USGS
science for a changing world

Prepared in cooperation with the Platte River Recovery Implementation Program and Crane Trust

Evaluation of Nocturnal Roost and Diurnal Sites Used by Whooping Cranes in the Great Plains, United States

Open-File Report 2016–1209

U.S. Department of the Interior
U.S. Geological Survey

Evaluation of Nocturnal Roost and Diurnal Sites Used by Whooping Cranes in the Great Plains, United States

By Aaron T. Pearse, Mary J. Harner, David M. Baasch, Greg D. Wright, Andrew J. Caven, and Kristine L. Metzger

Prepared in cooperation with the Platte River Recovery Implementation Program and Crane Trust

Open-File Report 2016–1209

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Director

U.S. Geological Survey, Reston, Virginia: 2017

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit http://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit http://store.usgs.gov/.

Suggested citation:
Pearse, A.T., Harner, M.J., Baasch, D.M., Wright, G.D., Caven, A.J., and Metzger, K.L., 2017, Evaluation of nocturnal roost and diurnal sites used by whooping cranes in the Great Plains, United States: U.S. Geological Survey Open-File Report 2016–1209, 29 p., https://doi.org/10.3133/ofr20161209.

ISSN 2331-1258 (online)

Acknowledgments

Funding and support for this project have been provided by the Platte River Recovery Implementation Program, Crane Trust, U.S. Fish and Wildlife Service, and Nebraska Environmental Trust. Location data were provided by partners of the Whooping Crane Tracking Partnership, which include the Crane Trust, U.S. Fish and Wildlife Service, U.S. Geological Survey, Platte River Recovery Implementation Program, and Canadian Wildlife Service. We thank D. Brandt, W. Harrell, F. Chavez-Ramirez, B. Strobel, M. Bidwell, C. Cooper, C. Smith, B. Krohn, T. Stehn, B. Hartup, M. Folk, S. Herford, W. Wehtje, L. Craig-Moore, R. Kindopp, L. Paterson, and J. Remple for assistance during captures or other logistical and administrative aspects of the overall tracking project. Field data were collected by A. Albrecht, D. Baasch, A. Brazeal, S. Cahis, J. Clymer, B. Gohmann, M. Gonnerman, M. Harner, N. Hayden, R. Joe, S. Kahlich, K. Klag, K. Koch, A. Lingenfelter, R. McLean, A. Orr, C. Reiland-Smith, S. Rios, K. Saxton, N. Smith, E. Suhr, E. Thompson, H. Wagner, T. Wooten, G. Wright, and D. Zorn. This project would not be possible without the support of and access provided by numerous landowners, land managers, and State wildlife agencies. S. King and G. Lingle provided content reviews to earlier versions of this report.

The U.S. Geological Survey–Platte River Priority Ecosystems Program and Ecosystems Mission Area provided partial financial support. Northern Prairie Wildlife Research Center supported logistical and administrative aspects of this work.

Contents

Figures

Appendix 1 Figure

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)

Evaluation of Nocturnal Roost and Diurnal Sites Used by Whooping Cranes in the Great Plains, United States

By Aaron T. Pearse,[1] Mary J. Harner,[2,3] David M. Baasch,[4] Greg D. Wright,[2,5] Andrew J. Caven,[2] and Kristine L. Metzger[6]

Introduction

The whooping crane (*Grus americana*) is one of two species of cranes in North America (Walkinshaw, 1973). This endangered species is well known for its ongoing recovery from the brink of extinction, serving as an encouraging narrative for wildlife conservation worldwide (Cannon, 1996; Clark and Westrum, 1989). Whooping cranes from the Aransas-Wood Buffalo population, the only self-sustaining and natural population, migrate through the Great Plains in the United States and Canada twice each year between breeding areas at Wood Buffalo National Park and surrounding lands near the border of the Northwest Territories and Alberta, Canada, and wintering areas along the gulf coast of Texas (Allen, 1952; Stevenson and Griffith, 1946). During their nearly 4,000-kilometer (km) migration, Aransas-Wood Buffalo whooping cranes negotiate the vast prairies of the Great Plains in search of suitable places to rest each night between primarily diurnal migratory flights (Kuyt, 1992). These nocturnal roost sites (hereafter called “roost sites”) constitute a key resource for whooping cranes. Without adequate roost sites, migratory birds would not be able to complete their twice-annual migrations (Hutto, 1998).

Conservation organizations and resource managers have applied best available science to define habitat requirements for whooping cranes during migration, but information has been limited because of the rarity of whooping cranes, their often undetected occurrences, and the limited specificity of geographic locations reported by the public. Characterization of habitats used by whooping cranes during migration has been based mostly on incidental observations, irregular accounts, or localized study (Austin and Richert, 2001; Johns and others, 1997; Lingle and others, 1984; Howlin and Nasman, 2016); and inferences from some of these accounts are hampered by innate biases in incidental observations (Hefley and others, 2013, 2015). Some limitations were overcome with the completion of a telemetry project in the early 1980s, where 13 juvenile birds within the Aransas-Wood Buffalo population were marked and followed during migration (Kuyt, 1992). In conjunction with these efforts, detailed characteristics of select roost sites used by birds were evaluated (Howe, 1989). These reports suggest that roost sites used by whooping cranes were mainly wetlands of various types and sizes, generally characterized by unobstructed visibility, moderate water depths, and being distant from human developments. Many of these characteristics have been translated into general management recommendations and used to guide management of migration habitats such as those along the Platte River in central Nebraska (Armbruster, 1990).

The Platte River Recovery Implementation Program (hereafter called the “Program”) began in part to provide benefits to endangered whooping cranes and their habitats primarily by conserving and managing lands and water of the central Platte River (Platte River Recovery Implementation Program, 2006). Because of uncertainty in defining quality stopover habitat for whooping cranes, the Program has directed studies to pursue such goals. Until recently (2016), the Program relied exclusively on information collected at roost sites used by whooping cranes along the central Platte River—the focal location of Program activities—to quantify stopover habitat and inform management strategies (Platte River Recovery Implementation Program, 2012). The Program developed seven specific metrics that described physical and hydrologic characteristics of roost sites along the Platte River used by whooping cranes (table 1). After collecting 11 years of data, the Program used summarizations from each metric to quantify criterion for identifying crane habitat (Platte River Recovery Implementation Program, 2012). The intent of these metrics and associated criteria were that they would represent near minimally suitable conditions, which they could use to identify available habitat likely to be used by whooping cranes along the Platte River. These criteria were identified by determining metric values observed at locations used by 90 percent of whooping cranes. Based on assumptions about what constituted suitable whooping crane habitat, most criteria were set at the 10th percentile of each metric, suggesting that,

[1]U.S. Geological Survey.

[2]The Crane Trust.

[3]University of Nebraska at Kearney.

[4]Headwaters Corporation.

[5]U.S. Forest Service.

[6]U.S. Fish and Wildlife Service.

for example, locations with disturbance features greater than or equal to (≥) 49 meters (m) could be considered potential migration habitat for whooping cranes (table 1). The only expectation was for water depth, where based on the expectation that cranes preferred shallow to deeper water, locations less than or equal to (≤) 20 centimeters (cm) might be considered potential crane habitat and the criteria would need to be estimated by the 90th percentile.

Notwithstanding the substantial effort to understand habitat associations along the Platte River, data collection at roost sites beyond the Platte River would allow for insight from a broader suite of locations, which may be advantageous for managing roost sites along the Platte River. To facilitate such data collection, we have leveraged location data collected since 2009 as part of a larger whooping crane research effort involving the Program, U.S. Geological Survey, Canadian Wildlife Service, U.S. Fish and Wildlife Service, and the Crane Trust (Pearse and others, 2015). The impetus for this work is the notion that characterizations of roost sites throughout the whooping crane migratory corridor can assist the Program with refining conservation targets to effectively manage and protect whooping crane habitat along the Platte River.

Purpose and Scope

The overall goal of this effort has been to provide information to the Program and other resource managers that manage and protect whooping crane habitat throughout the Great Plains by contributing to the understanding of roost site characteristics used by migrating whooping cranes. To accomplish this goal we collected data at stopover and roost sites that described: (1) physical characteristics, (2) hydrologic characteristics, (3) land use and land cover, (4) potential food resources available, and (5) natural and anthropomorphic disturbances and threats. This report focused on physical and hydrologic characteristics, specifically those characteristics used by the Program to define minimal habitat requirements. As a comparison, we estimated percentiles appropriate for each metric, which (except for water depth) was the 10th percentile; thus, if results indicated that the critical percentile of locations for a given metric are different than the current criterion, then the criterion may need to be adjusted accordingly. In this report, we provide insights as to how metrics collected at hundreds of roost sites from North Dakota to Texas compared with preliminary habitat criteria developed by the Program.

Study Area

The Great Plains is an extensive grassland ecoregion covering central parts of the United States and Canada. Since settlement in the 1800s, land cover and use of the ecoregion has changed dramatically as it was transformed primarily from tall, mixed, and short-grass prairies to a mosaic of agricultural lands including dryland farming, irrigated row crops, rangeland, and hay lands (Lingle 1987; Samson and Knopf, 1994). Palustrine, lacustrine, and riverine wetlands exist throughout the ecoregion, most notably in the Prairie Pothole Region, Nebraska Sandhills, Rainwater Basin, and Playa Lakes Region (Laubhan and Fredrickson, 1997). The Aransas-Wood Buffalo whooping crane migration corridor crosses the Great Plains north to south, and the center of the migration corridor generally bisects Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, and Saskatchewan (Pearse and others, 2015; Tacha and others, 2010). Efforts focused on the migration corridor, primarily from northern North Dakota to northern Texas (fig. 1). This area represented a diversity of landscapes used by the whooping cranes and was centered on the central Platte River, which was of primary interest in characterizing migration habitat.

Methods

We gathered location data from marked whooping cranes to identify locations for visitation by field crews. Location data were available from varying numbers of cranes fitted with telemetry equipment each migration season from 2012 to 2015. Between 2009 and 2014 at Wood Buffalo National Park and sites along the Texas gulf coast we captured cranes and attached platform transmitting terminals with global position system (GPS) capabilities (North Star Science and Technology LLC, Baltimore, Md.). Capture and marking methods were described in Pearse and others (2015). Transmitters were programmed to record four to five GPS locations daily at equal time intervals, which provided daytime (diurnal) and nighttime (nocturnal) locations. Capture and marking procedures were approved by the Animal Care and Use Committee at the Northern Prairie Wildlife Research Center.

After whooping cranes began their northerly (spring) or southerly (fall) migrations and used areas within the defined study area (fig. 1), we defined stopover sites as clusters of locations that included at least one nighttime location. We identified unique stopover sites if birds moved greater than (>) 15 km between nighttime locations from day-to-day, although we occasionally deviated from this rule based on expert opinion (Pearse and others, 2015). Within a roost site, we focused on the initial nocturnal roost site as defined by the location used by a whooping crane during their first night closest to 00:00 hours. This location was of primary interest because it represented an initial choice of habitat. In instances where cranes had extended stays within a stopover site, measurements also were collected at other roost sites if feasible, which typically included locations used repeatedly by the crane.

After identifying field locations to visit, technicians determined land ownership and contacted landowners or managers to request access to lands before scheduling a site visit. Although an attempt was made to visit nearly all identified roost sites, some sites were not visited for various reasons including inability to contact landowners, denied access to

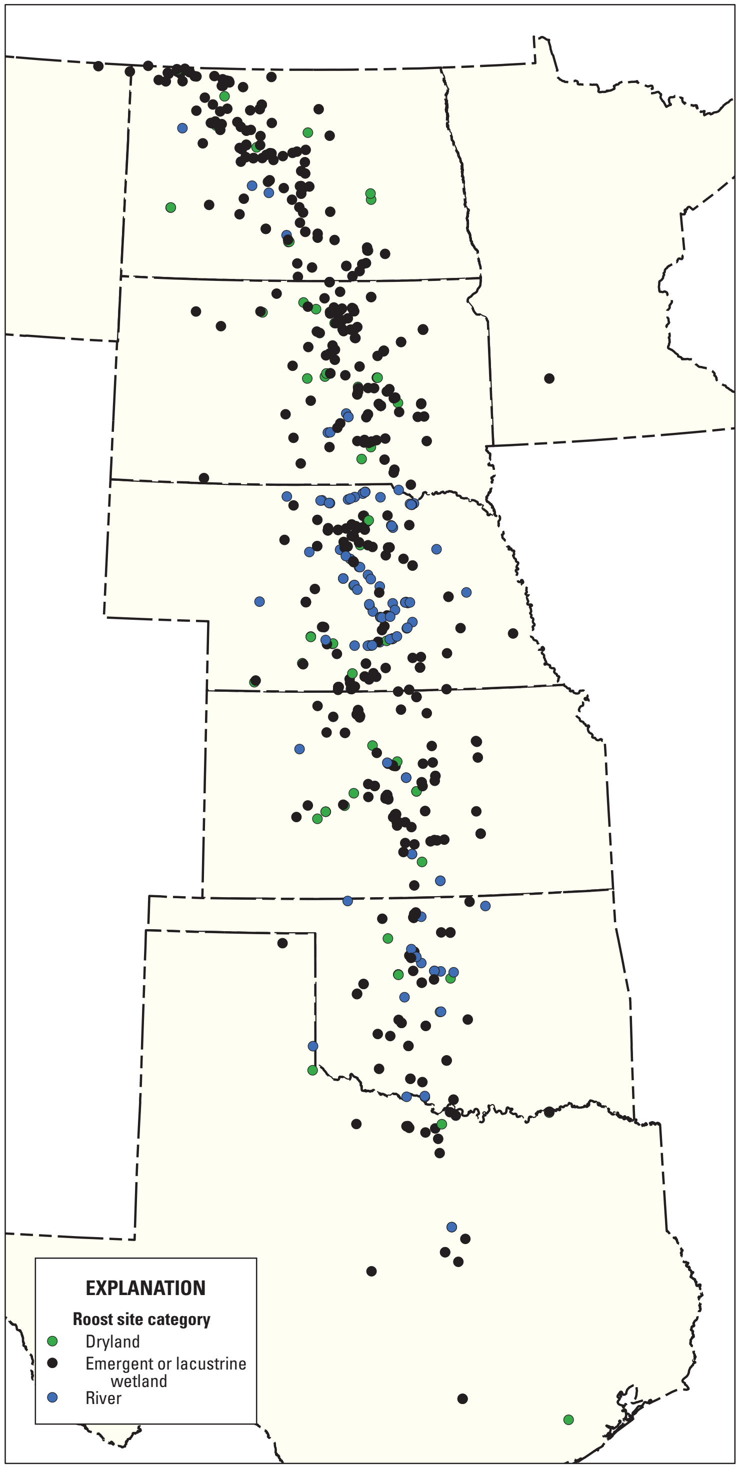


Figure 1. We characterized 504 roost sites used by whooping cranes marked with telemetry equipment during fall 2012–spring 2015.

property, logistical constraints (for example, inability to physically access site), or other feasibility issues. We attempted to visit roost sites within 7 days after whooping cranes were known to have left the area. This goal was developed so that conditions quantified by technicians would match those experienced by the cranes. We were especially concerned with water conditions, which could change quickly with precipitation or temperature (freeze and thaw).

On site, technicians collected characteristics at specific locations used by whooping cranes nocturnally (roost) and diurnally (day use). Generally, technicians collected data related to (1) physical characteristics, (2) hydrologic characteristics, (3) land use and land cover, (4) potential food resources available, and (5) natural and anthropomorphic disturbances and threats. Together, metrics describing roost site characteristics provided a depiction of places selected by whooping cranes during stops made during migration. Technicians used handheld GPS units to navigate to measured locations, which had been gathered from telemetry equipment on the cranes. Most GPS locations from telemetry equipment had a reported locational precision of less than (<) 26 m. In a separate test of locational accuracy, we determined the median distance between a known location and that retrieved from transmitters was 9 m (appendix 1).

For this report, roost sites fit into one of four roost site categories: emergent wetland, lacustrine wetland, river, or dryland (fig. 1). Emergent wetlands were defined as wetlands with various levels of persistence that included herbaceous hydrophytes and generally included small- to medium-sized wetlands (Cowardin and others, 1979). Lacustrine wetlands were deepwater habitats and wetlands, and included reservoirs, impoundments, or lakes (Cowardin and others, 1979). Sites with flowing water were included as river sites. Finally, sites without discernable surface water during the time of whooping crane use were classified as dryland sites.

As stated in the “Introduction” section, the Program developed seven metrics that define habitat for migrating whooping cranes along the Platte River. These metrics included: (1) distance to nearest disturbance, (2) distance to nearest obstruction, (3) unobstructed view width, (4) water depth, (5) wetted width, (6) suitable channel area, and (7) unobstructed channel width (table 1; Platte River Recovery Implementation Program, 2012). Similar to the Program, we defined disturbances as features that may affect whooping crane use of an area (Platte River Recovery Implementation Program, 2012). Disturbance categories were roads, dwellings, machinery, blinds (hunting or viewing), and other miscellaneous features. Similarly, obstructions were defined using Program guidance and included objects >1.5 m above ground that would impede the view behind the object (Platte River Recovery Implementation Program, 2012). Obstructions were identified in five categories for this report: herbaceous vegetation, woody vegetation, manmade obstructions, topography, and other miscellaneous obstructions. Detailed descriptions of specific metrics and other characteristics used in this report are provided in appendix 2.

Analytical Methods

The stated precision quality of the location was low for two instances (>75 m), suggesting that the evaluated location may have been at an unacceptable distance from where the whooping crane was located. We removed these sites before analyses. In addition, although multiple marked cranes used the same site at the same time in certain instances, we included site measurements once for these groups of cranes, rather than repeatedly for each known crane in a group. This was done to avoid overly weighting the sample with sites selected by groups of cranes, because habitat choice was likely not independent among group members.

When estimating percentiles for each of the seven metrics, we made various augmentations to the data. Where technicians did not identify a disturbance at a particular site, we substituted the missing distance value with the maximum value reported. Including such values allowed these locations

Table 1. Seven metrics used to characterize roost sites used by whooping cranes marked with telemetry equipment within the U.S. part of the Great Plains, 2012–15.

[Roost sites were categorized as wetland (emergent or lacustrine), river, or dryland sites. The Platte River Recovery Implementation Program developed habitat criteria threshold values for each metric to identify habitat along the central Platte River. ≥, greater than or equal to; m, meter; >, greater than; ≤, less than or equal to; cm, centimeter; <, less than]

Metric	Definition	Location types	Criterion
Distance to nearest disturbance	Distance from a point in any direction to the nearest feature, such as a road or residence that may affect whooping crane use of the area.	Wetland, river, dryland	≥49 m
Distance to nearest obstruction	Distance from a point in any direction to the nearest object >1.5 m above ground level that may preclude cranes from seeing beyond the object.	Wetland, river, dryland	≥23 m
Unobstructed view width	Shortest perpendicular distance between objects >1.5 m above ground level that may preclude cranes from seeing beyond the object.	Wetland, river, dryland	≥101 m
Water depth	Distance between water surface and the wetland or channel bed.	Wetland, river	≤20 cm
Wetted width	Distance within the unobstructed channel covered by water at observed river flow.	River	≥76 m
Suitable channel area	Percentage of river channel with water ≤20 cm deep or bare sand.	River	≥40 percent
Unobstructed channel or wetland width	Measured width of channel or wetland, including bare soil and vegetated areas, <1.5 m above ground level.	Wetland, river	≥85 m

to be included when estimating percentiles, and they were removed when estimating means and standard deviations. A similar technique was used in instances where technicians did not perceive an obstruction in specific directions from evaluated locations. Some locations within wetlands had measured water depths of zero, which were used to indicate a dry spot within a wetland that contained water. In addition, technicians did not measure water depths >1 m. We included such instances where water depth was >1 m as 100 cm when estimating percentiles only.

We summarized each of the seven metrics and include sample size, mean, standard deviation, 25th percentile, 50th percentile, 75th percentile, minimum, maximum, and the critical percentile associated with each metric (10th percentile for all metrics except water depth; 90th percentile for water depth). We expressed sample uncertainty in critical percentile estimates associated with each metric with the 95-percent confidence interval (CI). The CIs were estimated by calculating 5,000 bootstrap estimates and using the 2.5th and 97.5th percentiles as the lower and upper confidence bounds. We also determined the proportion of the 5,000 bootstrap estimates that were less than or equal to the Program's established criteria (greater than or equal to for water depth), which provided a probability value for determining if differences between observed values and Program criteria were because of chance alone. We used an alpha value of 0.05 to correspond with the 95-percent CI described above to evaluate the null hypothesis that estimated percentiles were not different from established criteria. Additionally, we calculated summary statistics and CIs for all roost sites sampled and for various groups related to the type of site evaluated where applicable, including emergent wetland, lacustrine wetland, river, and dryland sites.

We determined covariance among characteristics at roost sites by estimating all pair-wise Spearman's rank correlation coefficients. We chose rank correlations because some metrics had maximum values included rather than actual measurements (see above).

Results

Technicians visited and characterized 504 roost (fig. 1) and 83 day-use sites during seven migration seasons, 2012–15. Multiple marked whooping cranes were present at 56 roost and 11 day-use sites. The maximum number of marked cranes with active transmitters at any evaluated site was four, although a single crane was the most common. Technicians visited 23 roost sites in Texas, 60 in Oklahoma, 82 in Kansas, 136 in Nebraska, 95 in South Dakota, 105 in North Dakota, 1 in Minnesota, and 2 in Montana (fig. 1). Of roost sites visited, 380 were in wetlands (252 emergent, 128 lacustrine), 98 in rivers, and 26 in drylands. Number of days between cranes departing the area and technicians collecting data at roost sites averaged 11 days (median=10 days). Technicians were able to collect data at sites within 7 days at 35 percent of roost sites.

Of the 500 sites with the distance to nearest disturbance assessed, 83 percent had at least 1 disturbance feature noted by field technicians. Of those sites, mean distance was 600 m (standard deviation [SD]=693; number of sites [*n*]=415). The minimum measured distance was 26 m and maximum was 9,600 m. Based on a distribution where we included the maximum value for sites without a discernable disturbance feature, the current criterion of ≥49 m represented the 1st percentile, and the critical percentile was 150 m (fig. 2). For all roost sites and other categories, we found sufficient evidence to suggest the critical percentile estimates were larger than the current criterion, except for dryland sites (P=0.079; table 2). The most common nearest disturbance feature was roads (48 percent). Dwellings (29 percent), machinery (11 percent), blinds (7 percent), and other miscellaneous disturbances (5 percent) also were included as nearest disturbance features.

Of 501 sites with the distance to nearest obstruction, 99 percent of sites had at least 1 obstruction noted by field technicians. Of these sites, mean distance was 88 m (SD=113; n=496). Minimum measured distance was 1 m and maximum was 1,200 m. Based on a distribution where we included the maximum value for sites without a perceivable obstruction, the current criterion value of ≥23 m represented the 15th percentile, and the critical percentile was 18 m (fig. 2). For all roosts and lacustrine wetlands, we found evidence that the critical percentile was less than the current criterion, but failed to reject the null hypothesis for roost sites in emergent wetlands, rivers, and dryland sites (P≥0.108; table 2). Topography was the most common nearest obstruction (42 percent). Herbaceous vegetation (33 percent), woody vegetation (21 percent), manmade obstructions (2 percent), and other obstructions (2 percent) also were included.

Mean unobstructed view width for roost sites with recorded obstructions was 326 m (SD=506; n=490). Minimum measured unobstructed view width was 2 m and maximum was 7,204 m. Based on a distribution where we included the maximum value for sites without recorded view width, the current criterion value of ≥101 m represented the 22nd percentile, and the critical percentile was 60.5 m (fig. 2). We found evidence that the current criterion was greater than the critical percentile for all roost site categories except dryland sites (P=0.095; table 2).

Water depths were collected at 407 roost sites. Mean water depth at roost sites measured between 1 and 99 cm was 18 cm (SD=13 cm). Fourteen percent of sites had water depth of zero. Including these values, the current criterion value of ≤20 cm was the 70th percentile, and the critical percentile was 32 cm (fig. 2). All roost site categories had critical percentiles greater than the current criterion (table 2).

Roost sites with flowing water provided data for wetted width (n=90) and suitable channel depth (n=82) (table 2). Average wetted width was 249 m (SD=469). The criterion for this characteristic of ≥76 m represented the 27th percentile, and the critical percentile of this distribution was 38 m (fig. 2). Evidence suggested the critical percentile was less than the current criterion value (table 2). Average suitable channel area

Table 2. Summary statistics for seven metrics used to characterize roost sites used by whooping cranes marked with telemetry equipment within the U.S. part of the Great Plains, 2012–15.

[Roost sites were categorized as wetland (emergent or lacustrine), river, or dryland sites. Metrics are defined in table 1 and appendix 2. *n*, number of roost sites; LCL, lower 95-percent confidence limit of the critical percentile; UCL, upper 95-percent confidence limit of the critical percentile; *P*, proportion of bootstrap critical percentile estimates that exceeded the current criterion; m, meter; ≥, greater than or equal to; cm, centimeter; ≤, less than or equal to]

Metric (units)	Roost type	*n*[1]	Lower quartile	Median	Upper quartile	Critical percentile[2]	LCL	UCL	Current criterion[3]	*P*
Distance to nearest disturbance (m)	All roosts	500	274.5	572.5	1,200	150	119	175	≥49 m	0.000
	Emergent wetland	251	323	590	1,020	175	118	211	≥49 m	0.000
	Lacustrine wetland	127	230	500	1,030	128	79	173	≥49 m	0.000
	Dryland	25	278	570	1,500	120	39	278	≥49 m	0.079
	River	97	244	505	1,500	150	103	188	≥49 m	0.000
Distance to nearest obstruction (m)	All roosts	501	32	55	100	18	13	22	≥23 m	0.001
	Emergent wetland	251	32	57	97	20	17	24	≥23 m	0.108
	Lacustrine wetland	127	26	50	131	12	6	16	≥23 m	0.000
	Dryland	26	32	74.5	103	25	7	32	≥23 m	0.666
	River	97	34	55	92	18	10	29	≥23 m	0.222
Unobstructed view width (m)	All roosts	500	109.5	196	380	60.5	54.5	70	≥101 m	0.000
	Emergent wetland	251	119	205	361	70	58	90	≥101 m	0.000
	Lacustrine wetland	127	84	165	427	47	33	60	≥101 m	0.000
	Dryland	26	134	226	493	69	61	134	≥101 m	0.095
	River	96	118.5	198	306	60	45	96	≥101 m	0.007
Water depth (cm)	All roosts	407	5	12	22	32	30	35	≤20 cm	0.000
	Emergent wetland	217	6	13	22	31	28	37	≤20 cm	0.000
	Lacustrine wetland	109	6	13	25	34	30	40	≤20 cm	0.000
	River	81	4	10	17	31	21	46	≤20 cm	0.013
Wetted width (m)	River	90	71	142	246	38	33	56	≥76 m	0.000
Suitable channel area (percent)	River	82	40	60	75	20	10	30	≥40 percent	0.000
Unobstructed channel or wetland width (m)	All roosts	463	67	150	500	36	30	40	≥85 m	0.000
	Emergent wetland	242	67	133	429	33	29	40	≥85 m	0.000
	Lacustrine wetland	126	60	150.5	1,200	35	22	46	≥85 m	0.000
	River	95	109	169	292	44	28	73	≥85 m	0.008

[1]Number of roost sites visited and measurements taken for each metric and roost category.

[2]Value that defines threshold of 90 percent of whooping cranes using sites. This measure is the 10th percentile for all metrics except water depth, where the 90th percentile was used.

[3]Habitat criteria initially proposed by the Platte River Recovery Implementation Program to describe whooping crane migration habitat for each metric.

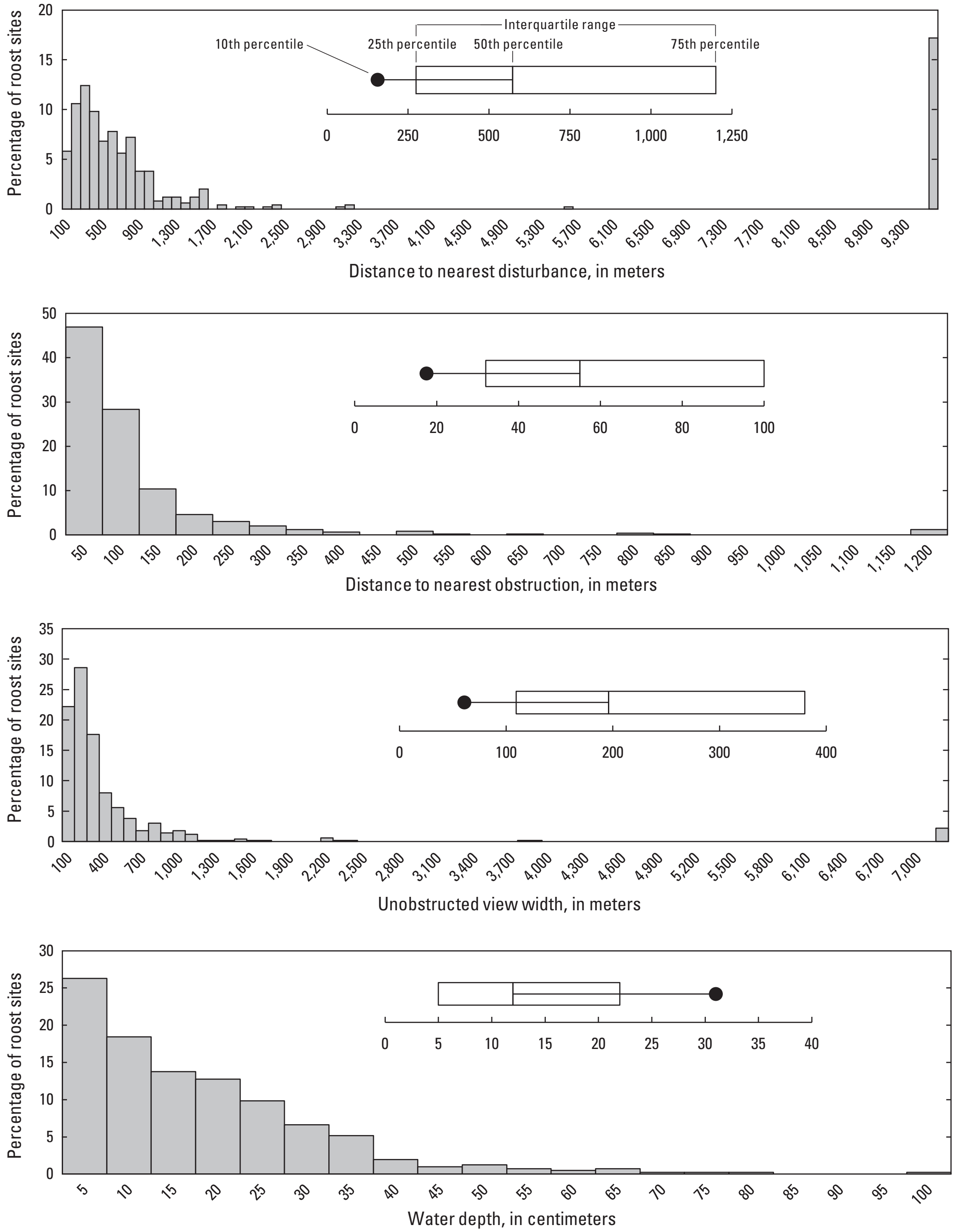


Figure 2. Histograms of the seven site metrics used to characterize roost sites used by whooping cranes marked with telemetry equipment within the U.S. part of the Great Plains, 2012–15. Box plots depict the 25th, 50th, and 75th percentiles, and the black circles represent the percentile identified as defining the Program's habitat criteria, which is the 10th percentile for all characteristics except water depth, where it is the 90th percentile.

was 57 percent (SD=26 percent). The current criterion for this metric of ≥40 percent was the 25th percentile, and the critical percentile of this distribution was 20 percent (fig. 2).

Roost sites with standing or flowing water provided data for unobstructed channel or wetland width (n=463) (table 2). Average unobstructed channel or wetland width was 605 m (SD=1,144). The current criterion for this characteristic of ≥85 m was the 32nd percentile, and the critical percentile of this distribution was 36 m (fig. 2). We found evidence to suggest the critical percentile was less than the current criterion value for all roost sites and categories (P≤0.008; table 2).

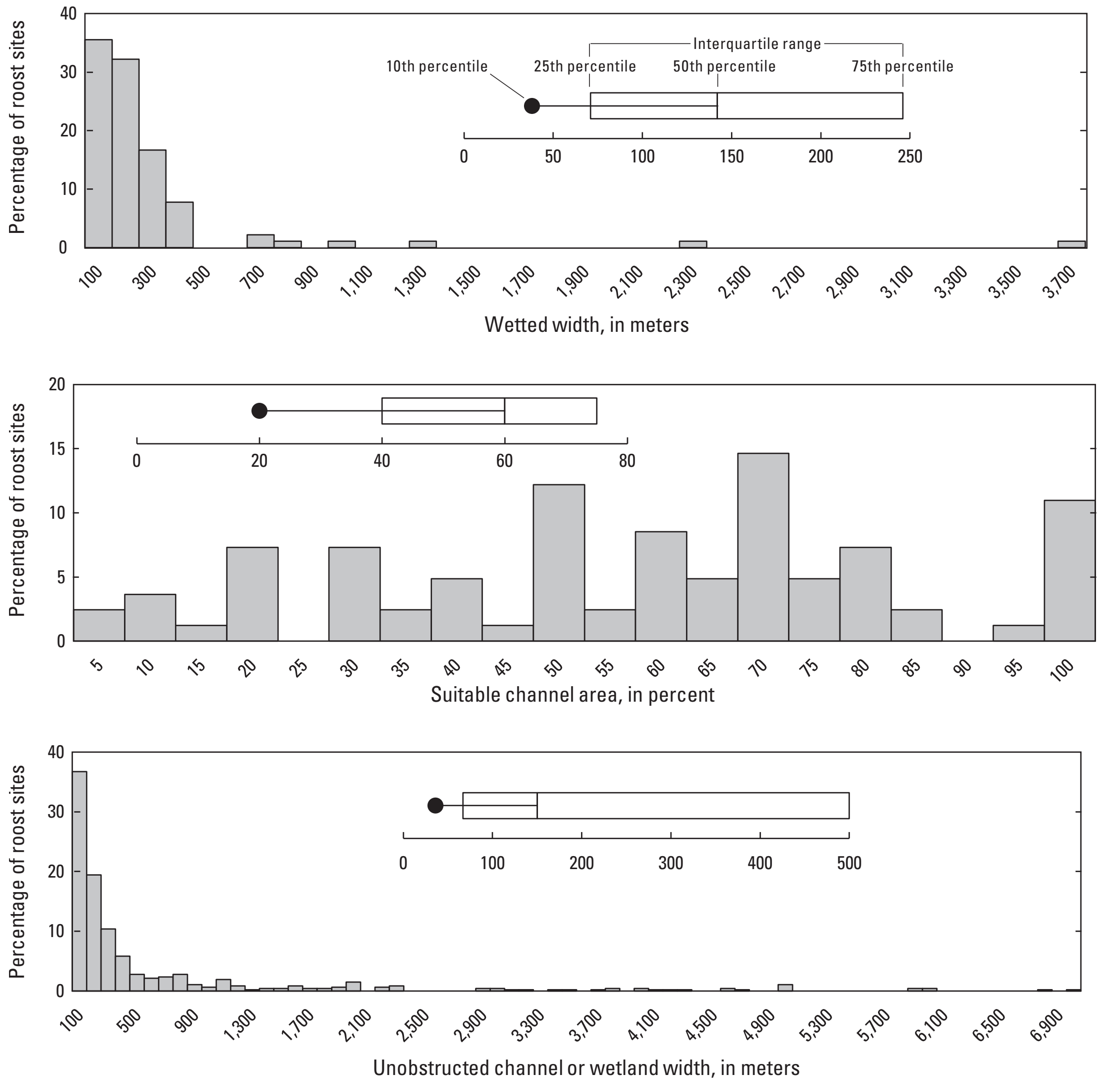


Figure 2. Histograms of the seven site metrics used to characterize roost sites used by whooping cranes marked with telemetry equipment within the U.S. part of the Great Plains, 2012–15. Box plots depict the 25th, 50th, and 75th percentiles, and the black circles represent the percentile identified as defining the Program's habitat criteria, which is the 10th percentile for all characteristics except water depth, where it is the 90th percentile.—Continued

Three of the seven habitat metrics had little rank correlation with other metrics (ρ≤|0.33|): distance to nearest disturbance, water depth, and suitable channel depth (table 3). The other four metrics—distance to nearest obstruction, unobstructed view width, wetted width, and unobstructed channel or wetland width—had a greater level of positive correlation with one another (ρ≥0.55; table 3).

Using criteria set by the Program (table 1), we determined how many roost sites met all criteria (for sites with data for three or more metrics). Of 500 potential sites, 41 percent met all criteria measured. Of those that did not meet all criteria, the average percentage of criteria they met was 67 percent. If we removed water depth as a discerning metric, the percentage of sites identified as available whooping crane habitat for all remaining criteria increased to 56 percent. If unobstructed channel or wetland width was disregarded, the percentage increased slightly to 53 percent. Disregarding both metrics increased the percentage identified as available whooping crane habitat to 71 percent of sites.

Using percentiles identified in our analyses to identify criteria for whooping crane habitat (table 2), 67 percent of 500 roost sites met all criteria when three or more metrics were collected. Of those not meeting criteria, average percentage met was 71 percent. Individually disregarding distance to nearest disturbance, water depth, or unobstructed channel or wetland width increased the percentage of sites identified as available crane habitat to 72–73 percent. Disregarding both distance to nearest disturbance features and water depth increased the percentage to 80 percent.

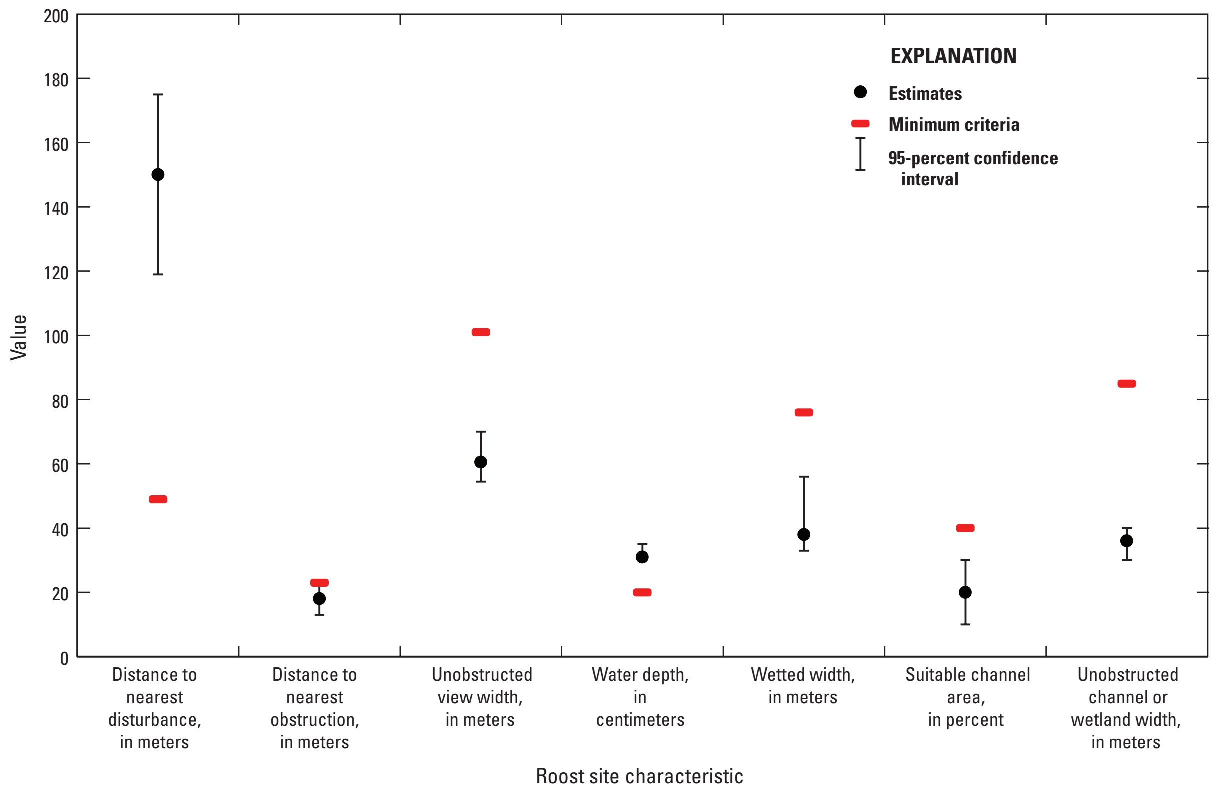


Figure 3. Estimated critical percentiles (black circles) and 95-percent confidence intervals of seven metrics used to characterize roost sites used by whooping cranes marked with telemetry equipment within the U.S. part of the Great Plains, 2012–15. Red dashes represent the Program's initial habitat criteria as determined from sites used by whooping cranes along the Platte River.

Table 3. Spearman rank correlations (ρ) of the seven metrics used to characterize roost sites used by whooping cranes marked with telemetry equipment within the U.S. part of the Great Plains, 2012–15.

[Values greater than or equal to 0.55 were considered highly correlated and are bolded. Metrics are defined in table 1 and appendix 2; --, perfectly correlated]

Metric	Distance to nearest disturbance, in meters	Distance to nearest obstruction, in meters	Unobstructed view width, in meters	Water depth, in centimeters	Wetted width, in meters	Suitable channel area, in percent	Unobstructed channel or wetland width, in meters
Distance to nearest disturbance	--	0.14	0.13	0.01	-0.10	0.03	0.19
Distance to nearest obstruction	0.14	--	**0.84**	0.12	**0.66**	-0.20	**0.55**
Unobstructed view width	0.13	**0.84**	--	0.08	**0.79**	-0.09	**0.56**
Water depth	0.01	0.12	0.08	--	0.10	0.07	0.19
Wetted width	-0.10	**0.66**	**0.79**	0.10	--	-0.33	**0.85**
Suitable channel area	0.03	-0.20	-0.09	0.07	-0.33	--	-0.13
Unobstructed channel or wetland width	0.19	**0.55**	**0.56**	0.19	**0.85**	-0.13	--

Of roost sites visited by technicians, 5 percent were identified as dryland sites. Fifty-two percent of these sites were in agriculture fields, 28 percent in upland grasslands, 16 percent in dry wetlands, which based on evidence at the site, were located in an identified wetland basin that had not contained water during that particular migration season, and 4 percent in lowland grasslands. Where evaluated, the average distance from these sites to nearest surface water was 480 m (*n*=20, minimum=10 m, maximum=5,336 m). Technicians were unable to find surface water near six dryland roost sites. Average vegetation height at these sites was 10.5 cm (SD=11.0, median=7.5 cm) and ranged from 0 to 38.2 cm. Twenty-seven percent of dryland sites were bare soil.

Technicians also visited and characterized 83 sites used by whooping cranes during the daytime. Of these day-use sites, 54 percent were classified as dryland sites, 45 percent as wetland sites, and 1 percent as river sites. Of dryland sites, most were in agricultural fields (69 percent), with the remainder in upland grasslands (22 percent) and lowland grasslands (9 percent). Of the wetland sites that were evaluated, most were emergent wetlands (79 percent) and the remaining were lacustrine wetlands. We estimated percentiles for five of the seven habitat criteria; we could not provide estimates for wetted width or suitable channel area because only one river day-use site was evaluated. Estimates were comparable to those determined at roost sites for most metrics: (1) distance to nearest disturbance (*n*=83), critical percentile=120 m, 95-percent CI=75–150 m; (2) distance to nearest obstruction (*n*=82), critical percentile=13 m, 95-percent CI=9–21 m; (3) unobstructed view width (*n*=82), critical percentile=60 m, 95-percent CI=44–86 m; (4) water depth (*n*=33), critical percentile=25 cm; 95-percent CI=12–40 cm; and (5) unobstructed channel or wetland width (*n*=34), critical percentile=30 m, 95-percent CI=25–38 m.

Discussion

The Program has identified criteria to identify whooping crane habitat along the central Platte River for the purposes of conservation planning, targeting acquisition, and directing management activities. They accomplished this task by first defining seven metrics based on a conceptual model of resources required by migrating whooping cranes. Many of these metrics were related to perceived safety and security at locations, as have been identified in other efforts for whooping cranes and sandhill cranes (*Antigone canadensis*) (Armbruster, 1990; Belaire and others, 2014; Folk and Tacha, 1990; Krapu and others, 1984). After identifying metrics, data collected on the central Platte River were used to empirically derive thresholds based on an explicit desire to define places where 90 percent of whooping cranes would likely roost. Depending on the nature of the relation envisioned for each metric, the threshold would be estimated by the 10th or 90th percentile (Platte River Recovery Implementation Program, 2012). We compared a diverse set of stopover sites across a larger portion of the whooping cranes' migration corridor with thresholds determined by the Program in order to validate these values using out-of-sample data. Overall, estimates derived from a set of sites over a larger geographic area generally did not correspond with critical values identified by the Program.

For all metrics except distance to nearest disturbance and water depth, the critical percentile was greater than the criterion initially derived by the Program. Differences in this direction suggested that if using a 10 percent (depth) or 90 percent (all other metrics) inclusion rule, all the Program's habitat criteria, except distance to nearest disturbance, were more restrictive when compared to our sample. Fewer whooping cranes may be able to use locations near disturbances, but more may be able to use a wider range of all other metrics than initially indicated. Magnitude of differences varied from 22 percent to 58 percent less than Program thresholds; thus, in most instances, differences were quite large. The critical percentile for water depth was 60 percent greater than the Program's identified threshold value. Whooping cranes are hypothesized to seek out shallow water and be constrained by deep water; thus, this result also suggests that they may be able to tolerate conditions more extreme than had been initially expected. In initially determining a water depth threshold, the Program decided to define a water depth threshold to the 70th rather than the 90th percentile. Their 90th percentile was 30.5 cm (Platte River Recovery Implementation Program, 2012), which is similar to the value we estimated and within the 95-percent CI. Finally, 90 percent of whooping crane locations from our sample were ≥150 m from the nearest disturbance feature, which was three times that estimated by the Program. It is likely that across the study area, whooping cranes found stopover habitats further from disturbance features than may be available to them when using the Platte River. Whooping cranes may be less constrained in using areas close to disturbance features in other parts of the migration area as compared to the Platte River.

Reasons for these disparities are speculative. Our sample was derived from a more diverse set of physical conditions than those experienced at the Platte River. This effort, therefore, likely included sites with greater variation, which inherently would move extreme percentiles, like the 10th or 90th percentiles, further from the central tendency. In addition, the sample of roost sites did not include observation bias, as locations were derived from transmitters on whooping cranes rather than by observing unmarked cranes. The Program relied primarily on aerial surveys of the Platte River to initially detect cranes. These surveys have the potential to miss crane observations for numerous reasons such as inability to complete surveys in low visibility conditions. We are uncertain of the presence or magnitude of observation bias in Program data. To date, missing data has been assumed to have occurred at random (no bias in the data), but this remains a potential source of error (Hefley and others, 2013, 2015).

Inspection of a correlation matrix of the seven habitat metrics revealed distance to nearest disturbance, water depth, and percentage suitable area were relatively independent measures describing roost sites used by whooping cranes as compared to the other metrics. The other four metrics—distance to nearest obstruction, unobstructed view width, wetted width, and unobstructed channel or wetland width—had modest to strong positive correlation with one another. Given high positive correlations, these four metrics were quantifying similar characteristics of the site, which given their nature, described the space available for roosting in the form of openness and ponded water. These metrics provided similar information about a roost site rather than four independent measures.

The Program set habitat criteria with the stated goal of defining areas used by 90 percent of migrating whooping cranes. We determined that less than one-half of roost sites would have met all thresholds and have been considered whooping crane habitat based on all available metrics. When using critical percentiles of this report, this rate increased to two-thirds of sites. We did not realize a 90 percent success rate because all measures are not highly correlated with one another; thus, many sites used by roosting whooping cranes met most but not all thresholds. Distance to nearest disturbance, water depth, and unobstructed channel or wetland width all had about the same rate of causing a site to fail to meet minimum habitat requirements when using critical percentiles presented in this report. These metrics could be targeted if there is a desire to modify areas to make them more acceptable as whooping crane stopover habitat using the presented conceptual model and seven threshold metrics as identified herein.

Of roost sites measured, 5 percent were not associated with surface water. Previous work determined whooping cranes roosted nearly exclusively in wetlands and used uplands primarily during the daytime as feeding sites (Howe, 1989). The use of dryland roost sites has been noted in sandhill cranes in the Platte River Valley in Nebraska, generally at times when the birds were forced off of the river because it was frozen or in the process of freezing (D. Brandt, U.S. Geological Survey, written commun.), and sandhill cranes roosting in the southwestern United States (Conring, 2016). Although use of dryland roost sites by whooping cranes was sporadic and rarely lasted more than one night, the use of these sites provides further evidence of the behavioral plasticity these birds possess in habitat selection. The large area of dryland in comparison to how often they use these sites suggests they in no way prefer to use dryland sites. Whooping cranes used dryland sites throughout the migration corridor and occasionally where seemingly suitable roost sites associated with surface water were nearby; thus, it does not appear likely that cranes used dryland sites solely because they were unable to find nearby wetland roost sites. Furthermore, their use of dryland sites, even as rare events, complicates future assessments of what is a potential whooping crane stopover habitat because before this work, we would have suggested dryland sites were largely not available as roost sites to cranes. Only considering wetland sites would not necessarily include all sites potentially used by cranes for roosting.

The characterization of 83 sites used by whooping cranes during the daytime revealed there were few differences in critical percentiles as compared with those from roosting sites. Presumably, whooping cranes have a similar pattern of habitat selection in regards to these specific metrics. If this pattern holds, it would be advantageous because conservation planners could consider just one set of thresholds in determining habitat quality. As had been noted previously by Howe (1989), 54 percent of daytime use sites were in the uplands, most commonly in agricultural fields or upland grasslands.

Identifying habitat criteria was done to represent locations most whooping cranes were likely to use during migration rather than identifying optimal or highly selected sites. Data on habitat availability (that is, sites that cranes perceive as potential sites for use) were not measured; thus, we cannot specifically discern selection for habitat metrics. Some of the sites used by roosting cranes likely do not represent those that are optimal (that is, maximize lifetime fitness) but rather reflect sites that were sufficient in meeting basic requirements and in context to those they had to choose from. When inspecting distributions of many of the metrics, we found them to have a long right tail, which for most characteristics except water depth, we would hypothesize would represent high-quality sites (fig. 2). Certain percentiles might provide better insight to identifying higher quality sites. Median values provide an easy interpretation as defining where 50 percent of cranes chose to roost, and the upper quartile (lower quartile for water depth) might serve to identify high-quality sites where 25 percent of cranes chose to roost. Use of any specific percentile is arbitrary for identifying a threshold, yet using multiple values could be useful to identify a quality gradient for sites.

Data Strengths and Weaknesses

We consider the roost and day-use site characteristics we have summarized to be robust and provide a good representation of sites used by whooping cranes during migration (appendix 3). This consideration is based on overcoming some of the limitations of past efforts. Initially, we were not constrained by observation bias. Many of the past efforts relied upon incidental sightings of whooping cranes and follow up visits by trained observers. Places used by cranes not easily accessible to people or in which biologists would not expect to find whooping cranes based on the existing literature are expected to have a high probability of being underrepresented (Austin and Richert, 2001; Hefley and others, 2015). Similar to past telemetry studies, if transmitters functioned properly, technicians were able to assess where cranes were each day without the need for independent observations. Another strength was the ability to mark a large percentage of the population and work over a large area. Past telemetry studies, because of the nature of the type of technology available, could follow only a few individuals during a limited number of migration seasons (Howe, 1989; Kuyt, 1992). With the advent of more sophisticated technology and an increase in the number of whooping cranes in the Aransas-Wood Buffalo population, we were able to monitor many times more cranes simultaneously. The use of multiple field crews also allowed us to collect data at multiple sites over a large geographic area simultaneously.

Inferences from results of this study depend on a representative sample. Certain aspects of our study design and field protocols suggest we may have sampled certain sites in greater proportion than whooping cranes actually used them (oversampling), specifically those located in Nebraska, on publically owned lands, and river sites. Sampling in this manner could bias estimates if values of interest differed greatly from overall estimates. We sampled sites only located within Nebraska during fall 2012, which served as a pilot field season. During this season we sampled 31 roost locations (6 percent of all locations). Critical percentiles from sites in Nebraska differed little for all metrics except wetted width, which was 71 percent greater than values from all sites (table 4). If the critical value for wetted width were biased high because of oversampling in Nebraska, a biased corrected estimate would be lower and deviate even further from the Program's criterion (fig. 3). Lands owned in public trust or by nonprofit organizations (public lands) represented 23 percent of roost sites visited. If cranes use roost sites on public lands less than was reflected in this sample, we likely oversampled public lands because gaining access to these sites was easier compared to contacting private landowners and requesting permission, which was not always granted. Critical percentiles were similar or greater on public compared with private lands (table 4); thus, oversampling public lands would lead to critical percentiles biased higher than they should have been if private land sites were included in the sample at the rate they were actually used by whooping cranes. Because of our interest in comparisons with the Platte River, we directed technicians to make extra efforts to sample all river sites available. When comparing values only at river sites with those from all roost sites, critical percentiles were nearly identical between river sites and all roost sites; the only deviation of any note was unobstructed channel or wetland width, where river roost sites had slightly greater values than at wetland roost locations (table 2). Collectively, nearly all sample biases that may have happened would have caused the estimated critical percentiles to be closer to draft values than they would have been if no sample bias existed.

Beyond potential for sampling bias described above, certain limitations of our approach are of note. Location accuracy from GPS generally is better than other available types of location data by orders of magnitude (Douglas and others, 2012), yet location error is evident especially if one considers errors in acquiring the initial location and in relocating that position to collect data (appendix 1). This error was about 10 m, which is small relative to many of the distance metrics measured (for example, distance to nearest disturbance). Other characteristics had values that would require more precise locations (for example, the critical percentile for distance to nearest obstruction was 18 m). Practitioners may want to use caution when interpreting this particular metric and consider focusing on some of the other correlated metrics instead. Few locations were observed per day, providing a limited perspective into the daily and nightly movements of birds. For nocturnal roosts specifically, we did not know if the birds remained in the same location for most of the night or made movements around the wetland or local area. Technicians did not visit sites while being used by cranes because we did not want to disturb them or influence normal movements. Technicians also delayed site visits because of the time required to gain access permission and logistics of traveling to sites in an efficient manner. Water depth, suitable channel area, and wetted width may have been affected by this delay. Wetted width for sites measured 10 days or earlier than when cranes left roost sites were slightly wider (critical percentile=44 m) than sites measured with greater delays (critical percentile=36 m). Water depth and suitable channel areas were comparable (32 cm for ≤10 days; 31 cm for >10 days; 20 percent for both). Many of the other metrics would have been less affected by delays in visiting sites because characteristics like presence of woody vegetation or roads were less prone to rapid change.

Conclusions

These data describe roost sites that whooping cranes have used in the U.S. part of their migration corridor and could provide a basis for determining tolerances for the specific metrics detailed within. For most metrics, threshold values initially used by the Program could be considered more conservative when compared to critical values presented, which would preclude a habitat designation in numerous places cranes may use. Distance to nearest disturbance was the one metric that our data suggest cranes may be more sensitive to than previously thought. Finally, when considering values collectively, less than one-half of sites would have been identified as migration habitat given initially defined Program habitat criteria. This level of conservativism was likely not intended. With the presentation of the results of this study, the Program can better understand how all these metrics function collectively to define the suitability of habitat throughout the migration corridor.

Table 4. Critical percentiles for seven metrics used to characterize roost sites used by whooping cranes marked with telemetry equipment within the U.S. part of the Great Plains, 2012–15.

[Roost sites were grouped based on location on private lands, on public lands, and in Nebraska. *n*, number of roost sites; m, meter; cm, centimeter]

Metric (units)[1]	Group	*n*[2]	Critical percentile[3]	Percent difference[4]
Distance to nearest disturbance (m)	All roosts	500	150	
	Private lands	377	125	-17
	Public lands	123	245	63
	Nebraska only	135	164	9
Distance to nearest obstruction (m)	All roosts	501	18	
	Private lands	378	14	-22
	Public lands	123	32	77
	Nebraska only	136	20	11
Unobstructed view width (m)	All roosts	500	60.5	
	Private lands	377	56	-7
	Public lands	123	110	82
	Nebraska only	135	55	-9
Water depth (cm)	All roosts	407	32	
	Private lands	306	31	-3
	Public lands	101	34	6
	Nebraska only	114	31	-3
Wetted width (m)	All roosts	90	38	
	Private lands	73	37	-3
	Public lands	17	65	71
	Nebraska only	62	65	71
Suitable channel area (percent)	All roosts	82	20	
	Private lands	69	20	0
	Public lands	12	20	0
	Nebraska only	60	20	0
Unobstructed channel or wetland width (m)	All roosts	463	36	
	Private lands	343	33	-8
	Public lands	120	110.5	207
	Nebraska only	132	37	3

[1]Metrics defined in table 1 and appendix 2.

[2]Number of roost sites visited and measurements taken for each metric and roost category.

[3]Value that defines threshold of 90 percent of whooping cranes using site. This measure is the 10th percentile for all metrics except water depth, where the 90th percentile is used.

[4]Percentage difference between critical percentiles for specific groups as compared to the values for all roost sites.

Summary

Endangered whooping cranes (*Grus americana*) of the Aransas-Wood Buffalo population migrate through the Great Plains twice each year. Although there is much interest in conservation and management for this species, information regarding characteristics of nocturnal roost sites used during migration has been limited and based largely on incidental observations. Using high-quality location data collected concurrently, we directed a companion field study designed to characterize sites used as roost or day-use sites to augment knowledge and assist the Platte River Recovery Implementation Program (hereafter called the “Program”) in identifying migration habitat for restoration, conservation, and management actions along the Platte River in central Nebraska. We collected data at 504 roost sites and 83 day-use sites used by marked whooping cranes in Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, Minnesota, and Montana. Roost sites were located in emergent wetlands (50 percent), lacustrine wetlands (25 percent), rivers (20 percent), and dryland sites (5 percent). Most day-use sites were characterized as dryland sites (54 percent), with the balance in wetlands

(45 percent) and rivers (1 percent). Habitat criteria thresholds initially derived by the Program to represent where 90 percent of whooping cranes used along the Platte River were different from those we measured over a larger section of the migration corridor. For most of the metrics, the Program's initial habitat criteria thresholds would be considered more conservative than critical values estimated from our data; thus, whooping cranes were seemingly able to tolerate a wider range of these metrics than initially suspected. One exception was the metric distance to nearest disturbance feature, where our results suggest that whooping cranes may be less tolerant to nearby disturbances in a larger part of the migration corridor compared to the Platte River. We also determined correlations among some metrics and that using the criteria collectively lead to <50 percent of sites we measured being considered whooping crane habitat by the Program. A better understanding of how metrics function collectively may be useful for future efforts in defining habitat for migrating whooping cranes.

References Cited

Allen, R.P., 1952, The whooping crane: New York, National Audubon Society Resource Report 3, 246 p.

Armbruster, M.J., 1990, Characterization of habitat used by whooping cranes during migration: U.S. Fish and Wildlife Service, Biological Report 90, 16 p.

Austin, J.E., and Richert, A.L., 2001, A comprehensive review of observational and site evaluation data of migrant whooping cranes in the United States, 1943–1999: U.S. Geological Survey, 136 p.

Belaire, J.A., Kreakie, B.J., Keitt, T., and Minor, E., 2014, Predicting and mapping potential whooping crane stopover habitat to guide site selection for wind energy projects: Conservation Biology, v. 28, p. 541–550.

Cannon, J.R., 1996, Whooping crane recovery—A case study in public and private cooperation in the conservation of endangered species: Conservation Biology, v. 10, p. 813–821.

Clark, T.W., and Westrum, R., 1989, High-performance teams in wildlife conservation—A species reintroduction and recovery example: Environmental Management, v. 13, p. 663–670.

Conring, C.M., 2016, Spatial ecology of the lower Colorado River Valley Population of greater Sandhill Cranes (*Grus canadensis tabida*): Texas Tech University, M.S. thesis 167 p.

Cowardin, L.M., Carter, V., Golet, F.C., and LaRoe, E.T., 1979, Classification of wetlands and deepwater habitats of the United States: Washington, D.C., U.S. Fish and Wildlife Service, U.S. Department of the Interior, 131 p.

Douglas, D.C., Weinzierl, R., Davidson, S.C., Kays, R., Wikelski, M., and Bohrer, G., 2012, Moderating Argos location errors in animal tracking data: Methods in Ecology and Evolution, v. 3, p. 999–1007.

Folk, M.J., and Tacha, T.C., 1990, Sandhill crane roost site characteristics in the North Platte River Valley: Journal of Wildlife Management, v. 54, p. 480–486.

Hefley, T.J., Baasch, D.M., Tyre, A.J., and Blankenship, E.E., 2015, Use of opportunistic sightings and expert knowledge to predict and compare whooping crane stopover habitat: Conservation Biology, v. 29, p. 1337–1346.

Hefley, T.J., Tyre, A.J., Baasch, D.M., and Blankenship, E.E., 2013, Nondetection sampling bias in marked presence-only data: Ecology and Evolution, v. 3, p. 5225–5236.

Howe, M.A., 1989, Migration of radio-marked whooping cranes from the Aransas-Wood Buffalo population—Patterns of habitat use, behavior, and survival: Washington, D.C., U.S. Fish and Wildlife Service Technical Report 21, 33 p.

Howlin, S., and Nasman, K., 2016, Correlates of whooping crane habitat selection and trends in use in the central Platte River, Nebraska: Platte River Recovery Implementation Program Report, 143 p.

Hutto, R.L., 1998, On the importance of stopover sites to migrating birds: Auk, v. 115, p. 823–825.

Johns, B.W., Woodsworth, E.J., and Driver, E.A., 1997, Habitat use by migrant Whooping Cranes in Saskatchewan: Proceedings of the North American Crane Workshop, v. 7, p. 123–131.

Krapu, G.L., Facey, D.E., Fritzell, E.K., and Johnson, D.H., 1984, Habitat use by migrant sandhill cranes in Nebraska: Journal of Wildlife Management, v. 48, p. 407–417.

Kuyt, E., 1992, Aerial radio-tracking of whooping cranes migrating between Wood Buffalo National Park and Aransas National Wildlife Refuge, 1981–84: Canadian Wildlife Service Occasional Paper 74, 50 p.

Laubhan, M.K., and Fredrickson, L.H., 1997, Wetlands of the Great Plains—Habitat characteristics and vertebrate aggregations, *in* Knopf, F.L. and Samson, F.B., eds., Ecology and Conservation of Great Plains Vertebrates: Springer, p. 20–48.

Lingle, G., Currier, P., and Lingle, K., 1984, Physical characteristics of a whooping crane roost site on the Platte River, Hall County, Nebraska: Prairie Naturalist, v. 16, p. 39–44.

Lingle, G.R., 1987, Status of whooping crane migration habitat within the Great Plains of North America: Proceedings of the 1985 North American Crane Workshop, v. 4, p. 331–340.

Pearse, A.T., Brandt, D.A., Harrell, W.C., Metzger, K.L., Baasch, D.M., and Hefley, T.J., 2015, Whooping crane stopover site use intensity within the Great Plains: U.S. Geological Survey Open-File Report 2015–1166, 12 p.

Platte River Recovery Implementation Program, 2006, Final Platte River Recovery Implementation Program—Full document with appendices: 731 p., accessed May 20, 2016, at https://www.platteriverprogram.org/PubsAndData/Pages/ProgramLibrary.aspx.

Platte River Recovery Implementation Program, 2012, PRRIP whooping crane minimum habitat criteria (DRAFT): 8 p., accessed May 20, 2016, at https://www.platteriverprogram.org/PubsAndData/Pages/ProgramLibrary.aspx.

Samson, F., and Knopf, F., 1994, Prairie conservation in North America: BioScience, v. 44, p. 418–421.

Stevenson, J.O., and Griffith, R.E., 1946, Winter life of the whooping crane: Condor, v. 48, p. 160–178.

Tacha, M., Bishop, A., and Brei, J., 2010, Development of the whooping crane tracking project geographic information system: Proceedings of the North American Crane Workshop, v. 11, p. 98–109.

Walkinshaw, L., 1973, Cranes of the world: New York, Winchester Press, 370 p.

Appendixes 1–3

Appendix 1. Accuracy Assessments of Location and Relocation

Introduction

Global positioning systems (GPS) allow for collection and relocation of points on the Earth with a high degree of accuracy. In this project, technicians navigated to locations initially derived from transmitters placed on whooping cranes (*Grus americana*) in order to collect site-specific data. Some metrics were likely more sensitive to location errors than others. Those more sensitive were distance to certain features on the landscape and water depth. We conducted a simple field test to estimate errors associated with locations we had acquired and were attempting to relocate.

Locations of whooping cranes were accompanied with one of four accuracy categories, described as less than (<) 26 meters (m), 26–50 m, 51–75 m, and 76–100 m. Although serviceable for crude relative accuracy assessments, these categories do not provide usable accuracy estimates of locations. Beyond errors in acquiring locations, we were interested to know if handheld GPS units used to navigate back to these locations would introduce extra sources of error (identified as relocation error). We were interested in three types of error: (1) location error, defined as the distance between the actual location and position reported by the transmitter; (2) relocation error, defined as the distance between the position reported by the transmitter and where technicians navigated to using a handheld GPS unit; and (3) total error, defined as the distance between the actual location and location that technicians navigated to using a handheld GPS unit (fig. 1–1).

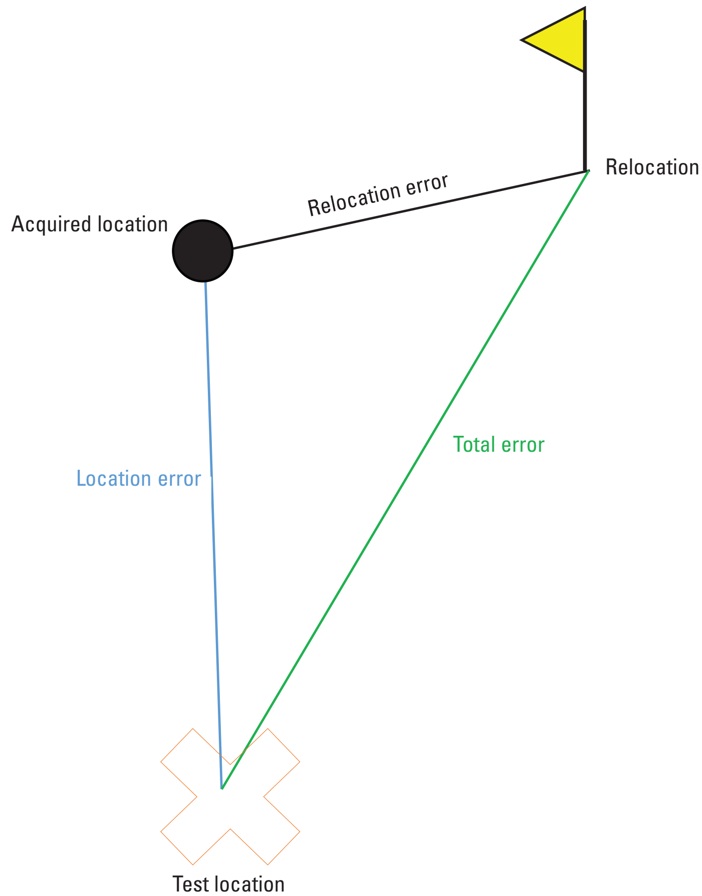


Figure 1–1. Graphical depiction of the field test to estimate location, relocation, and total error using known test locations, acquired locations from transmitters, and relocation points that technicians navigated to.

Methods

We conducted field tests in Hall County, Nebraska (40.794N latitude, 98.457W longitude). This location was about in the middle of the study area where information was collected at whooping crane roost sites.

For this field test, we used four transmitters that were identical to the units that were used to mark whooping cranes (North Star Science and Technology LLC, Baltimore, Maryland). Initially, we demarcated 15 permanent test locations by driving a steel rod into the ground. These locations were about 50–80 m apart. During September 2014, we turned transmitters on and positioned them at each of the test locations for multiple days, allowing them to acquire numerous GPS locations at each test site.

To estimate relocation error, we selected 2–5 unique acquired locations at each test location, 60 in total, and divided them into two groups. We used six observers that had no part in establishing test locations or moving transmitters in the initial phase of the field test. Observers were all technicians of the larger project that had previous experience using GPS units to locate points and collect field data. Before initiating tests, we drove the steel rods marking the known test locations completely into the ground so that their positions could not be determined by observers. On September 22 and 23, 2014, observers navigated to 30 locations and placed a numbered pin flag corresponding to one of 60 acquired locations in the same manner they would approach whooping crane locations. Technicians used two handheld GPS units that were being used in the project (Garmin eTrex 10 and Garmin GPS II Plus, Garmin International, Inc., Olathe, Kansas). After each observer placed pin flags, we used a 30-m tape to measure the distance between each pin flag and the corresponding steel rod, which marked the known location. We also used a submeter accurate GPS unit with satellite based augmentation system differential correction (GeoXH 2005, Trimble Navigation Limited, Sunnyvale, California) to record locations of each test location site and locations where technicians placed each pin flag (that is, relocation sites).

In a geographic information system (ArcMap 10.3, Esri, Inc., Redlands, California), we determined distances between test locations and acquired locations to estimate location error. We also measured distances between acquired locations and relocation sites to estimate relocation error. Acquired locations were initially in latitude and longitude, World Geodetic System of 1984. We projected these locations to Universal Transverse Mercator zone 14, using the North American Datum of 1983 (NAD 83). All locations from the GeoXH 2005 Trimble unit were collected in UTM zone 14 NAD 83. All calculations were done using this datum and projection.

To estimate location error, we summarized errors from all locations gathered from transmitters. For relocation error, we summarized all errors between acquired locations and relocation positions. Finally, to determine total error, we first had to calculate a sample weight for each observation because locations used in the field experiment were included multiple times within all acquired locations. Sample weights were necessary because we selected unique rather than random locations at each test location.

Results

Average distance between acquired locations (location error; number of sites [n]=211), and their respective known locations was 8.9 m (SD=5.7, 50th percentile=8.4, 68th percentile=10.6, 95th percentile=16.9, min=0.0 m, maximum=38.4 m). Of the 74 percent of observations identified in the <26 m accuracy category, average error was 7.5 m. The 26–50 m accuracy category included 20 percent of observations and had an average error of 10.1 m, whereas the 51–75 m accuracy category included just 6 percent of observations and had an average error of 20.9 m. Only one location was acquired in the final accuracy category (76–100 m), and its associated error was 27.9 m.

Average distance between acquired and relocated positions (relocation error) was 1.6 m (SD=1.6 m, n=179). The 50th percentile was 1.3 m, 68th percentile 1.8 m, and 95th percentile 3.8 m. Minimum relocation error was 0.1 m and maximum was 14.2 m.

Average distance between relocated positions and known locations (total error) was 8.5 m (SD=5.5 m, n=180). The 50th percentile was 8.9 m, 68th percentile 10.1, and 95th percentile was 15.3 m. The minimum total error was 0.8 m and maximum was 34.1 m.

Primary Findings

When comparing different types of potential positional errors, we found location error, defined as the distance from a point derived from the GPS unit on transmitters to a known location, was the largest source of error. Location error arose from multiple sources. There is inherent error in GPS position acquisition, which cannot be completely eliminated without differential correction and systems beyond what are currently in small transmitters such as the type deployed. Another source of error came from rounding of latitude and longitude values from the transmitter. The units used for this study provided both measures rounded to the one ten-thousandth. This meant that acquired points surrounding a fixed location would form a grid pattern, each location one ten-thousandth of a decimal degree from the other. At our field site in Nebraska, points forming such a grid were 8.4 m from one another on the x-axis and 11.1 m on the y-axis (distances would differ depending on geographic location). If the known location were in the center of this grid, any acquired point using a rounded latitude and longitude would be 7 m from the actual location. Future studies should consider requesting coordinates with greater precision to reduce this source of error.

By comparison, errors associated with navigating to positions using handheld GPS units (relocation error) were of lesser magnitude. We consider the level of error from this source to be negligible for our purposes.

Total error, or the distance between a known location and a point where technicians navigated to, was comparable to location error individually. In considering position errors with this project, 10 m could be used as a reasonable estimate of potential positional error, which was the 68th percentile of the data we used. We believe this level of error was acceptable for many of the metrics collected, yet results and conclusions should be considered with the knowledge that specific measured location was not exactly where the whooping crane was standing at the time the signal was transmitted.

Appendix 2. Description of Data and Metrics Presented

Location identification (ID)—Identifying value for each evaluated location. This variable is content rich and includes the date of initial use by the bird, the bird identification value, type of location (see below for descriptions), and a number sequentially representing how many of that type are in the dataset (for example, 2014_04_01_D56_R1).

Bird ID—Unique identifying value for each marked whooping crane.

Location type—Identifies whether a site was a roost site (RT) or a day-use site (DU).

Bird measured—An incremental integer for each uniquely marked whooping crane simultaneously at a particular site.

Date measured—Calendar date when location was visited and evaluated by field crew (MM/DD/YYYY).

Elapse—Number of days between when cranes last used a site and technicians collected data at the site.

State—U.S. State in which evaluated location lies.

Location classification—Categorical representation of location, originally identified as river, wetland, or nonwetland. River was identified when flowing water was present or location was in a known river system. Wetlands were identified when location was associated with surface water. Nonwetlands or drylands were places without surface water and no recent evidence of water.

Wetland classification—For rivers and wetlands, a greater subdivision describing locations. In this report, we used three classifications: river, emergent wetland, and lacustrine wetlands. River was identified where flowing water was present or location was in a known river system. Emergent wetland was identified for wetlands with various levels of persistence that had herbaceous hydrophytes and generally included small- to medium-sized wetlands. Lacustrine wetland was identified in deepwater habitat, generally associated with reservoirs, impoundments, and lakes.

Disturbance description—Described features that could make a crane flush and were visible from the location point. In this report, five categories of disturbances were used. Roads were any type of publically accessible road feature that had the possibility of a vehicle using it, but did not include trails through private property. Dwellings included all manmade buildings, occupied or abandoned. Machinery included any manmade mechanical objects, including vehicles, tractors, and center pivot irrigation systems. Blinds included manmade structures built with the suspected intent for hunting or viewing. Other miscellaneous disturbances included items that technicians believed could disturb cranes but not appropriate for other categories. If no identifiable disturbance feature was present, technicians recorded "None."

Disturbance distance—Distance in meters between the evaluated location and identified disturbance feature.

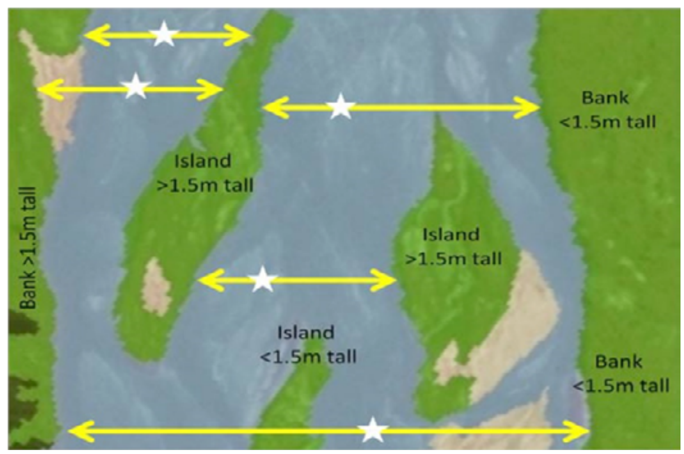
Obstruction description—Described objects greater than (>) 1.5 meters (m) above ground level that could potentially obscure a whooping crane's ability to see behind the object. In this report, we included five categories of obstructions. Topography was identified when physical land features precluded line of sight. Herbaceous vegetation was any nonwoody vegetation such as grasses, forbs, or emergent wetland vegetation. Woody vegetation was any nonherbaceous vegetation and generally included trees and shrubs. Manmade obstructions were any objects made and placed in a location by humans. Finally, we used other obstructions to identify a feature that could not be put in one of the other categories.

Obstruction distance—Distance in meters between the evaluated location and identified obstruction feature.

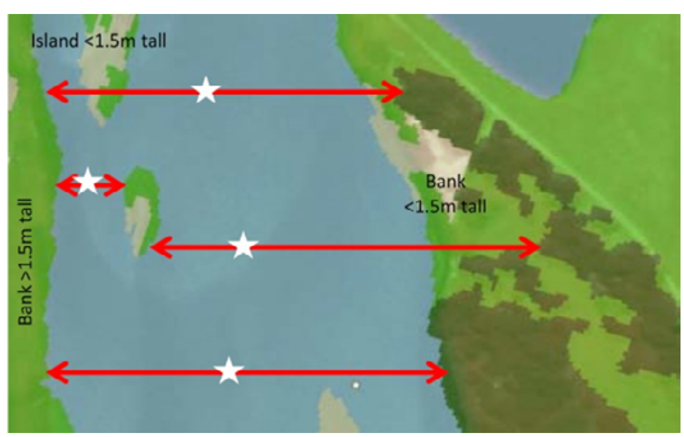
Distance to water—Distance in meters between the evaluated location and nearest surface water. If location was in water, it was recorded as zero.

Wetland width—Distance in meters across contiguous water area perpendicular to widest part of the contiguous water area. Wetland width was evaluated only for wetland sites and this measure described unobstructed channel width of wetland locations for analyses.

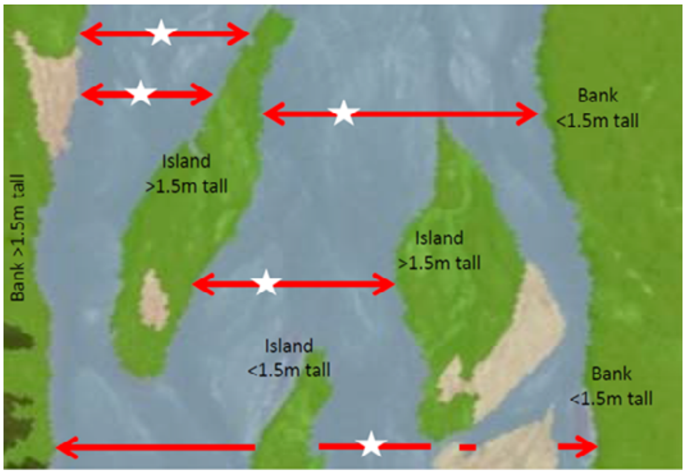
Unobstructed channel width—Perpendicular distance in meters across an active channel, between obstructions, and through the evaluated site as identified in the image below.



Unobstructed view width—For river sites, perpendicular distance between obstructions >1.5 m and through the evaluated site as identified in the figure below. This measurement may include land surfaces such as sandbars in addition to water. For other sites, we used distance to obstructions in four cardinal and four intercardinal directions to determine four view widths and used the minimum width as unobstructed view width for analyses.



Wetted width—Total width in meters of the wetted portion of the channel measured perpendicular to flow and through the evaluated site. Islands or other obstructions >1.5 m within the river and perpendicular to the evaluated site separate channels, and any water beyond them excluded. This metric was evaluated only for river sites.



Suitable channel depth—Percentage of river channel <20 cm deep or bare ground following a straight line perpendicular to the channel through the evaluated location. The metric was evaluated only for river sites.

Water depth—Distance in centimeters between the surface of the water and the wetland or river bed. A value of zero was entered if no water was present. For values >1 m, a value of 100 centimeters (cm) was added, although the actual measure was greater.

Average vegetation height—Average height in centimeters of vegetation at the evaluated location within a 20x50-cm quadrat frame. If in water, only vegetation above the surface water was recorded. If vegetation submerged or absent, the value was record as zero.

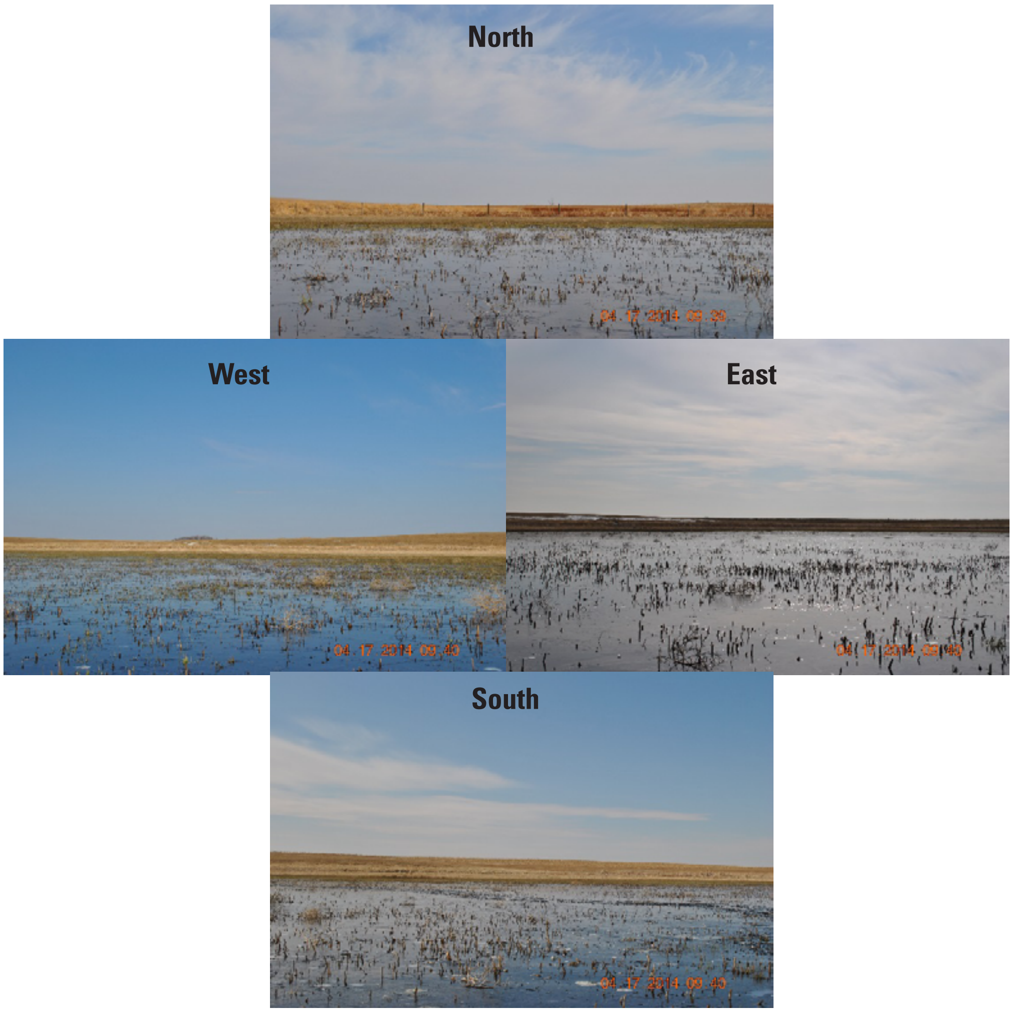
Migration season—Identifies the season (spring of fall) and year of data collection.

Public lands—Identifies locations on lands in public trust or those protected under easement.

Land cover—Describes basic type of land use or land cover at the measured site.

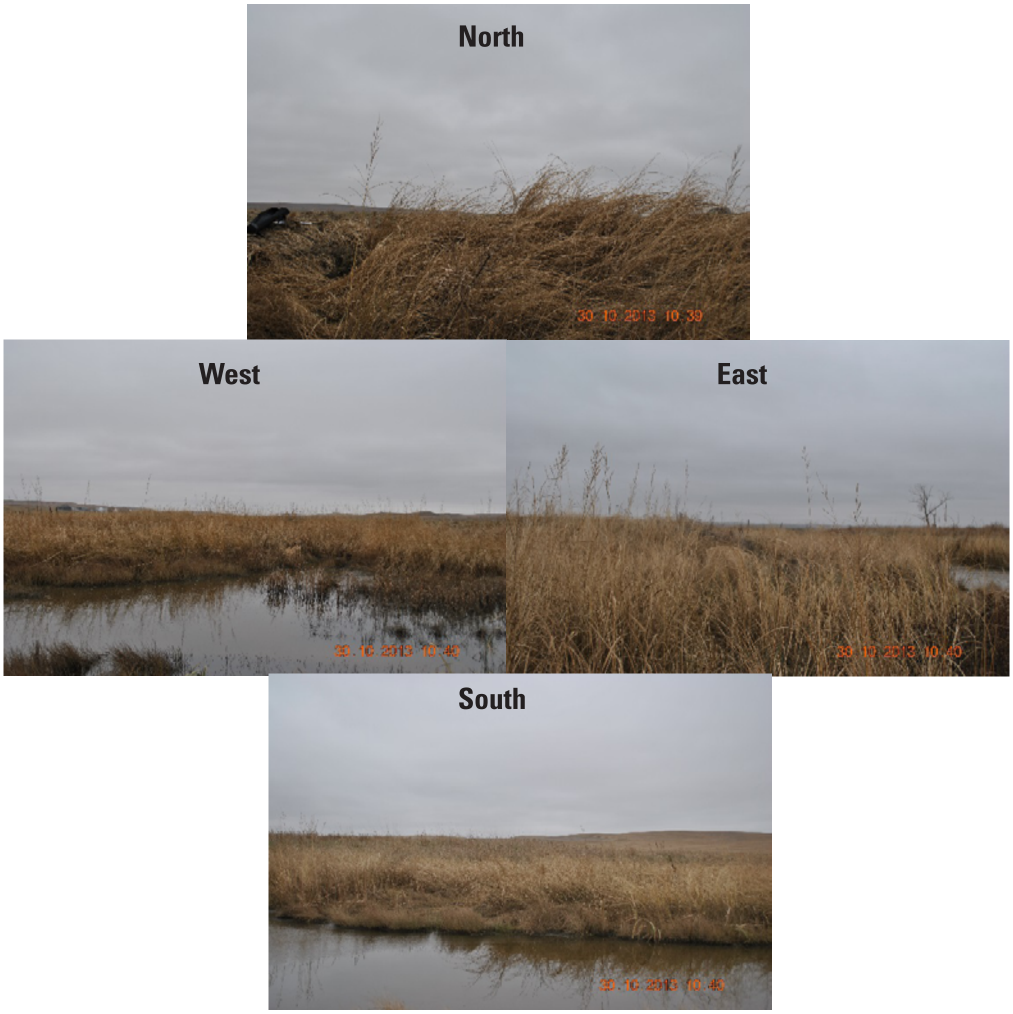
Appendix 3. Example Photographs of Stopover Sites used by Marked Whooping Cranes

Location—Hand County, South Dakota
Site identification—2014_04_06_D32_R1
Type of roost site—Emergent wetland
Dates used by whooping crane—04/06/2014–04/08/2014
Date photographs taken—04/17/2014



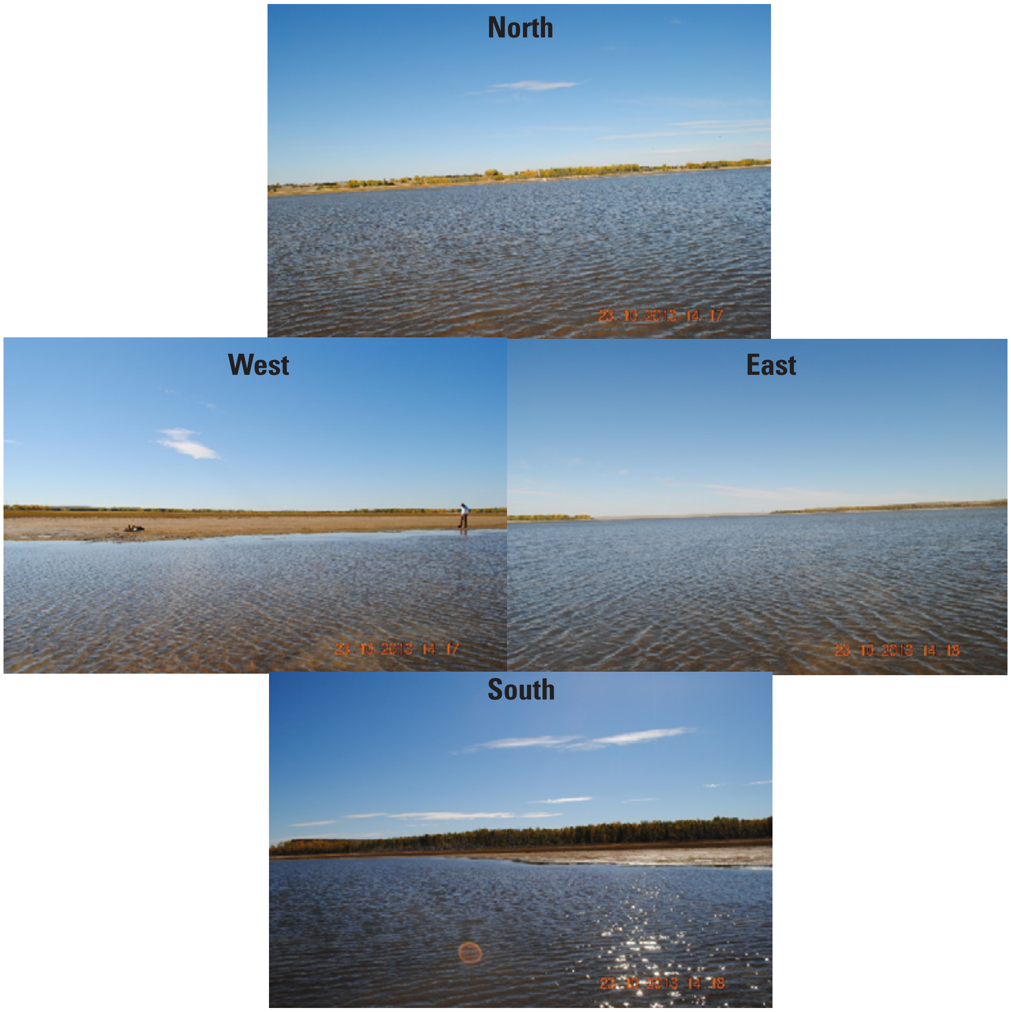
Panoramic photograph

Location—Dunn County, North Dakota
Site identification—2013_10_15_2012_25_R1
Type of roost site—Emergent wetland
Dates used by whooping crane—10/15/2013–10/16/2013
Date photographs taken—10/30/2013



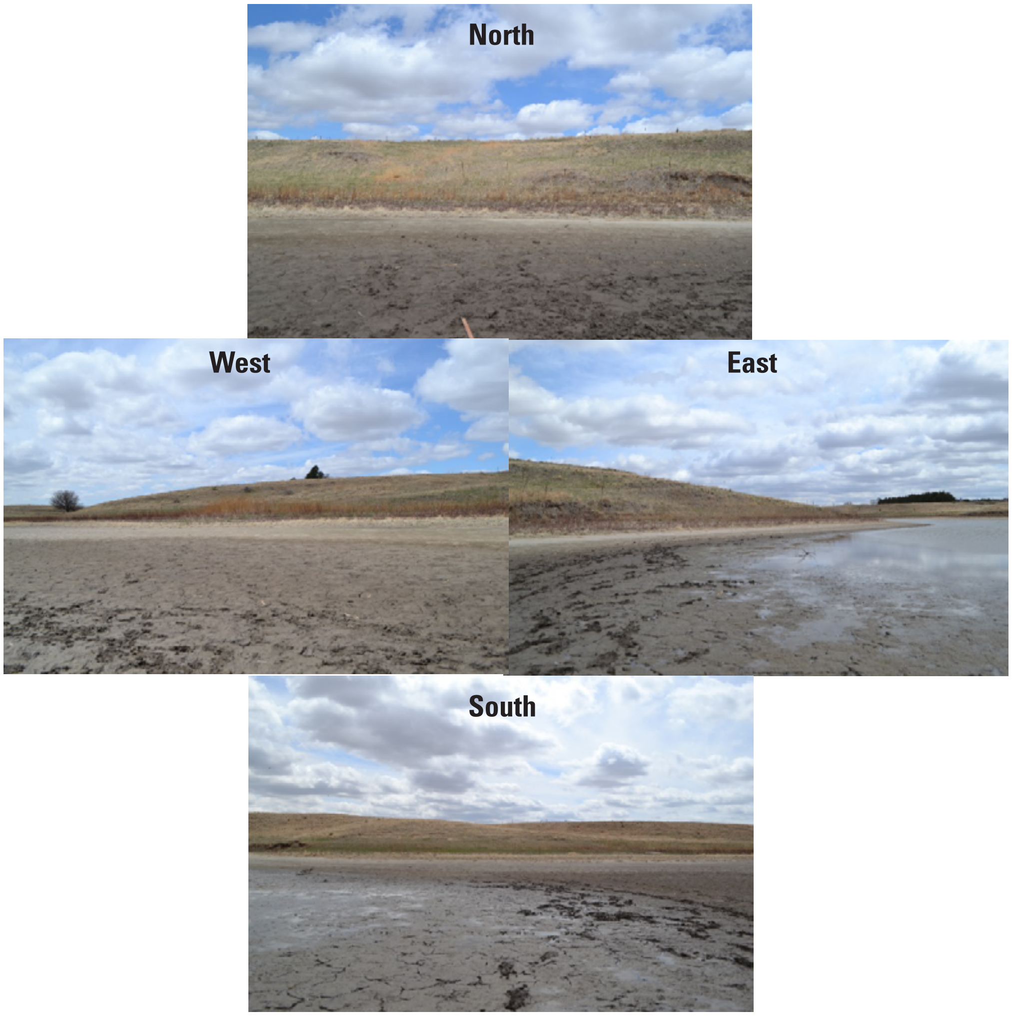
Panoramic photograph

Location—Norton County, Kansas
Site identification—2013_10_17_2012_25_R1
Type of roost site—Lacustrine wetland
Dates used by whooping crane—10/17/2013–10/18/2013
Date photographs taken—10/23/2013



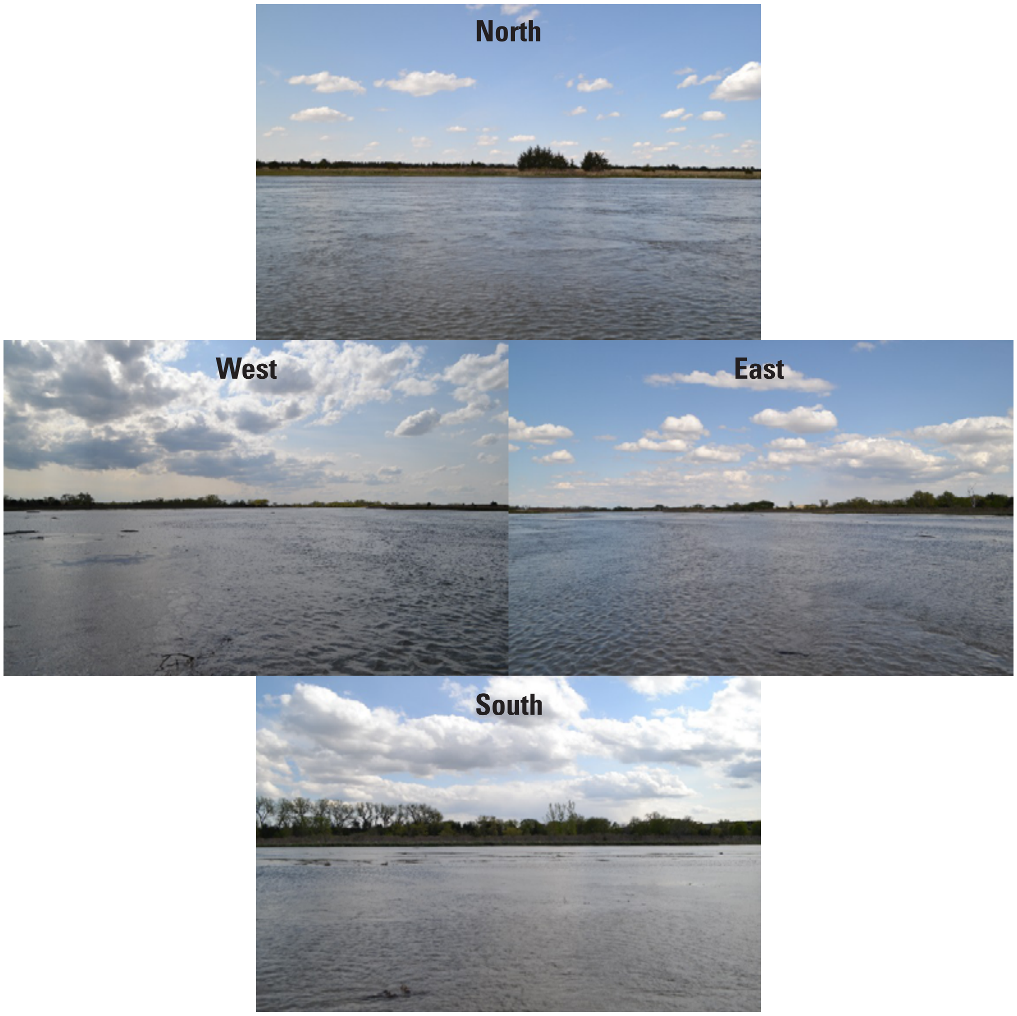
Panoramic photograph

Location—Franklin County, Nebraska
Site identification—2014_04_01_F45_R1
Type of roost site—Lacustrine wetland
Dates used by whooping crane—04/01/2014–04/11/2014
Date photographs taken—04/16/2014



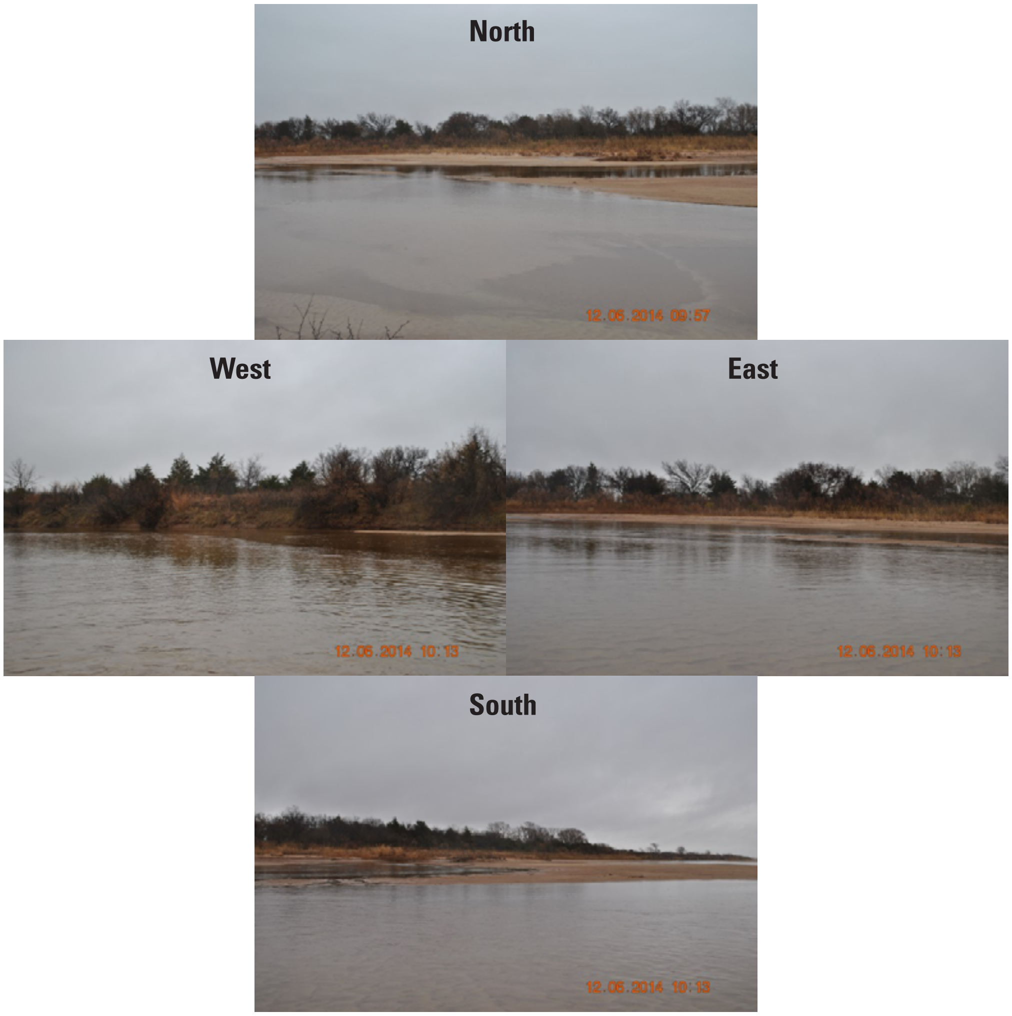
Panoramic photograph

Location—Custer County, Nebraska
Site identification—2014_05_06_D24_F47_R1
Type of roost site—River
Dates used by whooping crane—05/06/2014–05/07/2014
Date photographs taken—05/14/2014



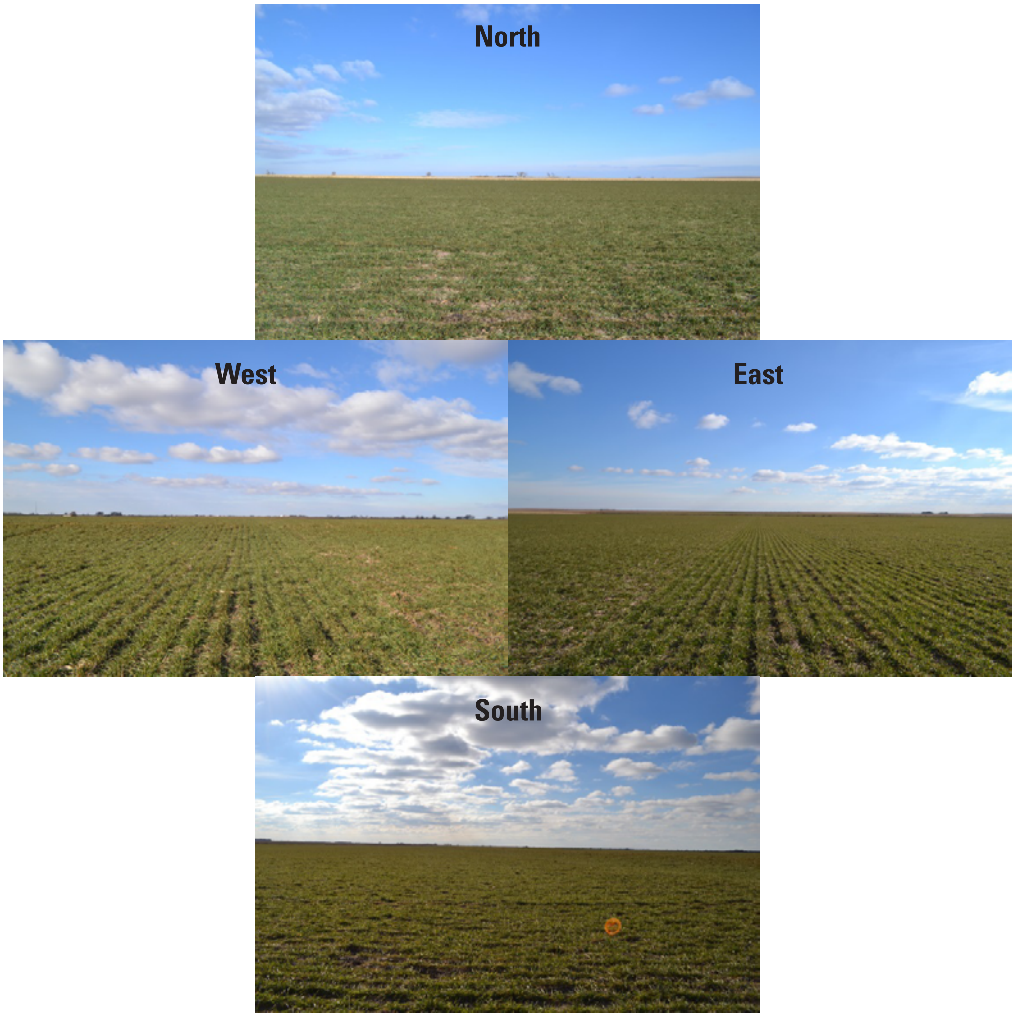
Panoramic photograph

Location—Kingfisher County, Oklahoma
Site identification—2014_11_09_D23_R1
Type of roost site—River
Dates used by whooping crane—11/09/2014–11/11/2014
Date photographs taken—12/05/2014

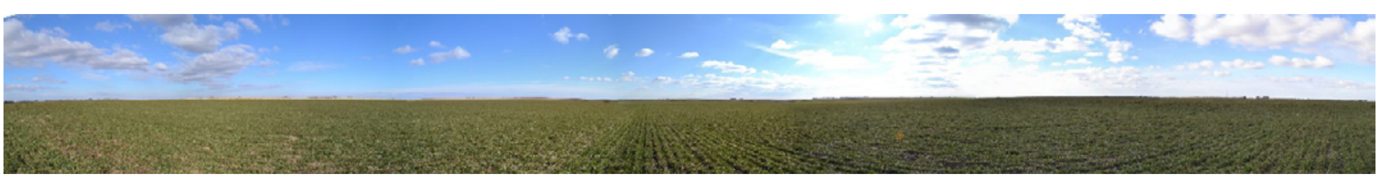


Panoramic photograph

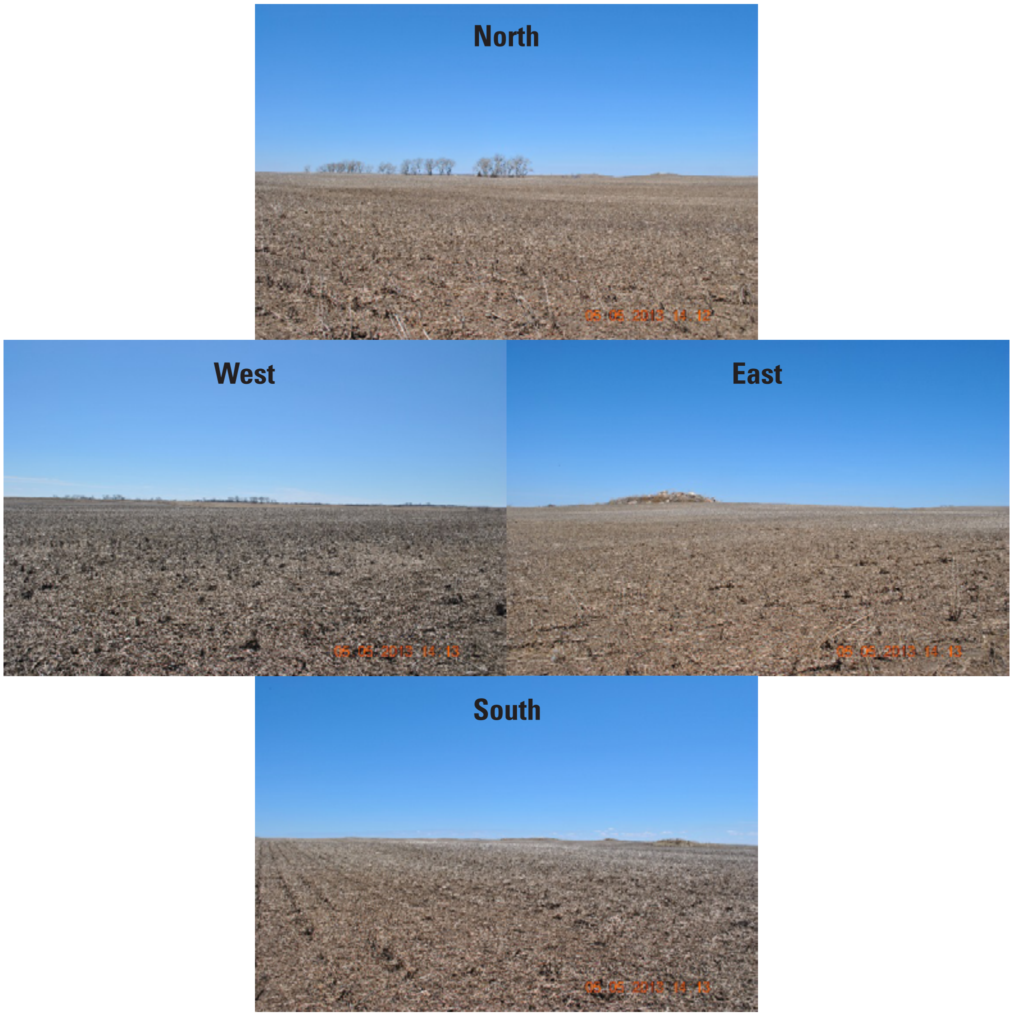
Location—Ellsworth County, Kansas
Site identification—2014_11_05_D24_C80_R1
Type of roost site—Dryland
Dates used by whooping crane—11/05/2014–11/06/2014
Date photographs taken—11/26/2014



Panoramic photograph



Location—Stutsman County, North Dakota
Site identification—2013_04_27_2012_21_R1
Type of roost site—Dryland
Dates used by whooping crane—04/27/2013–04/28/2013
Date photographs taken—05/06/2013



Publishing support provided by:
Rolla Publishing Service Center

For more information concerning this publication, contact:
Director, USGS Northern Prairie Wildlife Research Center
8711 37th Street Southeast
Jamestown, North Dakota 58401
(701) 253–5553

Or visit the Northern Prairie Wildlife Research Center Web site at:
http://www.npwrc.usgs.gov/

Pearse and others—**Evaluation of Nocturnal Roost and Diurnal Sites Used by Whooping Cranes in the Great Plains, United States**—Open-File Report 2016–1209

ISSN 2331-1258 (online)
https://doi.org/10.3133/ofr20161209