Jia et al. Avian Res (2019) 10:32
https://doi.org/10.1186/s40657-019-0170-9

Avian Research

RESEARCH Open Access

Population dynamics and habitat use of the Black-necked Crane (*Grus nigricollis*) in the Yarlung Tsangpo River basin, Tibet, China

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Abstract

Background: The Black-necked Crane (*Grus nigricollis*) is an internationally threatened crane living on the plateau, mainly in winter, in the Yarlung Tsangpo River basin in Tibet, western China. In the past five years, some economic development projects have been conducted in this area, posing potential threats to the wintering populations of the cranes and their habitats. Therefore, the current population dynamics of wintering Black-necked Cranes and habitat suitability in the Yarlung Tsangpo River basin were investigated.

Methods: Twenty counties were surveyed using the line transect method in December 2017 and January 2018, and we recorded the location, flock size, number of individuals, habitat types and presence of human disturbance in which they occurred. We compared the results from the middle wintering period in this survey with those from 2014.

Results: The highest number of cranes recorded was 8291, and the results showed that the cranes were mainly distributed in Lhaze, Namling, Samzhubze, and Lhunzub. A total of 577 and 495 flocks were recorded in the early and middle wintering periods, respectively. In the early wintering period, there were significant differences in the number of individuals across the different habitats, with crop stubble land and plowed land representing more than 30% of the total habitat utilization. In the middle wintering period, there were also significant differences in the number of individuals, and the utilization of crop stubble land represented over 60% of the total.

Conclusions: Wintering Black-necked Cranes mainly fed on spilled grains in stubble habitat after harvest. In the middle wintering period, some of the farmlands were plowed and irrigated, which resulted in food shortages in these areas, and the cranes tended to gather in mixed flocks of large size instead of as a single family. There were still considerable regional wintering populations decreases in Quxu, Nedong, and Sakya in 2018 compared with 2014, and these decreases were mainly due to some recently emerging threats, including farmlands being converted into areas of greenhouse cultivation, highway and railway construction, river dredging, the rapid development of the manufacturing and mining industries, and the lack of protection of important wintering sites.

Keywords: Black-necked Crane, Habitat use, Population dynamics, Tibet, Yarlung Tsangpo River basin

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Background

The Black-necked Crane (*Grus nigricollis*) is listed as a globally threatened species by the International Union for Conservation of Nature (IUCN) and is one of the most threatened cranes worldwide (Li 2014). Among the 15 known crane species, the Black-necked Crane is the only species that lives on plateaus year round. These cranes mainly breed on the Qinghai–Tibet Plateau in western China (Li et al. 2014; Zhang et al. 2014a, 2015), with another small breeding population in Ladakh (Chandan et al. 2014; Khan et al. 2014). They mainly winter in relatively low-altitude regions of the Qinghai–Tibet Plateau, such as the Yarlung Tsangpo River basin, and the Yunnan–Guizhou Plateau, such as Zhaotong in Yunnan Province and Weining in Guizhou Province (Gao et al. 2012; Ran et al. 2017), with small wintering populations in Bhutan (Phuntsho and Tshering 2014). There are approximately 10,000–10,200 Black-necked Cranes worldwide (Li 2014).

Because of the harsh natural conditions in the Yarlung Tsangpo River basin (including the Lhasa and Nyangqu rivers), relatively few systematic bird surveys have been conducted in this area. However, the Qinghai–Tibet Plateau Comprehensive Expedition Team from the Chinese Academy of Sciences has conducted bird surveys since the 1950s, and, until recently, a special census that targets Black-necked Cranes was carried out in the Yarlung Tsangpo River basin. The counts from 2014 to 2016 showed increasing Black-necked Crane wintering populations sizes of approximately 5500–6500 individuals (Zhang et al. 2014b; Yang et al. 2016), which accounted for more than 50% of all Black-necked Cranes worldwide. The Yarlung Tsangpo River basin has become an important wintering ground for the populations of Black-necked Cranes.

In the past five years, some economic development projects have been implemented in the Yarlung Tsangpo River basin, including the conversion of wetlands (lakes and rivers) into farmland and development zones, the conversion of farmland into areas containing greenhouses for vegetable cultivation, and the construction of expressways (Lhasa to Shigatse and Lhasa to Nyingchi) and railways (Lhasa to Shigatse), which inevitably destroy the local landscape and bring more human interference (Tsering et al. 2009; Li et al. 2011; Wu 2011; Wang et al. 2015). However, whether these activities pose threats to the wintering populations and habitats of Black-necked Cranes remains unknown. In this study, we determined the current population sizes and important locations for wintering Black-necked Cranes in the Yarlung Tsangpo River basin and explored the habitat suitability by comparing habitat use between the different wintering stages. Moreover, we also discuss the negative effects of human activities on the wintering populations of Black-necked Cranes, which will contribute to the conservation of Black-necked Crane populations and their habitats in this area, and propose effective management measures to create more suitable habitats in different wintering periods for Black-necked Cranes in the Yarlung Tsangpo River basin.

Methods

Survey time and areas

Wintering Black-necked Cranes usually arrive at the Yarlung Tsangpo River basin in mid-November, and the wintering populations reach a stable level in early December. The whole wintering period was divided into three stages: the early wintering period (from early to the end of December), the middle wintering period (from early to the end of January), and the late wintering period (from early to the end of February). Our surveys were conducted on 20–30 December 2017 and 20–30 January 2018, which represented the early and middle wintering periods, respectively. The surveyors were divided into west and east-route teams, with Quxu as the boundary between the two teams. Twenty counties were covered, and a total distance of approximately 1200 km was travelled from Lhaze to Sangri (Fig. 1).

Survey methods

The survey routes, sites and members were the same between the two surveys. We used 10× binoculars to scan along the routes from 9:00 to 19:00 every day. When cranes were detected, they were observed and counted using a monocular scope (20–60×, SWAROVSKI, Austria), and we recorded the location, flock size, number of individuals, habitat types and presence of human disturbance, including mining development, road and railway construction, reclamation, river dredging, and presence of greenhouses for vegetable cultivation. To avoid double counting, we ignored flocks flying over from behind. A flock was defined as a group of two or more cranes in close proximity and interacting with each other (Bishop et al. 1998).

Agriculture is the dominant land use in this area. Winter wheat (*Triticum* spp.) is grown in winter (from the end of September to the following August), whereas other crops, including highland barley (*Hordeum vulgare*), potatoes (*Solanum tuberosum*), rapeseed (*Brassica napus*), and spring wheat (*Triticum* spp.), are grown from April to September and harvested in autumn. The local villagers usually plow the barley or spring wheat farmland after the crops are harvested, which occurs at different times. Therefore, we divided the major habitat types into winter wheat farmland, crop stubble land (including barley, rapeseed and spring wheat), plowed field, pasture,

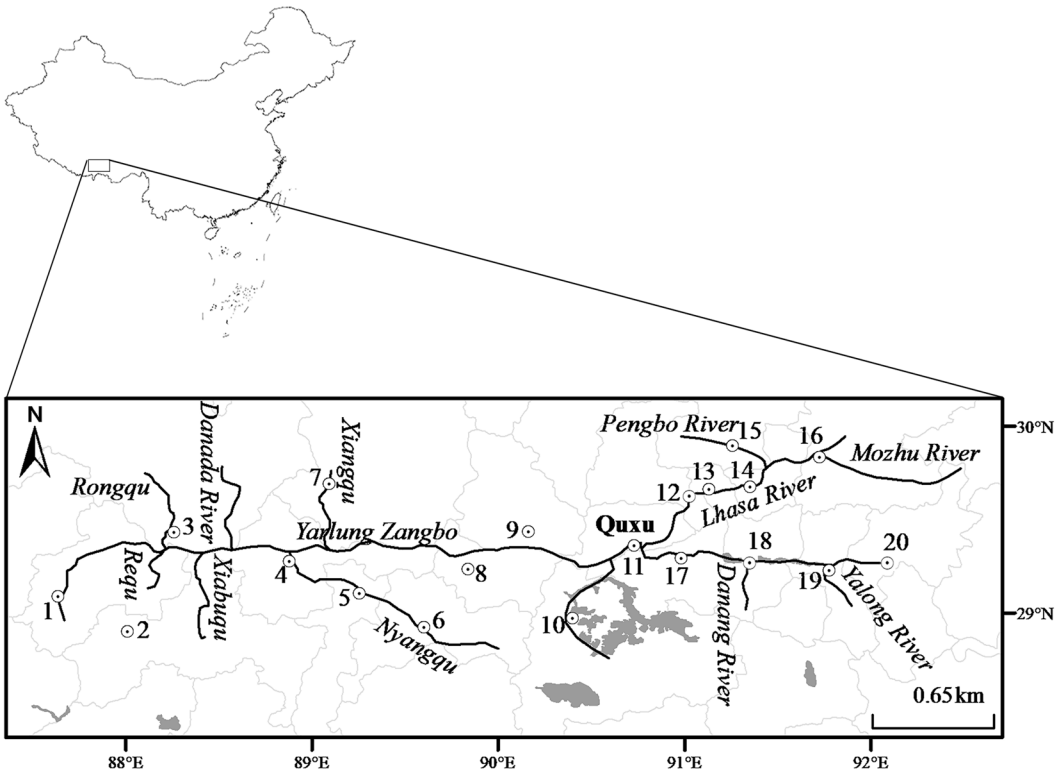

Fig. 1 Survey areas of the Black-necked Crane wintering ground in the Yarlung Tsangpo River basin in Tibet from December 2017 to January 2018. Major rivers are shown on the map, and location names are given in English, with Pinyin Chinese in parentheses: 1—Lhaze (Lazi), 2—Sakya (Sajia), 3—Thongmon (Xietongmen), 4—Samzhubze (Sangzhuzi), 5—Panam (Bailang), 6—Gyantse (Jiangzi), 7—Namling (Nanmulin), 8—Rinbung (Renbu), 9—Nyemo (Nimu), 10—Nakartse (Langkazi), 11—Quxu (Qushui), 12—Tolun Dechen (Duilongdeqing), 13—Lhasa (Lasa), 14—Taktse (Dazi), 15—Lhunzub (Linzhou), 16—Medro Gongkar (Mozhugongka), 17—Gonggar (Gongga), 18—Danang (Zhanang), 19—Nedong (Naidong), 20—Sangri (Sangri)

river, and marsh. When we analyzed the habitat use of Black-necked Cranes, we ignored flying individuals and flocks of the cranes.

To obtain the actual locations of each flock and individual crane, the positions of the observation sites were mapped with a GPS, and the distance between the cranes and surveyors was recorded using a laser range finder (ZEISS Victory 82 × 6 PRF). The direction from the cranes to the observers was measured with a compass, and then we determined the locations of the cranes in the ArcGIS software package (version 10.1, ESRI 2012, USA). We also visited local villagers to obtain information on agricultural cultivation, including crop species, farming time and farming system, and conducted field surveys of human disturbances to evaluate the current habitat conservation status.

Data analysis

A single family usually included 2–4 individuals with 1 or 2 adults and 1 or 2 chicks. To make statistics and analysis data more convenience, the mixed flocks, which means a combination of several Black-necked Crane families, were divided into four groups based on the numbers of cranes observed (5–10, 11–50, 51–100, and > 100).

We checked the data for normality, and variables whose residuals were not normally distributed were transformed before the analyses. A Chi-square test was used to analyze the significance of flock differences during the different wintering stages. One-way analysis of variance was used to identify differences in the numbers of individuals in the different habitat types. All tests were performed using the SPSS statistical software package (version 22.0, IBM 2013, USA). The data format was the mean ± SD. In addition, to analyze the trend in the number of cranes over time in the Yarlung Tsangpo River basin, we compared the results from the middle wintering period in this survey with those from the same period in 2014 (Zhang et al. 2014b).

Results

Distribution and population size

A total of 6260 Black-necked Cranes were recorded during the survey in the early wintering period (Table 1). The

Table 1 Black-necked Crane wintering population sizes in the Yarlung Tsangpo River basin, Tibet

Survey routes	Counties	Early wintering period in 2017	Middle wintering period in 2018	Middle wintering period in 2014[a]
East routes	Tolun Dechen	0	0	0
	Quxu	53	17	224
	Taktse	290	574	639
	Medro Gongkar	88	210	243
	Lhunzub	506	830	395
	Sangri	57	39	34
	Nedong	0	63	158
	Danang	3	2	16
	Gonggar	257	118	119
	Subtotal	1254	1853	1828
West routes	Gyantse	65	15	24
	Panam	22	66	77
	Samzhubze	1214	2735	572
	Namling	1335	1366	598
	Lhaze	1625	1711	1535
	Thongmon	348	308	287
	Sakya	387	236	540
	Rinbung	7	1	0
	Nyemo	3	0	0
	Subtotal	5006	6438	3633
	Total	6260	8291	5461

[a] Indicates that the data were obtained from Zhang et al. (2014b)

sites with the most cranes (> 1000 individuals) included Lhaze, Namling, and Samzhubze, followed by Lhunzub, Sakya, Thongmon, Taktse, and Gonggar (Table 1, Fig. 2a). In the middle wintering period, a total of 8291 Black-necked Cranes were recorded, which was an increase of 2031 cranes over that recorded during the early wintering period (Table 1). In terms of crane numbers, great increases were observed at Taktse, Lhunzub, Samzhubze and Lhaze between the different wintering periods, but great decreases were observed at Quxu, Gonggar, Gyantse, and Sakya (Table 1, Fig. 2b). Moreover, the number of cranes greatly declined in comparison to that recorded in 2014 at Quxu and Sakya (Table 1).

Flock size

In the early wintering period, a total of 577 flocks were recorded, with an average flock size of 10.4 ± 22.2 cranes ($n = 577$, range 2–185); in the middle wintering period, 495 flocks were recorded, with an average flock size of 14.6 ± 31.2 cranes ($n = 495$, range 2–238). The cranes tended to live in mixed flocks of larger sizes instead of as a single family in the middle wintering period (Fig. 3), and there was a significant decrease in the number of single families ($\chi^2 = 16.03$, $p < 0.001$, $n = 741$) and a significant increase in the number of flocks with 11–50 individuals ($\chi^2 = 6.25$, $p = 0.013$, $n = 155$).

Habitat use

In the early wintering period, there were significant differences in the number of individuals across the different habitats ($F = 3.634$, $p = 0.003$, $n = 566$). Crop stubble land and plowed land showed relatively higher habitat suitability, and the numbers of individuals in these areas accounted for 37.6% and 34.2% of all observed cranes, respectively (Table 2).

In the middle wintering period, there were also significant differences in the number of individuals in association with habitat use ($F = 2.249$, $p = 0.048$, $n = 486$). The numbers of individuals recorded in the crop stubble land were relatively higher than those recorded in association with other habitats and accounted for 60.2% of all observed individuals, which indicated that cranes mainly used the crop stubble land over plowed land and other habitat types in the middle wintering period (Table 2).

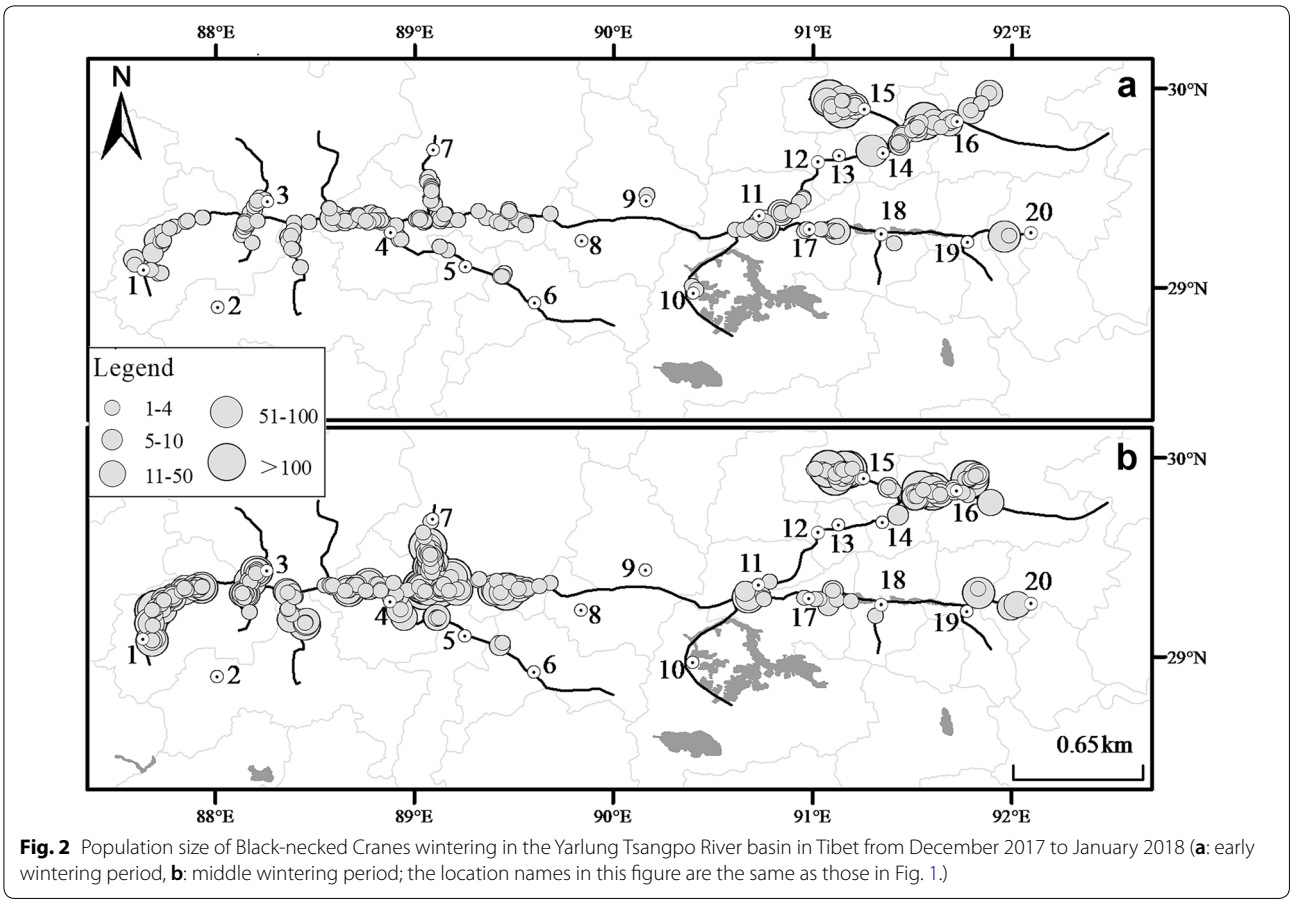

Fig. 2 Population size of Black-necked Cranes wintering in the Yarlung Tsangpo River basin in Tibet from December 2017 to January 2018 (**a**: early wintering period, **b**: middle wintering period; the location names in this figure are the same as those in Fig. 1.)

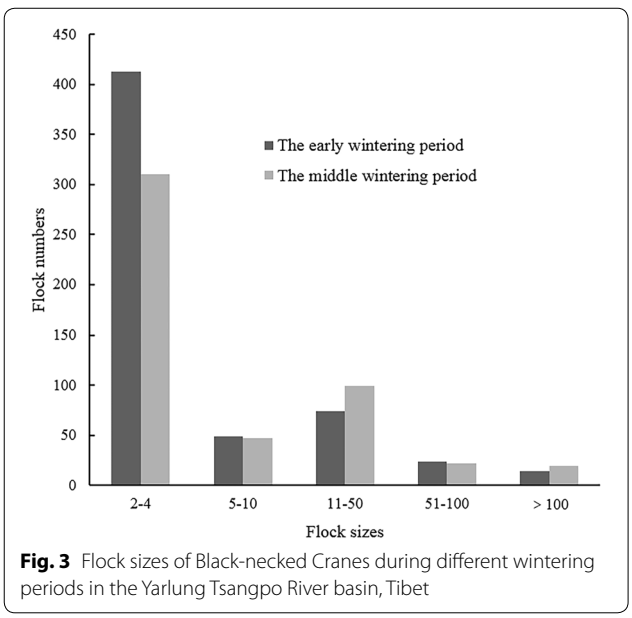

Fig. 3 Flock sizes of Black-necked Cranes during different wintering periods in the Yarlung Tsangpo River basin, Tibet

Discussion

We recorded a maximum of 8291 individuals in the Yarlung Tsangpo River basin during our surveys, which was a great increase of nearly 30% compared with the previous highest record in the region (6500 individuals) (Zhang et al. 2014b; Yang et al. 2016). Currently, there are eastern, central, and western wintering populations of Black-necked Cranes. Among them, the eastern populations (approximately 4300 cranes) winter in northeastern Yunnan and northwestern Guizhou (Li 2014; Yang and Zhang 2014), and the central populations (approximately 300 cranes) winter in northwestern Yunnan (Li 2014). The western populations winter in the Yarlung Tsangpo River basin of Tibet and Bhutan, of which more than 550 cranes have been recorded in Bhutan (Phuntsho and Tshering 2014). Together with the 8291 cranes observed during this survey in the Yarlung Tsangpo River basin, the western populations have been found to contain approximately 8700 cranes. Thus, the Black-necked

Table 2 Numbers of Black-necked Cranes in different habitats in the Yarlung Tsangpo River basin, Tibet

Types	Early wintering period			Middle wintering period		
	Number of individuals	Number of flocks	Average flock size	Number of individuals	Number of flocks	Average flock size
Pasture	247 (4.2%)	13 (2.4%)	19.0 ± 35.4	519 (7.5%)	40 (8.2%)	12.9 ± 24.1
Winter wheat land	414 (6.9%)	24 (4.3%)	17.3 ± 25.1	49 (0.7%)	14 (2.8%)	3.5 ± 3.6
Plowed land	2025 (34.2%)	274 (44.7%)	7.4 ± 17.7	771 (11.2%)	89 (18.3%)	9.3 ± 24.4
River	581 (9.8%)	35 (6.3%)	16.6 ± 30.6	1212 (17.6%)	84 (17.3%)	14.3 ± 19.7
Crop stubble land	2230 (37.6%)	201 (36.3%)	11.1 ± 22.3	4136 (60.2%)	245 (50.4%)	16.9 ± 36.6
Marsh	429 (7.2%)	19 (3.4%)	22.6 ± 39.9	189 (2.7%)	14 (2.9%)	13.5 ± 24.2

The numbers in parentheses indicate the percentages

Cranes in the Yarlung Tsangpo River basin account for over 81.2% of all Black-necked Cranes worldwide.

Significant increase of wetland in the Qinghai-Tibet Plateau may be an important reason for the increase in the number of cranes in the Yarlung Tsangpo River basin. At the breeding sites of the cranes, such as Cuoe, Cuona and Mujiu lakes on the Qiangtang Plateau, northern Tibet (Zhang et al. 2015), the glaciers have shrunk because of climate warming, and the precipitation has increased (Li et al. 2017). All these factors make the wetland area in Tibet increased (Niu et al. 2012; Gong et al. 2019), which has provided more breeding sites for the cranes.

Compared with early wintering period in 2017 (6260 cranes), the number of individuals have increased significantly in middle wintering period in 2018 (8291 cranes), especially in Samzhubze where the population increased by 125%. Since the field methodologies, survey routes and surveyors were the same between the two surveys, the following two aspects should be concerned for the considerable increase of population numbers in middle wintering period: (1) in middle wintering period, numerous farmlands were plowed and irrigated which made cranes unavailable for feeding as covering of soil and ice. Therefore, the populations which were dispersed and difficult to record in early wintering period became more stable, concentration and easy to record in middle wintering period. (2) Although only a few Black-necked Cranes were recorded before 2014 (Li 2014), it was reported the number of cranes increased considerably outside the Yarlung Tsangpo River basin, especially in Nyingchi in recent years (Han and Guo 2018) Although further evidence is needed, it is likely that Nyingchi population of the cranes maybe disperse and aggregate at the Yarlung Tsangpo River basin in the middle wintering period due to the food shortage and so on.

Our results indicated that the Black-necked Cranes used different habitats in different wintering periods. In the Yarlung Tsangpo River area, farmland is the main foraging site for cranes (Song et al. 1994; Bishop and Li 2002), which indicates the long-term importance of farmland in the Yarlung Tsangpo River basin for crane survival. Our field observations showed that the crop stubble in the highland barley land, spilled barley grains, low grass, and growing winter wheat were the main habitat used by the cranes, which was consistent with winter habitat use by Black-necked Cranes in Tibet (Bishop et al. 1998).

Our study revealed that in the middle wintering period, the cranes mainly used crop stubble land over plowed land as habitat sites, which was consistent with a study showing the use of cereal grains as a food resource by wintering Black-necked Cranes (Bishop and Li 2002). Because of the demands of agricultural farming and pest control, numerous farmlands are plowed and irrigated in the middle wintering period resulting in available food decrease as covering of soil and ice. As a result, cranes are rarely found in farmlands that have been plowed for a long time. Compared with the early wintering period, the distribution pattern of the cranes changed greatly inside of the surveyed counties. For example, inside Samzhubze, some areas of the highland barley land was plowed and irrigated in the middle wintering period, resulting many cranes aggregated other areas with highland barley farmland of Samzhubze, which also happened at Lhaze in the middle wintering period as well.

Although the crane populations generally increased, the numbers of cranes in Quxu, Taktse, Medro Gongkar, Nedong, and Sakya decreased compared with those found in 2014, especially in Quxu, Nedong, and Sakya, with great declined in the number of cranes (Table 1). This decreasing trend was generally consistent with the results of the survey conducted by Yang et al. (2016) in the same areas. In March 2018, we conducted an in-depth survey of Quxu, Nedong, and Sakya and found that there were five factors that adversely affected the Black-necked Crane populations and their habitats. (1) There were changes in farming patterns across the farmlands. Since

2013, Greenhouses have been recently constructed on some highland crop farmlands to grow melons and vegetables (Yang and Cangjue 2013), which is common in the eastern Yarlung Tsangpo River basin, especially in Quxu and Nedong. (2) Expressways were constructed from Lhasa to Nyingchi and to Shigatse, and these roads pass through the foraging sites at Quxu and Nedong. (3) Some important sites used by the Black-necked Cranes are not included in protected areas, such as those in Gonggar (approximately 200–300 cranes), Danang (approximately 1–20 cranes), and Nedong (approximately 100–200 cranes), and human disturbances from economic development are relatively higher in these areas. (4) There has been rapid development of the mining industry in Sakya, resulting in an increase in human activities and industrial wastewater, deteriorating the water quality of the Yarlung Tsangpo River basin. (5) A dredging project in the Lhasa River and the Yarlung Tsangpo River basin directly destroyed the habitats of the cranes, especially the roost sites.

Based on the current conservation status of the wintering grounds of Black-necked Cranes in the Yarlung Tsangpo River basin, we provide the following recommendations: (1) surveys on Black-necked Crane populations in the Yarlung Tsangpo River basin should be conducted regularly, and a detailed field survey guide should be developed. (2) The development of projects associated with manufacturing, mining, and other human activities, such as reclamation and dredging, should be strictly prohibited or controlled in the Yarlung Tsangpo River basin. (3) Communication and cooperation between the forestry and agricultural departments should be conducted to protect the wintering populations and habitats of Black-necked Cranes and to maintain the goals of agricultural development. (4) Because the water level has an important impact on Black-necked Cranes roost sites, the local water resource department should strengthen the management of the water level of the Lhasa River, Nyangqu River valley, and Yarlung Tsangpo River to meet the water level requirements of the cranes. (5) Some Black-necked Cranes distribution sites, such as those in Gonggar, Danang, and Nedong, are not currently included in protected areas and should be protected at the national level.

Conclusions

We recorded a maximum of 8291 Black-necked Cranes in our surveys in the Yarlung Tsangpo River basin, which was a great increase of nearly 30% compared with the previous highest record in the region. Wetlands change may be an important reason for the increase in the numbers of cranes in the Yarlung Tsangpo River basin. In addition, the comparison of the Black-necked Crane populations numbers and distributions during the two wintering periods showed that the cranes rarely selected plowed land for foraging sites in the middle wintering period, mainly using crop stubble land. There were considerable regional wintering population decreases in Quxu, Nedong, and Sakya in 2018 compared with 2014, and these decreases were mainly due to some recently emerging threats, including farmlands being converted into areas of greenhouse cultivation, highway and railway construction, river dredging, the rapid development of the manufacturing and mining industries, and the lack of protection of important wintering sites.

Acknowledgements
We thank the Forestry and Grassland Department of Tibet Autonomous Region who gave us great supports during our investigations.

Authors' contributions
RJ and TM prepared and revised the manuscript. GZ and DL conceived and designed the research. FZ, TM, GZ, DL and JL performed the field work. All authors read and approved the final manuscript.

Funding
This work was supported by the program from Forestry and Grassland Department of Tibet Autonomous Region.

Availability of data and materials
The data and materials used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
The investigations comply with the current laws of China in which they were performed.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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Received: 24 February 2019 Accepted: 15 August 2019
Published online: 23 August 2019

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