2008163).

Study site

Dashanbao National Nature Reserve (hereafter referred to as Dashanbao Reserve, 27°18′38″N, 103°14′55″E, altitudes of 3000-3200 m), is located in southwest China (Fig. 1), and is listed as a wetland of international significance under the Ramsar Convention on Wetlands. The Dashanbao Reserve is considered an important habitat for Black-necked Cranes, as well as other wintering water birds. It is also known for its upland wetland ecosystem (Zhong & Dao 2005). The study area covers 19,200 ha and is a warm, humid plateau monsoon climate region characterized by cool, wet summers and cold, dry winters. During winter months, frequent days of sustained freezing temperatures can be expected from December to January. The mean temperature in January was -1 °C, and in July was 12.7 °C. The mean annual temperature is 6.2 °C, with 123 frost-free days and 34.6 snow cover days per year. The mean annual precipitation is 1165 mm (Li & Zhong 2010).

A total of c. 1,200 Black-necked Cranes winter in the Dashanbao Reserve every year, feeding on agricultural farmlands, as well as wild grasslands (Kong 2008). For the purposes of this study, artificial dietary supplementation by humans was ignored because only c. 3 kg of corn are fed to less than 50 cranes every day (Kong et al. 2011), which would have little impact on the overall dietary composition and food selection for the cranes. Farmland included fields of cereal, potatoes and bastard speedwell. Wild grasslands were comprised of meadows with minimal water (Kong et al. 2011a). The study area covered most of the foraging sites of Black-necked Cranes. Local farming uses a 3-year rotation system, in which cereal is grown one year, followed by two years of potato or bastard speedwell, and then back to cereal. To this extent, the farmland is characterized by a mosaic of patches of cereal, potato and bastard speedwell that occupy about the same surface area each year.

Bird observations

Field data were collected from November 2013 to March 2015 in Dashanbao Reserve. Since Black-necked Cranes are highly vigilant and the landscape of the Dashanbao Reserve consists of rolling hills and valleys, we were unable to adequately observe the flocks from our vehicles across the road. Therefore, we selected three transect routes crossing the mountain ridge of the reserve at two sites which housed the largest flocks of cranes according to the reserve staff's experience and the suggestions from previous research in October 2013 (Kong et al. 2011a). We spent 3 days every week for 15 weeks each year observing the cranes whilst they fed. Feeding cranes were randomly chosen for video-taping for 5 minute intervals. Each food item consumed in the feeding area was recorded. During this time, the cranes were undisturbed and at a maximum distance of 80 m from our point of observation. However, most sightings were between 30 and 60 m from the birds. Based on personal observation, the cranes would startle and evacuate their feeding site when observed from a distance of less than 60 m. A Canon PowerShot SX30 IS digital camera with a 35× optical zoom was used for all the video recordings. A total of 508 five-minute good quality videos were recorded, ensuring sufficient clarity to accurately differentiate among all the consumed food types. For this study, we only used videos in which all the food types consumed were clearly identifiable. Poor quality recordings and those lasting less than 5 minutes were discarded from the study.

Foraging behavior

Food types were classified into 3 categories: (1) domestic crops (including grains, potatoes and bastard speedwell); (2) wild plants (including leaves, herbaceous plants, roots and tubers); and (3) animal matter (invertebrates). Video recordings of foraging cranes were examined in slow motion to quantify number of pecks per 5 minute interval. Every video was watched at least three times to confirm accurate identification of the food types consumed by the feeding crane. Depending on the types of food being eaten, and the peck frequency, four different types of feeding patterns were identified: (1) Hauling and dragging, without digging up the soil was primarily used for aboveground foods, consisting of leaves, and herbaceous plants. This was distinguishable from foraging on grains by the lower pecking frequency, and slower swallowing movements of the former (Figs. 2A, 2B; see video S6, picture S4). (2) Walking along a furrow with a high frequency of pecking and ingesting all of the target food quickly. This pattern was used primarily for aboveground food consisting of grains (see videos S2, S3). (3) Lastly, digging up the soil to find and consume underground food, such as roots and tubers (including potato and bastard speedwell) (see videos S1). Since roots and tubers are bulky for cranes to eat, they tend to peck at them more frequently until completely consumed. This behavior facilitates visual identification of when the cranes are eating roots and tubers. (4) Consumption of invertebrates is also easily identifiable by a visual pattern in which the cranes pecks at a plot of turf, catches its meal, and then quickly swallows it (Figs. 2C, 2D; see video S5, S4; picture S1). This pattern also leaves an obvious trace on the grassland that can be used for identification (see picture S2, S3)

Sampling area

Given the mosaic landscape of the Dashanbao Reserve, the sampling sites were selected based on two criteria: (1) The site needed to include a boundary of a large section of grassland bordered by farmland with three types of crops in cultivation. (2) The site must have been selected by at least one flock of cranes for foraging. Based on these two criteria, six plots of farmland (2-6 ha) and nine plots of grassland (13-43 ha) were selected using Google Earth followed by a field survey. The alternating proportion of land that each crop occupied was obtained via monthly sampling. The area of the sampling site was calculated using Arcgis 9.2 (ESRI Inc.).

Availability of different food types

To investigate the availability of consumable crops, wild plants and animal matter, we randomly selected sites within each farmland and grassland sampling area. We then proceeded to sample foods at intervals of 100 m along a straight line, guided by GPS localization. Due to difference of farming practices (unploughed and ploughed), we used a direct collection sampling method for cereal grains on unplouged plots and turned the soil for sampling cereal grains under unploughed lands. This method was used for sampling leaves and herbaceous plants, as well as potatoes, bastard speedwell, roots and tubers, and invertebrate within a depth of 10 cm inside the excavated quadrat. The length of a crane's bill is 12.4 cm (n = 10, 10.5~14.0 cm). The count and biomass of food types available in each quadrat (50×50 cm, 10 cm deep) were recorded. We placed 176 quadrats ~~were placed~~ in grain fields, and another 167 quadrats in potato and bastard speedwell fields in 2013-2015 (sampled monthly for eight months). Leaves and herbaceous plants, roots and tubers, and invertebrate were collected from 215 quadrats in grassland. The extracted food items were stored in plastic bags and frozen until processing. After defrosting, cereals, potatoes, bastard speedwell, roots and tuber, invertebrates and herbaceous plants were separated, dried (60℃, 48 h) and then weighed to determine dry biomass (0.001 g precision). We estimated the monthly availability for each crop type by multiplying the monthly surface for each type of farmland sampling area by the calculated means.

Weather variables

Daily temperature values were taken from Zhonghaizi in Dashanbao Reserve. For our analyses, we used the mean daily temperature, and the mean minimum daily temperature. We also counted the number of periods with three or more consecutive days with sustained low temperature (minimum temperature equal to or less than -10℃). These would be days when the ground would remain frozen, thus preventing the cranes from being able to dig for food.

Statistical analysis

Trophic diversity was estimated using Shannon's diversity index: $H' = -\sum P_i \ln (P_i)$ (Pielou 1966), where P_i represents the proportion of each food type. We calculated H' for each food type present on a monthly basis. Feed selection by cranes was analyzed using the Savage selectivity index: $W_i = U_i/D_i$, where U_i is the proportion of observations recorded for any one food type, and P_i is the proportion of total available biomass for each food type. The proportion U_i could be calculated using the formula $U_i = u_i/u_+$, where u_i represents ingestion of a specific food and u_+ represents the total count for that food types present in the location. Likewise, the proportion of consumed biomass for a food type could be calculates using the formula $D_i = d_i/d_+$, with d_i representing the consumed biomass of each food type, and d_+ the total available biomass of the food type in the study area (Savage 1931). This Savage selectivity index can range from 0 to infinity, with 0 indicating maximum negative selection, 1 indicating no selection bias and infinity indicating maximum positive selection (Manly 1993). The departure of the use of each food type from a distribution proportional to its availability was tested using the statistic $(W_i - 1)^2/SE(W_i)^2$ (Manly 1993), which follows a χ^2 distribution with 1 degree of freedom. The standard error of the index, $SE(W_i)$, was ~~is~~ calculated using the formula $\sqrt{(1 - D_i) / (u_+ \times D_i)}$ (Manly 1993).

The relationship between food type ingested and environmental variability was determined by applying the Spearman ~~Spearmen~~ correlation coefficient in SPSS 20. This analysis was used to assess correlations between the cranes' food selection, environmental food depth, and ambient temperatures (the mean daily temperatures, minimum daily temperatures, and number of days with frozen soil).

Results

Diet composition and monthly variation

Domestic crops (Grains and potatoes) and animal matter (invertebrates) collectively comprised the majority of Black-necked cranes diet, followed by bastard speedwell and wild plants (leaves and herbaceous plants, roots and tubers) (Fig. 3).

In November, the diet was dominated by the consumption of grains (44.77%), invertebrates (36.13%), and potatoes (14.78%). From December to February, the proportion of grains consumed changed to 91.64% and 81.04%, respectively. This increase is more than double the amount of grain consumed in November. In contrast, the highest consumption of invertebrates occurred in November and February, while the lowest was in December and January. Potato selection decreased from 14.78% in November to 3.18% in December, then slowly increased to 7.13% in January and 5.14% in February. Leaves and tubers increased from <1% in November and December to 5.86% and 4.87% in January and February, respectively. Herbaceous plants and bastard speedwell comprised a minimal proportion the diet during the entire winter (Fig. 3). The diversity of the diet (H’) was the highest in November and lowest in December, as compared to the other months (Fig. 4).

Food Selection

Wild plant food accounted for the largest proportion of food available in the Black-necked Cranes’ environment (leaves and herbaceous plants accounted for 46.58%, tubers for 43.19%). Animal matter (invertebrates 4.48%), and domestic crops (potato 1.65%, bastard speedwell 2.93%, and cereal grain 1.17%) accounted for a much lower proportion of total available food

(Fig. 5).

In comparing the six types (3 categories) of foods available to the foods selected, the Savage index showed that the cranes preferred grain, invertebrates, and potatoes in November, while grains were preferred from December to February (Table 1). Invertebrates were secondary preferred ~~preferences~~ in November and February, and potatoes were selected by cranes in November and January (Table 1).

Environment factor compared to food selection

Based on the results above, we analyzed the correlation between the amounts of food available in the environment and the amounts eaten by the cranes. We considered the main food types (grains, potato and invertebrates), and the effects of ambient temperature. The analysis revealed that invertebrate consumption was positively correlated with their availability in the environment (r = 0.857, p = 0.007, Fig. 6), as well as with increasing temperatures (mean temperature and mean of minimum temperature, Table 2, Fig. 3). Subsequently, feeding on invertebrates was negatively correlated with the number of days in which the ground was frozen (r = -0.892, p = 0.003). Meanwhile, mean temperatures were negatively correlated with the distributed depths where invertebrate were found (Table 2). Further analysis revealed that the two levels of distributed depths for invertebrates were positively correlated with the temperature values, that is 0-1 cm (Table 3), and 1.1~2 cm (Table 3), and were negatively correlated with the number of days with frozen ground (Table 3). The mean depth of the frozen ground was 4.93 cm in December (n = 10, 2.6~6.9 cm) and 3.12 cm (n = 5, 2.9~3.5 cm) in January (see picture S5, S6).

In contrast to what was observed for invertebrates, there was no correlation between potato consumption and either their availability in the environment, or variations in temperature (Table 2). For grains, the consumed amount had a negative correlation with temperature readings. Correspondingly, grain consumption was also negatively correlated with invertebrate availability, invertebrate soil depth, and invertebrate consumption (Fig. 6).

Discussion

Diet composition

The variation in diet of the Black-necked Cranes was systematically studied for the first time using video recording. The results revealed that the wintering diet of the Black-necked Crane in the Dashanbao Reserve mainly consisted of domestic crops (e.g. grains, potatoes), and invertebrate animals. Wild plants foods, such as leaves, herbaceous plants, and roots and tubers accounted for a much lower proportion of their diet, serving primarily for supplemental nutrition. These results are similar to those of a previous report in which fecal analysis was used to study the crop and wild plant consumption of a subpopulation of Black-necked Cranes wintering at Yarlung Zangpo Valley National Natural Reserve. However, the cranes in the Yarlung Zangpo Valley National Natural Reserve consumed minimal animal-based food (Bishop & Li 2001). It is important to note that initial estimates approximated that 14.0% of the Dashanbao Black-necked Crane's diet would consist of invertebrates. In comparison, animal matter comprises less than 10% of the diet for Common Cranes in the Holm Oak Dehesas (Avilét et al. 2002), and 2–3% of the diet for various crane species in different regions of the world (Irene 1980; Reinecke & Krapu 1986). Certain crane species feed primarily on animal matter while wintering in certain sites. These include, the Lesser Sandhill Crane (Davis & Vohs 1993), Whooping Crane (Pugesek et al. 2013), and Red-crowned Crane

(Li et al. 2014). Demoiselle Cranes (Sarwar et al. 2013), Florida Sandhill Cranes (Rucker 1992) and Common Cranes show similar preferences for invertebrates (Avilés et al. 2002). Current research on the proportion of animal-based foods in the diet of Black-necked Cranes has solely focused on describing species tendencies (Han 1995; Hu et al. 2002; Li & Li 2005; Liu et al. 2014b). Thus, there is a need for additional quantitative investigations into the Black-necked cranes feeding habits, including invertebrate consumption within these studies. Likewise, more data is needed to study the feeding habits of Black-necked cranes over a greater distribution of locations. This would greatly enhance our understanding of the dietary habits of this species.

Previous studies using fecal analysis to assess the proportion of the mentioned food categories in the Black-necked crane's diet have produced inconsistent results. These studies largely reported a wild herbivorous diet, while failing to mention the inclusion of invertebrates or domestic crops, such as grains and potatoes, in the diet of cranes the Dashanbao Reserve (Liu et al. 2014a). This inconsistency may be explained by two views: First, the different methods were used to analyze the diet. As an example, Liu et al. (2014a) mentioned fecal analyses failed to detect potato cuticles in the fecal sample of a crane that had consumed a large potato in the Dashanbao Reserve. This is due to the digestibility of the food type, which makes it difficult to detect via fecal analysis. Wild plant fiber may therefore have been easier to detect in feces than the potato and grain fibers or invertebrate residues, despite the latter two making up a larger proportion of the diet . With video observation, we were able to directly consider the frequency on which a particular food type was fed on, without concern for variations in digestibility. While, video observation enables the detection of even highly digestible food, it is often more difficult to identify the specific food types that are seen consumed in the video. Thus, it requires more careful observation and detection of feeding patterns to identify food items. This may also be seen as an advantage, as it can provide us with more complete foraging information, including actual foraging behavior. We are thus able to successfully estimate the digestible compositions of birds' diet (Robinson & Holmes 1982; Rundle 1982). On the other hand, it was inferred that the sampling time may have greater impact on identifying food types which change with monthly variations. For example, as a climate-restricted food, invertebrates are difficult for Black-necked Cranes to find in December and January (Fig. 3) (see below discussion). So we speculate that the bias of fecal analysis may be caused by different or discontinuous sampling times. Furthermore, grain yields are also vulnerable to severe frost at certain times of year (interview data), likely affecting their availability for cranes to feed on while wintering. Our observation period was conducted during years experiencing normal grain yield quantities, to avoid a potential bias in estimating the diet of Black-necked Crane in Dashanbao Reserve.

Monthly variation and diet selection

In November, a high proportion of the Black-necked Crane's diet consisted of domestic crops (principally grain) and invertebrate organisms (Fig. 3). The phenomena may be because the availability of those food types was the most highest during the time of early migration (November) as compared to the other three months (Fig. 6), or during the warmer weather (for invertebrates). The birds require a balanced diet, including a variety of nutrients from different food types. During the time when both grains and invertebrates were the most available, invertebrates were consumed more than they were consumed at any other time. In contrast, grains were consumed less than in other months (Fig. 3, Fig. 5). This suggests that the cranes likely prefer invertebrates over grains, potentially because invertebrate organisms provide a greater source of protein and calcium than available in grains. These nutrients are essential for their migration fitness and overall survival. Falling temperatures and freezing soils reduced the availability of invertebrates. Therefore, cranes primarily fed on grains during December and January (Fig. 3). While leave and tubers were frequently still available in January and could have been fed on as an alternative to the invertebrates, the cranes rarely fed on these during the winter.

Cranes consumed only a minimal quantity of wild plants despite their larger proportion of biomass available as compared to that of domestic crops (Fig. 5). It is possible that cranes prefer domestic crops over wild plants because (1) Herbaceous plants may have lower caloric content than grains; (2) Vegetation is still seriously sparse on grassland (Liu et al. 2014a); (3) There is insufficient density of vegetation suitable for the cranes to forage on (*Pedicularis, Stellaria*, *Polygonatum* and *Veronica)* (Kong et al. 2011a; Liu et al. 2014a).

Management implications

Our results supported previous reports that Black-necked Cranes generally prefer farmlands, and avoid grasslands (Kong et al. 2011a), likely due to the availability of domestic crops and invertebrates to feed on, as well as other habitat features. We agree with Kong’s views (2011b) that higher quantities and densities of food as well as looser soil structure in farmlands facilitate food collection by the cranes. In light of grassland degeneration, invertebrates as food sources remain in short supply. This food shortage is further exacerbated during icy conditions. We recommend that the protection administration supplement additional foods for cranes during icy periods, and restore grassland foraging habitat. This would support the cranes' need for dietary diversity and would benefit the farmers by reducing economic losses resulting from the cranes feeding on newly planted crop seeds. To further ease the conflict between cranes and local farmers, it is advisable to cultivate crops in a certain area that may be left unharvested for the cranes to eat. Furthermore, it is necessary to maintain adequate traditional croplands to sustain this vulnerable species, as many of these conventional cultivations have been replaced by more economic crops in the Dashanbao Reserve.

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Supporting Information

Video S1 The Black-necked Crane fed on potatoes. The adult crane on the right of video ate a piece of potato until the size of the food was just the right to swallow.

Video S2 The Black-necked Crane fed on grains. Two adult cranes with a juvenile walked along a furrow with frequency pecking and ingesting quickly.

Video S3 A flock of cranes fed on grains.

Video S4 The Black-necked Crane fed on earthworm.

Video S5 The Black-necked Crane fed on grubs. A adult crane used its bill to touched the soil surface, pecked a plot of turf, catch the worm and then swallowed it quickly, or the adult crane fed its baby.

Picture S1 Magnified into the view of the Black-necked Crane feeding on grub on grassland.

Picture S2 and Picture S3 Feeding trace of the Black-necked Crane on grassland

Video S6 A abundance of grubs and small amount of roots in a 50 × 50 cm sample on the grassland.

Video S7 The Black-necked Crane fed on leaves.

Picture S4 Magnified into the view of the Black-necked Crane feeding on herbaceous plant.

Picture S5 and Picture S6 Frozen ground of the grassland in icy period.

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Figures and Tables

Figure 1. Map of Dashanbao National Nature Reserve, showing the location of study area. Pentagram indicates the sampling sites.

Figure 2 Schematic views of Black-necked Crane *G. nigricollis* feeding on underground and belowground food. (**2 a**) and (**2 b**) the foraging behavior of hauling and dragging for aboveground food-stem and leaf, and herbaceous plant; (**2 c**). pecking a plot of turf; (**2 d**) catching it then swallowing it quickly.

Figure 3 Depicts monthly variations in dietary composition of Black necked crane *G. nigricollis* wintering in Dashanbao National Nature Reserve, China, as percentage of total items. Monthly detected items number for Black-necked Crane is shown above bars.

Figure 4 Shannon index of diversity (H') of diet with season for black necked crane *G. nigricollis* wintering in Dashanbao National Nature Reserve, China.

Figure 5 Monthly composition of the available biomass of food in the study area.

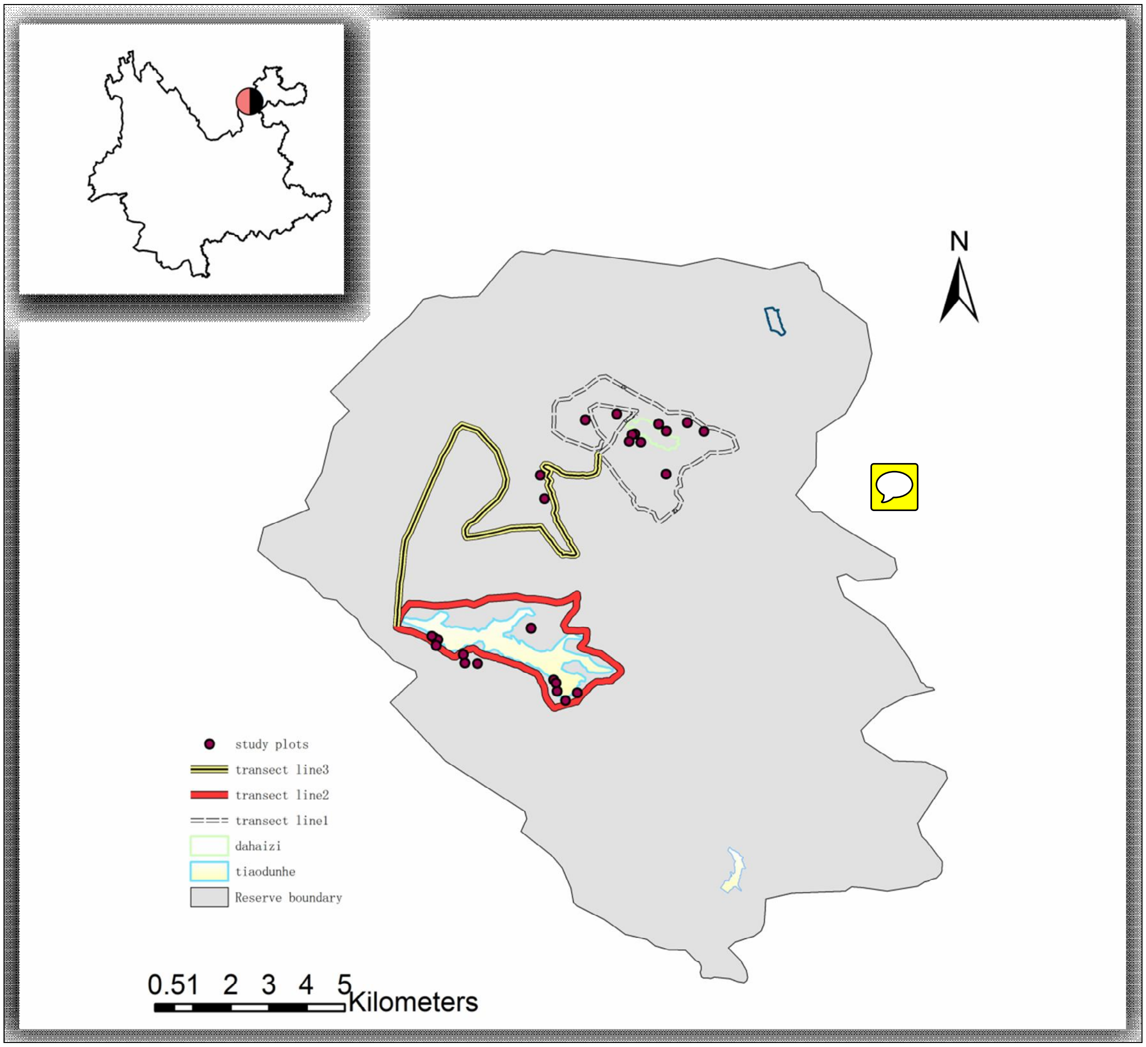
Figure 6 Monthly variations of the available and consumed numbers of grain and invertebrate in the study area.

Table 1 Food type selection by cranes *G. nigricollis* of six most available food types in Dashanbao National Nature Reserve China in relation to the month and year. Numbers are values of the Savage index (Wi). Significant food type selections are marked in bold.

Table 2 Spearman correlations between environment factors and food consumption of three food type grain, invertebrate and potato for cranes *G. nigricollis* in Dashanbao National Nature Reserve China.

Table 3 Spearman correlations between different level depths for invertebrate and food consumption of three food type grain, invertebrate and potato for cranes *G. nigricollis* in Dashanbao National Nature Reserve China.

Figure 1


N
study plots
transect line3
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Reserve boundary
0.51 2 3 4 5
Kilometers

26

Figure 2

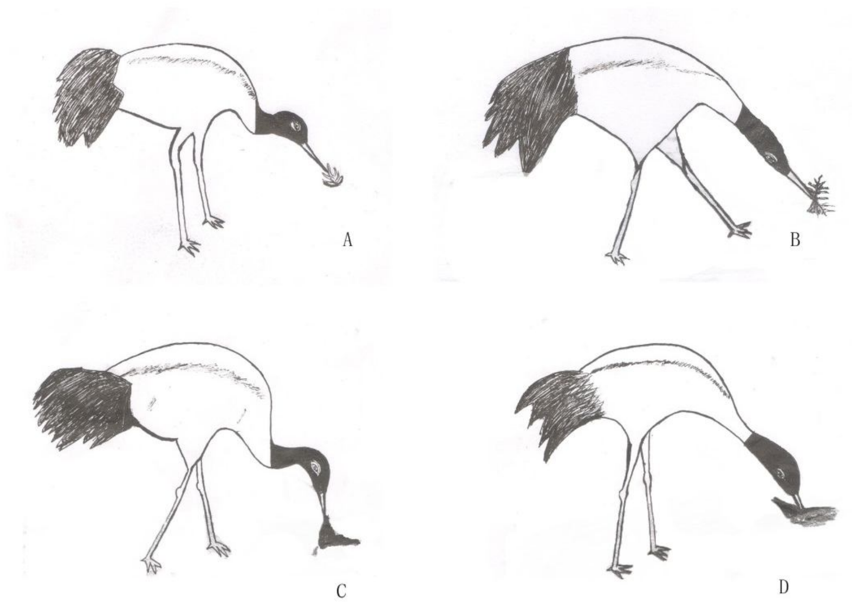


Figure 3

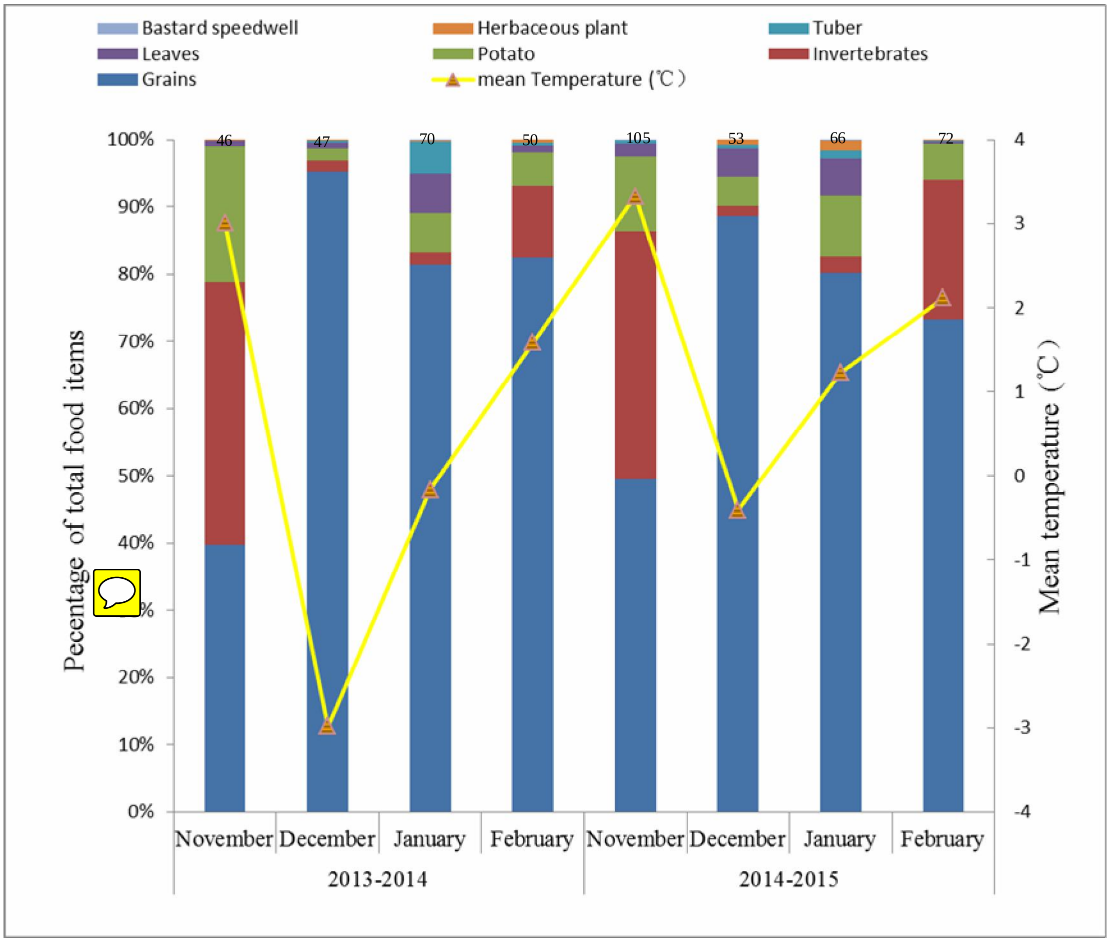
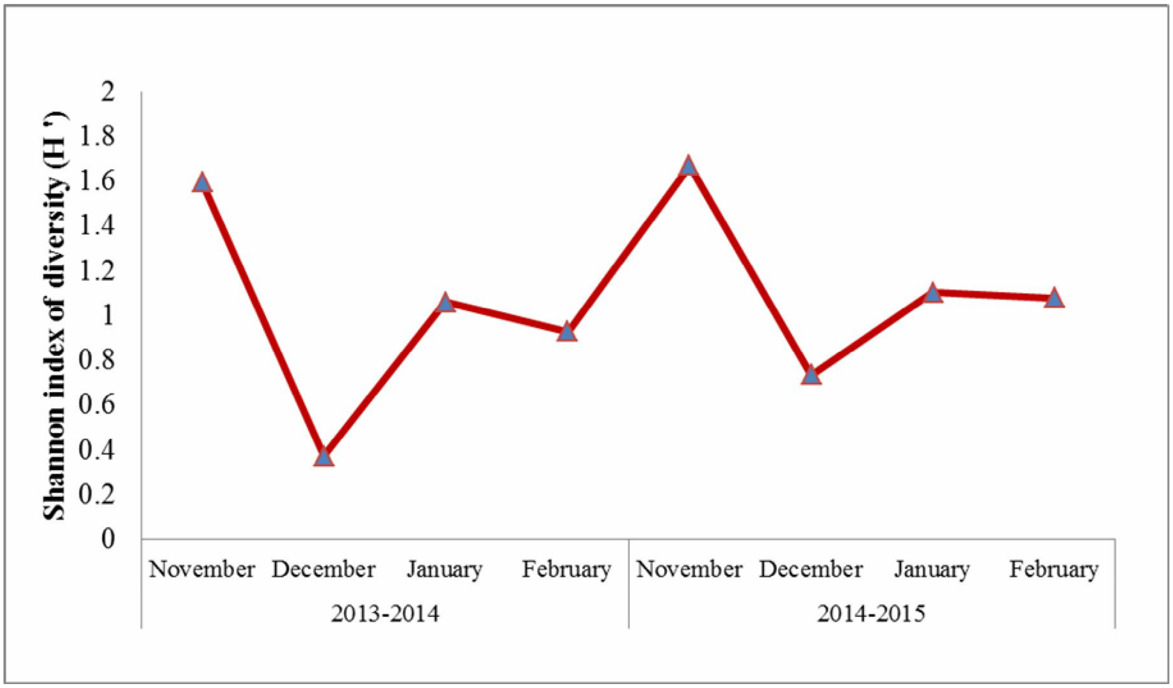
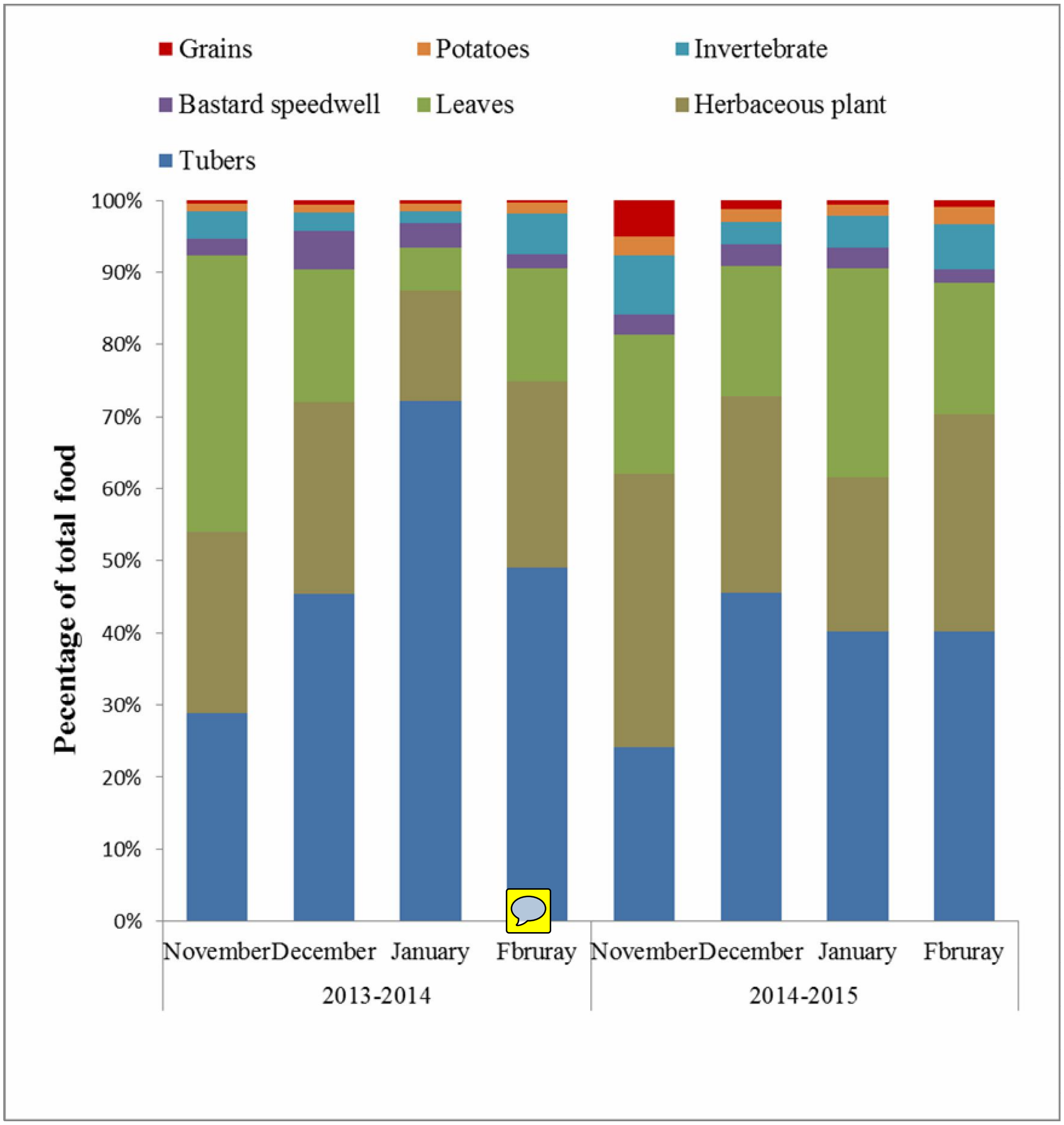

Bastard speedwell
Herbaceous plant
Tuber
Leaves
Potato
Invertebrates
Grains
mean Temperature (℃)
46
47
70
50
105
53
66
72
100%
90%
80%
70%
60%
50%
40%
20%
10%
0%
Pecentage of total food items
Mean temperature (℃)
4
3
2
1
0
-1
-2
-3
-4
November
December
January
February
November
December
January
February
2013-2014
2014-2015

Figure 4



Shannon index of diversity (H ')
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
November
December
January
February
November
December
January
February
2013-2014
2014-2015

Figure 5



Grains
Potatoes
Invertebrate
Bastard speedwell
Leaves
Herbaceous plant
Tubers
Pecentage of total food
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
November
December
January
Fbruray
November
December
January
Fbruray
2013-2014
2014-2015

534 **Figure**

535 **6**

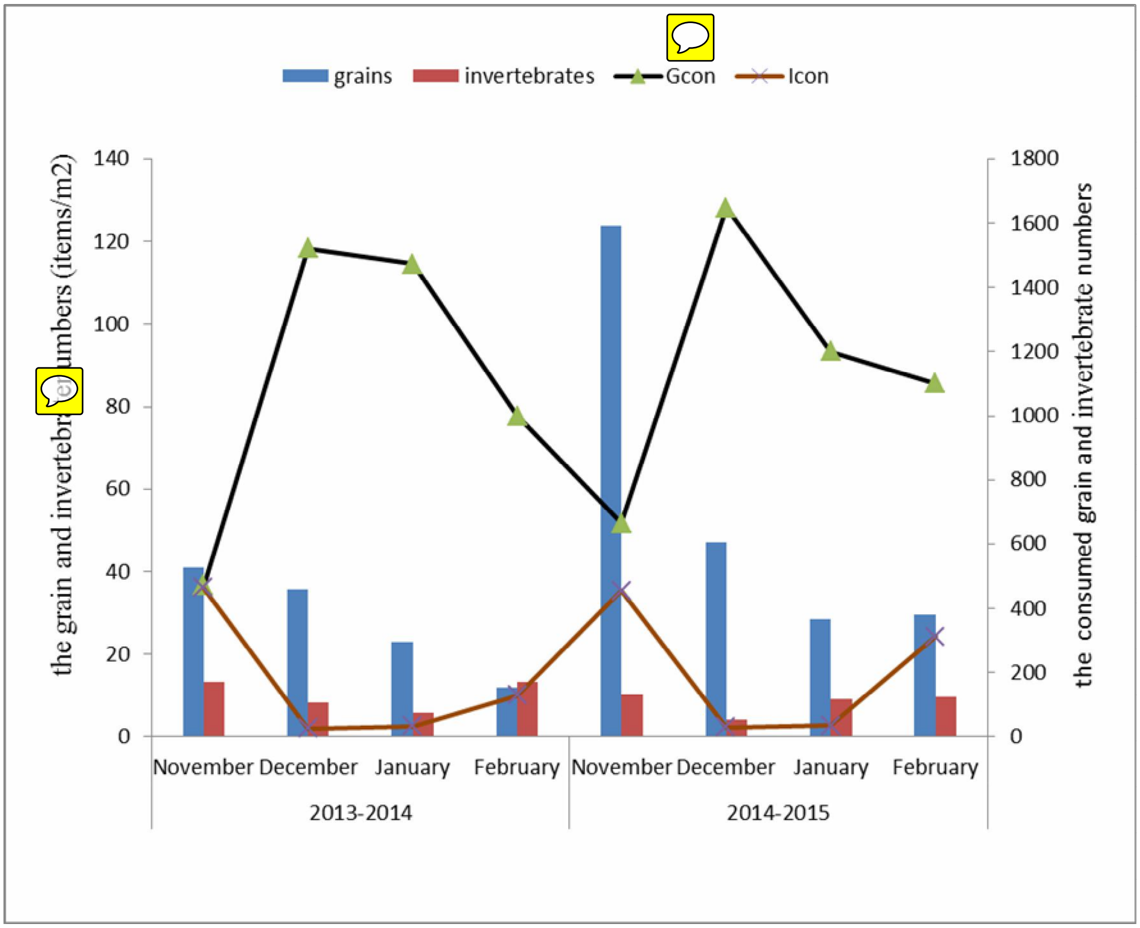


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Table 1

		Grains	Potato	Invertebrates	Leaves	Herbaceous plant	Tuber	Bastard speedwell
2013-2014	November	**10.34**	**3.37**	**16.32**	**0.05**	0.00	0.00	0.00
	December	**21.49**	**0.42**	1.32	0.62	**0.13**	**0.02**	0.00
	January	**26.71**	1.21	1.77	**2.85**	**0.01**	**0.07**	**0.01**
	February	**57.09**	1.08	**2.54**	**0.24**	**0.03**	**0.02**	0.00
2014-2015	November	**2.97**	1.05	**5.32**	**0.28**	0.00	**0.16**	**0.01**
	December	**15.07**	**0.62**	**0.43**	0.79	**0.03**	**0.02**	0.00
	January	**26.79**	1.06	**0.38**	**0.39**	**0.06**	**0.03**	**0.01**
	February	**24.41**	0.93	**4.79**	**0.05**	0.00	0.00	0.00

Table 2

	Gnum	Gdeo	Pnum	Pdep	Inum	Idep	Gcon	Pcon	Icont	MT	MMT	Tno
Gnum	1											
Gdeo	-0.5	1										
Pnum	.826*	-0.647	1									
Pdep	-.714*	0.595	-0.707	1								
Inum	-0.024	-0.19	0.323	-0.405	1							
Idep	0.167	0.31	-0.263	0.19	-.857**	1						
Gcon	-0.071	0.214	-0.395	0.452	-.952**	.905**	1					
Pcon	0.371	-0.216	0.410	-0.503	0.383	-0.491	-0.599	1				
Icont	0.19	-0.119	0.503	-0.476	.857**	-.810*	-.952**	0.695	1			
MT	0.238	-0.071	0.479	-0.452	.810*	-.762*	-.929**	0.671	.976**	1		
MMT	0.405	-0.024	0.527	-0.548	.714*	-0.571	-.833**	0.731*	.929**	.952**	1	
Tno	-0.41	0.181	-0.679	0.386	-.723*	0.687	.819*	-0.552	-.892**	-.916**	-.880**	1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). Gnum: the mean monthly grain number in environment; Pnumb: the number of potato in environment; Pdep: the depth of potato in soil; Inumb: the number of invertebrates in environment; Idep: the depth of invertebrates in soil; Gcon: the number of grains consumed by cranes; Pcon: the number of potato consumed by cranes; Insect [Isect]: the number of invertebrates consumed by cranes; MT: the monthly mean temperature; MMT: the monthly mean minimum temperature. Tno : No. days ~~with~~ below 0℃.

Table 3

	0-1cm	1.1-2cm	2.1-3cm	3.1-4cm	4.1-5cm	below 5cm
Inum	0.381	.738*	0.313	0.048	0.167	-0.167
Idep	-0.333	-.810*	-0.627	-0.31	-0.5	-0.071
Gcon	-0.571	-.857**	-0.277	0	-0.143	0.262
Pcon	.778*	0.515	-0.224	-0.228	-0.036	-0.347
Icont	.762*	.929**	0.108	-0.238	-0.071	-0.476
MT	.786*	.905**	0.048	-0.262	-0.143	-0.524
MMT	.833*	.833*	-0.108	-0.31	-0.214	-0.619
Tno	-.807*	-.928**	-0.067	0.434	0.217	0.434

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).