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Hillary L. Thompson
International Crane Foundation

Anne E. Lacy
International Crane Foundation

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Thompson, Hillary L. and Lacy, Anne E., "WINTER AND MIGRATORY HABITAT USE OF SIX EASTERN GREATER SANDHILL CRANES" (2016). *Proceedings of the North American Crane Workshop*. 336. <https://digitalcommons.unl.edu/nacwgproc/336>

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WINTER AND MIGRATORY HABITAT USE OF SIX EASTERN GREATER SANDHILL CRANES

HILLARY L. THOMPSON, International Crane Foundation, E-11376 Shady Lane Road, Baraboo, WI 53913, USA

ANNE E. LACY, International Crane Foundation, E-11376 Shady Lane Road, Baraboo, WI 53913, USA

Abstract: To better understand non-breeding ecology of sandhill cranes (*Grus canadensis tabida*), we harnessed 6 satellite GPS transmitters to adult cranes from 1 central Wisconsin breeding area. Using location data from these transmitters, we investigated non-breeding movements, including the routes and timing of migration. By combining satellite GPS data with a national land cover dataset, we also described habitat use on stopovers and wintering areas. Sandhill cranes tended to use larger home ranges on long stopovers (>3 days) than on short stopovers (3 days or less). The durations of northward migrations were longer and had more stopovers than southward migrations. We also documented a reverse migration pattern in 1 sandhill crane. There were differences in home range sizes of winter area and amount of time spent in the area (0.56-157 km², 29-101 days). Sandhill cranes departed from the breeding grounds, departed from wintering areas, and returned to the breeding grounds at about the same time each year, regardless of the distance migrated. Cranes departed from the breeding grounds in mid-November and returned in mid to late March. Non-breeding sandhill cranes seemed to select wetlands and row crop agriculture more often than grasslands, forested, or developed areas, but at varying rates in different wintering areas. Understanding winter and migratory habitat use and migration behaviors of sandhill cranes from different breeding areas can help us cranes in Wisconsin, as well as important use areas in the flyway.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 13:47-53

Key words: eastern population, greater sandhill crane, *Grus canadensis tabida*, habitat, migration, satellite telemetry, stopover, wintering grounds.

Productivity and survival of migratory cranes are influenced by behavior and use of habitat in each part of the annual cycle (Krapu et al. 1985). Understanding an individual's non-breeding movements and habitat use patterns can create a more complete picture of their life history. Habitat use and habitat quality on the wintering grounds influence an individual's body condition, which in turn influences migration patterns and subsequent survival and reproductive success (Strong and Sherry 2000, Ottosson et al. 2005).

Sandhill cranes (*Grus canadensis tabida*) in the eastern flyway have been extensively monitored on their breeding grounds, migratory stopovers, and wintering areas, but rarely have the same individual birds been studied throughout their entire annual cycle (Bennett and Bennett 1989, Littlefield 1995, Krapu et al. 2014). There have also been studies of cranes captured on stopover sites or wintering grounds and followed to their breeding areas, but few studies of wintering sandhill cranes from the same breeding areas (Nesbitt and Williams 1979, Krapu et al. 2011, Fronczak 2014). Researchers at the International Crane Foundation (ICF) have been studying sandhill cranes in a dense breeding population in central Wisconsin since 1990; in that time we have banded 607 sandhill cranes. Records of banded birds from this study area during the non-breeding

season have mostly come from opportunistic sightings of cranes with colored leg bands by the general public. Very few individuals have been observed on multiple occasions during the non-breeding season, so there is no information about wintering locations or non-breeding habitat use for the majority of the sandhill cranes from the study area.

One way to gain more information about sandhill cranes over a large spatial scale during the non-breeding season is through the use of satellite telemetry. By fitting cranes with satellite transmitters, we were able to collect location data from multiple birds simultaneously as they were migrating and wintering in different states. The goals of this study were to describe stopover sites, wintering areas, migration routes, and migration timing of multiple non-breeding sandhill cranes from the same breeding population. This information can help us better understand population dynamics and identify important winter or stopover locations for sandhill cranes in the eastern flyway and the types of habitat important for cranes throughout the year.

METHODS

All cranes in this study were adult birds from a dense breeding population of sandhill cranes near

Briggsville, Wisconsin (43°36'N, 89°36'W). This area is mostly agriculture and wetland systems with limited development. Four male and 2 female sandhill cranes were captured within the study area with alpha-chloralose according to the methods outlined by Hartup et al. (2014). One bird was captured in October 2011, 3 in September of 2012, and 2 in September of 2014. The crane caught in 2011 developed exertional myopathy during capture, was rehabilitated in captivity for 14 days, and released. Each bird was fitted with a platform terminal transmitter (PTT) on a backpack harness as well as uniquely colored leg bands. Each transmitter recorded a location every hour of every day beginning when the transmitter was placed on the bird. These included locations recorded while the birds were roosting. Transmitters transmitted 189-1,033 days during the study, and 2 transmitters were still functioning as of July 2015. Locations were recorded using the Argos and GPS systems, and all points accurate to less than 100 m were used for this study (Argos 2014). Transmitters collected 3,995-18,970 locations per individual.

We defined stopovers as locations where cranes stayed at least 2 nights between their breeding area and wintering area. Short stopovers were defined as places cranes stayed for 3 days or less, and long stopovers were places cranes stayed for more than 3 days. Wintering areas were defined as the southern terminus of a bird's migration. Due to unequal sample sizes and unequal variance, we used a Welch's 2-sample *t*-test to analyze differences in home range sizes between short and long stopovers, number of stopovers made on migration, and duration of migrations. Distance migrated and timing of migration were compared using a linear model. All statistical analyses were done with the program R (R Core Team 2015).

We conducted all spatial analyses using ArcGIS 10.2 (ESRI 2013). To calculate length of migration, we computed the distance from the center point of a crane's breeding territory to the center point of its wintering area. To describe habitat characteristics of areas used by sandhill cranes, we used CropScape, a land cover dataset that covered the entire study area during the time period of this study and focused on agricultural habitats (USDA 2013). For habitat use analysis, we grouped land cover classes into 6 categories (developed, grassland, forested, row crop, wetland, and other). We delineated home ranges on stopovers and wintering areas using 95% minimum convex polygons (MCP) (Mohr 1947) using the ArcMap minimum bounding geometry tool (ESRI 2013). To describe habitat characteristics of

areas available to cranes, we calculated the percent of each MCP home range composed of each habitat type. We then compared the habitat available within home ranges to the habitat of the locations of the bird, or the used areas, and calculated a preference index for each habitat category using methods outlined by Taft et al. (2008). We used 2-tailed 1-sample *t* tests to determine if preference indices for each habitat category were different from 1, or no preference.

RESULTS

Migration Patterns

These 6 sandhill cranes utilized a variety of migration routes and traveled to wintering areas in Indiana, Tennessee, Georgia, and Florida (Figure 1). The duration of southward migrations averaged 9.6 days and was shorter than northward migrations, which averaged 43.6 days ($P = 0.005$) (Table 1, Figure 2). On average, adult sandhill cranes left the breeding grounds on 21 November and arrived on their wintering areas 1 December. Cranes left their wintering areas around 4 February and arrived back on the breeding grounds on 19 March. Sandhill cranes also made more stopovers on northward migrations (mean = 4.1 stops) than on southward migrations (mean = 1.2 stops) ($P = 0.004$). Despite a wide range of distances migrated (304-1,774 km), these sandhill cranes did not demonstrate differences in the timing of departure from or arrival on the breeding grounds ($P > 0.05$) (Figure 3). Cranes wintering farther from the breeding grounds also did not leave wintering areas earlier than individuals wintering closer to the breeding grounds ($P > 0.05$).

Reverse Migration

In spring 2013 we documented a reverse migration, where a sandhill crane flew in the opposite direction to normal northward migration (Figure 4). The crane arrived at a staging area in northern Indiana on 14 March 2013 and in Sauk County Wisconsin on 18 March and then made a return flight to northern Indiana on 19 March, where it stayed until 28 March. The crane then flew north again and arrived on its breeding territory on 30 March, where it stayed for the rest of the breeding season.

Stopover Sites

On 19 migrations, the 6 sandhill cranes made 19

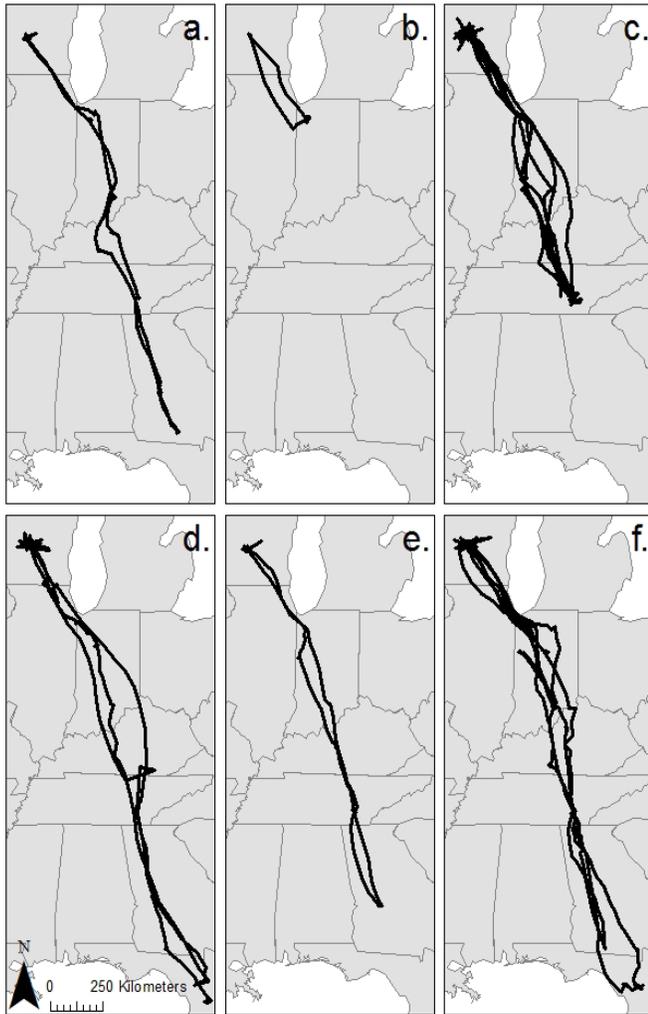


Figure 1. Migration routes used by each of the 6 sandhill cranes tracked in this study. All birds have breeding territories near Briggsville, Wisconsin. These migrations were made during a) fall 2014-spring 2015, b) fall 2011-spring 2012, c) fall 2012-spring 2015, d) fall 2012-fall 2013, e) fall 2014-spring 2015, and f) fall 2012-spring 2014.

short stopovers where they stayed for 3 days or less, and 30 long stopovers where they stayed for more

than 3 days. Cranes used larger home ranges on long stopovers than on short stopovers ($P = 0.001$) (Figure 5). Mean 95% MCP home range size used by sandhill cranes was 35.4 km² during long stopovers and 8.6 km² during short stopovers. Cranes used stopover sites in Wisconsin, Indiana, Kentucky, Tennessee, and Georgia. However, 24 of the 49 stopovers were made in the state of Indiana. On average, stopover home ranges consisted mostly of agriculture, forested, and grassland areas; but the majority of used locations were in agriculture or wetlands (Table 2). Sandhill cranes on stopovers used wetland and agricultural areas proportionally more than these habitats were available in the stopover home range (mean preference index greater than 1, $P < 0.001$, $P = 0.02$). Cranes selected against grassland, forested, and developed areas within their home ranges ($P = 0.01$, $P = 0.006$, $P < 0.001$, respectively).

Wintering Areas

During 9 winters, the 6 sandhill cranes wintered in Indiana, Tennessee, Georgia, and Florida. One individual tracked over 3 winters spent all 3 winters at Hiwassee Wildlife Refuge in Tennessee. Another individual tracked for 2 winters, spent 1 winter in Georgia and the second winter in Florida. Cranes spent an average of 65 days on their wintering areas (29-101 days). Home range sizes averaged 48.7 km² and ranged from 0.6 to 157.0 km². Wintering areas were mostly forested, wetland, and agricultural areas, but more than half of crane locations were in wetlands (Table 3). Sandhill cranes selected for wetland areas and against forested, developed, and grassland areas within their home ranges ($P = 0.01$, $P = 0.006$, $P < 0.001$, $P = 0.02$, respectively). Agricultural areas were used proportionally to their availability within home ranges ($P = 0.14$).

Table 1. Duration, departure and arrival dates, and number of stopovers made during southward and northward migrations by 6 sandhill cranes from a breeding area near Briggsville, Wisconsin, 2011-2015.

	Southward migration (<i>n</i> = 10)		Northward migration (<i>n</i> = 9)	
	Mean	Range	Mean	Range
No. stops	1.2	0-2	4.1	0-7
Duration (days)	9.6	1-24	43.6	1-83
Departure date	21 Nov	12 Nov-28 Dec	4 Feb	26 Dec-10 Mar
Arrival date	1 Dec	23 Nov-5 Jan	19 Mar	11-30 Mar

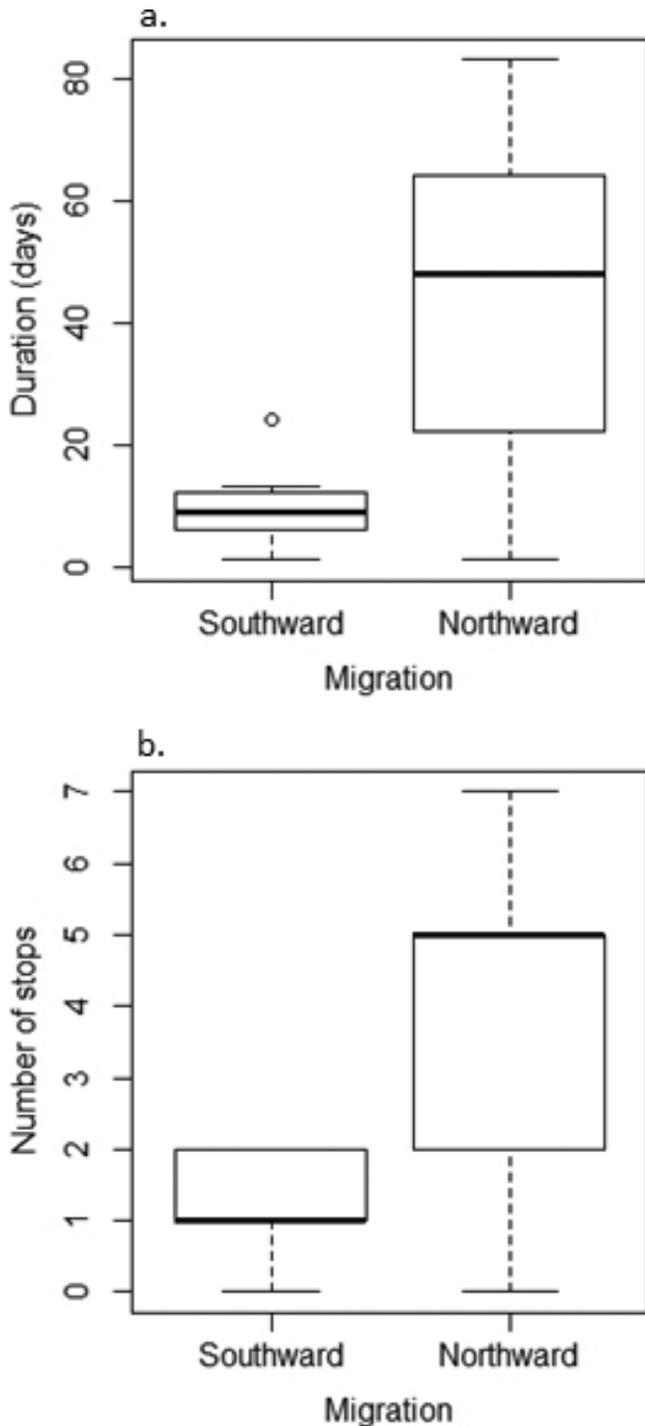


Figure 2. Migration duration (a) and number of stops (b) on southward and northward migrations made by 6 sandhill cranes from a breeding area near Briggsville, Wisconsin, 2011-2015. The duration of migration was measured by the number of days between when a bird began making large southward or northward movements and when it reached its southern or northern terminus. Stopovers were defined as when a crane would spend more than 2 nights in 1 location during migration.

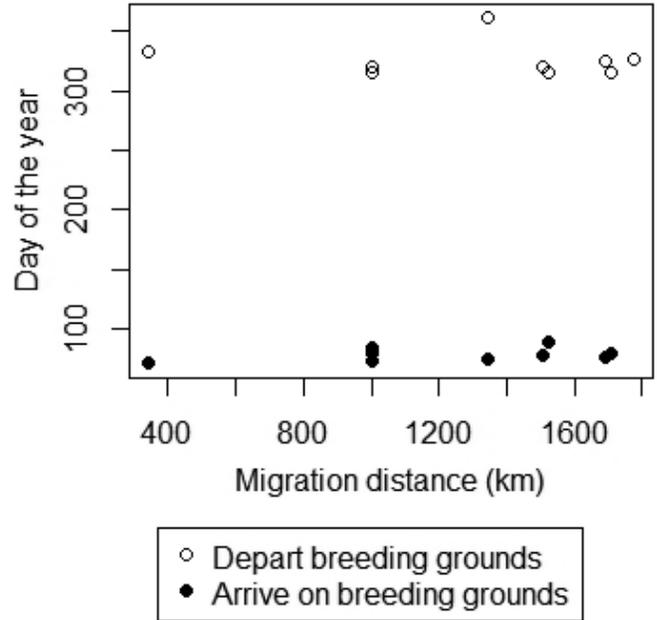


Figure 3. Timing of migration of 6 adult sandhill cranes migrating various distances from a breeding area near Briggsville, Wisconsin, 2011-2015.

DISCUSSION

Migration Patterns

Sandhill cranes from a dense breeding population in central Wisconsin migrated to wintering areas ranging from Indiana to Florida. While there were differences in the southern terminus of the migration route, there was considerable overlap in routes and stopover sites. Multiple birds tracked in this study used stopover sites at Jasper-Pulaski Fish and Wildlife Area in Indiana and Hiwassee Wildlife Refuge in Tennessee, both of which are known major stopover and wintering areas for sandhill cranes. These birds were very consistent in when they left the breeding grounds and when they returned. Departure dates from breeding grounds for birds from similar breeding areas were somewhat later than found by Fronczak (2014). This may be due to the fact that all of these birds were known breeding territorial adults that would benefit from spending the maximum time possible on the breeding grounds to defend and maintain their territory. For cranes migrating various distances, there were no differences in when birds left their wintering areas and began their northward migration. However, northward migrations

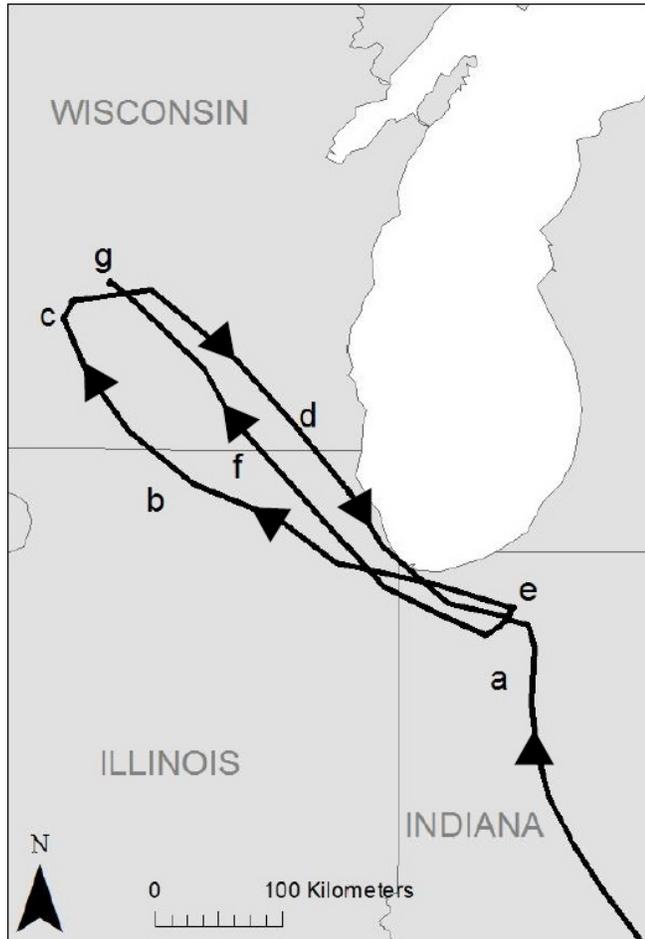


Figure 4. Example of a reverse migration exhibited by 1 sandhill crane during spring 2013. The bird traveled north to northern Indiana (a) where it stayed from 14 March until 16 March. On 17 March it flew north to Wisconsin (b), and stayed there on 18 March (c). On 19 March, it flew back to northern Indiana (d), and stayed there until 28 March (e). On 29 March, it flew to southern Wisconsin (f) and arrived on its breeding territory on 30 March.

were longer in duration and had more stopovers than southward migrations. It seems their strategy was to quickly migrate south, but move more slowly northward on the return trip, potentially dependent on appropriate weather conditions.

Reverse Migration

Reverse migrations have been documented in other species and are often attributed to severe weather events, poor body condition of the bird, inaccuracy in orientation of a bird, or as a search technique to refuel before crossing an ecological barrier (Åkesson et al.

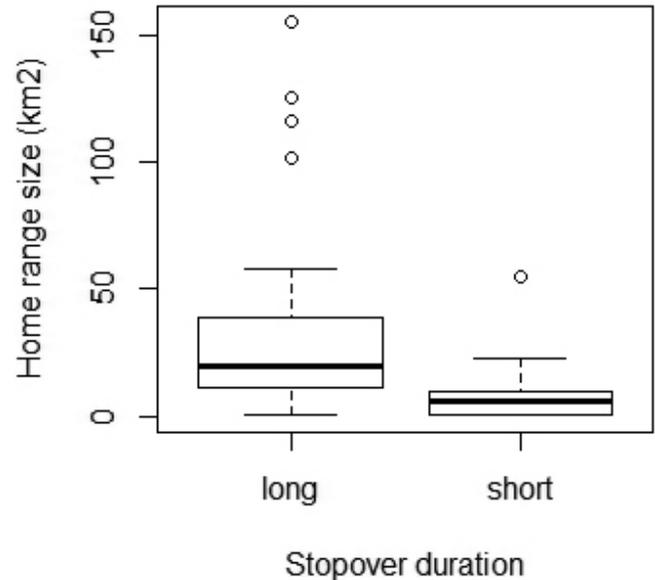


Figure 5. Home ranges (km²) of stopovers used for >3 days (long) or 3 days or less (short) by 6 sandhill cranes from a breeding area near Briggsville, Wisconsin, 2011-2015. Home ranges were calculated using a 95% minimum convex polygon around stopover locations.

1996, Komenda-Zehnder et al. 2002, D'Amico et al. 2014). In the case that we describe, of a sandhill crane arriving on the breeding grounds and returning to a staging area, the reverse migration was likely due to inclement weather. On 18 March 2013 in Briggsville, Wisconsin, the high temperature was 0°C (32°F) and snowing. The ground and water bodies were still frozen, making it difficult for cranes to forage, and potentially decreasing their security during nightly roosts. This could have potentially motivated a return flight to a staging area with above-freezing temperatures. When the crane arrived on its breeding territory on 30 March 2013, weather conditions were 10°C (50°F) and raining. Open water was available for roosting habitat, and foraging areas were open. These improved conditions likely prompted the crane to remain on its breeding territory.

Stopover Sites

Stopover sites used by these marked birds from 1 breeding population were similar to those used by sandhill cranes tagged on migration by Fronczak (2014) from a variety of breeding areas. There is significant overlap in staging areas used by cranes from throughout

Table 2. Habitat composition of stopovers used by 6 sandhill cranes from a breeding area near Briggsville, Wisconsin, 2011-2015. Home ranges were calculated using 95% minimum convex polygons.

	Agriculture		Wetland		Forested		Developed		Grassland	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Home range (%)	37.0	0.0-81.6	10.2	0.0-99.6	28.4	0.4-65.7	5.5	0.0-20.1	19.0	0.0-59.0
Bird locations (%)	40.1	0.0-97.8	35.7	0.0-100	10.2	0.0-75.8	0.8	0.0-15.8	13.1	0.0-64.9
Preference ratio	1.7	0.2-12.9	11.3	0.0-58.6	0.5	0.0-6.8	0.1	0.0-0.9	0.7	0.0-4.8

Table 3. Habitat composition of wintering areas used by 6 sandhill cranes from a breeding area near Briggsville, Wisconsin, 2011-2015. Home ranges were calculated using 95% minimum convex polygons.

	Agriculture		Wetland		Forested		Developed		Grassland	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Home range (%)	19.7	1.0-67.2	23.2	2.2-61.8	32.1	10.5-45.3	7.6	0.4-15.9	17.4	6.9-33.1
Bird locations (%)	14.9	0.0-51.8	59.1	3.6-89.5	11.9	0.2-46.8	4.4	0.0-37.2	9.7	2.6-19.1
Preference ratio	2.7	0.0-8.3	3.8	1.2-8.4	0.5	0.0-2.3	0.7	0.0-5.9	0.6	0.2-1.1

the breeding areas of the eastern population. Sandhill cranes also presumably used wetland habitats for roosting and agricultural habitats for foraging, which is consistent with stopover habitat use of sandhill cranes in the mid-continent population (Krapu et al. 2014). Due to the high use of some stopover sites by multiple sandhill cranes in our study as well as in other studies, and their consistent use of agricultural and wetland habitats on migration, land managers in the flyway could benefit cranes by planting crops (particularly corn) adjacent to wetland areas and leaving some forage in the fields (Iverson et al. 1987, Pearse et al. 2010).

Wintering Areas

We noticed large differences in wintering areas used by birds breeding in our study area. There were even differences for 1 individual bird in wintering areas used from 1 year to the next. However, this distribution of wintering areas is consistent with that used by sandhill cranes tracked by Fronczak (2014) from various breeding areas. Krapu et al. (2011) also reported that mid-continent population sandhill cranes from 1 breeding area used a variety of wintering areas which were also used by sandhill cranes from other breeding areas.

In these wintering areas, sandhill cranes preferred wetland habitat and selected against forested, developed, and grassland areas. They did not seem to prefer or avoid agricultural areas relative to their availability. This is different from the behavior

exhibited on stopover sites, where birds also preferred agricultural habitats. This may be due to the higher energetic costs of migration, and cranes increasing fat reserves during migration to potentially offset low food availability when they reach the breeding grounds. Otherwise, wintering habitat use of these cranes was consistent with previous studies of wintering sandhill cranes in this and other populations (Bennett and Bennett 1989, Ballard and Thompson 2000, Krapu et al. 2014). Even though there were differences in locations used, sandhill cranes tracked in this study consistently used wetland habitats in their wintering areas. Some of the same areas used by cranes as stopover sites were used by other cranes as wintering areas, so these areas may be targeted for wetland management to benefit migrating and wintering sandhill cranes.

ACKNOWLEDGMENTS

We thank A. Gossens, M. Engels, J. Barzen, and D. Moore for assistance with this project, many interns for their efforts in capturing sandhill cranes, and the International Crane Foundation for support.

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