WINTER HABITAT USE BY BLACK-NECKED CRANES *GRUS NIGRICOLLIS* IN TIBET

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Approximately 66% (3,900) of the world's Black-necked Crane population winter in south-central Tibet, People's Republic of China. We collected information on winter habitat use by cranes concurrent with population surveys conducted during four winters: 1990-91 through 1993-94. Barley and spring wheat stubble was the principal habitat type used by Black-necked Cranes during the day. Secondary river channels and reservoir shorelines were used for roosting. Intensive observations of Black-necked Cranes at two sites found that barley and spring wheat stubble field use exceeded relative availability whereas ploughed fields were underutilized in relation to availability. At both sites the highest percent of cranes feeding and highest use of agricultural fields by cranes occurred during morning hours. Midday hours were characterised by an increased use of riverine habitats for resting. Implementation of Agricultural Management Zones (AMZs) in primary Black-necked Crane wintering areas could serve to minimize conflicts with agricultural interests. We recommend in areas with a high amount of winter wheat, that fewer spring barley and spring wheat fields be ploughed immediately following autumn harvest.

Keywords: Black-necked Crane, Grus nigricollis, habitat use, Tibet.

The wintering population of Black-necked Cranes (*Grus nigricollis*) in south-central Tibet is one of six known wintering populations. Numbering >3,900 cranes, it represents approximately 66% of the world's known population (Bishop 1996). Within south-central Tibet the winter range extends from Lhaze east to Nedong and as far north as near Old Lhunzub on the northwest Lhasa River. With the Black-necked Crane's winter range overlapping that of the Bar-headed Goose *Anser indicus* (Bishop *et al.* 1997), these two species are the most visible wildlife species in this area of Tibet. They are often seen together foraging in agricultural fields and roosting at riverine and reservoir roost sites.

Beginning in winter 1990-91, a lack of information on Black-necked Crane winter habitat conditions and requirements in Tibet prompted the Tibet Plateau Institute of Biology in Lhasa Tibet and the International Crane Foundation of Baraboo Wisconsin USA to initiate a cooperative study. In this paper we describe (1) diurnal habitat-use patterns and their relationship to habitat availability and (2) nocturnal roost sites.

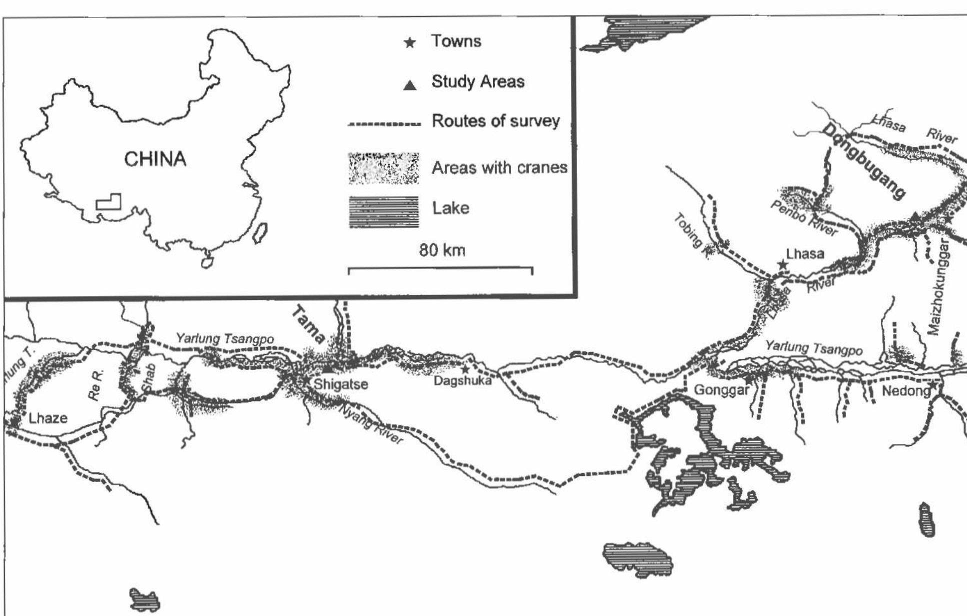
Study Area

Our primary study area was located in south-central Tibet (**Figure 1**), an area characterised by relatively high altitudes (3,400 - 4,100 m). Three major river valleys and their tributaries were included in the study area: Yarlung, Lhasa (Kyi Chu) and Nyang. For a more detailed description of all areas surveyed see Bishop and others (1997). Within the primary study area, two sites, Dongbugang and Tama (**Figure 1**), were selected for intensive studies of crane habitat use. Dongbugang (altitude 3,750 m) is located near the town of Maizhokunggar, approximately 90 km northeast of Lhasa on the north side of the Lhasa River. This area included three villages, inhabited by approximately 750 people. Our second site, Tama (altitude 3,900 m), is located 15 km east of Shigatse on the Yarlung River in Bianxiong Xiang of Shigatse Municipality and included four villages with a total human population of approximately 2,000.

Winters are cool and dry in south-central Tibet. Average monthly minimum and maximum temperatures at Lhasa during January, the coldest month, are -13.1° C and 5.7° C, respectively. The study area has a continental monsoon climate and an annual precipitation of 300 - 500 mm. October to April are the dry season, characterised by low precipitation (<10% of annual). Localised snowfall occurs infrequently and melts quickly. High winds occur regularly throughout south-central Tibet from January to April.

Major habitat types in the river valleys surveyed include: native pasture, stony pasture, shrub steppe, floodplain pastures, river, shortgrass marsh and agricultural lands. Dominant species in native pasture include *Pennisetum flaccidum*, *Orinus thoroldii*, and *Aristida*

Figure 1. Black-necked crane survey routes and intensive study sites.



triseta. Stony pasture is characterised by *Astragalus strictus* with scattered shrubs of *Sophora moorcroftiana,* and shrub steppe by *Sophora moorcroftiana*, *Berberis* spp., *Cargana tibetica*, and *Hippophae* spp. River floodplain pastures include grasses and shrubby vegetation found in upland habitats (eg. *Pennisetum flaccidum*, *Orinus thoroldii*, *Berberis* spp.) as well as *Ceratostigma minus*, and *Carex oxyleuca*. Shortgrass marsh, characterised by *Kobresia* spp. and *Blysmus sinocompressus,* was common in the Penbo River valley, a tributary of the Lhasa River, but was rare elsewhere. Irrigation ditches occur throughout agricultural fields and are often characterised by *Pedicularis roylei* and *Epilobium sikkimense*.

Agriculture is the dominant land use on the crane wintering areas with most lands managed for spring (naked) barley, spring wheat, and winter wheat production. Other crops include broadbeans and oil seed rape with broadbeans typically interplanted with spring wheat. Until the 1970's approximately 90% of the agriculture croplands were planted in spring barley. During the 1970's new strains of winter wheat tolerant of high-altitude winters were introduced throughout south-central Tibet (Gongbu Trashi, Agricultural and Animal Husbandry College, Bayi, Tibet, *pers. comm.*). When we began this study in 1990, Maizhokunggar County (approximately 85 km northeast of Lhasa), and areas from Shigatse west had discontinued growing winter wheat. However, winter wheat remained a major crop (>20% of croplands) north of Lhasa up to and including the Penbo River, south of Lhasa to the confluence of the Yarlung, as well as the counties along the eastern Yarlung River from Gonggar to Nedong (**Figure 1**).

Throughout most of south-central Tibet fields are tilled and planted using livestock (cattle and dzo, a hybrid yak-cow) and harvested with hand-held scythes. Agricultural machinery (including tilling, planting, and harvesting machines) are available in only a few areas. Crops are harvested in early autumn, August to September. Immediately after harvest or in early spring, fields are usually ploughed with an ard , a single-furrow, primitive plough. Irrigation is used extensively during the growing season, from April to September, and to a lesser extent in the winter. Grazing is the second dominant land use with sheep and goats the most important livestock providing meat, dairy products, hides and wool for both domestic use and barter.

With the disbanding of communes and state farms from the late 1970's through early 1980's, land was redistributed to private households on the basis of labor power (0.20 and 0.23 ha per child and adult, respectively). With each family's allocated lands scattered throughout an area, fields in Tibet are typically a heterogeneous patchwork of small (< 40 m x 40 m), harvested, ploughed, and planted plots While fields are privately owned, they are usually considered common property for purposes of winter grazing. Cattle, horse, donkey, and less often pig are grazed on harvested fields and pastures during the day and stable fed at night. Depending on the area, flocks of sheep and goats are usually grazed on harvested fields in early autumn, then grazed throughout the winter in nearby mountain pastures.

Methods

Field methods

Diurnal habitat use by wintering Black-necked Cranes was documented during population surveys conducted between 1 January-11 February 1991, 21 December 1991-22 January 1992, 10-20 February 1993, and 3-31 December 1993. While we surveyed all of our primary study area the first two winters, the other two field seasons were surveyed in portions only. Nocturnal roost sites for cranes were documented during sunrise searches along the northern Lhasa River during December 1991 and December 1993, and in the Penbo River valley in December 1991.

We surveyed cranes using a Toyota Landcruiser on the available road access, driving primary roads through each valley and their major tributaries. We stopped to scan with a 22x telescope every 2-3 km in suitable habitat, from any major vantage point or whenever a flock was observed. Where visibility to the river was limited, we used secondary roads or climbed to vantage points. In some areas, one side of a valley was not accessible by car.

Whenever cranes were observed, information collected included: location, flock size, habitat type, and distances from human habitation, road, and rivers, and proximity to any other animals. A flock was defined as a group of two or more birds in close proximity to each other and interacting. Major habitat types were classified as agricultural (croplands), edge (encompassing the interface between croplands and pastureland or between riverine and upland habitats), pastureland (native pasture, stony pasture, and shrub steppe), riverine, shortgrass marsh, or other habitats. Because it is not possible to distinguish barley stubble from spring wheat stubble at a distance, we combined these into one category of barley/spring wheat stubble. Whenever possible, supplemental information on local farming practices was obtained by interviewing county and village leaders.

We quantified habitat use at Dongbugang from 3-28 December 1990 and at Tama from 14 February-10 March 1991, for a total of 25 and 23 observation days, respectively. Each study area was divided into quadrats identified by natural landmarks. From 0900-1900 each day we conducted hourly scan samples (Lehner 1979) from elevated observation points recording numbers, quadrat location, habitat use, activity, and proximity to villages and rivers (Tama only). At Dongbugang we conducted observations from a rooftop that allowed us excellent visibility of the uplands (approximately 350 ha), but only limited views of the bordering Lhasa River. At Tama, the summits of two hills provided excellent viewing conditions of both upland habitat and the adjacent Yarlung River habitats.

Statistical analyses

Diurnal habitat use was determined for each winter survey as the percent occurrence within each habitat type based on total birds observed across all survey locations. Birds observed in habitats that could not be identified were excluded from the analyses. For the two intensive study areas, we calculated percent occurrence of crane flocks within each habitat type by time of day (0900-1159, 1200-1459, 1500-1759, and 1800-2100) and by social class (singles and pairs, families, and flocks). For these analyses, each flock was counted as one observation. We also determined the percentage of observations by time of day for three major activity classes: feeding, resting, and feeding and resting (flocks with substantial numbers both feeding and resting).

A Chi-square test for goodness-of-fit was used to test whether diurnal upland habitat use by cranes occurred in proportion to the available upland habitat types. For this analysis, upland habitats were classified as: barley/spring wheat stubble, planted winter wheat (Tama site only), ploughed cropland, pastureland, and ditches. We determined the amount of available upland habitat types for each area by first pacing quadrats to estimate their size. At the Dongbugang site we paced a subset of the upland quadrats (15 of 22 quadrats, 211 ha) that represented 87% of all observations. At Tama we paced all upland quadrats (n=31 quadrats, 913 ha). Quadrats ranged in size from 3.4-42.2 ha at Dongbugang and from 7.5-70.0 ha at Tama. Next, for each quadrat paced we visually estimated the proportion of each habitat type. Ditches occurred in all quadrats and were estimated at 2% of the habitat in each quadrat. Estimated hectares of habitat for each quadrat were then summed to determine the total available habitat.

Because fields on the two study areas are typically a patchwork of small, heterogeneous plots (<40 m x 40 m), when a crane flock straddled two habitat types (eg. barley stubble and ploughed fields), we assigned 50% of the birds to each habitat type. When a flock straddled both a ditch and cropland, 20% of the flock was estimated to be in the ditch, and 80% in the cropland.

For the Chi-square test for goodness-of-fit, use per habitat was the proportion of all bird hours recorded in each habitat as determined from all hourly scans (i.e. each bird observed per scan = 1 bird hour). When a statistical difference of $P < 0.05$ in usage versus availability was detected, Bonferroni 95% confidence intervals were used to determine which upland habitats were preferred or avoided (Neu *et al.* 1974, Byers *et al.* 1984, Manley *et al.* 1993).

Results

Diurnal Habitat Use

Winter Surveys. A total of 13,160 birds representing 1,175 diurnal crane locations were recorded during four winter surveys, including an average of 95% in three major habitat types: agricultural fields (74%), pastureland (10%), and riverine habitats (11%). Use of agricultural fields was similar between years, ranging from 66-80% with approximately one-half of those observations occurring in barley/spring wheat stubble (**Table 1**). While ≤ 5% of all observations occurred in winter wheat fields, we may have underestimated its use. Depending on the area, winter wheat was often barely visible during December surveys, and could have been mistaken for ploughed fields. Highest use of ploughed fields occurred during February 1993 surveys (38% of all birds). This was the latest survey we conducted and was limited to the Lhasa and eastern Yarlung Rivers. Counties on the southern Lhasa River

Table 1. Percent occurrence of Black-necked Cranes by habitat type and winter season, south-central Tibet, People's Republic of China. n = total birds observed.

Habitat	Jan-Feb 1991 n = 4,027	Dec 1991-Jan 1992 n = 4,953	Feb 1993[1] n = 2,711	Dec 1993[2] n = 2,469
Agriculture Habitat				
Barley/Spring Wheat Stubble	34.5	49.2	13.4	41.7
Ploughed Field	14.3	15.3	37.8	19.8
Ploughed Field and Stubble[3]	12.1	3.8	7.9	10.9
Winter Wheat	3.6	4.5	2.6	4.7
Ploughed Field and Winter Wheat[3]	0	1.4	0	1.5
Unknown Field	2.8	0	0	0.4
Ditch (dry)	5.8	1.2	4.7	1.4
Edge Habitat				
Crop/Pasture Interface	3.7	5.1	5.7	0.2
Pastureland Habitat				
Native Pasture	6.0	3.9	1.1	5.2
Stony Pasture	2.7	6.0	15.7	2.1
Shrub Steppe	0.8	0.3	0	0
Riverine and Palustrine Habitat				
River Edge <5m	6.3	3.8	5.7	3.3
Sandbar	0.8	1.1	0	0.6
Floodplain Pasture	5.2	0.5	4.9	2.1
Streambed (dry)	0	0.8	0.5	4.1
Tallgrass Marsh	0	2.2	0	0
Shortgrass Marsh	0.7	0.3	0	2.1
Other Habitats	0.5	0.6	0	0

[1] West-central Tibet not surveyed
[2] Incomplete survey west-central Tibet; no survey of east Yarlung River, Gonggar to Nedong
[3] Flocks straddled both habitats

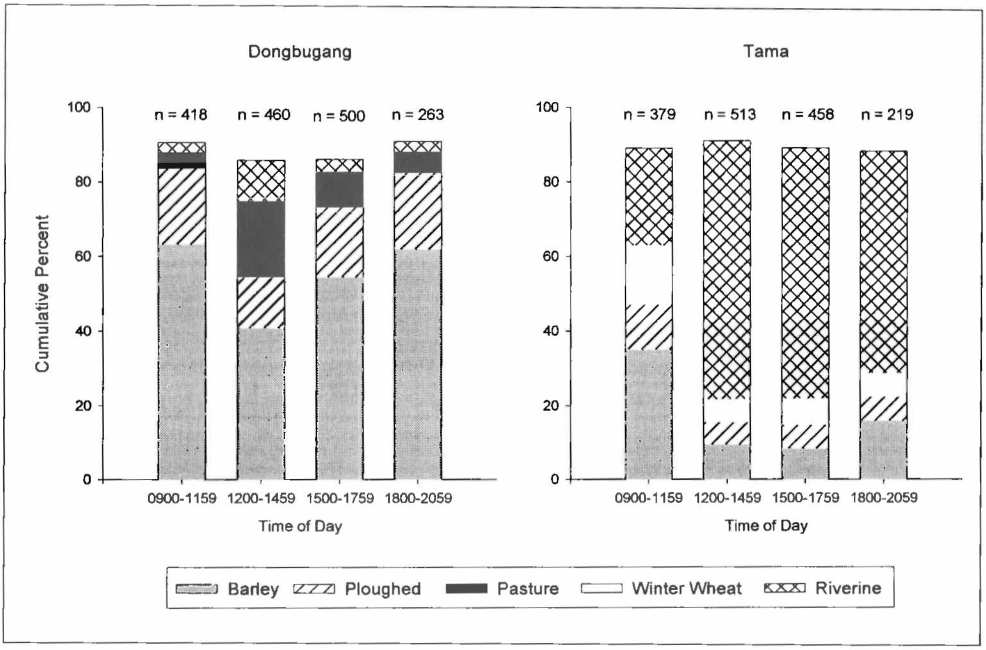


Figure 2. Black-necked Crane diurnal habitat use for major habitat types by time of day. Dongbugang Tibet, December 1990, and Tama Tibet, February-March 1991. Barley = barley and spring wheat stubble, *n* = number of flock locations.

and eastern Yarlung River emphasize autumn ploughing, and often waste grain is available in only small quantities.

Cranes were tolerant of human activity and often fed close to villages and roads. Although < 2% of all cranes were within 100 m of a village, an additional 32% were within 100 and 500 m. Similarly, we noted 7% of all cranes within 100 m of a primary road and 33% between 100 and 500 m from a road. Black-necked Cranes were often close to rivers, with 17% of all cranes observed within 100 m of a main or secondary river channel.

Dongbugang-North Lhasa River. An average of 129 $\pm$ 47 (SD) birds were recorded per hourly scan (range = 11-254) on this study site. Densities on upland areas ranged from 0.05-1.1 birds/ha. The maximum number of birds recorded in a single flock ranged from 62-226 birds/observation day.

The previous 1990 autumn at Dongbugang, approximately 70% of the harvested fields were barley, 10% rapeseed, and 20% spring wheat and broadbeans. For all social classes, barley stubble fields were the most frequently used diurnal habitat (x= 55%) followed by plowed fields (18%). Few flocks >30 birds fed exclusively in ploughed fields, although several flocks straddled ploughed and barley/spring wheat stubble fields. While small flocks ($\leq$ 30) often fed in pasturelands, few large flocks did (**Table 2**). Cranes rarely were noted close to villages, with only 1% of all observations within 100 m.

Feeding was the predominant diurnal activity across all habitats (84% of all cranes observed) followed by resting and sleeping (7.5%), and a combination of feeding and resting (6%). In agricultural fields >90% of both family groups and all other flocks fed. Family groups (1 or 2 adults with 1 or 2 chicks) in both riverine and pasture habitats fed more than other cranes. In river edge habitat (within 5 m of the river), 29% of the family groups fed whereas 85% of all other cranes rested. In native and stony pasturelands at Dongbugang, 71% of the family

Table 2. Percent occurrence of Black-necked Crane observations by habitat type and social class at Dongbugang and Tama, Tibet, Peoples Republic of China. Observations at Dongbugang conducted 3-28 December 1990 (N = 1,585), and at Tama 14 February-10 March 1991 (N = 1,464).

	Dongbugang, Llasa River						Tama, Yarlung River				
Habitat	1-2 *n*=403	Family[1] *n*=549	3-10[2] *n*=164	11-30 *n*=186	31-100[3] *n*=178	>100 *n*=105	1-2 *n*=296	Family[1] *n*=798	3-10[2] *n*=130	11-30 *n*=99	31-100[0] *n*=141
<u>Agricultural Habitat</u>											
Barley or Spring Wheat Stubble	52.1	58.8	53.0	44.6	65.7	51.4	6.8	16.2	14.6	25.3	41.8
Barley Stubble & Winter Wheat[5]	-	-	-	-	-	-	0.3	0.1	3.1	0	6.4
Ploughed Field	24.6	24.8	17.1	11.3	1.7	1.0	3.4	11.7	7.7	3	1.4
Ploughed Field & Stubble[5]	0.5	2.6	4.9	12.4	12.9	24.8	0.3	0.6	0.8	2	8.5
Winter Wheat	-	-	-	-	-	-	6.4	10.9	10.8	5.1	8.5
Ploughed Field & Winter Wheat[5]	-	-	-	-	-	-	0.7	1.8	1.5	1	2.8
Unknown Field	0.2	0.2	0	0	0	0	0.7	0.6	0.8	0	0
Ditch (dry)	1.5	2.7	0.6	1.1	7.9	7.6	1.4	6.6	3.1	8.1	2.8
<u>Edge Habitat</u>											
Crop/Pasture Interface	0.7	2.4	1.8	4.3	2.8	8.6	0	0.1	0	0	0
Crop or Pasture/River	0.2	0.5	0	1.1	0.	2.9	0.3	0	0	0	0
<u>Pasture Habitat</u>											
Native Pasture	11.7	5.8	11.0	8.1	1.7	1.9	2.4	0.6	0	1.0	0
Stony Pasture	2.5	0.9	4.9	7.5	1.1	0	-	-	-	-	-
<u>Riverine Habitat</u>											
River Edge <5m	5.7	1.3	6.1	9.1	6.2	1.9	25.7	18	20.8	18.2	15.6
Floodplain Pasture	-	-	-	-	-	-	51.4	32.5	36.2	36.4	12.1
<u>Other Habitats</u>	0.2	0	0.6	0.5	0	0	0.3	0.3	0.8	0	0

[1] 1 or 2 adults with 1 or 2 chicks
[2] Does not include flocks of 3-4 birds where chick presence or absence could not be determined
[3] Maximum flock size was 254
[4] Maximum flock size was 83
[5] Cranes straddled both habitats

groups fed compared with 41% of all other cranes.

When habitat use is examined by time of day, morning (0900-1159) and late afternoon (1800-2059) hours were spent primarily in croplands (**Figure 2**). Although our study area included few quadrats bordering the river, midday habitat use (1200-1459) was characterised by an increased use of river edge and pastureland (at Dongbugang, typically located adjacent to the river). This movement to the river during the early afternoon hours coincided with an activity shift from feeding to resting, with percentage of birds resting increasing from 4% in the morning to 25% during 1200-1459 (**Figure 3**).

Tama-Yarlung River. High winds forced us to discontinue observations before 1900 on 11 of the 23 field days. Because at times portions of the study area were obscured by dust, it was not possible to calculate a meaningful average number of birds per hourly scan. Compared to Dongbugang, however, total crane numbers at Tama were lower. Hourly scans with >100 birds across the entire study area (including riverine habitats) occurred on 10 of the 23 days (max = 169 birds/scan). The maximum number of birds recorded in a single flock ranged from 40-83 birds/observation day.

The previous 1990 harvest at Tama included approximately 45% spring barley, 19% spring wheat, 20% winter wheat, and 15% rapeseed and broadbeans. Upland habitats at Tama included minimal (<1%) native pasture. At Tama, cranes on upland areas tended to use agricultural fields bordering the river. Some 39% of all observations were within 150 m of the river (n=666 upland observations). At the same time, cranes were never observed in 14 upland quadrats (284 ha, 31% of the upland study area), and were observed ≤ 2 times in another six upland quadrats (172 ha, 19% of the upland study area).

At Tama, riverine habitats (within 5 m of the river and floodplain pastures) were the most

Figure 3. Black-necked Crane primary activity by time of day. Dongbugang Tibet, December 1990, and Tama Tibet, February-March 1991. n = number of flock locations.

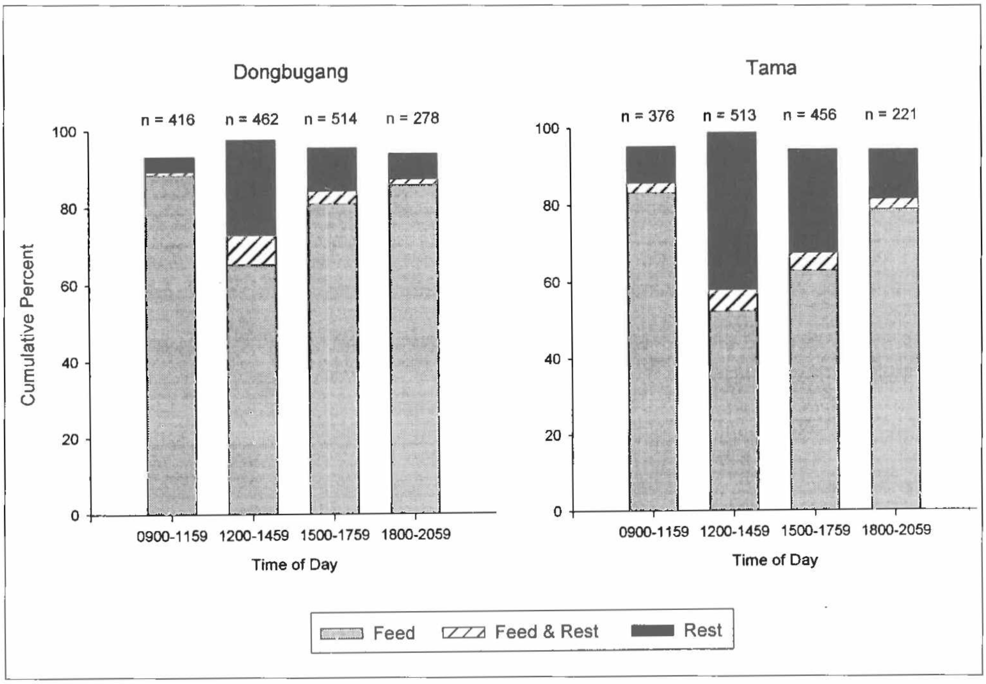


Table 3. Upland habitat selection of Black-necked Cranes wintering at two sites in south-central Tibet, winter 1990-91.

Site and Habitat Type	Crane Hours	% Availability[a]	% Use	Preference Index[b]	Selection Ratio[c]	95% C.I.[d] Lower	95% C.I.[d] Upper	Selection[e]
Dongbugang								
Barley or Spring Wheat Stubble	22,294	52	78	1.52	0.47	78	79	+
Ploughed Field	4,718	34	16	0.48	0.15	16	17	-
Ditch (dry)	564	2	2	0.96	0.30	2	2	
Native Pasture	1,009	13	3	0.27	0.08	3	4	-
Total	29,255	100	100	3.24	1.00			
Tama								
Barley or Spring Wheat Stubble	5,119	27	62	2.31	0.76	61	64	+
Ploughed Field	1,157	50	14	0.28	0.09	13	15	-
Ditch (dry)	294	2	4	1.79	0.59	3	4	+
Winter Wheat	1,640	21	20	0.96	0.32	19	21	
Total	8,210	100	100	5.34	1.76			

[a] Upland habitats only

[b] Preference index = % use/% availability

[c] Selection ratio: probability that category i selected if all resources equally available

[d] Ho: % use = % available

[e] + indicates use exceeded availability, - indicates habitat underutilised in relation to availability

frequently used diurnal habitats (x = 56.7% observations), followed by barley/spring wheat stubble fields (16.3%; **Table 2**). Similar to Dongbugang, morning hours (0900-1159) were when the highest numbers of observations were recorded in agricultural habitats. A shift to riverine habitats during the afternoon hours coincided with an increased percentage of birds resting (41%) during 1200-1459 (**Figure 3**). There was a slight shift back to croplands in the late afternoon hours (1800-2100) prior to flying to roost (**Figure 2**).

Among social classes, the largest percentage of observations in the riverine habitats were of pairs (77%). Family groups and flocks $\leq$ 30 birds were observed in riverine habitats in >50% of all their observations. Large flocks (range 31-83 birds, n=141), were observed in riverine habitats only 28% of the time, the remaining time spent in agricultural fields (**Table 2**). Cranes were rarely seen close to villages. Only 2% of all upland observations occurred within 100 m of a village, and almost 80% of the cranes observed on uplands were >300 m from a village.

Feeding was the predominant diurnal activity across all habitats (69% of all cranes observed) followed by resting and sleeping (21%), and a combination of feeding and resting (6%). Similar to Dongbugang, >90% of all cranes at Tashigang fed while in agricultural fields. Family groups fed more often than all other cranes while along the river edge (44% vs. 12%) and in floodplain pasture (69% vs. 56%).

Upland Habitat Selection

To assess habitat preference by study site, we compared the observed use of upland habitat types (based on total bird hours as determined from diurnal scan samples) with the availability of upland habitats within each intensive study site. Chi-square analyses of diurnal locations indicated that at both study sites, cranes used upland habitats disproportionately (P < 0.001) to their respective availability within the study site. At both Dongbugang and the Tama study sites, barley/spring wheat stubble fields were preferred and ploughed fields avoided by cranes. At Dongbugang no winter wheat was planted in the 1990-91 winter. At Tama winter wheat comprised 21% of the upland habitat and was used in proportion to its availability (20%;**Table 3**). Ditches were preferred by cranes at Tama, and used in proportion to their availability at Dongbugang. Native pasture was avoided at Dongbugang, but did not occur at Tama.

Selection ratios, the estimated probability that a category is selected if all resources are equally available, indicate that at Dongbugang barley/spring wheat stubble fields were selected about three times and six times the probability of ploughed fields and native pastures, respectively. At Tama, barley/spring wheat stubble fields were estimated to be selected more than twice the probability of a winter wheat field, and eight times the probability of a ploughed field (**Table 3**).

Roost Sites

In the Penbo River Valley north of Lhasa, as many as 500 Black-necked Cranes roost on the shorelines of two large reservoirs, Houtou and Kazi. Elsewhere, cranes roost in the slower moving waters of the secondary channels of the Lhasa, and Yarlung Rivers. They also roost on some of the major tributaries of the Yarlung and Lhasa Rivers, such as the Re River near Tashikang. During December 1990 and 1993 we located and took measurements at nine roost sites on the Lhasa River. All sites were located on secondary river channels with light to moderate currents. Average channel width was 29.4 m (min=10 m, max=60 m). At two sites, the secondary channel was frozen. At the remaining seven sites, water depth in the channels ranged from 4 cm to >100 cm. Based on feathers, and droppings, we estimated that the cranes roosted in water depths averaging 15.8 cm (n=7). For all roost sites, the substrate was cobble, or cobble with sand.

At seven roost sites, views in at least one direction were obstructed within 20 m by river shorelines ranging in height from 100-200 cm. For all roosts, however, visibility in at least two directions was >1 km. Vegetation on surrounding upland and floodplain areas was typically dominated by shrubs (*Sophora* *moorcroftiana* and *Myricaria* spp.) and grasses (*Astragalus strictus* and *Pennisetum flaccidum*) with heights from 30-80 cm. Adjacent upland and floodplain areas were often used for grazing livestock, during the day. Our sample, however, was biased towards accessible roosts, and hence closer to human settlements. Of the roosts we located, distance from human settlements ranged from 500-2000 m.

Discussion

Several factors have contributed to the importance of south-central Tibet for the world's population of Black-necked Cranes. The agricultural fields adjacent to the Lhasa, Yarlung, and Nyang Rivers and their major tributaries provide abundant feeding habitat. The broad expanse of river channels along the Lhasa and in portions of the Yarlung River together with reservoirs in the Penbo River Valley provide high quality roosting habitat. While south-central Tibet's major river valleys include the highest human population densities for this region, compared with the rest of China, densities are very low. Cranes are often tolerant of farmers working nearby in agricultural fields, and disturbance to cranes by livestock herders is most often temporary, with cranes flushing short distances in response to disturbance (Bishop *et al.*, unpubl. data). The predominance of Buddhism also provides a cultural basis that prohibits hunting or in any way hurting animals, and lends additional strength to the Black-necked Crane's government-protected status.

Black-necked Cranes are opportunistic and omnivorous feeders (Bishop 1996). In Tibet, cereal grains are important nutrient sources for wintering cranes. Fecal analyses has shown that more than 70% of the total foods consumed by wintering Black-necked Cranes in Tibet are barley, spring wheat, and winter wheat (Bishop and Li, unpubl. data), indicating they are the principal food source. This reliance on cereal grains has also been documented for the Sandhill Crane (*Grus canadensis*) in North America. Iverson and others (1982) examined stomach contents of 300 Sandhill Cranes and found that cereal grains (wheat, barley, corn, and milo) made up over 96% of the aggregate volume of food items from winter through spring migration. And, in a study of Sandhill Cranes wintering in western Texas, Tacha and others (1987) estimated that cereal grains provided >95% of the energy during winter based on time and energy budgets.

Black-necked Cranes used unploughed waste grain fields and ditches in excess of their availability and demonstrated an avoidance of ploughed fields relative to their availability. This preference may reflect the greater availability of surface residue in stubble fields and ditches (often reservoirs for wind-blown waste grain). Bishop and Li (unpubl. data) found that compared with barley and spring wheat stubble fields, ploughed fields in south-central Tibet have significantly lower residue cover and surface waste grain. Similar habitat use patterns have been observed in Sandhill Cranes during spring at Saskatchewan Canada and central Alaska. On upland areas Sandhill Cranes exhibited the highest preference index for wheat stubble in Canada and barley stubble in Alaska, whereas tame grass pasture and ploughed fields were avoided (Iverson *et al.* 1987). Black-necked Cranes wintering in and around the Caohai Nature Reserve in Guizhou, however, showed a markedly different preference towards agricultural fields. There, farmlands (primarily corn, bean, potatoes) were the least preferred habitats, while sedge meadows and grasslands were the most preferred habitats. The area around Cahohai, however, is highly populated, and human disturbance by farmers ploughing and planting were believed to negatively affect crane use of agricultural fields (Li 1997).

At both Dongbugang and Tama, the highest percent of cranes feeding and highest use of agricultural fields by cranes occurred during morning hours. Midday use was characterised by an increased use of the river edge and at Tama, in floodplain pastures accompanied by increased resting behavior. At Dongbugang use of agricultural fields during late afternoon hours (1800-2059) was almost equivalent to morning use. Bishop (1988) noted a similar diurnal pattern with radio-tagged Florida Sandhill Cranes (*Grus canadensis pratensis*) where cranes spent morning and late afternoons primarily in improved pastures or croplands, with midday habitat use characterised by an increased use of wetlands.

Management Implications

Currently there appears to be an abundance of suitable roosting habitat on the Lhasa and Yarlung Rivers. Some roosting habitat, however, could be lost due to dam construction and tree planting. Recently the China Electricity Council in Beijing announced that a large dam will be built as part of hydroelectric project at Zhikong on the Lhasa River, approximately 25 km northeast of Maizhokunggar (Anon. 1993). This dam could have a tremendous impact on the more than 1,000 Black-necked Cranes that winter along the Lhasa River.

Dams reduce water flow downstream, peak flow, and the duration of the peak flow. The result is that sandbars and other floodplain herbaceous habitats are not scoured or flooded as before thus allowing for the invasion of trees, brush and shrub. The ultimate effect of a dam can be a change in river morphology, including a decrease in channel width and channel area. This means a loss of roost habitat for the cranes. On the Platte River in the United States, diminished flow due to upstream dams has resulted in a reduction of the channel width by as much as 85% over a century (Williams 1978). Krapu and others (1984) found that Sandhill Cranes do not tolerate Platte River channels where visibility has been sharply reduced, and ultimately, thousands of cranes have abandoned much of their former staging area in the Platte Valley (Krapu *et al.* 1982). The proposed project at Zhikong on the Lhasa River must take into account the need to maintain high peak flows of a long enough duration and great enough frequency to insure that crane roosting habitat will not be lost to an invasion of shrubs and trees.

In some areas of the Lhasa and Yarlung River Valleys, large expanses of *Salix*, *Populus*, and *Hippophae* trees are being planted. Before large areas of trees are planted on either the Lhasa or Yarlung Rivers, the area should be surveyed during the winter for crane roost sites to insure that roost habitat is not limiting. For example, along a 19 km stretch of the Lhasa River northwest of Maizhokunggar town approximately 150 cranes winter. Suitable roosting habitat is available in only a 4 km segment where the river broadens into several channels and there are sandbars. Any tree planting along this 4 km river floodplain would be detrimental for the cranes.

Agriculture, more than any other human activity, has had an important effect on Black-necked Cranes. Most counties where cranes winter in Tibet require that farmers plough their fields immediately after harvest to control weeds and increase production. While it varies, in some counties almost 100% of the barley and spring wheat fields are ploughed in autumn. The immediate effect of ploughing is to make available invertebrates such as earthworms, snails, and insects. However, ploughing leaves little waste grain available on the surface for cranes to eat.

During this study, high-altitude varieties of winter wheat constituted a principal crop along the Lhasa River at Dagze, Quxu, and Doilungdeqen Counties, and along the eastern Yarlung River in the Gonggar, Chiteso, Dranang, and Nedong counties. Since then, their cultivation has increased, including in counties such as Maizhokunggar where it was not grown for several years. On our crane surveys we found that areas growing a high percent of winter wheat have lower numbers of Black-necked Cranes (Bishop *et al.*, unpubl. data). We believe this may be because winter wheat offers little food on the surface for cranes, even though the cranes will eat the planted seeds. A combination of large amounts of winter wheat and of ploughed barley and ploughed spring wheat fields could increase the likelihood of crop depredation to winter wheat by cranes because of the reduced waste grain available as a food resource.

There is a need to find a compromise between agriculture and crane conservation needs. Currently Implementation of Agricultural Management Zones (AMZs) in primary Black-necked Crane wintering areas could serve to minimize conflicts between Black-necked Cranes, Bar-headed Geese and agricultural interests (see Bishop *et al.* 1997, Bishop *et al. in press*). Based on our current knowledge of habitat use, we recommend in areas with a high amount of winter wheat, that fewer spring barley and spring wheat fields be ploughed in autumn. By leaving some harvested fields unploughed between November and March, the preferred waste grain would be more readily available on the surface. Stubble fields could also serve as lure crops to draw cranes away from planted winter wheat, and minimize crop depredation.

Ultimately, the effectiveness of modifying current agricultural practices as a crane conservation strategy will need to be evaluated closely and revised based on experience and research. The economic costs of altering agricultural practices to benefit cranes, including changes in harvest yields, must be compatible with farmers' living needs. There is a need for agricultural studies that experiment with ploughing schedules and their effect on crop yields. Future studies of Black-necked Cranes wintering in Tibet, especially those interested in calculating necessary food supplies for cranes, should experiment with the effects of habitat quality on crane use, including the amount and dispersion of grain stubble fields and the availability of surface waste grain throughout the winter months.

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