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Study on Assessing the Population Size of Black-necked Cranes in Dashanbao

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Abstract: *This study aims to evaluate the population size of Black-necked cranes in Dashanbao National Nature Reserve through food availability assessment. Monitoring of crane populations from 2012 to 2015 revealed that although population numbers fluctuated during migration seasons, they generally remained below 1,200 individuals, with a duration of 120 to 127 days. A daily food intake model was further applied to assess the environmental carrying capacity for Black-necked cranes in Dashanbao. The results indicate consistent carrying capacity from 2012 to 2014, with a slight decline from 2014 to 2015. The carrying capacity based on available food energy is 4.3 to 5.1 times the current level, potentially supporting approximately 6,000 individuals. A comparison of energy availability in two foraging habitats from November to March between 2012 and 2015 showed that agricultural habitats provided the highest total energy in March, exceeding the cranes' requirements by 2.2–3.0 times. Conversely, grassland habitats offered the highest total energy in November. The total energy available in grassland habitats during November was 2.5–4.3 times the energy requirement of Black-necked cranes. This study assessed the population size of Black-necked cranes in Dashanbao, evaluating their energy acquisition status across different seasons and habitats. This provides crucial evidence for future conservation and management efforts.*

Keywords: *Population, Foraging Habitat, Food Availability, Food Threshold*

1. Introduction

Goss-Custard et al. [1] noted that two models should be used to estimate the carrying capacity of migratory birds that overwinter: the Daily Ration Model (DRM) and the Spatial Depletion Model (SDM). The DRM model calculates the maximum number of bird-days by dividing the total available food in an area by the daily food requirement per individual bird. This model assumes that individuals can be distributed freely without causing any disturbance. The formula is: Bird-days = Food availability (g dry weight) × Metabolic energy (kcal/g dry weight) / Daily energy expenditure (kcal/day). Many studies use models of daily food intake to estimate bird carrying capacities [2-5]. The nutritional carrying capacity is currently widely used in migratory bird research, particularly in models of daily food intake [1]. Spatial carrying capacity is primarily influenced by the animal's activity range and habitat area. It is derived by combining the minimum spatial requirements for wildlife survival and reproduction with simulation studies using Geographic Information Systems (GIS) and spatial modeling techniques[6]. It is generally used to estimate the home range size of birds during the breeding season, thereby determining the number of birds that can be supported. The spatial carrying capacity approach was employed to estimate the breeding-season carrying capacity for the Greater Sand Plover[7]. Additionally, the food threshold model can estimate environmental carrying capacity based on its food threshold. The threshold represents the food density at which, after sustained measurement in an area, birds cease to remove large quantities of food over a specific period. The food threshold may no longer support large flocks[8]. This assumes minimal disturbance or competition from other animals when foraging. Although food density declines significantly during this period and cannot sustain large numbers of individuals, a small number of birds continue foraging. This persistence is probably due to constraints on food accessibility imposed by various environmental factors, such as the availability of food, the time it takes to search between locations and the need to be vigilant. These factors cause these individuals to remain at the foraging site.

The Black-necked Crane (*Grus nigricollis*) is classified as a Class I nationally protected wildlife species in China and listed in Appendix I of CITES. The IUCN lists it as Vulnerable. The Qinghai-Tibetan Plateau in China is the main breeding area for Black-necked cranes, while the southern regions of the plateau at lower elevations and the Yunnan–Guizhou Plateau serve as wintering area (only a small number are found in Bhutan and India). Currently, the global Black-necked crane population is estimated at approximately 15,552 individuals, with around 5,577–5,715 residing on the Yunnan-Guizhou Plateau [9]and roughly 2,200 in Dashanbao, Zhaotong, Yunnan [10]. Food availability is one of the primary factors determining their survival status. This study estimated the population size of Black-necked cranes in Dashanbao using the daily food intake model and the food threshold model within the nutritional carrying capacity.

The Dashanbao National Nature Reserve in Zhaotong (hereinafter referred to as "Dashanbao Reserve"), Yunnan recorded approximately 325–400 cranes in 1989 and 1990, with numbers gradually increasing to 930 by 2002. Specific population statistics include: Huang Guozhu et al.[11] surveyed cranes in Dashanbao Reserve, Zhaotong City in October 1989 and February 1990. They found 70–110 individuals at DaHaiZi, 200 at Tiaodun River, and 55–90 at ZhuanShanbao, totaling 325–400 birds. In 1990 and 1994, Dashanbao was successively designated as a municipal-level protected area and a provincial-level nature reserve. Surveys conducted during these periods recorded approximately 200 and 721 cranes, respectively [12]; On January 18 and 19, 2002, Li Fengshan and Yang Fang [13]recorded 916 and 930 cranes respectively in Dashanbao Reserve. In January 2003, the Dashanbao Reserve was formally designated a national-level nature reserve. From 2003 to 2011, the crane population increased to 1,154 individuals, peaking at 1,235 in 2008. The highest recorded count occurred on November 18, 2008, reaching 1,375 individuals. From 2020 to 2023, the average population averaged 1,500 individuals, with the highest recorded count of 2,342 occurring on November 25, 2023. These figures are derived from monitoring data collected by the Dashanbao Reserve. Between 1989 and 2023, the Black-necked crane population increased nearly fourfold in Dashanbao Reserve. In 2002-2003, in response to the national policy of returning farmland to forests, the reserve organized the conversion of 675 hectares of farmland back to forest. In 2009, 283 hectares were converted back to wetland. To better restore and protect wetlands, the reserve implemented artificial grass planting across 950 hectares from 2008 to 2009. Due to enhanced national conservation efforts for Black-necked cranes, the population within Dashanbao Nature Reserve increased by 488% in 2003 compared to its establishment in 1993 [14]. The population of cranes within the Reserve grew by 488% between its establishment in 1993 and 2003. Over the subsequent two decades from 2004 to present, the population has generally shown steady growth with slight increases, exhibiting a rapid growth trend from 2019 to 2022 [10]. Assessing the impact of foraging habitats on Black-necked crane populations is crucial for determining whether crane population will continue to increase in Dashanbao Reserve. This evaluation will provide scientific basis for the IUCN's global conservation status assessment of Black-necked cranes.

2. Study area

The Dashanbao National Nature Reserve for Black-necked Cranes is located in Zhaoyang District, Zhaotong City, northeastern Yunnan Province (103°15′–103°24′E; 27°18′–27°29′N), 79 km from Zhaotong City. The Dashanbao Reserve serves as the primary wintering and migration stopover site for the Eastern population of Black-necked cranes, while also providing habitat for other waterfowl species. The reserve currently hosts a wintering population of approximately 1,500 Black-necked cranes (accounting for about 1/7 of the global population). The cranes overwinter here for five months (early November to early March of the following year).

The study area covers 19,200 ha and is a warm, humid plateau with a monsoon climate 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 for January is -1 ◦C, and for July 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 1,165 mm (Li & Zhong, 2010). Strong winds are common in the reserve, with an average of 52 windy days per year, peaking at 82 days, predominantly concentrated in winter and spring.

Black-necked cranes in Dashanbao Reserve primarily feeding on agricultural farmlands, as well as wild grasslands. Farmland included fields of cereal *(Avena sativa* and *Fagopyrum tataricum*), potatoes (*Solanum tuberosum*) and turnip (*Brassica rapa var. rapa)*[15]. meadows with minimal water (Kong et

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al., 2011a) and dominated by orchard grass (*Dactylis glomerata*), bluegrass (*Poa annua*), *Leontopodium*, *Trifolium*, *Pterospermum heterophyllum*, *Pedicularis densispica*, *Luzula multiflora*, *Hemiphragma heterophyllum*[16]. The cranes have been reported to forage on *Pedicularis*, *Stellaria*, *Polygonatum* and *Veronica.*

The Dashanbao Reserve encompasses Tiandun River, DaHaizi, Lelizhai Reservoirs. The DaHaizi Reservoir has a catchment area of around 3.5 square kilometres, an average depth of approximately 2.5 metres, and a water storage capacity of 0.8 square kilometres. Due to low reservoir levels, the shallow water zones and surrounding wetlands of Dahuazi Reservoir currently serve as the most concentrated wintering habitat for cranes within the reserve.

3. Methods

3.1 Population Survey

Black-necked crane numbers were monitored at three roosting sites within the Dashanbao Reserve: DaHaizi, Tiandun River, and Lelizhai. Field bird observation data were collected from November to late March annually between 2013 and 2015. A team of 2–4 observers was assigned to each roosting site. Counts were conducted daily from 6:30 to 8:00 a.m. using binoculars, except severe weather. The data from each team was then consolidated.

3.2 Sampling

To investigate the availability of grains, potatoes, and invertebrates consumed by Black-necked cranes, we conducted sampling along three selected transects[17]. The first sampling point was randomly selected, with subsequent points established at 100-meter intervals and geolocated using GPS. To investigate the availability of consumable crops, animal matter and wild plants, we proceeded to sample foods using quadrats (50×50×10 cm deep) placed at intervals of 100 m along a straight line, guided by GPS localization. We used a direct collection sampling method for cereal grains on unploughed plots and turned the soil for sampling cereal grains *(Avena sativa* and *Fagopyrum tataricum*) on ploughed lands. The latter method was used for sampling potatoes, turnips, invertebrates (earthworms and Coleoptera larvae) within a depth of 10 cm. The length of a crane's bill is 12.4 cm (n = 10, 10.5–14.0 cm). Assuming grain particles constitute the smallest food items consumed by cranes, and that most overwintering invertebrate larvae and earthworms exceed grain particle size, only invertebrate individuals larger than 4 mm were considered during sampling. Within each plot, the number, biomass, and depth of each food type were recorded. Over the two-year period from 2013 to 2015 (8 months), a total of 176 grain fields and 222 potato and turnip fields were sampled. Earthworms, scarab beetle larvae were collected from 295 grassland plots (2013-2015, 8 months). Excavated food items were placed in pre-prepared plastic bags, labeled, and either processed immediately or refrigerated prior to processing. Grain, potatoes, invertebrates were sorted separately, dried at 60°C for 48 hours, and weighed (accurate to 0.001 g). The biomass of collected food was multiplied by area to calculate the monthly food availability for Black-necked cranes.

3.3 Food Threshold

To determine the crane's food threshold, surveys were conducted from November 2013 to February 2014 on selected farmland (4.91 ha) and grassland (12.75 ha), ensuring sampling sites hosted large flocks (approximately 30–60 individuals). Based on the species' site fidelity, feeding areas were identified. Weekly surveys (2–3 days per week) tracked feeding activities and recorded population numbers until only 2–4 individuals remained. Observation frequency decreased during foggy or snowy days. The survey spanned 8 weeks (24 days total). Subsequently, sampling was conducted based on crane droppings and feather-shedding locations, yielding 36 grain field plots, 22 potato field plots, and 20 grassland plots. Sampling methods followed Section 2.1. The critical threshold for crane feeding was recorded as the quantity of food remaining in the sample plot after a large flock of cranes decreased in size to 2–4 individuals following a feed at a fixed location.

3.4 Daily Energy Intake (DEI)

The methods employed by Chávez-Ramírez [18], Fox et al. [19] and Dong et al. [20]indicate that the cranes consume 1,839 kJ/d. With an assimilation rate of 80.52%, the estimated daily energy acquisition

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for the Black-necked cranes is 2,284 kJ/d.

3.5 Estimation of Energy Carrying Capacity (ECC)

First, convert the critical biomass of potatoes, grain particles and invertebrates into unit energy values. Then, divide each by the DEI to obtain the energy carrying capacity of each food source, expressed as bird-days per hectare (bird-days/ha). To calculate the critical energy carrying capacity of farmland, the unit energy values of the three main food sources for cranes (potatoes, oats and buckwheat) must be averaged to determine the total energy available on the farmland. This figure is then divided by the daily energy requirement of a crane. The critical energy carrying capacity for grasslands is calculated based on the energy value of invertebrate larvae. The calculation process for the average energy carrying capacity of farmland and grasslands is the same as above.

3.6 Estimating the Total Area of Black-necked Crane

Based on habitat selection criteria proposed by Kong Dejun [15], four environmental factors were selected: slope < 10°, northeast-facing slope, distance from night roost ≤ 2000 m, and distance from nearest water source ≤ 1000 m. Based on these habitat selection criteria, Dong Haoyan et al. [19]determined the potato habitat area to be approximately 1,518 ha (with a crane utilization rate of about 78.73%), oat habitat area was approximately 281 ha (crane utilization rate 78.73%), buckwheat habitat area was approximately 182 ha (crane utilization rate 78.73%), wetland area was 119 ha, and grassland area was 6035 ha (crane utilization rate 61.89%).

4. Results

4.1 Population Size of the Black-necked Crane

The Black-necked crane population stabilized at 787 individuals on November 14, 2012. After declining to 610 individuals on March 18, 2013, the population began a rapid decrease, fluctuating between 610 and 1,310 individuals for 124 days (Figure 1).

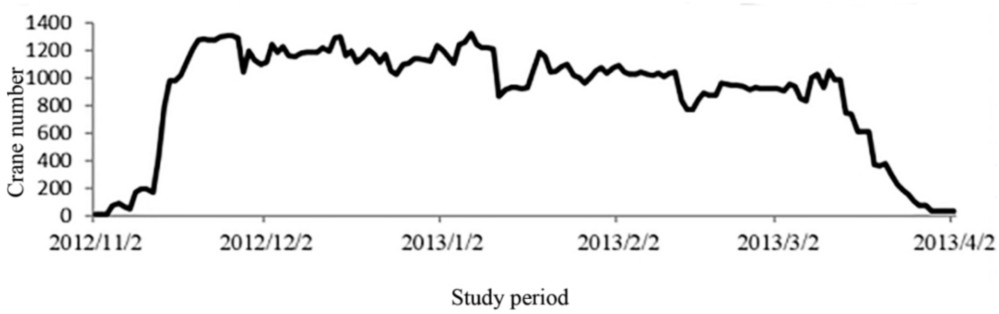

Figure 1 Changes on population of Black-necked Cranes at Dashanbao Reserve in 2012-2013.

The population of the crane stabilized at 740 individuals on November 17, 2013. Migration commenced after the population declined to 693 individuals on March 24, 2014. The population remained between 693 and 1,223 individuals for 127 days. The population stabilized at 834 individuals on November 20, 2014 (Figure 2). Migration commenced after numbers declined to 846 by March 20, 2015, with the population fluctuating between 846 and 1,269 individuals over 120 days (Figure 3). Analysis of the 2012-2015 Black-necked crane population dynamics reveals that although monthly fluctuations occurred, the population remained relatively stable below approximately 1,100 individuals for periods of 120-127 days, except during migration seasons (November and March). To facilitate the calculation of Black-necked crane carrying capacity, the population size was set at 1,100 individuals for 130 days. This resulted in an actual carrying capacity of 1.4×10^5 bird-days.

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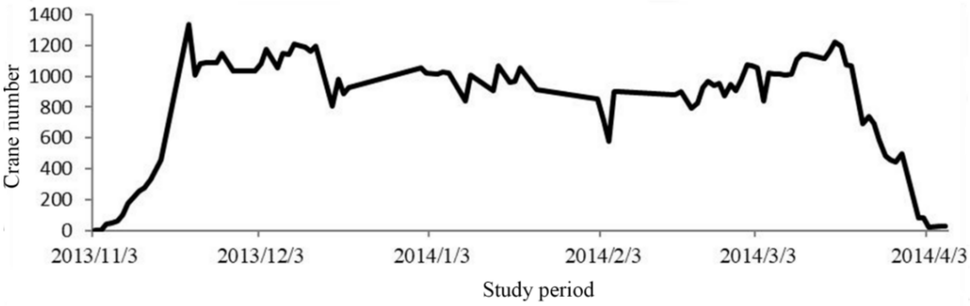

Figure 2 Changes on population of Black-necked Cranes at Dashanbao Reserve in 2013-2014.

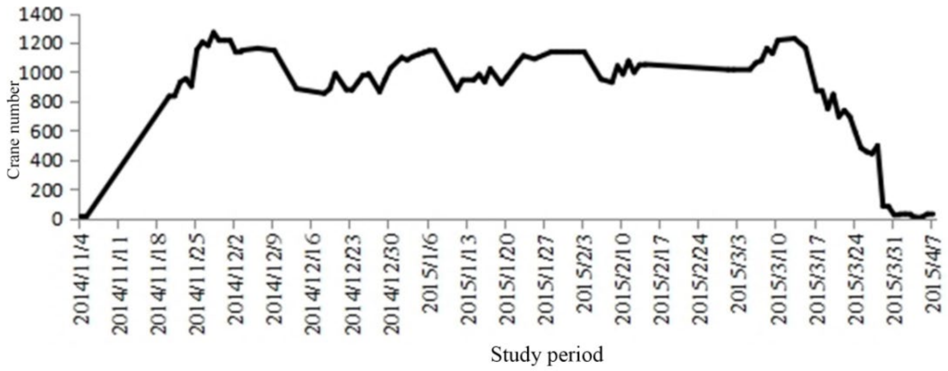

Figure 3 Changes on population of Black-necked Cranes at Dashanbao Reserve in 2014-2015.

4.2 Black-necked Crane Carrying Capacity

The results indicate that Black-necked crane carrying capacity remained relatively consistent between 2012 and 2014, with a slight decline observed between 2014 and 2015 (Table 1). Comparing the carrying capacities from three wintering seasons with the current carrying capacity of 1.4×10^5 bird-days, the food-energy-based carrying capacity for cranes was found to be approximately 4.3–5.1 times the current carrying capacity (Table 1), indicating a potential population size of around 6,000 individuals.

Table 1 Estimated Carrying capacity and current carrying capacity of Black-necked Crane in 2012-2015.

Year	Food type	Sample N	Mean available biomass (g/m^2)	Food Energy (kJ /g)	Total food energy (kJ)	Carrying capacity (bird-days)	Current carrying capacity	Approximately times
2012-2013	potato	76	7.33	15.46	1.22×10^9			
	Avena sativa	41	0.14	17	5.27×10^6			
	Fagopyrum tataricum	32	0.44	16.68	1.05×10^7			
	invertebrate	84	0.50	20.4	3.81×10^8			
					1.62×10^9	7.1×10^5	1.4×10^5	5.1
2013-2014	potato	82	6.72	15.46	1.12×10^9			
	Avena sativa	61	0.50	17	1.88×10^7			
	Fagopyrum tataricum	43	0.61	16.68	3.82×10^6			
	invertebrate	58	0.57	20.4	4.34×10^8			
					1.58×10^9	6.9×10^5	1.4×10^5	4.9
2014-2015	potato	152	5.61	15.46	9.34×10^8			
	Avena sativa	71	0.51	17	1.92×10^7			
	Fagopyrum tataricum	52	0.89	16.68	2.13×10^7			
	invertebrate	192	0.51	20.4	3.89×10^8			
					1.36×10^9	6.0×10^5	1.4×10^5	4.3

Further analysis of the total energy provided by farmland and grassland habitats in different months across years versus the energy required by cranes during specific periods revealed that the highest total energy in March exceeding other months, reaching 3.01×10^8 (2284 kJ/bird/day × 1100 birds × 130 days)

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by 2.2–3.0 times in farmland (Table 2). In grassland, higher total energy in November than other months. The total energy supplied in November was 2.5–4.3 times greater than the energy requirement of cranes during that period (Table 2).

Table 2 Total food energy in inter-monthly for two habitat in 2012-2015.

Habitat	Month	Total food energy (kJ)		
		2012	2013	2014
Farmland	11	7.1×10^8	6.4×10^8	5.5×10^8
	12	5.7×10^8	4.2×10^8	5.1×10^8
	1	5.1×10^8	2.7×10^8	3.1×10^8
	2	3.0×10^8	2.3×10^8	2.8×10^8
	3	7.1×10^8	8.9×10^8	6.6×10^8
Grassland	11	8.7×10^7	1.3×10^8	7.6×10^7
	12	5.1×10^7	4.8×10^7	3.5×10^7
	1	3.9×10^7	2.4×10^7	6.1×10^7
	2	5.7×10^7	9.9×10^7	7.4×10^7
	3	7.1×10^7	5.6×10^7	7.1×10^7

5. Discussion

Based on food energy, the estimated carrying capacity for Black-necked cranes was approximately 4.3–5.1 times the actual carrying capacity, indicating a potential population of about 6,000 individuals. From 2012 to 2015, the total energy provided by both habitats from November to February each year was 1.5–2.9 times the energy required by cranes during the corresponding period. However, the total energy provided in March each year far exceeded the energy required by cranes during the same period. The current crane population is estimated at 1,500–2,200 individuals, which has not yet reached the environmental carrying capacity of Dashanbao. The current population growth of cranes is relatively stable. Assuming habitat conditions and food availability remain unchanged, it is projected that the population will continue to grow steadily in the future. However, future changes in traditional crops and the potential environmental impacts of cash crops (such as pesticide use), the gradual restoration of wetlands and grasslands, and changes in the habitat of the crane breeding grounds may affect the environmental carrying capacity for Black-necked cranes in this region. Detailed research will be required in the future.

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