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Brian W. Johns
Environment Canada, Canadian Wildlife Service

Eric J. Woodsworth
Environment Canada, Canadian Wildlife Service

Ed A. Driver
Environment Canada, Canadian Wildlife Service

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BRIAN W. JOHNS, Environment Canada, Canadian Wildlife Service, 115 Perimeter Road, Saskatoon, SK S7N 0X4, Canada
ERIC J. WOODSWORTH, Environment Canada, Canadian Wildlife Service, 115 Perimeter Road, Saskatoon, SK S7N 0X4, Canada
ED A. DRIVER, Environment Canada, Canadian Wildlife Service, 115 Perimeter Road, Saskatoon, SK S7N 0X4, Canada

Abstract: We investigated habitat use by migrating whooping cranes (*Grus americana*) in Saskatchewan between 1986 and 1990. At foraging and roosting sites and a sample of randomly selected sites we measured various habitat parameters. Palustrine and lacustrine wetlands were the most frequently used wetlands. Temporary and seasonal wetlands were the primary roost habitat during spring migration, and semi-permanent and permanent wetlands were frequently used during the fall. Cranes were attracted to areas of higher than average wetland density. Land use within 2 km of roost sites was intensively modified by man. Cereal crops were the most used feeding areas. Mean distances to potential disturbance were lower in spring than in fall. Because the wetlands used were primarily in private ownership, a cooperative approach to wetland preservation is needed between wildlife managers and landowners.

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Key words: *Grus americana*, habitat use, migration, Saskatchewan, whooping crane.

Though the current whooping crane breeding area lies within Wood Buffalo National Park (WBNP), Canada, the historical nesting area encompassed the prairies of southern Canada and the north-central United States (Allen 1952). Saskatchewan was once the center of the former nesting area in Canada. The last recorded nesting site outside the WBNP area was at Luck Lake, Saskatchewan, in 1927 (Hjertaas 1994).

Whooping cranes do not currently breed in Saskatchewan, but individuals of the Wood Buffalo/Aransas population spend several days to weeks in the province each year (Johns 1992). Each spring and fall, this remnant population migrates through Saskatchewan between the breeding area in WBNP, Northwest Territories, and wintering grounds on the Aransas National Wildlife Refuge, Texas (Allen 1956).

From a radio tracking study of whooping crane migration (Howe 1989), Saskatchewan ranked third in reported crane spring stopovers (12.8%), behind Kansas and Nebraska. However, the Saskatchewan stopovers comprised 43.7% of all crane use-days during the spring migration. In the fall migration period, whooping cranes made more extended stopovers in central Saskatchewan than anywhere else along their migration route (Johnson and Temple 1980, Howe 1989, Armbruster 1990). Forty percent (40.4%) of fall stopovers occurred in Saskatchewan, accounting for 68.4% of crane use-days during fall migration.

Though the value of south-central Saskatchewan as a fall staging area for whooping cranes was described by Howe (1989), Johns (1992), and Kuyt (1992), the lack of detailed information on how this staging area is used by migrating whooping cranes prompted the Canadian Wildlife Service to conduct this investigation. This report documents habitat use by whooping cranes on the Saskatchewan staging area for the period 1986 to 1990.

We thank all the observers who reported whooping crane sightings, and the landowners who allowed us access to their land. Thanks also go to T. Stehn and D. Nieman for reviews of earlier drafts of the paper.

STUDY AREA

Known and potential whooping crane habitat in Saskatchewan exists in a 300-km-wide band which crosses the province diagonally for 1,000 km from just south of Lake Athabasca in the northwest to Estevan in the southeast. We examined traditional and non-traditional sites from the Mixedwood Forest and Aspen Parkland interface (Bird 1961, Harris et al. 1983, Kabzems et al. 1986) to the Canada-U.S.A. border. This encompasses the agricultural portion of the province and all of the historical breeding area in Saskatchewan. If staging or stopover sites (Armbruster 1990) exist on the northern igneous (granitic) shield of Saskatchewan (Richards and Fung 1969), these sites remain to be reported.

The landscape of agricultural Saskatchewan is comprised of a series of low, gently rolling hills, deposits of terminal moraine from the last glaciation, interspersed with river valleys and flat glacial lacustrine plains between the southern edge of the Mixedwood Forest (54° 30'N) and the international border (49° 00'N). Cultivated fields, small groves of aspen (*Populus tremuloides*), and hundreds of thousands of wetlands dot the farmland landscapes. Eighty percent of this land is cultivated; the dominant crop, wheat, represents 65% of the cultivated acreage while barley and canola are the next 2 most common crops. The area is crisscrossed with paved and secondary roads in a 2- by 1-mile grid. Historically, 2 of the 4 quarters of each section were settled, a maximum of 140,000 farmsteads by 1945 (Driver 1991). Subsequently, the number of farmsteads dropped to the current 59,000 active farms (Saskatchewan Agriculture and Food 1991). Many of the 80,000 abandoned farmsteads now are incorporated into cultivated fields.

Table 1. Characteristics of whooping crane roost sites (%) in Saskatchewan, 1986–90.

Variable	Spring	Fall	Random	Variable	Spring	Fall	Random
Wetland system (*n*)	(55)	(46)	(28)	Site security	Stable	Stable	Stable
Riverine	0	6	4	Turbidity (*n*)	(48)	(47)	(26)
Lacustrine	16	61	36	Clear	88	66	85
Palustrine	84	33	61	Turbid	6	21	4
Wetland type (*n*)	(48)	(29)	(26)	Saline	6	13	12
I	21	0	8	Substrate (*n*)	(44)	(42)	(28)
III	52	14	31	Soft mud	52	83	50
IV	19	31	19	Hard mud	32	10	32
V	8	55	42	Detritus	11	0	11
Site ownership (*n*)	(55)	(46)	(27)	Sand	2	0	7
Private	96	85	96	Ice	2	0	0
Provincial	4	13	4	Other	0	2	0
Federal	0	2	0	Dominant emergents (*n*)	(47)	(35)	(23)
Site description (*n*)	(47)	(48)	(28)	*Scholochloa*	40	6	26
Semi-permanent marsh	62	48	43	*Scirpus*	19	43	26
Flooded cropland	21	2	7	*Carex*	19	29	22
Lake	9	40	21	*Typha*	2	11	13
River	0	4	0	Other	19	11	13
Reservoir	6	6	4	Vegetation density (*n*)	(53)	(47)	(28)
Dugout	0	0	11	None	17	32	21
Flooded pasture	0	0	4	Scattered	19	13	14
Wet meadow	2	0	4	Clumped	11	17	7
Creek	0	0	7	Choked	28	0	18
Other species (*n*)	(56)	(48)		Ringed	25	38	39
None	22	20		Wetland class (*n*)	(56)	(46)	(26)
Sandhill cranes	15	33		Emergent wetland	59	22	35
Geese	24	33		Unconsolidated bottom	25	59	46
Ducks	24	5		Aquatic bed	14	4	8
Swans	5	10		Unconsolidated shore	2	9	0
Shorebirds	10	0		Rocky shore	0	2	0
Adjacent habitat (*n*)	(54)	(44)	(24)	Streambed	0	4	4
Stubble	41	32	13	Forested wetland	0	0	8
Fallow	33	16	46	Wetland modifier (*n*)	(56)	(47)	(28)
Cultivated stubble	13	0	8	Permanently flooded	5	32	50
Swathed crop	0	5	0	Semi-permanently flooded	16	53	18
Flooded cropland	2	0	0	Seasonal	57	9	21
Pasture	9	32	17	Saturated	0	0	4
Flooded pasture	0	2	0	Temporarily flooded	7	0	4
Hay meadow	2	5	0	Intermittently flooded	11	0	0
Wet meadow	0	9	4	Artificially flooded	4	4	4
Other	0	0	13	Intermittently exposed	0	2	0

METHODS

To determine locations and to assess the characteristics of the habitat whooping cranes use in prairie Saskatchewan, we obtained reported sightings of cranes from the Whooping Crane Hot Line (Johns 1992) as well as from other observers. All locations were plotted on 1:250,000 and 1:50,000 Geological Survey of Canada (GSC) topographic map sheets and 1:20,000 aerial photo-mosaics which were produced by Central Survey and Mapping, the Province of Saskatchewan.

Habitat composition and land use characteristics for spring and fall migrating cranes were evaluated for all observed roost and feeding locations between fall 1986 and spring 1990. Thirty-seven habitat attributes (Appendix A) were recorded for these sites; several are similar to those described in Howe (1987) and Armbruster (1990). Major measurements at upland foraging locations included 17 categories for site description and adjacent habitat, topographic slope, visibility in 4 cardinal directions, security of the site, associated bird species, and the extent of similar habitat. Visibility was measured at 1.4 m above ground, the average crane head height (Armbruster 1990). Water depth, water quality, substrate type, shoreline slope, dissolved solid conductance, dominant emergent vegetation, and wetland classification were noted for observed roosting and potential roost sites selected at random (Appendix A). Wetland classification followed Stewart and Kantrud (1971) and Cowardin et al. (1979). The area of wetlands and upland habitats (fields, aspen groves, farmsteads) within 2 km of roost and potential roost sites was measured electronically from 1:20,000 photo-mosaics.

Roost site data were divided into traditional and nontraditional categories, the former representing townships with multiple sightings or adjacent townships each with at least 1 sighting, the latter being single sightings in isolated townships. Roost site data were also divided into sites used by family groups and non-family groups. All variables were evaluated to determine whether their distributions were normal before proceeding with comparative statistical analyses. Distance to buildings, roads, and powerlines; shoreline slope; and pH, all normally distributed, were analysed with canonical discriminant analysis (SAS Institute Inc. 1990). Logistic regressions were performed on non-normally distributed quantitative data of sets of variables including topographic slope, wetland area, distance to feeding site, distance to trees, specific conductance, and visibility. Measures of central tendency were made for most mensural values; these values provide the initial description of roost and feeding sites.

RESULTS AND DISCUSSION

Roost Site Characteristics

Two wetland systems, palustrine and lacustrine, were frequented by whooping cranes migrating through Saskatchewan. Palustrine wetlands were most frequently used during spring (84% of the sites observed, $n = 55$) (Table 1). Use of palustrine sites in fall was only 33% ($n = 46$). During spring, 16% of whooping crane observations were from lacustrine wetlands compared with 61% use in the fall. The remaining 6% of fall roosting sites were riverine. Distribution of potential wetland systems available to cranes differed substantially from the observed results. In the random sample, 61% of the wetlands were classified as palustrine and 36% belonged to the lacustrine system.

The wetlands within the 2 systems generally belong to 1 of 4 wetland classes (Stewart and Kantrud 1971). Class I and III represent the more ephemeral wetland type and are referred to as temporary and seasonal wetlands, respectively. These classes were most common during the period April through July and had a 73% visitation rate ($n = 48$) from cranes migrating northward. Temporary and seasonal wetlands undergo considerable or complete water drawdown primarily from evapo-transpiration processes. With the disappearance of more than 95% of Class I and III wetlands, fall migrating cranes shift to favourable Class IV (semi-permanent) and Class V (permanent) wetlands (Tables 1 and 2). During the fall period, these wetlands represented 86% of the observed roosting wetlands. The remaining fall roosting habitat was composed of Class III wetlands. The degree to which Class IV and V wetlands are used in successive migrations is extremely small. We found few instances of repeated use of the same or nearby wetlands. Thirteen localities were used by a number of different cranes during the study period but never more than once by the same crane. Four additional sites were used by the same birds on a subsequent migration. Spring "staging" areas are much less predictable because of the vagaries of fall precipitation and spring run-off that help create temporary and seasonal wetlands.

Table 2. Frequency of wetland types used by migrating whooping cranes in Saskatchewan, 1986-90.

Type	Family groups		Non-family groups		Random
	Spring	Fall	Spring	Fall	
Class I	3	0	7	0	2
Class III	7	1	18	3	8
Class IV	0	5	8	5	5
Class V	2	7	2	9	11

The majority of wetlands are relatively fresh (Stewart and Kantrud 1971) with salinities less than 5,000 micromhos (Table 3, Fig. 1) and slightly alkaline, pH averaging 7.7 in late spring and 7.9 in fall (Table 3). On average, wetlands used for roosting were large. Spring sites averaged 36 ha ($\pm$136.9 SD), whereas fall roosts were 14 times as large, averaging 508 ha (Table 3). Crane use of wetlands depends primarily on wetland size and permanency. Fewer than 5% of the approximately 1-2 million wetlands in the spring landscape are greater than 1 ha (U.S. Department of Interior and Environment Canada 1995). Large wetlands exist primarily on glacial lake basins, on glacial lake deltas, and at the edges of terminal moraine deposits.

Family groups were attracted to areas of relatively high wetland density. Within a 2-km radius of a roosting site, approximately 16% of the area was wetlands compared to 9% for randomly selected sites (Fig. 2). However, this trend was not significant. A similar trend was noted for cross-

Table 3. Characteristics of whooping crane roost sites ($\bar{x}$) in Saskatchewan, 1986-90.

Variable	Spring			Fall			Random		
	n	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD
Specific conductance (micromhos/cm^3)	30	4,080	13,294	30	6,178	12,880	22	1,825	1,852
pH	35	7.7	0.48	32	7.9	0.56	22	8.0	0.55
Wetland area (ha)	39	36.0	136.9	38	508	1,806	28	974	4,687
Water depth (cm)	30	15.8	7.2	32	12.9	7.5			
Shoreline slope (°)	46	2.2	1.02	32	2.1	1.18	28	5.7	8.23
Visibility[a]	220	1.9	1.05	188	2.5	1.38	112	1.98	1.30
Distance to nearest trees (m)	43	237	267	39	303	379	24	150	223
Distance to upland feeding site (m)	23	419	782.1	37	992	1,248.6	23	177	239.7
Distance to nearest buildings (m)	52	714	468	45	1,037	488	24	578	491
Distance to nearest roads (m)	43	616	631	41	654	488	26	474	327
Distance to nearest powerlines (m)	29	687	437	22	845	508	10	319	287
Topographic slope (°)[b]	224	4.5	4.8	192	3.3	4.7	112	4.0	4.1

[a] 1 = <100m, 2 = 0.1-0.25 km, 3 = 0.25-0.5 km.
[b] Average within 500 m.

fostered whooping cranes in southern Colorado (Shenk and Ringelman 1992).

Armbruster (1990) considered the optimum water depth at roosting sites to be less than or equal to 30 cm. In Saskatchewan, water depth at spring roost sites averaged 15.8 cm in depth (range 3-30), whereas depths at fall sites were on average 2.9 cm shallower (Table 3). These results are similar to those reported by Ward and Anderson (1987) and Howe (1989).

Regardless of season, sites selected by cranes had very gently sloping littoral zones ($\bar{x}$ = 2.15°) (Table 3) which were significantly different from the 5° average of the shoreline slopes ($P < 0.001$) in the random sample of the Saskatchewan migration corridor. These shallower basins used by migrating cranes may afford greater protection from predators. Shallow basins of moderate area may allow cranes to roost at greater distances from shore. This may provide a distance discouragement to predators while providing a visibility (Table 3) advantage to the crane. A basin with a more abrupt shoreline reduces the width of safety zone.

Ninety-six percent of spring roosts and 85% of fall roosts were on private land (Table 1). Because most of these are

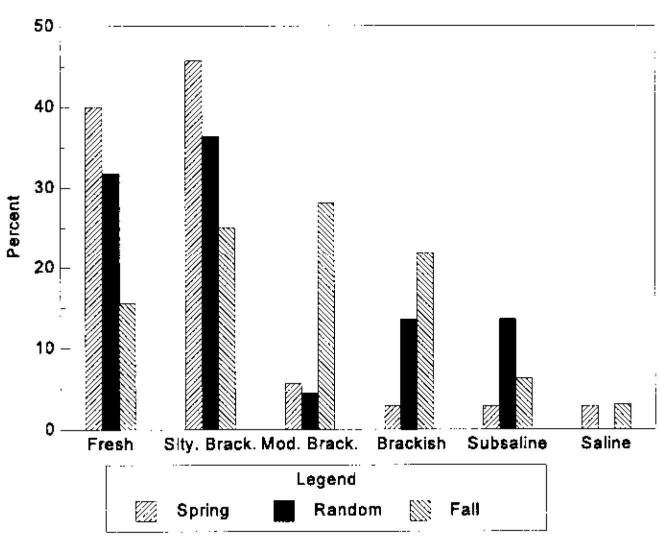

Fig. 1. Water quality of whooping crane roost wetlands in Saskatchewan, 1986-90 (Stewart and Kantrud 1971).

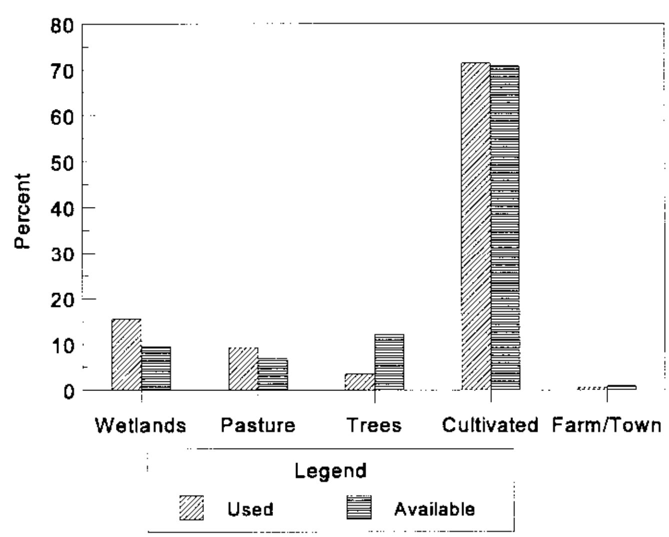

Fig. 2. Land use within 2 km of whooping crane family roost wetlands in Saskatchewan, 1986-90.

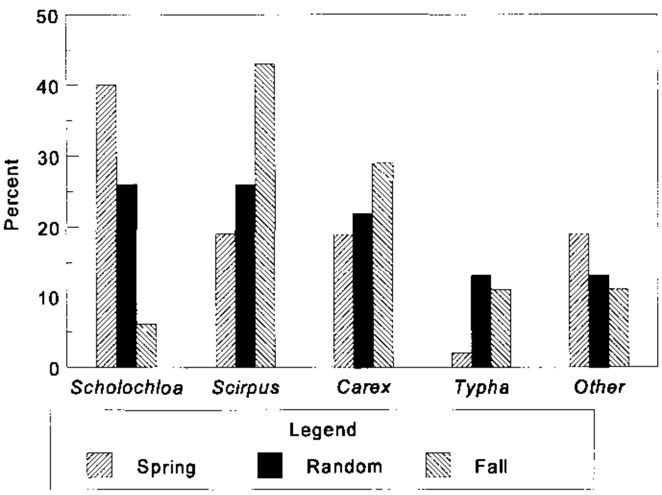

Fig. 3. Dominant emergent vegetation at whooping crane roosting sites in Saskatchewan, 1986-90.

located within cultivated fields with vegetation <0.3 m in height, they provide an increased safety factor to cranes. This surveillance factor also appeared to influence how close the roost was to trees. Roost sites were at greater distances from trees ($\bar{x}$ = 237 m in spring and 303 m in fall) than were random sites ($\bar{x}$ = 150 m) (Table 3).

On most large lacustrine wetlands, small, widely dispersed stands of *Typha* spp. and *Scirpus* spp. occur. This emergent vegetation does not appear to impede cranes' surveillance of their surroundings. In spring, growth has yet to begin and many of the overwintering stems are bent over and compressed by snow and/or broken by strong winds. By fall this emergent vegetation also is reduced in height from its summer stature. Most of these stems measure 0.6 to 1.2 m; the flower spike of *Typha* is 1.2-1.6 m in height, compared to an average height of 1.4 m for cranes. Class I and III habitat is dominated by grassy species of *Scholochloa* spp. and *Carex* spp. (Fig. 3).

In the southern half of Saskatchewan, the potential for feeding sites within 1 km of a roost site was greater (P = 0.0001) during spring migration (94.9%) than fall (72.9%). This difference was reflected in the distance the cranes fed from their roosts, averaging 419 m in spring and 992 m in fall (Table 3). Within the entire migratory corridor, Howe (1989) found foraging site distance from roost ranged from 100 to 8,000 m, 56.2% of these within 1 km of a roost.

There were no significant differences between roost sites used and random sites in the number ($\bar{x}$ = 3.0 and 3.6, respectively) and percent land area (0.6% and 0.9%) of farmyards and towns within 2 km of the roost site (Fig. 2). Roosts were, however, generally more isolated from human disturbance (buildings) ($\bar{x}$ = 714 m in spring and 1,037 m in fall) than randomly selected wetlands ($\bar{x}$ = 578); whooping cranes seemed less tolerant of human disturbance in fall than in spring, but differences were not significant (Table 3). Differences in tolerance to human disturbance between spring and fall may be related to the amount of disturbance the cranes experience in the intervening months before migration. The cranes' northern breeding grounds are isolated from human intrusion, unlike their southern wintering area. In a study of cross-fostered whooping cranes in Colorado, mean distance from roosts to buildings during fall migration was 738 m (Shenk and Ringelman 1992), similar to spring distances in Saskatchewan.

Whether cranes are aware of overhead wires, posing a threat to them while flying, has yet to be determined. However, the roost sites they chose were significantly farther (P < 0.0001) (Table 8) from overhead wires (687 m in spring, 845 m in fall) than were random sites (319 m) (Table

Table 4. Characteristics of upland feeding sites (%) used by whooping cranes in Saskatchewan, 1986-90.

Variable	Spring	Fall
Site description (n)	(99)	(98)
Stubble	82	77
Cultivated stubble	18	8
Pasture	0	6
Swathed grain	0	5
Fallow	0	1
Hay meadow	0	1
With other species (n)	(105)	(103)
None	80	58
Sandhill cranes	14	35
Geese	3	3
Ducks	3	1
Cattle	0	3
Crop type (n)	(98)	(87)
Wheat	62	57
Barley	28	36
Durham	7	3
Oats	2	3
Adjacent habitat (n)	(98)	(96)
Stubble	53	45
Fallow	37	21
Cultivated stubble	5	0
Swathed crop	0	4
Pasture	3	19
Flooded pasture	0	1
Hay meadow	0	7
Wet meadow	0	1
Other	2	1
Site security	Stable	Stable
Site ownership		
Private	100	100

Table 5. Characteristics of upland feeding sites ($\bar{x}$) used by whooping cranes in Saskatchewan, 1986–90.

Variable	Spring			Fall		
	n	$\bar{x}$	SD	n	$\bar{x}$	SD
Visibility[a]	408	2.4	1.1	404	2.9	1.38
Distance to nearest trees (m)	58	277	166	81	258	172
Distance to nearest buildings (m)	96	682	421	96	767	441
Distance to nearest roads (m)	56	399	3,223	81	528	611
Distance to nearest powerlines (m)	45	535	336	49	895	900
Topographic slope (°)[b]	408	2.1	3.6	404	1.8	3.1

[a] 1 = <100m, 2 = 0.1–0.25 km, 3 = 0.25–0.5 km.
[b] Average within 500 m.

3). In a sample of 35 roost sites in Colorado, Shenk and Ringelman (1992) found mean distances to be only 471 m from powerlines during fall migration.

Feeding Site Characteristics

Mean values and variation for the studied habitat characteristics of observed spring and fall feeding sites are given in Tables 4 and 5. This study and Howe (1989) found that the principal feeding sites for migrating whooping cranes were croplands adjacent to roost sites. The primary feeding sites in Saskatchewan were nearly all upland sites. Harvested cereal crop fields comprised 100% of all spring feeding sites and 85% of fall foraging sites (Table 4). Wheat stubble fields in Saskatchewan are the primary spring foraging sites for sandhill cranes (Iverson et al. 1982). There was no significant difference between spring and fall use of crop types (Table 6). Wheat fields (primarily red spring wheat) made up 60.5% of all feeding sites in croplands, and barley accounted for 31.5% (Fig. 4). During the study period, wheat crops averaged 3.6 million ha per year or 59.4% of the seeded cropland in the migration corridor through Saskatchewan and barley constituted 12.4% (Saskatchewan Agriculture and Food 1991) (Fig. 4).

As demonstrated with roost sites, visibility at feeding sites was also greater in fall than in the spring (Table 5). Upland feeding sites provided a greater degree of visibility ($\bar{x}$ = 2.4 in spring, 2.9 in fall) than did roost sites ($\bar{x}$ = 1.9 in spring, 2.5 in fall). Roost sites are in basins that tend to

Table 6. Comparison between spring and fall feeding site use by whooping cranes in Saskatchewan, 1986–90.

Variable	Significance	Test
Overall	$P = 0.48$	
Parameter estimates		
Average slope	$P = 0.47$	Logistic
Visibility	$P = 0.30$	regression[a]
Distance to trees	$P = 0.26$	
Other species	$P = 0.003$	Categorical
Crop type	$P = 0.36$	analysis[b]
Overall multivariate	$P = 0.26$	
Univariate[c]		
Distance to buildings	$P = 0.07$	Canonical
Distance to roads	$P = 0.45$	discriminant
Distance to powerlines	$P = 0.10$	analysis

[a] Significance of maximum likelihood estimates of parameters in the full model, from PROC LOGISTIC; overall significance is assessed by the score statistic.
[b] CATMOD procedure; method used is logistic regression for categorical variables. Significance of parameter estimates are shown for the full maximum likelihood model on these variables.
[c] Univariate results produced by CANDISC procedure, using same data as the multivariate test, i.e., only observations with no missing data for these variables.

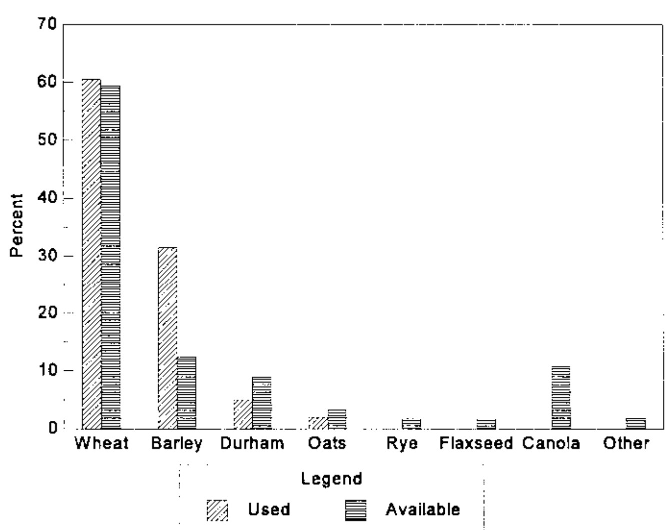

Fig. 4. Crop types used by whooping cranes as feeding sites in Saskatchewan, 1986–90 (Saskatchewan Agriculture and Food 1991).

Table 7. Comparison between spring and fall roosting site use by whooping cranes in Saskatchewan, 1986–90.

Variable	Significance	Test
Overall	$P = 0.54$	
Average slope	$P = 0.64$	Logistic
Visibility	$P = 0.61$	regression
Area	$P = 0.45$	
Distance to feeding site	$P = 0.58$	
Specific conductivity	$P = 0.41$	
Distance to trees	$P = 0.35$	
Disturbed vs. undisturbed	$P < 0.0001$	Categorical
Other species	$P < 0.0001$	analysis[a]
Overall multivariate	$P = 0.78$	
Building distance	$P = 0.12$	Canonical
Road distance	$P = 0.96$	discriminant
Powerline distance	$P = 0.94$	analysis
Shore slope	$P = 0.89$	
pH	$P = 0.89$	

[a] No multivariate categorical analysis was possible. Results shown are for analysis of single variables in PROC CATMOD.

provide reduced horizontal visibility, whereas feeding locations are primarily in harvested cropland virtually devoid of any tall vegetation. The exceptions were isolated groves of aspen and willow (*Salix* spp.). There were no seasonal differences in proximity to trees ($\bar{x}$ = 277 m in spring and 258 m in fall) (Tables 5 and 6), distances being similar to those of roosts (Table 3).

There were slight differences between seasons in distance to nearest buildings ($P = 0.07$) and roads ($P = 0.45$), but none of these differences was significant (Tables 5 and 6). During fall migration, however, the mean distance from family groups to nearest buildings was 904 m, whereas non-family groups appeared more tolerant and averaged only 615 m to nearest buildings. There was no significant difference between family and non-family groups in distance to nearest road (421 and 426 m, respectively). The distance to the nearest powerline averaged 535 m in spring and 895 m during fall migration ($P = 0.10$).

There was a significant difference ($P = 0.003$) between seasons in whether whooping cranes fed alone or with other species (Table 6). When whooping cranes fed with other species, they most frequently were observed with sandhill cranes. Fourteen percent of spring feeding sites were in association with sandhills, and 35% of all fall feeding locations also contained sandhill cranes (Table 4).

Differences Between Roost and Random Sites

Roost site characteristics did not differ between seasons

Table 8. Comparison between sites used by migrating whooping cranes and random sites in Saskatchewan, 1986–90.

Variable	Significance	Test
Overall	$P = 0.28$	
Average slope	$P = 0.13$	Logistic
Visibility	$P = 0.13$	regression
Area	$P = 0.61$	
Distance to feeding site	$P = 0.46$	
Specific conductivity	$P = 0.81$	
Distance to trees	$P = 0.39$	
Overall multivariate	$P < 0.0001$	
Distance to powerlines	$P < 0.0001$	Canonical
Shore slope	$P = 0.0006$	discriminant
pH	$P = 0.29$	analysis
Distance to roads	$P = 0.17$	
Distance to buildings	$P = 0.003$	

(Table 7), so the data were combined and then compared with a sample of random sites. Overall significant differences ($P = 0.0001$) between roost and random sites in distance to buildings, roads, and powerlines were found through canonical discriminant analysis (Table 8). Shore slope was shallower and pH was lower at used sites. Univariate tests showed that shore slope and distance to powerlines and buildings were significantly different between roost and random sites (Table 8). Joint comparisons of topographic slope, visibility, wetland area, distance to feeding fields, specific conductance, and distance to trees were not significant, either as a group or individually within the logistic regression analysis. Univariate tests yielded significant differences between roost and random sites for distance to feeding fields and trees and for shoreline slope; these results do not contradict the logistic regression result, but were due to larger non-missing sample sizes.

MANAGEMENT IMPLICATIONS

Choice of roost site appears to be influenced by several natural and manmade landscape features. Whooping cranes use wetlands that are at a greater distance from disturbance (buildings) and threats (powerlines). These wetlands generally have shallower slopes and lower pH values. Roost sites in close proximity (< 1 km) to feeding fields appear to be preferred. This preference to feed close to the roost is beneficial in terms of reduced energy costs and accumulation of potential energy reserves for migration. In addition, the farther the cranes have to fly, if flight is at low altitudes, the greater the chance of encountering an electrical transmission line.

Since most of the roost sites occur on private land, a cooperative approach between wildlife managers and farmers must be taken to preserve wetlands for cranes. Incentives to preserve wetlands on private lands through programs such as the North American Waterfowl Management Plan will benefit not only whooping cranes but all species associated with those wetlands.

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Appendix A. Variables measured at used and potential whooping crane migration stopover sites in Saskatchewan, 1986-90.

Site use by season	Feeding sites Spring	Feeding sites Fall	Roost sites Spring	Roost sites Fall	Random sites
Site description	X	X	X	X	X
Adjacent habitat	X	X	X	X	X
Extent of similar habitat	X	X	X	X	X
Crop type	X	X			
Food source	X	X			
Foods eaten	X	X			
Slope to the north	X	X	X	X	X
Slope to the south	X	X	X	X	X
Slope to the east	X	X	X	X	X
Slope to the west	X	X	X	X	X
Visibility to the north	X	X	X	X	X
Visibility to the south	X	X	X	X	X
Visibility to the east	X	X	X	X	X
Visibility to the west	X	X	X	X	X
Site security	X	X	X	X	X
Site ownership	X	X	X	X	X
Distance to buildings	X	X	X	X	X
Distance to trees	X	X	X	X	X
Distance to powerlines	X	X	X	X	X
Distance to roads	X	X	X	X	X
Road type	X	X	X	X	X
Presence of other species	X	X	X	X	
Water depth			X	X	X
Turbidity			X	X	X
Substrate			X	X	X
Dominant emergents			X	X	X
Vegetation density			X	X	X
Wetland system[a]			X	X	X
Wetland subsystem[a]			X	X	X
Wetland class[a]			X	X	X
Wetland modifier[a]			X	X	X
Wetland type[b]			X	X	X
Shoreline slope			X	X	X
Wetland area			X	X	X
Distance to upland feeding			X	X	X
Specific conductance			X	X	X
pH			X	X	X

[a] Cowardin et al. (1979).
[b] Stewart and Kantrud (1971).