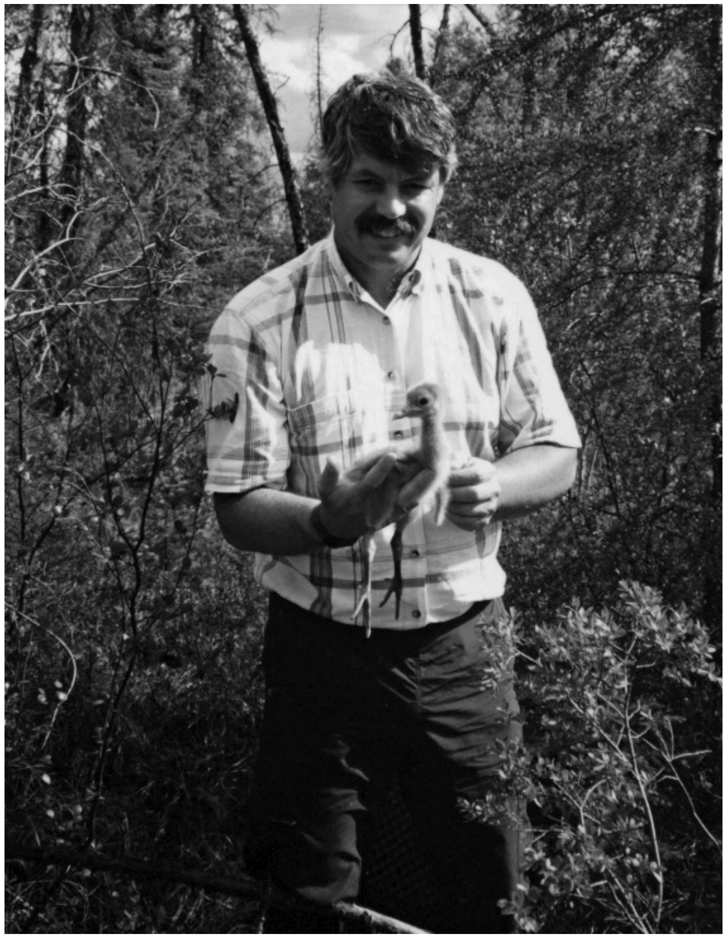
PROCEEDINGS OF THE
TWELFTH NORTH AMERICAN CRANE WORKSHOP

13-16 March 2011
Grand Island, Nebraska



FRONTISPIECE. Brian Johns, retired biologist with the Canadian Wildlife Service (CWS), was awarded the sixth L. H. Walkinshaw Crane Conservation Award on 16 March 2011 in Grand Island, Nebraska. Brian received his Bachelor of Science Advanced degree from the University of Saskatchewan in 1973 and began his career with the CWS that same year. During his 36 years with CWS, he conducted research on canvasbacks, sandhill cranes, whooping cranes, loggerhead shrikes, and various songbirds in the grasslands, parklands, and boreal forests of Alberta, Saskatchewan, and Manitoba. In the 1980s he was involved with radio-tracking migrant whooping cranes through prairie Canada and investigations of their habitat use. Brian has diligently represented Canada on the Whooping Crane Recovery Team, working closely with other crane caretakers, biologists, and government representatives. His research has included population monitoring, philopatry, effects of egg collection, and the banding of juvenile whooping cranes. He has also studied potential reintroduction habitat in Saskatchewan and Manitoba and tracked sandhill crane migration routes from those habitats. Brian logged more than 1,500 hours of aerial surveys over the crane nesting area and authored over 20 publications. Brian was a primary force in getting the whooping crane recovery plan updated and approved in 2007 and has started efforts to have Critical Habitat declared in Canada. In recognition for his work, he has received Nature Saskatchewan's Conservation Award, the Whooping Crane Conservation Association's Honor Award, and the Jerome Pratt Whooping Crane Award. Brian is known for his tremendous knowledge of whooping cranes, his birding skills, and his friendship to all he has met and with whom he has worked. Brian retired from CWS in October 2009 and he is greatly missed. (Photo by Doug Bergeson.)

Front cover: Sandhill cranes flying to roost on the Platte, March 2011, by K. S. Gopi Sundar, International Crane Foundation.

Back cover: Scenes from the Twelfth Workshop in Grand Island, Nebraska, by David Aborn, Jane Austin, Heidi Messerly, Glenn Olsen, Gopi Sundar, and anonymous contributors.

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Lewis, J. C., editor. 1982. Proceedings of the 1981 crane workshop. National Audubon Society, Tavernier, Florida, USA.

Lewis, J. C., editor. 1987. Proceedings of the 1985 crane workshop. Platte River Whooping Crane Maintenance Trust, Grand Island, Nebraska, USA.

Wood, D. A., editor. 1992. Proceedings of the 1988 North American crane workshop. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report 12, Tallahassee, Florida, USA.

Stahlecker, D. W., and R. P. Urbanek, editors. 1992. Proceedings of the sixth North American crane workshop. North American Crane Working Group, Grand Island, Nebraska, USA.

Urbanek, R. P., and D. W. Stahlecker, editors. 1997. Proceedings of the seventh North American crane workshop. North American Crane Working Group, Grand Island, Nebraska, USA.

Ellis, D. H., editor. 2001. Proceedings of the eighth North American crane workshop. North American Crane Working Group, Seattle, Washington, USA.

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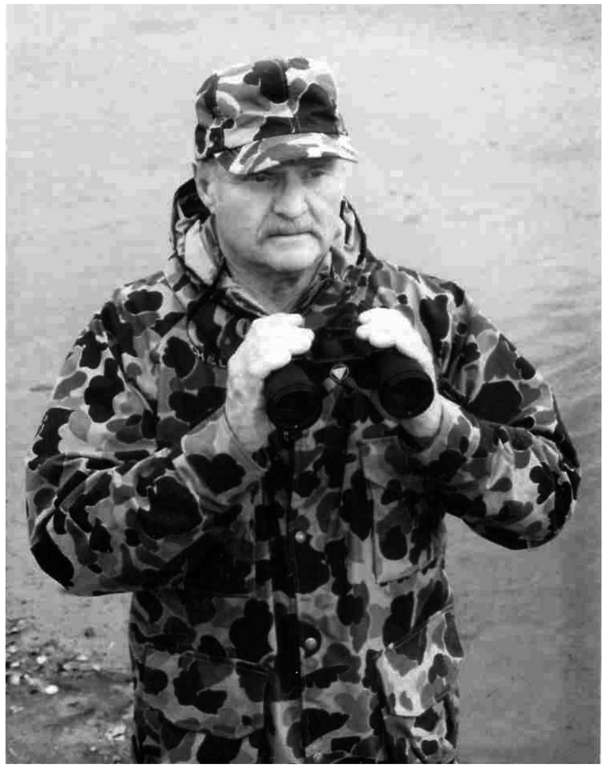
PREFACE

The North American Crane Working Group (NACWG) is an organization of professional biologists, aviculturalists, land managers, non-professional crane enthusiasts, and others interested in and dedicated to the conservation of cranes and crane habitats in North America. Our group meets approximately every 3 years to exchange information pertaining to sandhill cranes and whooping cranes and occasionally reports on some of the other cranes species. Our meeting in Grand Island, Nebraska, 13-16 March 2011, marked a new and exciting chapter in our organization's history. For the first time, we held our meeting jointly with another organization, The Waterbird Society. The collaboration was both informative and enjoyable, and members from both organizations benefitted from the knowledge gained, as well as the personal interactions. We look forward to the opportunity for similar collaborations with The Waterbird Society and other organizations that might arise in the future. The workshop was organized by Felipe Chavez-Ramirez, and we thank him for his efforts. The field trips to see the Rainwater Basin wetlands and the restoration of the Platte River were enlightening and enjoyable, as were the evening socials and crane viewing at the Platte River Whooping Crane Trust, and having Jane Goodall join us for the tribute to Ernie Kuyt was an added plus. The NACWG Board of Directors consisted of President Jane Austin, Vice-President Richard Urbanek, Treasurer Daryl Henderson, Felipe Chavez-Ramirez, Barry Hartup, and Sammy King. The scientific program consisted of 34 scientific talks and 12 posters. The papers included in this volume are some of the ones presented at the workshop. The papers submitted for publication in the Proceedings are peer-reviewed according to scientific journal standards. We thank the following referees for their contribution to the quality of this volume:

Bart A. Ballard, Jeb A. Barzen, Kevin A. Calhoon, Randall B. Hammon, Matthew A. Hayes, Heidi F. Messerly, Shannon H. Moore, Javier G. Navarez, Felipe Chavez-Ramirez, Scott G. Somershoe.

Tara Rinderer assisted with final proofing.

David A. Aborn, Editor
February 2014



CHARLES "CHUCK" R. FRITH
1933-2010

We recently lost another member of the flock. Although it's difficult to single out an individual who had the greatest impact on the conservation gains that we enjoy today along the Platte, my vote would go to Chuck Frith.

He graduated in 1974 with a M.A. from then Kearney State Teachers College. His thesis, *The Ecology of the Platte River as Related to Sandhill Cranes and Other Waterfowl in Southcentral Nebraska*, was the first to bring attention to the importance of the Platte River. He spent countless hours interviewing local landowners and hunters regarding their recollections of cranes and waterfowl along the river, and he worked with the National Audubon Society to establish the first wildlife sanctuary along the Platte, what is now Rowe Sanctuary.

He also worked with The Nature Conservancy and identified the land that became Mormon Island Crane Meadows. In 1979 he was presented the Oak Leaf Award from The Nature Conservancy in recognition of that effort. In 1982 he received the Department of Interior's Meritorious Service Award "in recognition of an exemplary career in the conservation of fish and wildlife and their habitats", and in 1992 he was recognized as the Wings Over the Platte Crane Conservationist of the Year.

He may be gone, but he helped lay a solid foundation for the conservation efforts going on today, and for that we are the beneficiaries.

Gary Lingle,
Gibbon, Nebraska

CONTENTS

DISTRIBUTION, ABUNDANCE, AND MIGRATION TIMING OF GREATER AND LESSER SANDHILL CRANES WINTERING IN THE SACRAMENTO-SAN JOAQUIN RIVER DELTA REGION OF CALIFORNIA

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Abstract: The Sacramento-San Joaquin River Delta region of California (hereafter, Delta region) is an important wintering region for the Central Valley Population of greater sandhill cranes (*Grus canadensis tabida*) and lesser sandhill cranes (*G. c. canadensis*), but basic information about the ecology of these birds is lacking to design a biologically sound conservation strategy. During the winters of 2007-08 and 2008-09, we conducted roost counts, roadside surveys, aerial surveys, and tracked radio-marked birds to define the geographic area used by sandhill cranes in the Delta region, document migration chronology, and estimate subspecies-specific abundance. Radio-marked sandhill cranes arrived in our study area beginning 3 October, most arrived in mid-October, and the last radio-marked sandhill crane arrived on 10 December. Departure dates ranged from 15 January to 13 March. Mean arrival and departure dates were similar between subspecies. From mid-December through early-February in 2007-2008, the Delta population ranged from 20,000 to 27,000 sandhill cranes. Abundance varied at the main roost sites during winter because sandhill cranes responded to changes in water conditions. Sandhill cranes used an area of approximately 1,500 km^2 for foraging. Estimated peak abundance in the Delta region was more than half the total number counted on recent Pacific Flyway midwinter surveys, indicating the Delta region is a key area for efforts in conservation and recovery of wintering sandhill cranes in California. Based on arrival dates, flooding of sandhill crane roost sites should be staggered with some sites flooded in early September and most sites flooded by early October. Maintained flooding through mid-March would provide essential roosting habitat until most birds have departed the Delta region on spring migration.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:1-11

Key words: abundance, California, *Grus canadensis*, migration chronology, Sacramento Delta, sandhill cranes, San Joaquin Delta.

California's Central Valley is an important wintering region for sandhill cranes (*Grus canadensis*), both for the Central Valley Population of greater sandhill crane (*G. c. tabida*, hereafter referred to as greaters) and the Pacific Flyway Population of lesser sandhill crane (*G. c. canadensis*, hereafter referred to as lessers) (Pacific Flyway Council 1983, 1997). Sandhill cranes are patchily distributed in the Central Valley using areas where agricultural practices appear to meet their ecological needs and undisturbed roost sites are available (e.g., Pogson and Lindstedt 1991). The Sacramento-San Joaquin Delta region of California (hereafter Delta region) is a major wintering site for sandhill cranes in the Central Valley, and is particularly important for greaters (Pogson and Lindstedt 1991), listed as threatened in California (CDFW 2013).

Because of the importance of the Delta region for wintering sandhill cranes, agencies and conservation groups have acquired, enhanced, and managed lands for use by sandhill cranes. Most of this activity has centered on 5 major roost complexes in the Delta region; the Isenberg Sandhill Crane Reserve owned by California Department of Fish and Wildlife (CDFW), Stone Lakes National Wildlife Refuge (NWR) and San Joaquin River NWR owned by U.S. Fish and Wildlife Service (USFWS), Cosumnes River Preserve, established by The Nature Conservancy (TNC) in partnership with the Bureau of Land Management (BLM) and with multiple agency ownerships, and the more recent acquisition of Staten Island by TNC. All these properties include a portion of habitat managed to provide winter roost sites for sandhill cranes.

Periodic monitoring has confirmed sandhill cranes

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are using all areas currently managed for roost habitat (Pogson and Lindstedt 1991, Ivey and Herziger 2003), but basic information about the timing of use and subspecies composition are lacking. Moreover, no annual surveys are conducted to estimate crane abundance and define their distribution in the Delta region. Such basic information is necessary for proper sandhill crane management in the face of new environmental threats. For example, the recent spread of West Nile virus into California has caused landowners and managers to reduce the amount of shallow, standing water that might support mosquitoes during summer and early fall (e.g., CDFW 2007). Data on the timing of arrival and expected abundance over time at key roost sites in fall will provide the information needed to justify the timing and size of flooded roost sites to maintain sandhill crane use on traditional sites.

Our study addresses key questions about the abundance and distribution of sandhill cranes that winter in the California's Sacramento-San Joaquin Delta. Specifically, we quantify the timing of arrival, residence time, and timing of departure at major roost sites, track changes in roost use from fall through winter, estimate subspecies specific sandhill crane abundance, and define the distribution of sandhill crane occurrence in the Delta region during winter. When combined with information on habitat use and individual movements, this information will be critical for the development of biologically sound conservation plans for sandhill cranes wintering in the Delta region.

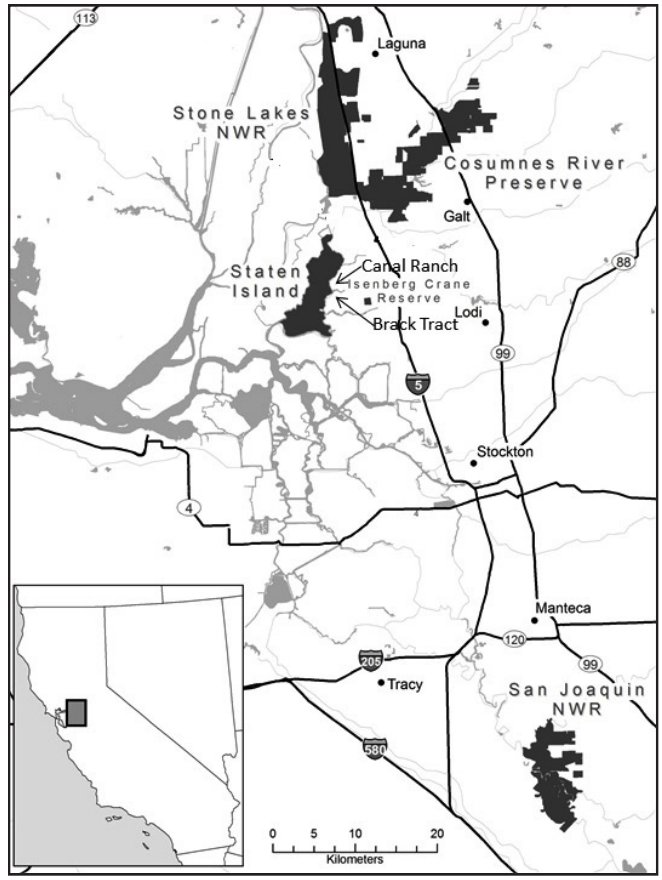

Figure 1. Map of the Sacramento-San Joaquin Delta and the San Joaquin River National Wildlife Refuge where distribution, abundance, and arrival and departure dates of greater and lesser sandhill cranes were studied, 2007-2009. Grey areas are waterways.

STUDY AREA

Our study focused on the Delta region but we also collected some information on sandhill crane abundance in the San Joaquin NWR region (Fig. 1). Our study concentrated specifically on several properties managed to provide night roost sites for sandhill cranes that subsequently support most of the sandhill cranes that winter in the Delta region (Pogson and Lindstedt 1991, Ivey and Herziger 2003), including Staten Island, Canal Ranch, Cosumnes River Preserve, Brack Tract, and Stone Lakes NWR. The study area was primarily rural agricultural landscapes bordered by urban communities. Agricultural land uses included field and silage corn, fall-planted (winter) wheat, rice, alfalfa, irrigated pasture, dairies, vineyards and orchards. The area also contained tracts of oak savannah and floodplain wetlands along the Cosumnes and Mokelumne rivers. The San Joaquin NWR region (located in Stanislaus County, approximately 12 km west of Modesto) includes the refuge and private croplands similar to the Delta region.

METHODS

Capture, Radio-marking, and Tracking

We captured and radio-marked a total of 33 greaters, 44 lessers, and 1 Canadian sandhill crane (*G. c. rowani;* identified morphologically, hereafter referred to as Canadian) on wintering, spring staging, and breeding areas. We captured 33 greaters and 28 lessers using rocket nets baited with corn (Urbanek et al. 1991) and noose lines (Hereford et al. 2000) at Staten Island or Cosumnes Preserve between 17 October 2007 and 27

February 2008. Additionally, to increase our sample of marked birds, we used rocket nets to capture 6 lessers on a spring staging site (Ladd Marsh Wildlife Management Area) near LaGrande, Oregon, in April 2008 and used noose lines to capture 10 lessers on their breeding grounds near Homer, Alaska, in August 2008.

For each sandhill crane captured, we determined subspecies based on morphological differences (Johnson and Stewart 1973). We marked each individual with a U.S. Geological Survey aluminum leg band and a unique combination of color bands. Finally, we radio-marked each sandhill crane with a VHF transmitter (Sirtrack, Hawkes Bay, New Zealand, Model AVL6171) that was mounted to a tarsal band (Krapu and Brandt 2001). Transmitters weighed approximately 30 g (<1% of body mass), had a life expectancy of 730 days, and were equipped with a mortality sensor. The 10 birds captured in Alaska were marked with platform terminal (satellite) transmitters mounted to a tarsal band. All birds were released at their capture site within an hour after capture.

We attempted to locate each radio-marked sandhill crane daily, from October through mid-March, using hand-held 3-element Yagi antennas and a truck-mounted null-peak antenna system (Balkenbush and Hallett 1988, Samuel and Fuller 1996); however, our relocation rate averaged every 2 days, varied by individual, and primarily depended on sandhill crane movement within our study area. We used a Global Positioning System (GPS) linked to a computer system to enter bird identification number, local site name, truck location, date, time, and bird bearings from multiple locations. We used Program Locate III (Pacer Computing, Tatamagouche, NS, Canada) to triangulate locations (Nams 2005). We conducted 7 aerial searches (Gilmer et al. 1981) over the 2 winters of our study of areas throughout central California to locate sandhill cranes that left the Delta region. During aerial surveys, we also mapped locations that looked suitable as sandhill crane night roosts.

Our handling of sandhill cranes was conducted under the guidelines of the Oregon State University Animal Care and Use Committee (project #3605) to ensure methods were in compliance with the Animal Welfare Act and United States Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training policies. Sandhill cranes were captured under CDFW permit SC-803070-02 and U.S. Geological Survey federal banding permit MB#21142.

Migration Chronology

We used telemetry information from our radio-marked sandhill cranes to characterize fall migration arrival and spring migration departure dates relative to our study area during fall 2008 and spring 2009. We defined arrival date as the first date each sandhill crane was found during fall in the study area and departure date as the last date they were detected in late winter. We calculated the number of days our marked sandhill cranes were at our study sites in the Delta region (i.e., winter residency period) from our telemetry records by totaling days that individuals were found at our study sites in the Delta region. We used the Student's *t*-test to assess if either mean arrival date in fall of 2008 or departure date in spring of 2009 differed by subspecies.

Sandhill Crane Abundance

Roost counts.—We conducted biweekly counts of sandhill cranes at the 5 major night roost complexes in the our study area (Staten Island, Brack Tract, Canal Ranch Tract, Cosumnes River Preserve, and Stone Lakes NWR) between 5 October 2007 and 27 February 2008 to document seasonal patterns of abundance and estimate peak sandhill crane population size in the Delta region. We also conducted roost counts at the San Joaquin River NWR monthly during October 2007 through February 2008. We conducted each count over a period of 2 or 3 days but all sites within each roost complex were counted on the same night or morning. We conducted surveys by stationing observers with binoculars at key locations around a roost complex to count all sandhill cranes as they flew into a roost site at sunset or during early morning before they left their roost. We did not have permission to survey the Canal Ranch roost complex on 3 December, so we report estimates only for 3 dates with complete roost count data.

Aerial surveys.—To generate an unbiased estimate of abundance that included a measure of precision, we conducted aerial surveys (e.g., Caughley 1977, Dugger et al. 2005) on 14 and 28 January and 5 February 2008. We first partitioned the study area into high and low density survey blocks based on our understanding of roost site distribution and relative sandhill crane abundance (Ivey and Herziger 2003). In the Delta region, we created 3 high density survey blocks centered on the major roost complexes at Stone Lakes

NWR, Staten Island and adjacent Brack Tract and Canal Ranch, and the Cosumnes River Preserve. The remainder of the Delta region was classified as a low density survey block. In the San Joaquin NWR region, we identified 1 high density block associated with San Joaquin NWR that was imbedded in a larger, low density, block. We partitioned each survey block into a series of 1-km-wide survey strips oriented north-south. We stratified our sample effort by survey block size and randomly selected (without replacement) a sample of transects to survey within each block, adding transects until the total transect area equaled or exceeded 10% of the total block area. We used the same set of transects for each survey.

We conducted surveys from a fixed-wing aircraft flying 300 m above the ground and at a speed of 160 km/hr. We used markers on the aircraft window to identify transect boundaries, and 2 observers counted sandhill cranes out each side of the aircraft while the pilot flew a line down the middle of each survey strip.

For each survey, we estimated sandhill crane abundance as (Caughley 1977):

$$\hat{Y} = RZ$$

where Z = area of total census

R = average density per unit area = $\Sigma y_{ji}/\Sigma z_i$

where y_{ji} = total sandhill cranes j counted on transect i

z_i = area of transect i

variance was calculated as:

$$[N(N-n)/n(n-1)]/(\Sigma y2 + R2\ \Sigma z2 - 2R\ \Sigma yz)$$

We estimated abundance separately for high and low density survey blocks then combined the 2 estimates for an estimate of total population size for each survey. We estimated abundance for the Delta and San Joaquin River NWR regions separately, and provide totals for these 2 regions.

Abundance by subspecies.—Because we could not identify sandhill cranes to subspecies during roost counts or aerial surveys, we conducted roadside surveys at the Cosumnes River Preserve, Staten Island, and Brack Tract to differentiate the subspecies and estimate the relative abundance of greaters and lessers in the Delta region. Counts by roadside surveys were conducted biweekly by 2 experienced observers during morning feeding periods (0700-1000 hr) from early October through mid-February in 2007-08 and 2008-09. We counted all flocks from vehicles using binoculars and spotting scopes and assigned all sandhill cranes observed as greaters or lessers using morphological characteristics described by Drewien and Bizeau (1974): 1) greaters are approximately 25-33% taller and more massive; 2) greaters are lighter gray in late fall and winter; 3) greaters have longer and more massive bills in relation to head length; and, 4) greaters have sloping foreheads in comparison to lessers which have rounded foreheads. A few sandhill cranes appeared intermediate in size and were likely Canadians. Our abundance estimates for greaters probably included a few Canadians, but because only 1 of the 60 sandhill cranes that we captured had the morphological measurements of a Canadian (see Johnson and Stewart 1973), this source of bias is likely very low.

We used the estimate of the ratio of greaters to lessers derived from roadside surveys to calculate subspecies-specific abundance for 4 roost count dates (3, 17, 31 December 2007 and 14 January 2008). We could not conduct a roadside survey at the Cosumnes River Preserve on 17 December because of poor road conditions; therefore, we took the mean proportion of the roadside surveys for dates immediately before and after 17 December as our estimate to estimate subspecies proportions for that roost count data. Based on the arrival and departure dates of our radio-marked sandhill cranes, our 3 December to 14 January survey interval occurred after all sandhill cranes had arrived and ended before any birds had departed for spring migration. This interval included the period previously known to support peak numbers of greaters in the Delta region (Pogson and Lindstedt 1991). To adjust the total roost count data, we used the proportion estimate generated from the roadside survey that was closest to the roost count date. Finally, because sandhill crane abundance varied by roost complex, we generated proportion estimates (of greaters to lessers) separately for each roost complex and applied that ratio to estimate the number of greaters and lessers at each roost. To derive relative abundances for roosts where we did not have roadside surveys we used proportions from the next nearest roost area: for Stone Lakes NWR we applied the estimate from the Cosumnes River Preserve; and for Canal Ranch we applied the estimate averaged from Staten Island and Brack Tract. We then summed estimates from each roost to arrive at the total. We did not have data on subspecies proportions for the San Joaquin NWR region because no roadside surveys were conducted there. We report values as mean ± SE.

Sandhill Crane Distribution

We plotted all locations for radio-marked sandhill cranes on a map of the study area. We supplemented that data with observations of flocks seen from the ground and air during our searches for radio-marked birds. We combined these data sets to generate a map of sandhill crane distribution as well as roost locations in the Delta region.

RESULTS

Migration Chronology

Sandhill cranes were reported arriving in our study area as early as 6 September 2007 (M. Ackerman, personal communication), and 9 September 2008 (B. Tadman, personal communication). In 2008 we detected the first radio-marked lesser on 3 October, and the first radio-marked greater on 4 October. Peak arrival occurred slightly earlier for greaters than lessers in 2008 (Fig. 2); however, the average arrival date was similar (t = 1.22, P = 0.23) between radio-marked greaters (13 Oct ± 2 days) and radio-marked lessers (17 Oct ± 3 days). The average departure date was also similar (t = 1.03; P = 0.30), for greaters (25 Feb ± 1 days) and lessers (22 Feb ± 2 days) (Fig. 2). Lessers began departing the study area earlier yet some lingered longer in the Delta region than the greaters (latest departure 13 March versus 7 March, respectively). Winter residency was 22% longer for greaters (130 ± 7 days) than for lessers (107 ± 4 days; t = 2.78, P < 0.01).

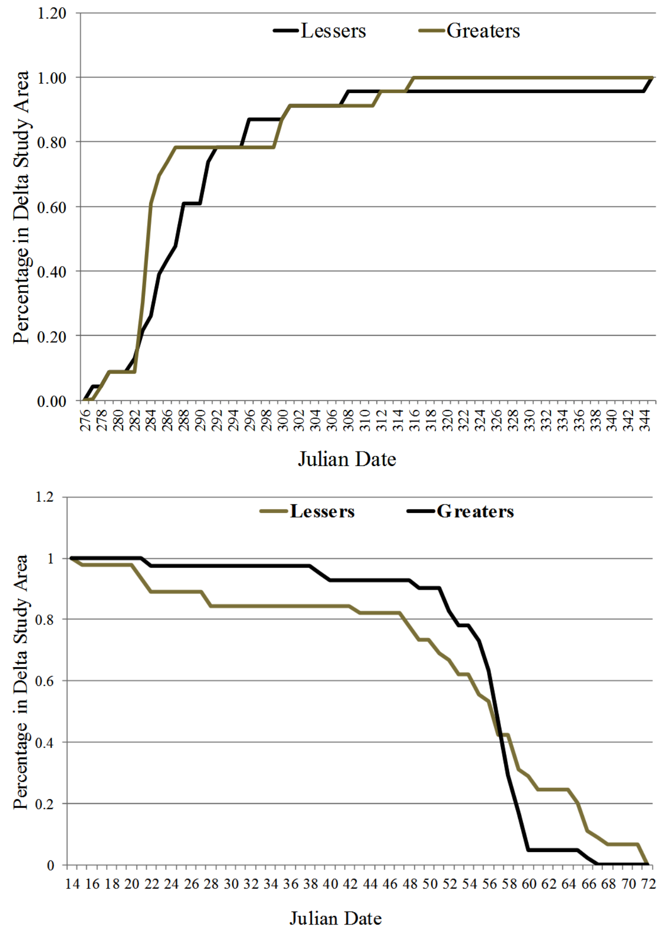

Figure 2. Chronology of arrival in fall 2008 (top) and departure in spring 2009 (bottom) of radio-marked greater and lesser sandhill cranes to the Sacramento-San Joaquin Delta, 2008. The lines represent the proportion of radio-marked birds on the study area at each date. Julian date 276 is 2 October, date 344 is 10 December, date 14 is 14 January, date 66 is 7 March, and date 72 is 12 March.

Abundance

Roost counts.—The total number of roosting sandhill cranes in the Delta region increased from a low of 6,421 (5 Nov 2007) to a high of 27,213 (11 Feb 2008, Fig. 3). The season mean was 15,037 ± 4,529. Table 1 shows the largest average abundance was recorded at Brack Tract roost complex (7,423 ± 2,129) followed by Staten Island (4,898 ± 1,045), Canal Ranch (4,095 ± 1,425), Cosumnes River Preserve (1,539 ± 339), and Stone Lakes NWR (345 ± 40). Early in the season, most sandhill cranes roosted at Staten Island, however as winter progressed sandhill cranes shifted to Brack Tract and by end of winter most sandhill cranes were roosting in the Brack Tract roost complex. Peak counts recorded at each site included 24,487 at Brack Tract, 10,995 at Staten Island, 7,215 at Canal Ranch, 4,347 at Cosumnes River Preserve, and 598 at Stone Lakes NWR (Table 1). Counts for San Joaquin River NWR averaged 2,310 (± 132), and peaked at 2,895 in February (Table 1).

Aerial surveys.—Based on aerial surveys conducted in 2008, we estimated 19,183 ± 1,500 (95% CI: 16,243-22,123; Coefficient of Variation [CV]: 0.07) sandhill cranes in the combined Delta and San Joaquin NWR regions on 14 January, 9,028 ± 769 (95% CI: 7,520-10,535; CV: 0.01) on 28 January and 21,125 ± 1,903 (95% CI: 17,395-24,855; CV: 0.09) on 5 February. Estimates for the Delta region during those same 3 surveys were 15,687 ± 843 (95% CI: 14,214-17,519; CV: 0.05), 8,086 ± 724 (95% CI: 7,362-8,810; CV:

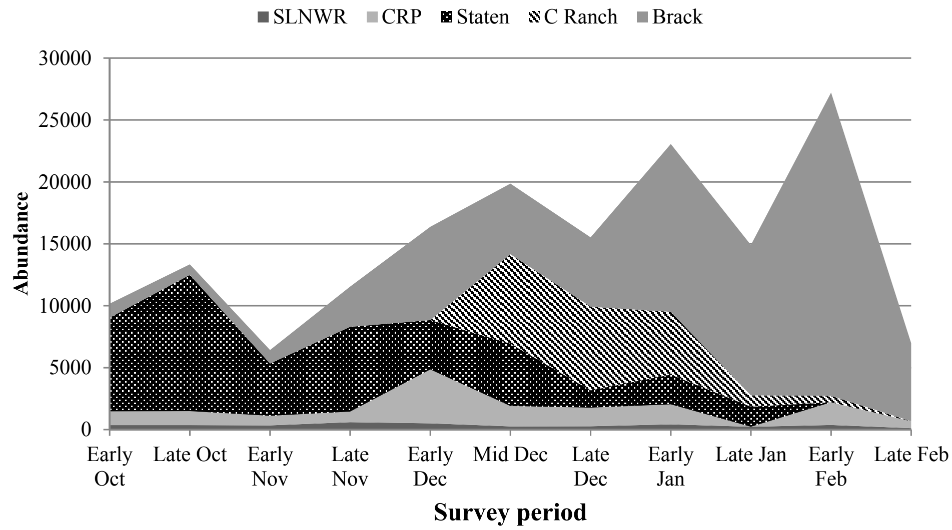

Figure 3. Counts of sandhill cranes (all subspecies combined) at all major roosts sites (Brack Tract, Canal [C] Ranch, Staten Island, Cosumnes River Preserve [CRP], and Stone Lakes National Wildlife Refuge [SLNWR]) in the Sacramento-San Joaquin Delta, California, as determined from evening roost counts conducted every 2 weeks during the winter 2007-08.

0.09), and 18,405 ± 1,795 (95% CI:14,886-21,923; CV: 0.10), while estimates for the San Joaquin River NWR region during those 3 surveys were 3,496 ± 657 (95% CI: 2,208-4,783; CV: 0.18), 942 ± 45 (95% CI: 853-1,030; CV: 0.05), and 2,720 ± 108 (95% CI: 2,508-2,932; CV: 0.04), respectively. In the Delta region, only a few sandhill cranes were observed south of Highway 12 or west of Isleton where we did not conduct roost count surveys, therefore our roost counts included a high percentage of the total Delta region population.

Abundance by subspecies.—The proportion of sandhill cranes that we identified as greaters during roadside surveys varied from 1.0% to 80.4% with higher proportions of greaters generally observed at the Cosumnes River Preserve than other areas (Table 2). We estimated that the number of greaters roosting in the Delta Region ranged from 2,166 to 6,866, while the number of lessers ranged from 12,867 to 17,690 (Table 3).

Table 1. Roost count comparisons of sandhill cranes at all major roost sites (Brack Tract [BT], Canal Ranch [CR], Cosumnes River Preserve [CRP], Staten Island [SI], and Stone Lakes National Wildlife Refuge [SLNWR]) in the Sacramento-San Joaquin Delta region and the San Joaquin National Wildlife Refuge, (SJNWR) California, fall-winter 2007-08.

Week	BT	CR	CRP	SI	SLNWR	SJNWR
08 Oct	1,132	-[a]	1,105	7,565	362	-[d]
22 Oct	852	-[a]	1,137	10,995	358	-[d]
05 Nov	1,083	-[a]	775	4,230	333	-[d]
19 Nov	3,255	-[a]	850	6,846	598	2,537
03 Dec	7,540	-[b]	4,347	3,986	506	-[d]
17 Dec	5,706	7215	1,650	5,041	251	2,264
31 Dec	5,605	6758	1,504	1,397	261	-[d]
14 Jan	13,551	5064	1,621	2,403	417	-[d]
28 Jan	12,140	915	-[c]	1,622	230	2,895
11 Feb	24,487	525	1,834	-[a]	367	-[d]
25 Feb	6,306	-[a]	564	-[a]	113	2,484
Average	7,423	4,095	1,539	4,898	345	

[a] Roost site was dry.
[b] Did not have permission to survey.
[c] Roads were too wet to survey.
[d] Did not survey on these dates.

Distribution

Sandhill cranes were found primarily in Sacramento and San Joaquin counties, but also in east Yolo, Solano, and Contra Costa counties (Fig. 4). This area includes both the Central Delta and Cosumnes and Stone Lakes areas, and is approximately 1,500 km^2, bounded on the west by the Sacramento River and the Deep Water Ship Channel, on the north by Elk Grove and South Sacramento, on the south by Highway 4 to Stockton and on the east by Lodi, Galt, and rural communities of Herald and Wilton. This area includes the Cosumnes River floodplain (below Wilton), the Mokelumne River floodplain (below Galt), the Sacramento River floodplain (below Freeport), and the Delta tracts and islands which lie east of the Deep Water Ship Channel, east of the Sacramento River channel

Table 2. Proportion of greater (G) and lesser (L) sandhill cranes observed during 4 roadside surveys of feeding fields around 3 major roost complexes in the Sacramento-San Joaquin Delta, California, during winter 2007-08. "*n*" indicates the total number of cranes observed during surveys at all 3 sites.

		Roost complex					
		Brack		Cosumnes		Staten Island	
Week	*n*	G	L	G	L	G	L
3 Dec 2007	5,180	0.014	0.986	0.182	0.818	0.083	0.917
17 Dec 2007	3,788	0.074	0.926			0.065	0.935
31 Dec 2007	5,416	0.093	0.907	0.783	0.217	0.093	0.917
14 Jan 2008	8,152	0.678	0.322	0.804	0.196	0.014	0.986

between Rio Vista and Antioch, north of Highway 4, and west of Interstate Highway 5.

DISCUSSION

Migration Chronology

Sandhill cranes first arrived in our Delta region study area during the first week of September, earlier than the third week of September as reported by Pogson and Lindstedt (1991) in the mid-1980s. The difference may be due to changes in cropping practices that have benefited sandhill cranes. For example, at Staten Island before the mid-1980s, corn harvest was not begun until mid-September and continued to November. With more corn planted due to the falling price of wheat, the start date for harvest was moved up in order to harvest the entire crop early. Earlier crop harvesting has permitted earlier flooding of harvested fields to serve as roost sites on the island (J. Shanks, personal communication). Possibly some sandhill cranes learned that resources are available earlier in the Delta region and therefore arrived from migration earlier than they had in the past. Also, the earlier arrival might be attributed to an increasing population of greater sandhill cranes since the mid-1980s (see Littlefield 2002) or because the breeding population has expanded southward in the Sierra Nevada to locations that are shorter migration distances from the Delta region (see Ivey and Herziger 2001).

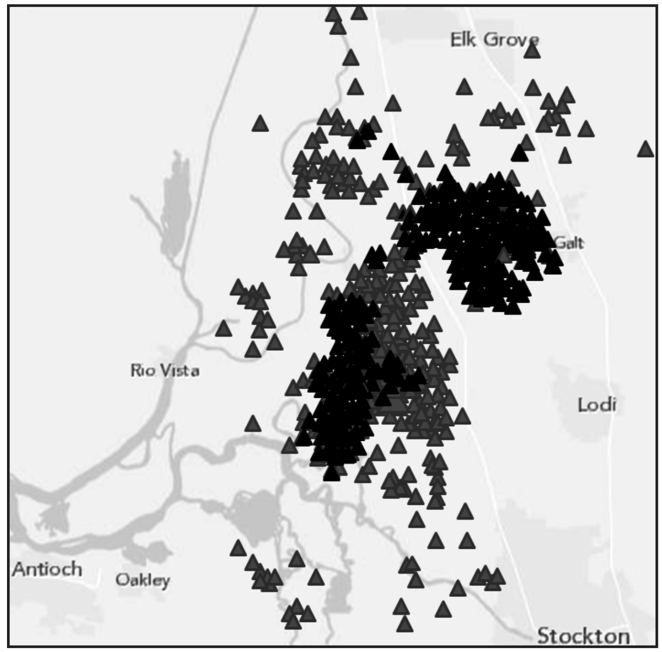

Figure 4. Distribution of greater (black triangles) and lesser sandhill crane (grey triangles) winter foraging locations in the Sacramento-San Joaquin Delta, California, winters 2007-08 and 2008-09, as determined by locations of radio-marked cranes from ground and air surveys.

Despite the earlier initial arrival dates of some birds, only a small number of sandhill cranes were present

Table 3. Abundance of greater (G) and lesser (L) sandhill cranes at 5 roost complexes (Brack Tract, Cosumnes River, Staten Island, Canal Ranch, and Stone Lakes NWR) in Sacramento-San Joaquin Delta, California, on 3 dates during winter 2007-08.

	Date					
	17 Dec		31 Dec		14 Jan	
Roost	G	L	G	L	G	L
Brack Tract	422	5,284	521	5,084	3,444	10,107
Cosumnes River	792	858	1,173	331	1,297	324
Staten Island	328	4,713	130	1,267	34	2,369
Canal Ranch	503	6,712	630	6,128	1,757	3,307
Stone Lakes NWR	121	130	204	57	335	83
Total	**2,166**	**17,697**	**2,658**	**12,867**	**6,867**	**16,190**

in September. Our radio-marked birds arrived about 1 month later in October coincident with the arrival of large numbers of sandhill cranes into the region. Despite the considerable difference in the length of migration between subspecies (see Pacific Flyway Council 1983, 1997), the arrival chronology of our radio-marked lessers and greaters was similar. These subspecies flocks occasionally share fall staging areas and their movements south may be synchronized by favorable weather conditions for migration to the Central Valley. Arrival dates for lessers to the Delta region were very similar to mean arrival times for lessers to wintering areas in Texas (Krapu et al. 2011), despite the fact that lessers wintering in California use different migration routes and staging areas than birds wintering in Texas (Petrula and Rothe 2005, Krapu et al. 2011).

During our study, sandhill cranes used roosts throughout our study area into early March, much later than reported by Pogson and Lindstedt (1991), who noted sandhill cranes departed Brack Tract, Staten Island, and Canal Ranch in late January. We attribute this difference to changes in management that currently maintains roosts for sandhill cranes later during winter. The general chronology of spring departure was similar for both subspecies. However, lessers tended to begin their departure earlier than greaters but finished departing after the all greaters had left.

Abundance

During mid-winter surveys in the Pacific Flyway in 2008 and 2009, 51,981 and 49,238 sandhill cranes were counted, respectively (Collins and Trost 2010). A comparison of our results with previous work in the Delta region suggests the total abundance of sandhill cranes in the Delta region has increased since the 1980s. Previous aerial counts ranged from 3,380 during 1983-1989 (CDFW, unpublished data) to 17,030 in the late 1990s (Ducks Unlimited, unpublished data) and 11,625 in 2000-2001 (CDFW, unpublished data). Roost count and aerial survey data are not directly comparable, but it is likely that the sandhill crane population in the Delta region is higher today than in the 1980s. The highest estimate from our aerial surveys was similar to the estimate from the air in the late 1990s; however, our methods differed because previous surveys were assumed to be complete counts while our estimates were generated using sampling statistics.

Our population estimates from aerial surveys were relatively precise, with coefficients of variation ranging from 5 to 10% during all but 1 survey. This precision indicates that an aerial-based survey for sandhill cranes in the Delta may be a valid method to estimate their population size or at least derive an index of population size. Such a survey would have to be coupled with ground surveys to derive the percentage of the total population comprised of greaters and lessers. The aerial survey estimates were consistently smaller than the abundance estimates from roost counts (on average 37% less), and the roost count estimates were well above the 95% confidence limits for the aerial survey. Given the large discrepancy, additional work is needed to determine the more accurate method of surveying cranes, but aerial surveys may provide a precise index of crane abundance.

The increase in sandhill crane numbers in the Delta region since the 1980s reflects an overall increase in sandhill cranes in the Pacific Flyway from counts of 10,000 in the 1980s to counts of over 50,000 in recent years (Collins and Trost 2010). A comparison of peak counts for the Delta region relative to the total sandhill crane population in the Pacific Flyway indicates about one-third of all sandhill cranes that wintered in the Pacific Flyway used the Delta region during the 1980s. Our peak roost count of >27,000 sandhill cranes in mid-February indicates that more than half of all sandhill cranes in the Pacific Flyway may currently use the Delta region, so both the absolute and relative importance of this region for wintering sandhill cranes has increased since the 1980s. The increase of sandhill cranes in the Delta region could reflect improved roosting and foraging conditions in the Delta region from the conservation efforts of the past 3 decades or could be the result of habitat loss and degradation elsewhere which would force the sandhill cranes to increase their presence in the Delta region.

Roost count data indicate that the population of sandhill cranes using the Delta region increased from October through mid-February. Pogson and Lindstedt (1991) noted a similar pattern for greaters during the 1980s. However, our radio-marked greaters had all arrived in the Delta region by the end of November and lessers had all arrived by early December. Furthermore, movement data indicate that once greaters arrived in the Delta region they were relatively sedentary (Ivey et al. 2011). This discrepancy between increases in roost counts and movement data may be because our telemetry results were based on a relatively few individuals and may not have encompassed movement trends of the population.

Previous to this study only a few population estimates were made of greaters and lessers wintering in the Central Valley or the Delta region. Pogson and Lindstedt (1991) estimated 6,800 "large cranes" wintered in the Central Valley in 1983 and 1984, while Littlefield (2002) estimated that 6,000 greaters wintered in the Sacramento Valley during the early 1990s. Both estimates apparently combined greaters with the Canadian subspecies which are more common in the Sacramento Valley (G. Ivey, personal observation) so their counts are likely biased high. Using roost counts and roadside surveys to allocate total count data to subspecies, our estimate for the number of greaters using the Delta region ranged from 2,166 to 6,800. The maximum number of greaters counted during a single set of roadside surveys in the Delta region was 1,786. Our estimate of 6,800 is likely biased high because in January large flocks of lessers were using Brack Tract for roosting while foraging to the south in areas not covered by our roadside surveys; therefore greaters were over-estimated in our roadside survey proportions. The number of sandhill cranes using Brack Tract during the feeding count in January 2008 was less than 3% of the number roosting, further suggesting our estimates of proportions might be biased. In comparison, our roadside surveys counted 24% and 41% of birds roosting at Brack Tract in mid and late December. Therefore, we think that the true number of greaters in the Delta region was between 2,000 and 3,000 birds, which is a significant portion of the Central Valley Population. Additional work to develop a more precise survey methodology, including using random sampling of subspecies composition of foraging flocks from ground surveys to assess subspecies composition, and possibly including distance sampling with aerial surveys (see Ridgway 2010), is needed to accurately estimate the population size of each subspecies of sandhill crane wintering in California's Central Valley.

The changing distribution of sandhill cranes among roost complexes in the Delta region was likely in response to changes in roost site conditions. Managers at Staten Island began flooding roost sites relatively early in fall during both years of our study, which attracted early arriving sandhill cranes. As winter proceeded additional roost sites at Brack Tract and Canal Ranch were flooded both years, and sandhill cranes spread out to take advantage of these sites. By mid-winter during both years, managers at Staten Island began drying several large roosts which likely induced birds to shift their roosting to nearby Brack Tract. At the Cosumnes River Preserve, roost sites remained available throughout winter and sandhill crane numbers were relatively stable there the entire season. This pattern of habitat use suggests the abundance and distribution of sandhill cranes in the Delta region can be influenced by changing the distribution of their roosts.

In addition to responding to habitat changes, the proportion of greaters to lessers differed by habitat areas. Greaters were proportionately more abundant in the Cosumnes River Preserve and Stone Lakes NWR and lessers dominated in the Central Delta. Reasons for this pattern are not clear but may be related to a preference by lessers for alfalfa (see Ivey et al. 2011) which is widely grown in the Central Delta and rarer near the Cosumnes River Preserve and Stone Lakes Refuge. Differences in proportions of the subspecies may have been due to difference in physical characteristics of roosts that favored or constrained use by 1 subspecies compared to the other. Greaters are also socially dominant over lessers (G. Ivey, unpublished data), which may have allowed them to dominate proportional use of the Cosumnes River preserve which grew rice, a food resource preferred by both subspecies (Ivey et al. 2011).

Distribution

In comparing our data to that from a 1980s study reported in Pogson and Lindstedt (1991), the winter range for sandhill cranes in the Delta region has decreased. While development of conservation areas such as Cosumnes River Preserve and Stone Lakes NWR has improved habitat conditions for wintering sandhill cranes, significant loss of foraging habitat has occurred over the past 3 decades on private lands in the region (primarily from conversion to vineyards) and such losses are continuing (see Littlefield and Ivey 2000). Within their Delta region winter range, large areas of habitat have been lost primarily due to conversions to incompatible crops (e.g., vineyards and orchards) and to the expansion of the cities of Elk Grove and Galt. Most noticeable has been the increase in grape vineyards, but in more recent years other incompatible crops such as turf farms, olives, and blueberries have further reduced compatible foraging area (Littlefield and Ivey 2000). For example, between 2003 and 2007, approximately

335 ha of cropland used regularly by sandhill cranes at Canal Ranch was converted to olive trees (G. Ivey, personal observation). If such habitat losses continue, this could further influence sandhill crane use of the Delta region and possibly limit the regional carrying capacity for sandhill crane populations in the future.

MANAGEMENT IMPLICATIONS

Based on arrival dates, flooding of some sites managed for crane roosting should begin slowly in early September and managers should provide larger areas for roosting cranes by early October. Maintaining flooded roosts until mid-March when most birds leave the Delta region for spring migration would provide roosting habitat throughout their wintering period. For areas specifically managed for the welfare of greaters (e.g., Staten Island) our data suggests that maintenance of roost sites through the first week of March would be beneficial, based on departure times for greaters. Our estimates for the population of greaters using the Delta region represent a significant percentage of the total population. Therefore, this region should be considered a key area for efforts in conservation and recovery of this listed subspecies.

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LITERATURE CITED

Balkenbush, J. A., and D. L. Hallett. 1988. An improved vehicle-mounted telemetry system. Wildlife Society Bulletin 16:65-67.

California Department of Fish and Wildlife [CDFW]. 2013. State and federally listed endangered and threatened animals of California. CDFW, Sacramento, California, USA.

California Department of Fish and Wildlife [CDFW]. 2007. Yolo Bypass Wildlife Area land management plan. <http:// http://www.dfg.ca.gov/lands/mgmtplans/ybwa/>. Accessed 12 Dec 2013.

Caughley, G. 1977. Sampling in aerial survey. Journal of Wildlife Management 41:605-615.

Collins, D. P., and R. E. Trost. 2010. Pacific Flyway data book: waterfowl harvests and status, hunter participation and success in the Pacific Flyway and United States. U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Portland, Oregon, USA.

Drewien, R. C., and E. G. Bizeau. 1974. Status and distribution of greater sandhill cranes in the Rocky Mountains. Journal of Wildlife Management 38:720-742.

Dugger, B. D., S. L. Melvin, R. S. Finger. 2005. Abundance and community composition of waterfowl and wading birds using the channelized Kissimmee River floodplain, Florida. Southeastern Naturalist 4:435-446.

Gilmer, D. S., L. M. Cowardin, R. L. Duval, L. M. Mechlin, C. W. Shaiffer, and V. B. Kuechle. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. U.S. Fish and Wildlife Service Resource Publication 140, Washington, D. C., USA.

Hereford, S. G., T. E. Grazia, M. Nagendran, and A. Hussain. 2000. Use of traditional Indian trapping methods to capture sandhill cranes. Proceedings of the North American Crane Workshop 8:220.

Ivey, G. L., and C. P. Herziger. 2001. Distribution of greater sandhill crane pairs in California, 2000. California Department of Fish and Wildlife, Sacramento, California, USA.

Ivey G. L., and C. P. Herziger. 2003. Sandhill crane monitoring at Staten Island, San Joaquin County, California, 2002-03. The Nature Conservancy, Cosumnes River Preserve, Galt, California, USA.

Ivey, G. L., B. D. Dugger, C. P. Herziger, M. L. Casazza, and J. P. Fleskes. 2011. Sandhill crane use of agricultural lands in the Sacramento–San Joaquin Delta. Final report to Bay-Delta Authority, Sacramento, California, USA.

Johnson, D. H., and R. E. Stewart. 1973. Racial composition of migrant populations of sandhill cranes in the northern plain states. Wilson Bulletin 85:148-162.

Krapu, G. L., and D. A. Brandt. 2001. Use of satellite telemetry to identify temporal and spatial distribution of the midcontinent sandhill crane population throughout the annual cycle. Proceedings of the North American Crane Workshop 8: 222.

Krapu, G. L., D. A. Brandt, K. L. Jones, and D. H. Johnson. 2011. Geographic distribution of the Mid-Continent Population of sandhill cranes and related management applications. Wildlife Monographs 175:1–38.

Littlefield, C. D. 2002. Winter foraging habitat of greater sandhill cranes in northern California. Western Birds 33:51-60.

Littlefield, C. D., and G. L. Ivey. 2000. Conservation assessment for greater sandhill cranes wintering on the Cosumnes River Floodplain and Delta regions of California. The Nature Conservancy, Cosumnes River Preserve, Galt, California, USA.

Nams, V.O. 2005. LOCATE III. Pacer, Truro, Nova Scotia, Canada.

Nesbitt, S. A., S. T. Schwikert. 2005. Wing-molt patterns - a key to aging sandhill cranes. Wildlife Society Bulletin 33:326-331.

Pacific Flyway Council. 1983. Pacific Flyway management plan: Pacific Flyway Population of lesser sandhill cranes. Pacific Flyway Study Committee (Pacific Flyway Representative USFWS), Portland, Oregon, USA.

Pacific Flyway Council. 1997. Pacific Flyway management plan for the Central Valley Population of greater sandhill cranes. Pacific Flyway Study Committee (Pacific Flyway Representative USFWS), Portland, Oregon, USA.

Petrula, M. J., and T. C. Rothe. 2005. Migration chronology, routes, and distribution of Pacific Flyway Population of lesser sandhill cranes. Proceedings of the North American Crane Workshop 9:53-67.

Pogson, T. H., and S. M. Lindstedt. 1991. Distribution and abundance of large sandhill cranes, *Grus canadensis*, wintering in California's Central Valley. Condor 93:266-278.

Ridgway, M. S. 2010. Line transect distance sampling in aerial surveys for double-crested cormorants in coastal regions of Lake Huron. Journal of Great Lakes Research 36:403–410.

Samuel, M. D., and M. R. Fuller. 1996. Wildlife radiotelemetry. Pages 370-418 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. Fifth edition. The Wildlife Society, Bethesda, Maryland, USA.

Tacha, T. C., S. A. Nesbitt, and P. A. Vohs. 1992. sandhill crane. The birds of North America Monograph 31 *in* A. Poole, P. Stettenheim, and F. Gill, editors. The Academy of Natural Sciences, Philadelphia and American Ornithologists' Union, Washington, D.C., USA.

Tacha, T. C., S. A. Nesbitt, and P. A. Vohs. 1994. Sandhill Crane. Pages 77-94 *in* T. C. Tacha, and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Urbanek, R. P., J. L. McMillen, and T. A. Bookhout. 1991. Rocket-netting greater sandhill cranes on their breeding grounds at Seney National Wildlife Refuge. Pages 241–245 *in* J. T. Harris, editor. Proceedings of the 1987 international crane workshop, 10 May 1987, Qiqihar, Heilongjiang Province, China. International Crane Foundation, Baraboo, Wisconsin, USA.

CHARACTERISTICS OF SANDHILL CRANE ROOSTS IN THE SACRAMENTO-SAN JOAQUIN DELTA OF CALIFORNIA

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Abstract: The Sacramento-San Joaquin Delta (Delta) region of California is an important wintering region for 2 subspecies of Pacific Flyway sandhill cranes (*Grus canadensis*): the Central Valley Population of the greater sandhill crane (*G. c. tabida*) and the Pacific Flyway Population of the lesser sandhill crane (*G. c. canadensis*). During the winters of 2007-08 and 2008-09 we conducted roost counts, roadside surveys, aerial surveys, and tracked radio-marked birds to locate and assess important habitats for roosting cranes in the Delta. Of the 69 crane night roosts we identified, 35 were flooded cropland sites and 34 were wetland sites. We found that both larger individual roost sites and larger complexes of roost sites supported larger peak numbers of cranes. Water depth used by roosting cranes averaged 10 cm (range 3-21 cm, mode 7 cm) and was similar between subspecies. We found that cranes avoided sites that were regularly hunted or had high densities of hunting blinds. We suggest that managers could decide on the size of roost sites to provide for a given crane population objective using a ratio of 1.5 cranes/ha. The fact that cranes readily use undisturbed flooded cropland sites makes this a viable option for creation of roost habitat. Because hunting disturbance can limit crane use of roost sites we suggest these 2 uses should not be considered readily compatible. However, if the management objective of an area includes waterfowl hunting, limiting hunting to low blind densities and restricting hunting to early morning may be viable options for creating a crane-compatible waterfowl hunt program.

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Key words: California, *Grus canadensis*, habitat management, hunting disturbance, roost sites, Sacramento-San Joaquin Delta, sandhill crane.

The Sacramento-San Joaquin Delta (hereafter, Delta) is an important wintering region for 2 subspecies of Pacific Flyway sandhill cranes (*Grus canadensis*): the Central Valley Population of the greater sandhill crane (*G. c. tabida*, hereafter, greaters) and the Pacific Flyway Population of the lesser sandhill crane (*G. c. canadensis*, hereafter, lessers) (Pacific Flyway Council 1983, Pacific Flyway Council 1997). Greaters, which are listed as threatened in California (California Department of Fish and Wildlife [CDFW] 2013), are a priority for conservation actions, while lessers are considered a California Species of Conservation Concern (Littlefield 2008). However, little is known about winter use of roost sites and characteristics of roost sites used by wintering cranes that could aid in designing a biologically sound conservation strategy for cranes in the Delta.

Other than on the Platte River in Nebraska (e.g., Krapu et al. 1984; Norling et al. 1992; Folk and Tacha 1990; Parrish et al. 2001; Davis 2001, 2003), little work has been done to quantify habitat types used by roosting cranes. In the Platte River system, cranes roost in the shallow waters (1-21 cm) and sandbar islands within the river channel. While the water depth information likely has broad applicability, other habitat characteristics of the North Platte River are not found in California. Additionally, there are no published studies about the suitability of flooded agricultural fields as roost sites for cranes or information that quantifies how roost site size correlates with crane abundance at the roost. In this study, we characterize the features of crane roosts at both the individual site and roost complex scales, correlate roost abundance with roost size, and correlate roost use with recreational waterfowl hunting activity to increase our understanding of crane roosting ecology and support crane habitat conservation and management.

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STUDY AREA

We centered our study on several properties in the Delta that are specifically managed to provide night roost sites for cranes, and which subsequently support most of the cranes that winter in the region (Pogson and Lindstedt 1991, Ivey and Herziger 2003, U.S. Fish and Wildlife Service 2007), including Cosumnes River Preserve, Staten Island and adjacent Canal Ranch and Bract Tracts (which includes the Isenberg Crane Reserve), and Stone Lakes National Wildlife Refuge (NWR) (Fig. 1). The Delta region is primarily rural agricultural landscapes bordered by urban communities. Agricultural land uses include field and silage corn, fall-planted wheat, rice, alfalfa, irrigated pasture, dairies, vineyards, and orchards. The region also contains large tracts of oak savannah and floodplain wetlands along the Cosumnes and Mokelumne river floodplains.

We trapped cranes at Cosumnes River Preserve and Staten Island. The Cosumnes River Preserve (9,915 ha within our study area) was established by The Nature Conservancy (TNC) and is a conglomeration of lands owned or under conservation easements by TNC and its agency partners. It provides habitats for cranes including seasonal wetland roost sites, oak savannahs, organic rice, and other crops. Staten Island (3,725 ha) was a large corporate farm that was purchased by TNC and was managed as an income-producing farm but with a focus on providing habitat for cranes and other wildlife and developing wildlife-friendly farming practices that can serve as a demonstration to other farmers in the region (Ivey et al. 2003). Cranes use roosts at Staten Island and adjacent Canal Ranch and Brack Tracts as a complex. We define a complex as an association of flooded fields and wetlands in close proximity to each other (none > 1 km from another flooded site). Brack Tract contains Isenberg Crane Reserve, owned and managed by the California Department of Fish and Wildlife, and consisted of 2 seasonal wetland sites (totaling 60 ha) that were surrounded by private agricultural lands, including a large area of flooded rice fields that also provided roosts. Stone Lakes NWR has developed 410 ha of seasonal wetland sites that were used as night roosts and which were also adjacent to private agricultural lands. The refuge also managed croplands such as irrigated pasture, alfalfa, and occasionally grain crops for cranes and other wildlife.

METHODS

We defined a roost as a site used by cranes at night. We cataloged locations of sandhill crane roost sites in the Delta during 2007-08 and 2008-09 by tracking radio-tagged cranes and through observations from the ground. We captured and radio-tagged a total of 77 sandhill cranes during 17 October 2007 and 27 February 2008 in the Delta, and during April and August 2008 at northern breeding and staging areas before they returned to the Delta (see Ivey et al. 2014 for detailed methods of crane capture, handling, and tracking). Our handling of cranes was conducted under the guidelines of the Oregon State University Animal Care and Use Committee (project #3605) to ensure methods were in compliance with the Animal Welfare Act and United States Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training policies. Cranes were captured under CDFW permit SC-803070-02 and U.S. Geological Survey federal banding permit MB#21142.

We mapped each roost site, categorized the habitat as either wetland or flooded cropland, noted whether the site was used for waterfowl hunting, calculated the density of hunting blinds, and estimated the size (ha) of each using ArcGIS version 9.2 (ESRI, Redlands, California). Many of the individual sites were directly adjacent to each other (separated by dikes or secondary roads) and individual cranes tended to shift their choices for roosting among adjacent sites. We mapped adjoining sites of the same type (i.e., agriculture or wetland) as 1 site, rather than each field or wetland separately. Sites either >200 m apart, separated by paved roads or rivers, or adjacent to roosts of different habitat types were mapped separately. We calculated the mean ± SE size for wetland and agricultural roosts sites and complexes of associated roost sites, and compared the means using a Student's *t*-test.

We conducted biweekly counts of cranes using the 3 major night roost complexes in our study area (Staten Island [including the adjacent Brack and Canal Ranch Tracts], Cosumnes River Preserve, and Stone Lakes NWR) between 5 October 2007 and 27 February 2008 to document seasonal abundance of cranes and compare abundance with roost site size (ha) and type (wetland versus agricultural). We conducted each count over a period of 2 or 3 days, but all sites within each roost complex were counted on the same night. We conducted surveys by stationing observers with

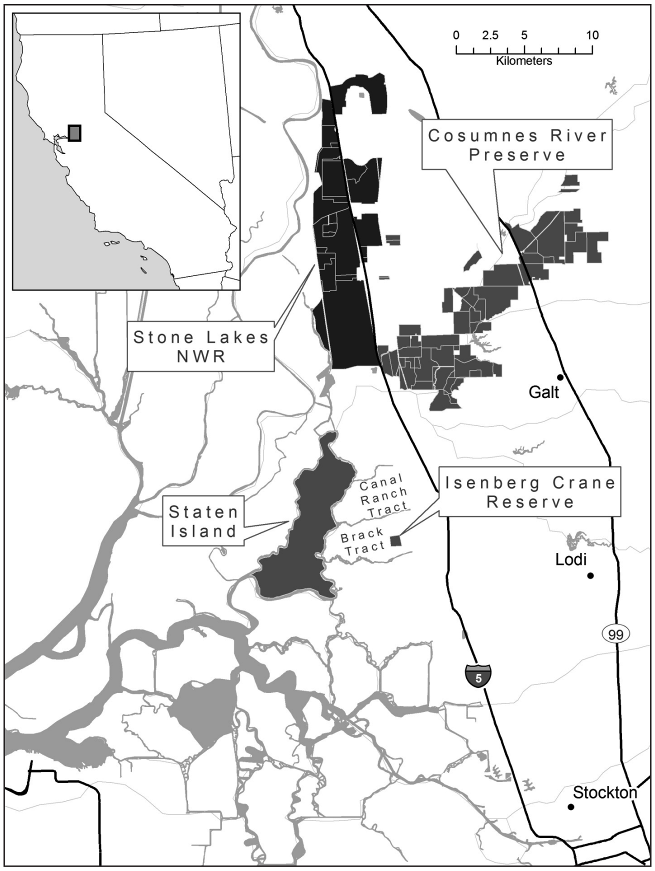

Figure 1. Map of the Sacramento-San Joaquin Delta study area where characteristics of sandhill crane (*Grus canadensis*) winter night roosts were studied, 2007-2009.

binoculars at key locations around a roost complex to count all cranes as they flew into a roost site at sunset or during early morning before they left their roost. We used roost counts at our major roost sites to relate roost size with peak roost site counts in 2007-08. We used linear regression to test the hypothesis that size of the roost site or complex was an important determinant of crane population size at a roost site or complex. Count data were not normally distributed, so we used a square-root transformation to normalize the data. We combined our roost counts and roost site areas for each of 4 habitat complexes (Cosumnes Preserve, Staten-Brack-Canal Ranch, and Stone Lakes NWR) and used peak counts at roost complexes for each roost complex size, which changed over time. We used a Student's *t*-test to compare crane densities between the 2 roost site categories (wetland versus flooded cropland).

We used observations of cranes at night roost sites to characterize water depths chosen by cranes. Roosts were visited during early morning periods, before all cranes had departed the roost. Because roosting cranes are not all independent (e.g., family groups and flocks roost together) our unit of analysis was subgroups or individual cranes of the same subspecies within a flock roosting at the same depth. For example, within a cluster of cranes, a group of cranes of the same subspecies standing together at the same depth were measured as 1 sample, while other groups or individuals standing at different depth were measured as a separate sample, which included several or single individuals. Water depth measurements were estimated visually as the proportion of a crane's tarsometatarsus that was submerged. Values were recorded to the nearest 10% increment. We converted the percentage value to water depth by multiplying each by the average tarsometatarsus length for each subspecies (from Johnson and Stewart 1973) adjusting values by 1.5 or 2 cm to account for height of the foot for lessers and greaters, respectively. We hypothesized that flooded croplands would support higher densities of cranes as field topography is relatively level compared with wetlands, so a larger percentage of the area would provide optimal depths for roosting. We used a Student's *t*-test to compare roost water depths between the subspecies and between the 2 roost site types (wetland habitat versus cropland). All means are reported ± SE.

We qualitatively assessed the impact of waterfowl hunting disturbance on roost site use by cranes by observing crane behavior at roosts before, during, and after the waterfowl hunting season relative to the density of hunter blinds and frequency at which hunting occurred at each roost site. Waterfowl hunting occurred on portions of all roost complexes that we surveyed, including the Cougar Wetlands Unit of the Cosumnes Preserve, the wetlands of the Sun River Unit of Stone Lakes NWR, and most of the flooded sites at Staten Island. Hunting at the Cougar Wetlands was administered by the Bureau of Land Management (BLM), that permitted all-day hunting from 6 permanent blinds, every Saturday during waterfowl season at a comparably high density (4 ha/blind). Hunting on the Sun River Unit roost site was administered by the U.S. Fish and Wildlife Service (USFWS) on a reservation system for 7 permanent blinds at a density of 5 ha of water area per blind. Hunting was allowed from a half hour before sunrise until noon on Wednesdays and Saturdays during the season (early October - late January). At Staten Island, the hunt program was

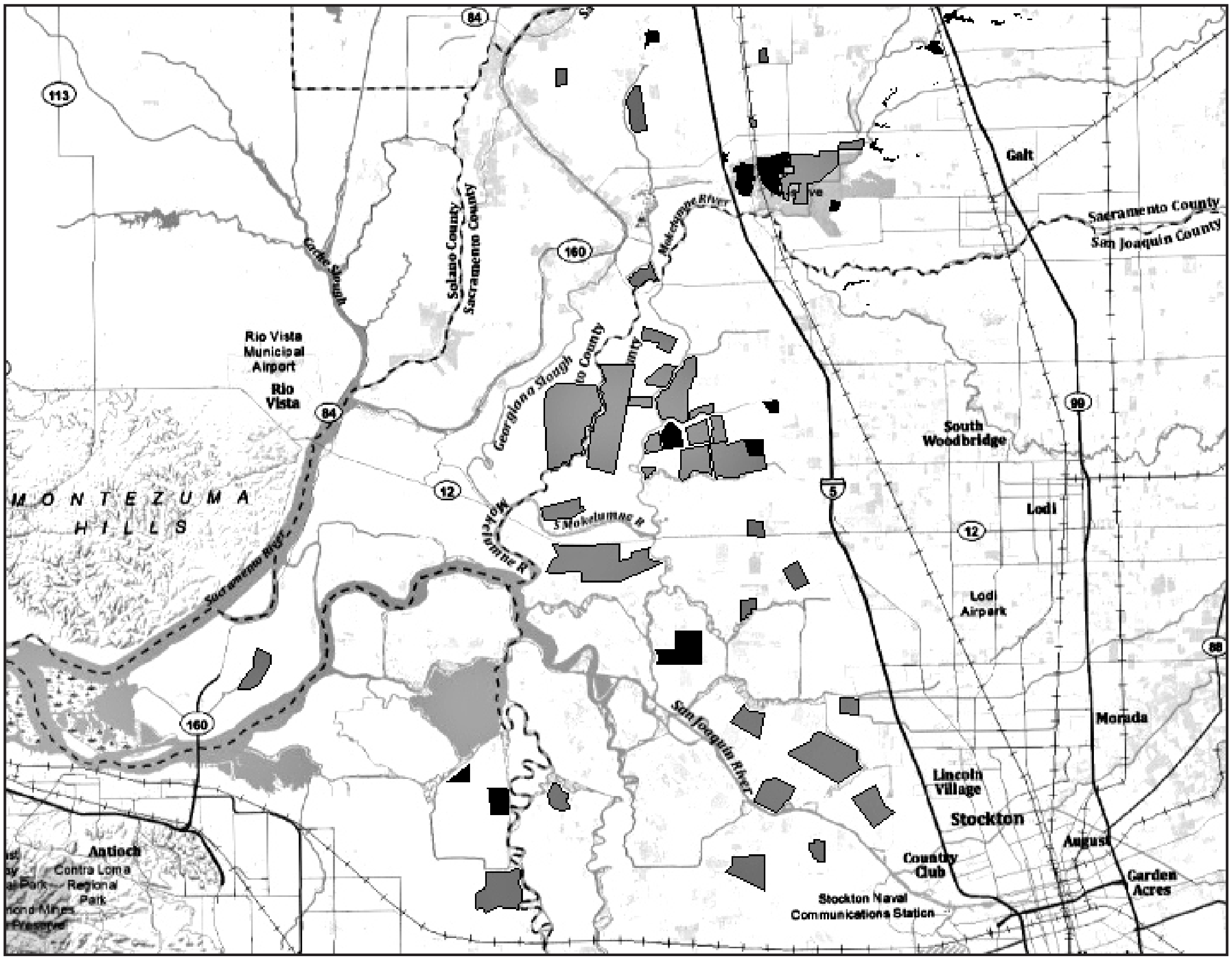

Figure 2. Location of winter night roost sites used by sandhill cranes (*Grus canadensis*) in the Sacramento-San Joaquin Delta, 2007-08 and 2008-09 (Black = wetland roosts; Dark Grey = flooded cropland roosts).

administered by the property manager. Hunting was limited to 12 permanent blinds placed at low density (63 ha/blind). Waterfowl hunting was allowed from a half hour before sunrise until 10 AM on Wednesdays, Saturdays, and Sundays.

RESULTS

We mapped 69 sites used as night roosts in the Delta (Fig. 2): 35 sites in flooded croplands and 34 sites in seasonal wetlands. Most wetland roosts were managed as seasonal or semipermanent wetlands and typically flooded through fall and winter; fields were primarily post-harvest grain fields (e.g., rice, corn, or wheat) flooded after harvest through winter. Timing and duration of flooded fields varied considerably, primarily to meet the objectives of farmers, with the exception of fields on the conservation areas which were generally flooded most of the fall and winter period specifically to provide for crane and waterfowl use. Managed roost sites were typically flooded through fall and winter, while other sites were temporarily available following heavy rains, or because of flooding for cropland management. Of the wetland roost sites, approximately 90% were constructed wetlands. Roost sizes ranged between 27 and 2,068 ha and averaged 117 ± 20 ha (median 52 ha). Cropland roost sites were larger (191 ± 33 ha) than wetland roost sites (49 ± 10 ha; $t = 4.32$; $P < 0.0001$).

We collected data on peak roost site population size for 19 roosts within our 5 main roost complexes. Larger roost sites supported larger peak numbers of cranes ($R^2 = 0.54$; $t = 3.09$, $P < 0.1$). Similarly, larger roost complexes supported larger peak numbers of cranes

(R^2 = 0.58; t = 4.56, P < 0.01). For all sites, the mean density was 1.4 ± 0.26 cranes/ha and the slope of the relationship between density and roost site size was zero (R^2 = 0.01; P > 0.05), indicating that crane density did not change with roost size. The mean density of cranes using cropland roost sites (1.9 ± 0.31 cranes/ha) was higher than for wetland roost sites (1.0 ± 0.22) (t = 2.55; P < 0.05).

We estimated water depth on 94 individual or groups of cranes (n = 46 lessers and 48 greaters) at 19 different roosts on 16 different days between 1 February 2008 and 20 November 2008. Mean roost water depth was similar between agricultural and wetland roost sites (P > 0.60) and mean roost depth used was similar between greaters (10.3 ± 0.6 cm) and lessers (10.6 ± 0.6 cm; t = 0.33, P = 0.75).

The impact of hunting intensity varied by roost complex. We never observed cranes roosting at the Cougar Wetlands Unit, which had a high density of hunting blinds and was hunted all day, every Saturday during waterfowl season. Cranes used the Sun River Unit for roosting in early October during 2007 and 2008, before waterfowl season opened; however, they left the site after opening day both years, and were only infrequently found roosting there following the initial hunting disturbance, each hunting season. In 2008, before the hunting season started, we recorded a peak of 286 cranes roosting in the Sun River Unit, while no cranes roosted there the night of opening day of hunting, and we only found cranes roosting there twice (totaling 31 and 38 cranes) out of 9 subsequent bi-weekly counts (7 during hunting season). Also, one of our radio-tagged greaters was roosting there from its arrival in the region on 5 October, through the night before the opening of waterfowl hunting on 18 October. Following the opening day hunt, it moved with other cranes at the site to the Cosumnes River Preserve. Cranes continued to use hunted roost sites throughout the waterfowl season at Staten Island. The number of cranes roosting on Staten Island actually increased (by 36%), immediately after opening day of waterfowl season, suggesting that Staten Island recruited birds that were displaced from other hunted roost sites in the area.

DISCUSSION

The typical roost site in our study was a large expanse of open, shallow water that was mostly isolated from disturbance. A North Dakota study identified large expanses of shallow water not close to shore as the most important roost site characteristics (Soine 1982), while studies along the Platte River in Nebraska determined that areas of wider river channels received higher crane use (Krapu et al. 1984; Norling et al. 1992; Folk and Tacha 1990; Parrish et al. 2001; Davis 2001, 2003). Along the Platte River, roost sites disturbed by nearby roads or bridges supported lower densities of roosting cranes (Krapu et al. 1984, Parrish et al. 2001). Also, an Indiana study reported that the nearer a roost was to another roost, the more likely that it would be used (Lovvorn and Kirkpatrick 1981).

A high percentage (48%) of the roost sites that we documented were flooded croplands, a habitat type that has rarely been reported in other winter studies. Cropland roost sites were mentioned as being used during migration in Indiana (Lovvorn and Kirkpatrick 1981). Other studies reported cranes roosting on managed and natural wetlands in Indiana, North Dakota, Colorado, Nebraska, Alaska, Georgia, and California (Lovvorn and Kirkpatrick 1981, Soine 1982, Kauffeld 1982, Iverson et al. 1987, Bennett and Bennett 1989, Pogson and Lindstedt 1991), flooded playas and shallow lakes in Texas and North Dakota (Lewis 1976, Carlisle and Tacha 1983, Iverson et. al 1985), and shallow riverine sites along the Platte River in Nebraska (Krapu et al. 1984, Norling et al. 1992, Folk and Tacha 1990, Parrish et al. 2001, Davis 2001, 2003). In California, a previous study in the Delta also documented cranes using flooded fields for roosting (Ivey and Herziger 2003), but a study in the early 1980s did not document such use in the Delta (Pogson and Lindstedt 1991). Flooding of grain fields as a general practice has increased in northern California over the past 2 decades (Fleskes et al. 2005), primarily for agricultural purposes, but also to provide waterfowl hunting opportunities and in specific cases on our study area in an effort to provide roost sites for cranes. Our results suggest that sandhill cranes will readily adapt to using flooded agricultural fields as roost sites and that flooding cropland is one option for creating sandhill crane roosts.

The mean density of cranes roosting in flooded croplands was higher than in wetlands. We believe this was because flooded croplands tend to provide more area of ideal roost water depths due to their flat topography, and also because they were usually adjacent to unflooded grain field foraging sites. However, wetland roost sites likely provide additional values beyond just water depth to cranes, such as providing alternate foods like macroinvertebrates. A Nebraska study reported that cranes preferred wetlands during the day (Iverson et al. 1987), and a previous study in the Delta also documented preference for wetlands (Ivey and Herziger 2003). During our study the majority of cranes roosted at cropland sites because, on average, roosts in agricultural fields were larger than wetland roosts and crane density was highest in agricultural roosts.

We found positive relationships between roost site size and crane abundance at a roost at both the individual roost site and roost complex scales. An Indiana study (Lovvorn and Kirkpatrick 1981) found that roost sites were more likely to be used if they were near other roost sites, but no other study has examined the relationship between roost size and either peak count or crane density. In landscapes managed for wintering and staging cranes, it is important to understand how much roost water should be available, as there is a trade-off between increasing the size of a roost site versus maximizing suitable foraging habitat. Areas inundated to provide roost habitat are not generally good foraging habitat for cranes. Roost size only explained about half the variation in our data; other likely factors influencing bird use of roosts include food availability in the foraging landscape around roost complexes, migration timing, disturbance (e.g., hunting), and changing conditions at other roost sites (e.g., dewatering, disturbance increase). These additional factors could be explored in greater depth if a more complete understanding of crane roosts is desired.

The water depths used by cranes at each roost in our study was similar to what cranes have used in other regions that are thought to provide high quality habitat. Cranes in our study used depths ranging from 3 to 21 cm, with a mode of 7 cm. Similarly, along the Platte River in Nebraska, cranes were reported to prefer depths of 1–13 cm for roosting, with the highest proportions of depths used being between 1 and 7 cm (Norling et al. 1992), and ≤ 21 cm by Folk and Tacha (1990). Other studies in Nebraska, Indiana, and Oregon have reported that cranes roosted in water less than 20 cm deep (Frith 1976, Lovvorn and Kirkpatrick 1981, Latka and Yahnke 1986, Littlefield 1986, Armbruster and Farmer 1992, Norling et al. 1992). In 1 exception to this pattern, a study along the North Platte River in Nebraska documented 14% of the cranes using depths from 21 to 35.6 cm (Folk and Tacha 1990).

Although our data are qualitative, when cranes have a choice, it appears they prefer to avoid sites used for waterfowl hunting as night roosts. Some temporarily used roost sites were only used before or after waterfowl season. Our results are similar to findings in Indiana (Lovvorn and Kirkpatrick 1981), while a study in Saskatchewan documented that cranes would not tolerate repeated hunting disturbance at roosts (Stephen 1967). Even with very limited waterfowl hunting at the Sun River Unit, cranes immediately left the site for a few weeks and were only found roosting there on 2 of 7 surveys later during the waterfowl season. Cranes in Michigan and Wisconsin also abandoned roosts on or immediately after the opening day of waterfowl hunting season (Walkinshaw and Hoffman 1974, Bennett 1978). Most hunted sites in the Delta are hunted all day, usually 3 days a week (Wednesday, Saturday, and Sunday), which limits opportunities for cranes to roost or loaf during the day at these sites. Based on our observations of the hunting program at Staten Island, cranes seem particularly sensitive to hunting disturbance in the late afternoon when they are flying to roost sites and also during mid-day when they often use roost sites for loafing.

Staten Island was an exception to the general rule that cranes avoided hunted sites as roosts. This is likely in part because most of the permitted hunters were only able to hunt on Sundays, resulting in low hunting frequency. Similar to other hunted roost sites, cranes are flushed from Staten Island roosts when shooting begins, but because hunting is only allowed until 10:00 AM, cranes have a chance to return to the sites undisturbed to loaf in late mornings (they usually return about 11:00 AM) and to roost in the evenings. Cranes at Staten Island may also tolerate the hunting disturbance better, because of lower hunter density and larger roost sites. The pattern of increased roosting numbers at Staten Island following opening day was also noted in a previous study (Ivey and Herziger 2003).

MANAGEMENT IMPLICATIONS

To plan for crane roost sites for a given population objective for cranes, we suggest (based on the mean density of 1.4 ± 0.26 cranes/ha that we observed) using a ratio of 1.5 cranes/ha (~60 cranes/100 acre) as a minimum roost site area goal. Considerations for design and management of wetlands and flooded cropland roosts include providing large roost site complexes (100-1000 ha, depending on the number of cranes to support) because larger sites likely give cranes more security from predators. Individual sites within a managed roost complex should be >5 ha, of mostly level topography, and dominated by shallow water (5-10 cm depths). The depth of water used by cranes may be a reasonable indicator of roost site availability. We suggest that if cranes are commonly seen roosting where water depths are greater than 20 cm, it is an indication that ideal roost sites are limited. Seasonal wetlands will provide more values to cranes than flooded croplands, but flooded croplands may be a better option for building crane habitat into a working agricultural farm. Flooding of croplands to provide temporary roost sites might also be of value to expand crane roosting habitat options in other crane wintering or staging regions.

Disturbance caused by waterfowl hunting appears to limit crane use of roost sites; thus, we suggest these 2 uses should not be considered readily compatible. However, if the management objective of an area includes waterfowl hunting, then the Staten Island program of very low hunter densities and limited, early morning hunting, can serve as a model for a crane-compatible waterfowl hunt program.

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LITERATURE CITED

Armbruster, M. J., and A. H. Farmer. 1982. Draft sandhill habitat suitability model. Pages 136-43 *in* J. C Lewis, editor. Proceedings of the 1981 crane workshop. National Audubon Society, Tavernier, Florida, USA.

Bennett, A. J. 1978. Ecology and status of greater sandhill cranes in southeastern Wisconsin. Thesis, University of Wisconsin, Stevens Point, USA.

Bennett, A. J., and L. A. Bennett. 1989. Wintering population of greater sandhill cranes in the Okefenokee Swamp, Georgia. Wilson Bulletin 101:87-93.

California Department of Fish and Wildlife [CDFW]. 2013. State and federally listed endangered and threatened animals of California. CDFW, Sacramento, California, USA.

Carlisle, M. J., and T. C. Tacha. 1983. Fall migration of sandhill cranes in west central North Dakota. Journal of Wildlife Management 47:818-821.

Davis, C. A. 2001. Nocturnal roost site selection and diurnal habitat-use by sandhill cranes during spring in central Nebraska. Proceedings of North American Crane Workshop 8:48-56.

Davis, C. A. 2003. Habitat use and migration patterns of sandhill cranes along the Platte River, 1998-2001. Great Plains Research 13:199-216.

Fleskes, J. P., W. M. Perry, K. L. Petrik, R. Spell, and F. Reid. 2005. Change in area of winter-flooded and dry rice in the northern Central Valley of California determined by satellite imagery. California Fish and Game 91:207-215.

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

Frith, C.R. 1976. Crane habitat of the Platte River. Pages 151-156 *in* J. Lewis, editor. Proceedings of the [1975] international crane workshop. Oklahoma State University Publishing and Printing, Stillwater, USA.

Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1985. Habitat use by sandhill cranes wintering in western Texas. Journal of Wildlife Management 49:1074–1083.

Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1987. Habitat use by midcontinent sandhill cranes during spring migration. Journal of Wildlife Management 51:448–458.

Ivey, G. L., B. D. Dugger, C. P. Herziger, M. L. Casazza, and J. P. Fleskes. 2014. Distribution, abundance, and migration timing of greater and lesser sandhill cranes wintering in the Sacramento-San Joaquin River Delta region of California. Proceedings of the North American Crane Workshop 12:1-11.

Ivey, G. L., and C. P. Herziger. 2003. Sandhill crane monitoring at Staten Island, San Joaquin County, California, 2002-2003. The Nature Conservancy, Cosumnes River Preserve, Galt, California, USA.

Ivey, G.L., C.P. Herziger, and M. Gause. 2003. Farming for wildlife: an overview of agricultural operations at Staten Island, San Joaquin County, California. The Nature Conservancy, Cosumnes River Preserve, Galt, California, USA.

Johnson, D. H., and R. E. Stewart. 1973. Racial composition of migrant populations of sandhill cranes in the northern plain states. Wilson Bulletin 85:148-162.

Kauffeld, J. D. 1982. Management of migratory crane habitat on Alamosa and Monte Vista National Wildlife Refuges. Pages 117-121 *in* J. C. Lewis, editor. Proceedings of the 1981 crane workshop. National Audubon Society, Tavernier, Florida, USA.

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

Latka, D. C., and J. W. Yahnke, 1986. Simulating the roosting habitat of sandhill cranes and validation of suitability-of-use indices. Pages 19-22 *in* J. Verner, M. L Morison, and C. J. Ralph, editors. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. University of Wisconsin Press, Madison, USA.

Lewis, J. C. 1976. Roost habitat and roosting behavior of sandhill cranes in the southern central flyway. Pages 93-104 *in* J. C. Lewis, editor. Proceedings of the [1975] international crane workshop. Oklahoma State University Publishing and Printing, Stillwater, USA.

Littlefield, C. D. 1986. Autumn sandhill crane habitat use in southeast Oregon. Wilson Bulletin 98:131-137.

Littlefield, C. D. 2008. Lesser sandhill crane. Pages 167-172 *in* W. D. Shuford, and T. Gardali, editors. California bird species of special concern: a ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. Studies of Western Birds 1. Western Field Ornithologists, Camarillo, California, and California Department of Fish and Wildlife, Sacramento, California, USA.

Lovvorn, J. R., and C. M. Kirkpatrick. 1981. Roosting behavior and habitat of migrant greater sandhill cranes. Journal of Wildlife Management 45:842–857.

Norling, B. S., S. H. Anderson, and W. H. Hubert. 1992. Roost sites used by sandhill cranes staging along the Platte River, Nebraska. Great Basin Naturalist 52:253-261.

Pacific Flyway Council. 1983. Pacific Flyway management plan: Pacific Flyway Population of lesser sandhill cranes. Pacific Flyway Study Committee (Pacific Flyway Representative USFWS), Portland, Oregon, USA.

Pacific Flyway Council. 1997. Pacific Flyway management plan for the Central Valley Population of greater sandhill cranes. Pacific Flyway Study Committee (Pacific Flyway Representative USFWS), Portland, Oregon, USA.

Parrish, T. L, W. A. Hubert, S. H. Anderson, M. J. Pucherelli, and W. Mangus. 2001. Distributions of roosting sandhill cranes as identified by aerial thermography. Prairie Naturalist 33:93-99.

Pogson, T. H., and S. M. Lindstedt. 1991. Distribution and abundance of large sandhill cranes, *Grus canadensis*, wintering in California's Central Valley. Condor 93:266-278.

Sidle, J. G., H. G. Nagel, R. Clark, C. Gilbert, D. Stuart, K. Wilburn, and M. Orr. 1993. Aerial thermal infrared imaging of sandhill cranes on the Platte River, Nebraska. Remote Sensing of Environment 43:333-341.

Soine, P. J. 1982. Roost habitat selection by sandhill cranes in central North Dakota. Pages 88-94 *in* J. C. Lewis, editor. Proceedings of the 1981 crane workshop. National Audubon Society, Tavernier, Florida, USA.

Stephen, W. J. D. 1967. Bionomics of the sandhill crane. Canadian Wildlife Service Report Series 2, Ottawa, Ontario, Canada.

U.S. Fish and Wildlife Service. 2007. Stone Lakes National Wildlife Refuge comprehensive conservation plan. Stone Lakes National Wildlife Refuge, Elk Grove, California, USA.

Walkinshaw, L. H., and R. H. Hoffman. 1974. Southern Michigan sandhill crane survey. Jack-Pine Warbler 52:102-114.

EFFECTS OF WIND FARMS ON SANDHILL CRANE PLAYA OCCUPANCY ON THE TEXAS HIGH PLAINS

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Abstract: Wind energy is essential for a shift to carbon-emission free energy, however there has been very little research investigating the disturbance caused by wind farms on the landscape. Texas is a leading state in wind power capacity, and the High Plains of Texas support over 80% of the midcontinent population of sandhill cranes (*Grus canadensis*) every winter. Historically, cranes used saline lakes for fresh water and predator protection, but recent hydrological changes due to agricultural practices have reduced the availability of the lakes for wintering birds. Playa wetlands currently represent the main source of water and roosting habitat in the High Plains. We examined crane occupancy of playa wetlands in 4 counties of Texas during the fall and winters of 2009-10 and 2010-11. In addition to recording presence/no presence, we recorded multiple variables and used information theory and AIC*c* to develop models which best explained crane occupancy. Using occupancy modeling methods to survey playas in Texas resulted in no combination of variables explaining crane presence or absence in playas, most likely because cranes likely move between playas freely on their winter habitat. As playas are a vital part of their winter ecology, sandhill crane use and movement between them should be further examined to better describe crane use of their winter landscape and better plan and manage for large scale habitat alterations, such as the large increase in the number of wind turbines across the High Plains.

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Key words: *Grus canadensis*, playas, roost site, sandhill cranes, Texas, wind farms.

Wind energy is a major component of the carbon-emission free energy policy, and is one of the fastest growing energy technologies in the world (American Wind Energy Association 2011). Texas currently accounts for one-third of the nation's installed wind power. Wind farms are ideally situated along wind corridors in rural agricultural areas (Wiser and Bolinger 2008), which puts them in direct conflict with migrating and wintering birds. The High Plains of Texas support over 80% of the midcontinent population of sandhill cranes (*Grus canadensis*, hereafter cranes) every winter. Multiple studies have suggested that wind farm development and maintenance have the potential to disturb daily movements and can displace birds (Drewitt and Langston 2006, Kuvlesky et al. 2007, Langston and Pullen 2003). Cranes are easily disturbed by the presence of cars, and human activity in the vicinity of roost sites increases the probability they will abandon those sites (Bautista et al. 1992, Burger and Gochfeld 2001, Lewis 1974). Consequently cranes may be disturbed by wind farms because of turbine movement and farm maintenance.

Crane flocks generally spend the majority of their day foraging in agricultural fields (Ballard and Thompson 2000) and the evening roosting in one of the many playa wetlands, which provide fresh water and predator protection (Lewis 1974). Winter wetland habitat preservation, including the prevention of displacement from areas of disturbance (Drewitt and Langston 2006), is vital to prevent crane population declines (Lewis 1974, Safina 1993).

Historically, saline lakes in Texas provided winter roosting sites and the freshwater streams connected to them provided water for the sandhill cranes. However, recent hydrological changes due to agricultural practices have reduced the availability of the saline lakes and freshwater streams (D. Haukos, personal communication). The current predominant hydrological features on the high plains are playa wetlands which occur in high numbers across the southern High Plains. They are hydrologically unconnected and receive the majority of their water from direct rainfall and runoff (Casula 1995). Consequently, though the Texas High Plains contain 19,340 playa basins, the amount of playa habitat available to cranes is dependent on yearly precipitation and can vary widely (Haukos and Smith 1994).

Cranes prefer to roost in wetlands that are shallow, on level terrain, bordered by sparse vegetation or lacking vegetation altogether and in an isolated location, away from human disturbance (Kessel 1984, Lewis 1976, Lovvorn and Kirkpatrick 1981, Safina 1993,

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Soine 1982). Sandhill cranes winter in family groups containing the adult female, adult male, and juveniles born just a few months prior; hence, the predator protection playas provide is vital to their survival (Lewis 1974). It has been noted in some studies that the cranes exhibit strong site fidelity to specific areas in their range and juveniles will often return to the areas where they wintered with adults, indicating they learned these use areas from their parents (Drewien et al. 1999, Meine and Archibald 1996, Tacha 1981). Returning to familiar habitat and roost sites probably increases the chances of survival for these long-lived birds and illustrates the importance of maintaining crane habitat.

Human activity in the vicinity of a roost site can cause cranes to abandon the area (Bautista et al. 1992, Kessel 1984, Lewis 1974), so understanding how the presence of wind turbines affects the use of this necessary resource is needed when managing winter habitat for cranes. We examined crane occupancy of playa wetlands in 4 counties of Texas, each of which contained 1 or more wind farms. Our hypothesis was that the presence of wind farms will cause cranes to avoid otherwise acceptable playas, negatively affecting crane occupancy of playas within wind farms.

STUDY AREA

We conducted this study in the High Plains region of Texas, which is composed mainly of short-grass prairie (elevation 1,000-1,500 m). The north and west regions of the High Plains are a plateau of 80,000 km^2 and one of the largest and flattest areas of contiguous geography in the world (Casula 1995). This area has mostly been converted from short and mid-grass prairie to food and fiber production with its main exports being cotton, sorghum, and wheat (Bolen et al. 1989).

For this study we surveyed within the Texas counties of Carson, Floyd, Crosby, and Dickens. Three of these counties contained wind farms which include the Pantex wind farm (Carson County), Llano Estacado wind farm (Carson County), Whirlwind wind farm (Floyd County), and MacAdoo wind farm (Dickens County). These wind farms range from 26 to 100 turbines, and all wind farms contained at least 1 wet playa during the years (October through February, 2009-2011) in which they were surveyed. All 4 counties contained more than 50 available roosting playas each survey year. The land use in the area consisted of urban, fallow pasture/playa, winter wheat, cotton, sorghum, corn, and soybeans.

METHODS

Using Google Earth, the National Wetlands Inventory (U.S. Fish and Wildlife 2011) and ArcMap 9.3 (ESRI, Redlands, CA) to identify potential playas, we ground-truthed all identified playas in each of the study counties in each year to determine whether they held water that year. Sandhill cranes arrive in the Texas High Plains as early as late September. Generally, precipitation during the months of May - July has a large influence on the amount of playa habitat available to the cranes when they first arrive. The first year of the study (2009) was a fairly dry year for the area, receiving only 32.7 cm in precipitation, compared to the regional long term average of 47.5 cm (National Weather Service 2009), and we were able to survey all the wet playas in the study counties (51 total). During the second year (2010) the Texas high plains received almost twice as much precipitation (67.2 cm) in the Floyd, Crosby, and Dickens area as the previous year, and there were too many playas to survey with available personnel (National Weather Service 2010).

After identifying all wet playas, we numbered them, and using a random number generator, randomly chose 40 playas from those 3 study counties for a total of 71 playas surveyed in all 4 study counties (Figure 1, 2). Using occupancy modeling methods, a technician and LN surveyed each playa 3 times, either twice in the morning and once in the evening or vice versa, or until we detected crane presence. Detection probability for cranes was equal to 1 due to their visibility on the flat landscape and their tendency to be vocal. After we determined cranes were roosting in a playa we did not survey it again (MacKenzie et al. 2006).

All playas were on private land, so we surveyed them from the closest county road or highway. Morning surveys began 1 hour before sunrise, and evening surveys began 1 hour before sunset (Iverson et al. 1985, Tacha 1986). If we heard cranes at a playa, we recorded it as occupied; however, if we did not hear cranes and it was too dark for cranes to be visible, we did not record it as unoccupied. Once we determined cranes were occupying a playa, or had spent 30 minutes observing the playa with no sign of cranes arriving or leaving, we moved to the next playa (Bennett 1978). We concluded surveying when we observed cranes leaving the playas in the morning and when it became too dark to see cranes in the evening.

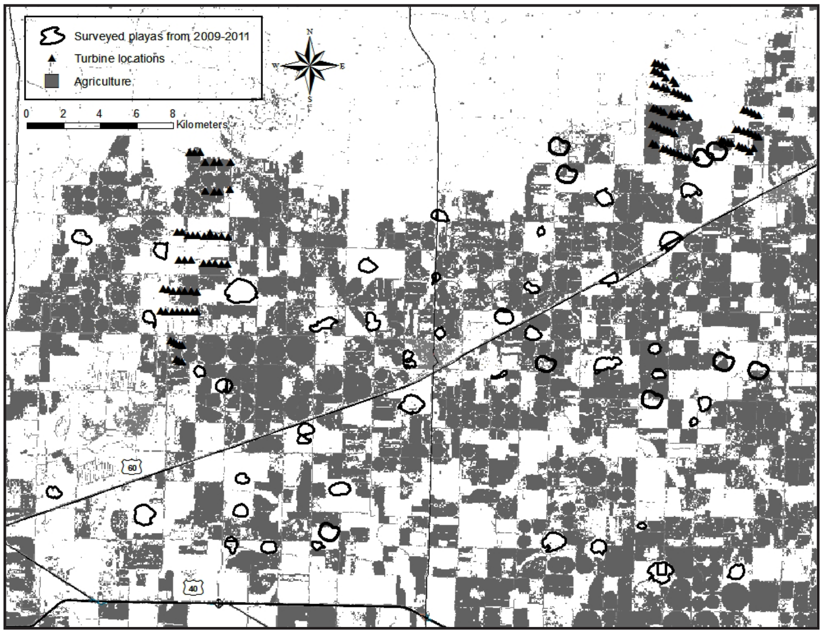

Figure 1. Playas surveyed for sandhill crane occupancy, Carson County, Texas, 2009-2011.

The majority of playas existed on private land and we were not able to access them, so to the best of our ability, we recorded the following variables to create models for a logistic regression using Akaike's Information Criteria for small sample sizes (AIC*c*) (Burnham and Anderson 2004): size (determined from the NWI); vegetation height as either low, medium, or high; slope as either low, medium, or high; and visibility as either low, medium, or high. These measurements were not exact and were recorded relative to the surrounding area. We also recorded the distance to the nearest road (DR), the distance to the nearest highway (DH) ,the distance to the nearest turbine (DW) measured from the middle of the playa, the distance to the nearest foraging area (DNF), as well as the patch size of the field (PS). All distances were determined using ArcMap 9.3 (ESRI, Redlands, CA).

Using SAS/STAT software (SAS Institute, Inc., 2000) we used descriptive statistics to compare variables between occupied and non-occupied playas and used analysis of variance to test for differences. We calculated logistic regression using the program R (R Development Core Team, 2004) to estimate the contribution of each individual measured variable and all possible combinations of the variables (models) to the occupancy of each playa. We then calculated second order AIC*c* values, differences between AIC*c* values of all models and the lowest scoring model (Δ_i) and Akaike weights (ω_i) for each model (Burnham and Anderson 2004).

RESULTS

The only differences between the variables of occupied playas and unoccupied playas was the size of the playa (n = 102, P = 0.003) and the height of the vegetation (n = 102, P = 0.01) (Tables 1 and 2). We were unable to identify a model, using logistic regression and AIC*c* criteria that had sufficient strength to explain crane occupancy. Models having their ΔAIC within 1-2 of the minimum have substantial support (Anderson 2008, Burnham and Anderson 2004). Analyzing the models using AIC*c* resulted in 9 models with the ΔAIC between 1 and 2; however, when the model probabilities (ω_i) were calculated, none had a probability larger than 0.06 (Table 3). Most ranked models contained playa size, vegetation height, and slope.

DISCUSSION

Wintering sandhill cranes in Texas roosted in playa wetlands with features fairly similar to roosts used by cranes in other studies in the western U.S. (Iverson et al. 1985; Lewis 1974, 1976; Lovvorn and Kirkpatrick 1981), i.e., large, flat and with good visibility. A comparison between the characteristics of occupied

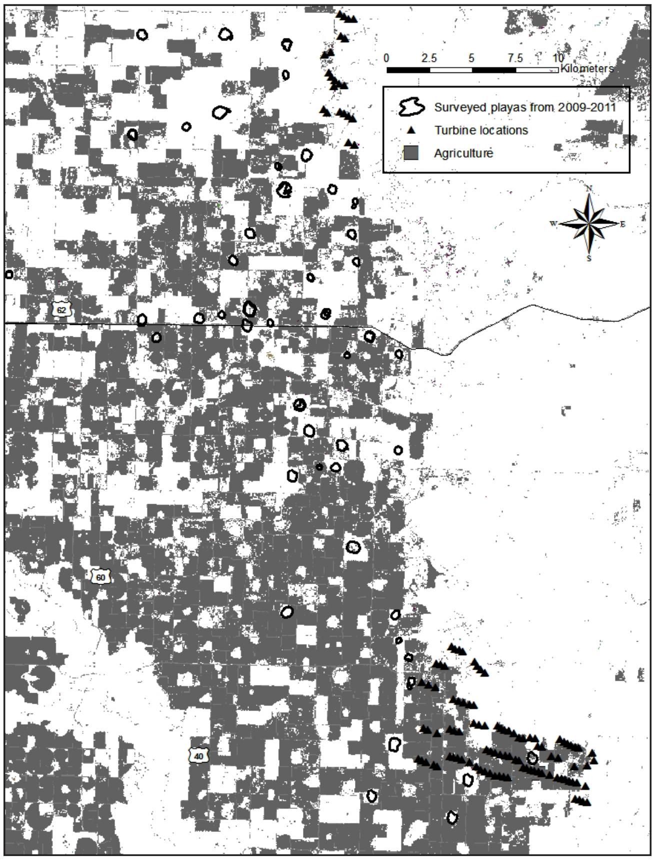

Figure 2. Playas surveyed for sandhill crane occupancy, Floyd, Carson, and Dickens counties, Texas, 2009-2011.

and unoccupied playas revealed the only significant differences between them was the size of the playa and the height of the vegetation (Tables 1 and 2). In both cases, it was unoccupied playas that possessed characteristics expected to be seen at occupied playas; larger size and lower vegetation.

Our goal was to discover if distance to disturbance (road or wind turbine) had an effect on the occupancy of a playa, but analysis of the collected data did not yield any combination of variables that explained playa occupancy or non-occupancy by sandhill cranes. Our methods of determining occupancy were based on an assumption that cranes would return to the same roost site during the time they occupied the area. The results of this study, coupled with field observations, suggest that some playas that were recorded as unoccupied were in reality, occupied. This would result in false negatives and would explain why the ANOVA analysis, regression analysis and AIC did not explain variation in occupancy.

Playa wetlands in west Texas have never been formally surveyed for crane occupancy. The few studies conducted in west Texas observed sandhill cranes in the saline lakes (Iverson et al. 1985). During these studies (1985), cranes were not observed using playa wetlands. This is in stark contrast to 2009-2011, when cranes were found occupying over 37% of surveyed playas within 4 counties. With the continuing disappearance of the saline lakes due to changing hydrology, playa wetlands are becoming increasingly important for freshwater access and roosting habitat. Based on previous studies (Bennett 1978, Davis 2003, Iverson et al 1985, Lewis 1976) done in different areas, we made the assumption that sandhill cranes return to the same roost each night, so if cranes were not seen or heard at a roost sight after 3 visits, that roosting site was recorded as not occupied. These previous studies differed from ours because they included large, permanent lakes, and most were conducted at staging areas. However, Iverson et al. (1987) found that during spring migration, radio-marked sandhill cranes had little site fidelity. Our

Table. 1 Descriptive statistics on playa wetlands occupied by sandhill cranes in the Texas High Plains, 2009-2011. Vegetation height, slope, and visibility data evaluated categorically: 1 = Low, 2 = Med, 3 = High. Significant differences at the 0.05 level between occupied and unoccupied playas shown in bold (*P* ≤ 0.01). Other differences were not significant (*P* ≥ 0.06).

	Size (ha)	**Veg**	Slope	Visibility	Nearest road (m)	Nearest turbine (m)	Nearest highway (m)	Nearest foraging area (m)	Foraging patch size (ha)
Mean	**36**	**1.6**	1.4	2.5	372	8,646	4,153	548	87
SE	**3**	**0.1**	0.1	0.1	60	993	499	51	21
Median	**29**	**2**	1	3	318	8,441	3,742	479	48
SD	**20**	**0.6**	0.6	0.6	369	6,122	3,073	314	129
Min.	**8**	**1**	1	1	10	486	659	127	4
Max.	**91**	**3**	3	3	2,006	23,074	14,361	1,456	773
n	**38**	**38**	38	38	38	38	38	38	38

Table 2. Descriptive statistics on playa wetlands unoccupied by sandhill cranes in the Texas High Plains, 2009-2011. Vegetation height, slope, and visibility data evaluated categorically: 1 = Low, 2 = Med, 3 = High. Significant differences between occupied and unoccupied playas shown in bold ($P \leq 0.01$). Other differences were not significant ($P \geq 0.06$).

	Size (ha)	Veg	Slope	Visibility	Nearest road (m)	Nearest turbine (m)	Nearest highway (m)	Nearest foraging area (m)	Foraging patch size (ha)
Mean	**67**	**1.4**	1.5	2.5	477	9,664	3,250	471	76
SE	**8**	**0.1**	0.1	0.1	115	823	344	42	9
Median	**49**	**1**	1	3	260	10,718	3,072	398	52
SD	**65**	**0.6**	0.6	0.6	927	6,588	2,755	341	75
Min.	**2**	**1**	1	1	0	113	0	100	2
Max.	**409**	**3**	3	3	5,178	26,809	10,805	1,798	316
n	**64**	**64**	64	64	64	64	64	64	64

Table 3. Top ΔAIC*c* (ΔAIC*c* = 0-2) and model probabilities exploring sandhill crane playa occupancy in the Texas High Plains, 2009-2011.

Model[a]	ΔAIC	ω_i (model probability)
Size,veg,slope	0	0.062
Size,veg,slope.DH	0.739	0.043
Size,veg	0.808	0.041
Veg,slope	1.211	0.034
Veg,slope,DH	1.237	0.033
Size,veg,DH	1.407	0.031
Size,veg,vis	1.754	0.026
Size,veg,slope,DNF	1.965	0.023

[a] Size = playa size (ha); veg = vegetation height as either low, medium, or high; slope = playa slope as either low, medium, or high; vis = visibility around playa as either low, medium, or high; DH = distance to nearest highway; DNF = distance to the nearest foraging area.

observations during the course of the study suggest that wintering cranes similarly move among the playas and do not return to the same roost spot every night. Multiple times while scouting potential survey routes we would see cranes occupying playas. A few weeks later, while conducting official surveys we would survey those playas 3 times without ever detecting cranes. It is very probable that even after surveying a playa 3 times with no detection of cranes, cranes occupied that playa at some point during the winter season.

Though we were unable to determine if wind farm disturbance affects crane occupancy of playas, we observed roosting behavior which suggests that cranes use a hierarchical selection of playas. Other studies have demonstrated that good roosting playas are very large with good visibility. During 2009, a very dry year, the number of wet playas was limited. There were 2 playa wetlands within wind farms that had the attributes of preferred wetlands described in other studies. These playas were consistently occupied by cranes during the dry year of 2009. However, in 2010 when precipitation was higher and more playas were available, no playas within a wind farm were occupied. Our observations suggest that cranes are not roosting in playas near wind farms, unless there are very few playas to choose from. Once more playas are available, cranes abandon the playas near and within the wind farms, suggesting a cost associated with using roosting habitat within wind farms.

While previous studies in West Texas have focused on the saline lakes (Iverson et al. 1985), we observed during our 2-year study that cranes occupying the playas did not move to the saline lakes until almost all of the playas were frozen. Furthermore, some cranes stayed in the playas all winter, never moving to the saline lakes before starting their northward migration in the spring. Crane use of the playas has increased since the 1990s as the freshwater springs discharging into the saline lakes have dried up (D. Haukos, U.S. Fish and Wildlife Service, personal communication). If the saline lakes are further degraded in the future, cranes may start relying even more on the playas for roosting and fresh water in the winter, especially during warm years when playas are available as roosting habitat all winter long.

Multiple roosting studies have commented on the fact that cranes are easily disturbed from roosting sites by human activity and many times do not return (Bennett 1978; Lewis 1974, 1976; Lovvorn and Kirkpatrick 1981; Stephen 1967), suggesting that increased human activity and increased road traffic in wind farms may affect crane occupancy. Future research should be done to better determine what influences the occupancy of a playa, how cranes move among them, and what causes abandonment of certain playas and fidelity to others.

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LITERATURE CITED

American Wind Energy Association. 2011. AWEA third quarter market report. <http://www.awea.org/learnabout/industry_stats/upload/3Q-2011-AWEA-Market-Report-for-Public-2.pdf>. Accessed Sep 2011.

Anderson, D. R. 2008. Quantifying the evidence about science hypotheses. Pages 83-103 *in* D. R. Anderson, editor. Model based inference in the life sciences. Springer Science and Business Media, New York, New York, USA.

Ballard, B. M., and J. E. Thompson. 2000. Winter diets of sandhill cranes from central and coastal Texas. Wilson Bulletin 112:263-267.

Bautista, L. M., J. C. Alonso, and J. A. Alonso. 1992. A 20-year study of wintering common crane fluctuations using time series analysis. Journal of Wildlife Management 56:563-572.

Bennett, A. J. 1978. Ecology and status of greater sandhill cranes in southeastern Wisconsin. Thesis, University of Wisconsin, Stevens Point, USA.

Bolen, E. G., L. M. Smith, and H. L. Schramm. 1989. Playa lake: prairie wetlands of the southern high plains. Bioscience 39:615-623.

Burger, J., and M. Gochfeld, 2001. Effects of human presence on foraging behavior of sandhill cranes (*Grus canadensis*) in Nebraska. Bird Behavior 14:81-87.

Burnham, K. P., and D. R. Anderson. 2004. Understanding AIC and BIC in model selection. Sociological Methods and Research 33:261-304.

Casula, K. 1995. Classification of playa lakes based on origin, morphology, and water quality parameters. Texas Tech University, Lubbock, Texas, USA.

Davis, C. A. 2003. Habitat use and migration patterns of sandhill cranes along the Platte River, 1998-2001. Great Plains Research 13:199-216.

Drewien, R. C., W. M. Brown, J. D. Varley, and D. C. Lockman. 1999. Seasonal movement of sandhill cranes radiomarked in Yellowstone National Park and Jackson Hole, Wyoming. Journal of Wildlife Management 63:126-136.

Drewitt, A. L., and R. W. Langston. 2006. Collision effects of wind-power generators and other obstacles on birds. Annals of New York Academy of Sciences 1134:233-266.

Haukos, D. A., and L. M. Smith. 1994. The importance of playa wetlands to biodiversity of the Southern High Plains. Landscape and Urban Planning 28: 83-98.

Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1985. Distribution and abundance of sandhill cranes wintering in western Texas. Journal of Wildlife Management 49:250-254.

Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1987. Habitat use by mid-continent sandhill cranes during spring migration. Journal of Wildlife Management 51: 448-458.

Kessel, B. 1984. Migration of sandhill cranes, *Grus canadensis*, in east-central Alaska, with routes through Alaska and western Canada. Canadian Field Naturalist 98:279-292.

Kuvlesky, W. P., L. A. Brennan, M. L. Morrison, K. K. Boydston, B. M. Ballard, and F. C. Bryant. 2007. Wind energy development and wildlife conservation: challenges and opportunities. Journal of Wildlife Management 71:2487-2498.

Langston, R.H.W., and J. D. Pullan, 2003 Windfarms and birds: an analysis of the effects of wind farms on birds, and guidance on environmental assessment criteria and site selection issues. Report T-PVS/Inf (2003) 12. BirdLife International to the Council of Europe, Bern Convention on the Conservation of European Wildlife and Natural Habitats.

Lewis, J. C. 1974. Ecology of the sandhill crane in the southeastern Central Flyway. Dissertation, Oklahoma State University, Stillwater, USA.

Lewis, J. C. 1976. Roost habitat and roosting behavior of sandhill cranes in the southern Central Flyway. Pages 93-104 *in* J. C. Lewis, editor. Proceedings of the [1975] international crane workshop. Oklahoma State University Publishing and Printing, Stillwater, USA.

Lovvorn, J. R., and C. M. Kirkpatrick. 1981. Roosting behavior and habitat of migrant greater sandhill cranes. Journal of Wildlife Management 45:842-8.

MacKenzie, D., J. D. Nichols, J. A. Royle, K. H. Pollack, and L. L. Bailey. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, Burlington, Massachusetts, USA.

Meine, C., and G. W. Archibald. 1996. The cranes: status survey and conservation action plan. International Union for Conservation of Nature, Gland, Switzerland.

National Weather Service. 2009. Weather of West Texas. <http://www.srh.noaa.gov/lub/?n=events-2009-20091231_summary>. Accessed Sep 2011.

National Weather Service. 2010: Weather of West Texas. <http://www.srh.noaa.gov/lub/?n=events-2010-20101231_summary>. Accessed Sep 2011.

R Development Core Team. 2004. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Safina, C. 1993. Population trends, habitat utilization, and outlook for the future of the sandhill crane in North America: a review and synthesis. Bird Populations 1:1-27.

SAS Institute, Inc. 2000. SAS/STAT software version 8. SAS Institute, Inc., Cary, North Carolina, USA.

Soine, P. J. 1982. Roost habitat selection by sandhill cranes in central North Dakota. Pages 88-94 *in* J. C. Lewis, editor. Proceedings of the 1981 crane workshop. National Audubon Society, Tavernier, Florida, USA.

Tacha, T. C. 1981. Behavior and taxonomy of sandhill cranes from mid-continental North America. Dissertation, Oklahoma State University. Stillwater, USA.

Tacha, T. C., D. E. Haley, and R. R. George. 1986. Population and harvest characteristics of sandhill cranes in southern Texas. Journal of Wildlife Management 50:80-83.

U.S. Fish and Wildlife Service. 2010. National wetlands inventory. <http://www.fws.gov/wetlands/>. Accessed Jan 2011.

Wiser, R., and M. Bolinger. 2008. Annual report on U.S. wind power installation, cost, and performance trends: 2007. NREL Report No. TP-500-41435.

EVALUATION OF A NUTRACEUTICAL JOINT SUPPLEMENT IN CRANES

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Abstract: Osteoarthritis is a problem that threatens the reproductive capabilities of captive populations of endangered cranes. In our pilot study, we used 5 cranes with a history of unilateral, chronic tarsal pathology in a cross-over design to gauge the effects of the primary ingredient (NEM®, ESM Technologies LLC, Carthage, MO) of the nutraceutical Steadfast® (Novus Nutrition Brands, LLC, St. Charles, MO). We evaluated the ingredient for acceptance, safety, and short-term efficacy. To evaluate efficacy, we collected goniometric measures to determine range of motion in each tarsal joint before and after a 5-week experimental period where NEM® was offered in pelleted feed. We also determined time spent in locomotion from estimates of activity once per week. The ingredient was determined to be both acceptable as offered and apparently was safe for the cranes. There were no significant changes in the birds' weights or body condition scores during any period of the trial. There was a significant increase in overall tarsal flexion measurements in the 5 birds' affected legs ($P = 0.04$), and 1 bird showed +14 degrees of improvement in flexion. No changes were seen in measures of tarsal extension or in either measure in unaffected legs. The behavioral data was inconclusive due to the small sample size and large variation in the weekly estimates within individuals. Though there was evidence of increased joint mobility in all birds in this small pilot study, further study is needed to determine if NEM® is efficacious for managing osteoarthritis in cranes.

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Key words: cranes, goniometry, nutraceutical, osteoarthritis, Steadfast®, NEM®.

Musculoskeletal abnormalities are prevalent in cranes. A retrospective survey at the International Crane Foundation (ICF), Baraboo, Wisconsin, showed musculoskeletal problems were the second leading cause of morbidity in whooping cranes (*Grus americana*) (Hartup et al. 2010). Known etiologies for avian lameness include infection, endocrine imbalance, developmental problem, nutritional deficiency, or trauma (Curro et al. 1992). Cranes have long life spans; if an injury occurs early in life, a crane may face chronic problems for many years with repercussions affecting individual welfare, reproduction, and conservation goals. Recurring mild lameness is often a sign of progressive osteoarthritis, also known as degenerative joint disease (Olsen et al. 1996). Osteoarthritis may lead to declines in joint function and captive breeding success; for example, by limiting proper incubation postures and lowering hatchability of naturally incubated eggs (Gabel and Mahan 1996).

Current therapy for degenerative arthropathies in cranes typically involves administration of non-steroidal anti-inflammatory drugs (NSAIDs) and changes in husbandry (Olsen et al. 1996, Cole et al. 2009). However, NSAIDs may not be suitable for long-term therapy. Mild hemorrhage of the proventricular mucosa has been documented in some cranes with short- and long-term exposure to meloxicam and piroxicam, respectively. Renal lesions have also been noted postmortem in cranes dosed with flunixin meglumine while at ICF. Siberian cranes (*Grus leucogeranus*) and whooping cranes administered varying levels of flunixin meglumine were diagnosed with visceral gout at necropsy (ICF unpublished data). Mortality occurred in 4 of 5 Siberian cranes and 1 of 4 whooping cranes given flunixin meglumine. No side effects or mortality were noted in other crane species administered flunixin meglumine, including blue cranes (*Anthropoides paradiseus*), hooded cranes (*G. monacha*), sandhill cranes (*G. canadensis*), and sarus cranes (*G. antigone*).

Steadfast® is a nutraceutical supplement currently marketed for dogs and horses to improve joint health by providing relief from discomfort and promoting mobility (Novus Nutrition Brands, LLC, St. Charles, MO). It is composed of eggshell membrane (NEM®, ESM Technologies LLC, Carthage, MO), organic chelated trace minerals, antioxidant vitamins, and other nutrients that support joint, bone, and connective tissue health (Dierenfeld et al. 2010). The NEM® includes components such as collagen, hyaluronic acid, glucosamine, chondroitin sulfate, durmatan sulfate, desmosine, amino acids, and peptides. Dierenfeld et al. (2010) measured levels of the cartilage blood biomarker CTX-II to evaluate the efficacy of Steadfast® in camels. The decrease in levels of this cartilage marker has been shown to correlate with a decrease in inflammation and increased weight bearing in rats (Wedekind et al. 2010). However, it is unknown whether this biomarker is present in avian species since the composition of avian cartilage is different than that of mammals. Avian articular cartilage contains high levels of both collagen I and collagen II; the primary collagen in articular cartilage is collagen II in mammals (Eyre et al. 1978). Despite the differences in cartilage composition, there are many morphological and biochemical similarities between degenerative joint disease in mammalian and avian species (Anderson-Mackenzie et al. 1997). These similarities suggest that Steadfast® may also have some benefit in degenerative joint disease in birds.

This pilot study was conducted to determine the acceptance, safety, and potential efficacy of NEM®, and to determine if a larger trial is warranted. We expected birds to show improvements in joint health as evidenced by increased range of motion of the affected joint and increased locomotion behavior during the course of the study.

METHODS

Five cranes with chronic tarsal abnormalities were used in this study (Table 1). The birds were housed with mates in 15 × 18-m outdoor pens covered by flight netting with chain-link fencing along each side and grass covered soil as a substrate. Each pen included a 4.2 × 4.2-m indoor enclosure with a deep bedding of wood shavings over concrete substrate. Pelleted food and fresh water were provided ad libitum in buckets in the enclosures (Hartup and Schroeder 2006).

We used a cross-over study design where cranes received either the NEM® ingredient in their diet at 800 ppm (0.08% in reconstituted crane maintenance pellets, Zeigler Brothers Inc., Gardners, PA) or a placebo diet (original pellets without NEM®) for 5 weeks, followed by a 2-week washout period (placebo diet). The cranes then received the opposite treatment for an additional 5 weeks. Each crane served as its own control while on the placebo diet. Though the study was designed to be blinded, an unexpected food shortage in the experimental diet caused the researcher to become un-blinded. Since all cranes in the study were part of a breeding pair and food was shared, both pen mates received NEM®. Food was weighed before and after each feeding to determine the amount removed. Given that we could not determine the exact amount eaten by each member of the pair, we assumed that each crane ate half of the food removed from the feed bucket. The first trial period took place from 12 July 2010 to 15 August 2010; the second from 30 August 2010 to 3 October 2010.

On day 0 and day 35 of each 5-week period, specific data were collected. A physical examination was performed (by B. Hartup), with special attention paid to the hind limb joints. Each crane was weighed and assigned a body condition index (BCI) score (1-5 scale, 1 = minimal pectoral muscle mass with prominent sternum, 5 = robust, well rounded pectoral muscle mass, sternum palpated with difficulty) (Olsen et al. 1996). Also, the range of motion of each crane's tarsal joints was measured with a goniometer (Fig. 1). This measurement was taken by either K. Bauer or B. Hartup. A goniometer measurement of 180° was defined as a full flexion while a measurement of 0° was defined as full extension. A total of 4 measurements were taken: full flexion of the right leg, full extension of the right leg, full flexion of the left leg, and full extension of the left leg. Measurements were taken by aligning the fulcrum of the goniometer with the center of the tarsal joint. Gentle pressure was applied to the joint to achieve either full extension or full flexion. One arm of the goniometer was aligned parallel with the tibia and the other with the tarsometatarsus. To our knowledge, this is the first documentation of this methodology to determine range of motion in avian tarsal joints.

In addition, digital video cameras already present at ICF were used to monitor the movements of the

Table 1. Summary of the cranes used in the nutraceutical trial.

ID	Species	Age (years)	Sex	Musculoskeletal problem
Bubba	*Grus americana*	26	M	Slipped tendon (left tarsus)
Rattler	*G. americana*	42	M	Degenerative arthritis (left tarsus)
Dushenka	*G. leucogeranus*	29	M	Slipped tendon (left tarsus)
Kavir	*G. leucogeranus*	16	F	Previous injury to lateral collateral ligament (right tarsus)
Ranjit	*G. leucogeranus*	24	F	Slipped tendon (left tarsus)

Figure 1. Goniometry measurement of tarsal flexion in a crane.

birds for 50 minutes per week during each 5-week period on a randomly selected day and time between 0700 and 1000 hours. This footage was assessed by 1 of 2 individuals, either K. Bauer or an intern aviculturist trained by K. Bauer, in order to record an activity budget of each crane, accounting for what percentage of time each crane spent in daily activities such as walking or resting. To decrease inter-observer variability, both observers participated in practice observation sessions. Behaviors for this activity budget were placed into 1 of 5 categories: foraging, locomotion, comfort, resting, or social interaction. If the crane spent time in its house, which was outside of the view of the camera, the behavior was recorded as out of sight. A behavior was recorded every 30 seconds during the 50 minute period for each crane, for a total of 100 data points. If the crane was recorded as out of sight for more than 40 of those data points, the data was discarded and the crane was given a new observation time for the week. If insufficient data points were again recorded, the 2 sets of data from the 2 observations periods were combined.

A food shortage shortened 1 crane's experimental period. The crane received the diet through day 16 of the 5-week period, and its final evaluation took place on day 17 of the trial period. Behavior data was collected for the first 3 weeks of this period.

The primary author was blinded to the treatment assigned each crane during the 2 5-week periods. We used unpaired *t*-tests to compare food consumption between periods among the cranes. Normal distributions were confirmed by visual inspection and review of skewness and kurtosis calculations on each set of treatment and control data and deemed acceptable. To analyze the goniometry data, BCI scores, and weights, we used a nonparametric Wilcoxon signed-rank test for paired samples (Statview 5.0.1, SAS Institute, Inc, Cary, NC). The Wilcoxon test is an alternative to the paired *t*-test applicable to small datasets and uses a ranking of differences between each pair of observations. The resultant *Z*-statistic tests the hypothesis that the sum of the ranks is equal to 0, assuming the distribution of ranks is symmetric around 0. The larger positive or negative number reflects greater differences between paired values. Statistical significance was established at $P < 0.05$.

RESULTS

Acceptance and Safety

Four of 5 individuals consumed significantly less of the experimental diet than the placebo diet, while the fifth individual consumed more of the experimental diet than the placebo diet (all $P < 0.01$, Table 2). Because the experimental diet was reconstituted in order to incorporate the nutraceutical product, the resulting feed did not maintain its cylindrical shape well. Each crane pair regularly reduced their experimental diet to a fine dust, but the placebo pellets always remained intact. This led to more frequent replacement and/or sifting of the experimental diet pellets, and ultimately led to the depletion of the experimental diet supply.

During the physical examinations at the end of the experimental diet period, 2 birds were diagnosed with additional abnormalities. One bird had developed pododermatitis (bumblefoot), and another had increased lateral instability in the tarsus, possibly due to an acute lateral collateral ligament injury. Both abnormalities occurred in the previously unaffected leg. No significant differences were observed in weights ($P = 0.58$) or BCI scores ($P = 0.29$) taken at day 35 of each period (Table 3).

Efficacy

We detected significant differences in baseline flexion and extension measurements between the

Table 2. Mean ± SD daily pelleted feed intake (g) of individual birds during 2 trial periods.

ID	Placebo diet	Experimental diet
Bubba	165 ± 38	126 ± 33
Rattler	138 ± 27	173 ± 36
Dushenka	200 ± 38	180 ± 29
Kavir	185 ± 44	151 ± 31
Ranjit	202 ± 64	164 ± 46

Table 3. Weights (kg) and body condition scores (1-5 scale) of individuals following 35 days consumption of either a placebo or experimental diet containing a nutraceutical joint supplement.

ID	Weight, placebo diet	Weight, experimental diet	BCI, placebo diet	BCI, experimental diet
Bubba	4.9	5.2	2	2.5
Rattler	5.6	5.6	2	2
Dushenka	6.6	6.4	4	2.5
Kavir	4.9	4.8	4	3
Ranjit	5.8	5.5	3	3

cranes' affected and unaffected legs taken at days 0 and 35 of the placebo diet period and day 0 of the experimental diet period (both $P < 0.01$, Table 4). After 35 days of consumption of the experimental diet, there was a significant change in the flexion measurements of the affected leg among the 5 cranes ($P = 0.04$), but not the extension measurements ($P = 0.72$, Table 5). No significant changes were observed in the measurements for the unaffected leg of any crane post-treatment.

Behavior varied greatly from week to week for each crane both on the experimental and the control diet. No identifiable trends were observed for the amount of time the cranes spent in locomotion during the experimental diet period.

Table 4. Control goniometry (in degrees, mean ± SD) based on 3 measurements from unaffected and affected legs of 5 cranes with chronic tarsal abnormalities. An overall decreased range of motion in the affected legs of the birds is reflected in lower flexion and greater extension measurements.

	Unaffected leg	Affected leg
Flexion	169.3 ± 6.8	152.8 ± 18.4
Extension	6.5 ± 2.6	9.6 ± 4.8

DISCUSSION

Acceptance and Safety

Overall, we believe that the diet containing NEM® was well accepted by the cranes used in this trial and appeared safe. The addition of the NEM® altered the normal delivery of the pellets, i.e., pellets containing NEM® were quickly reduced to crumbles. It may also have altered the palatability of the pellets. Overall, the amount of experimental diet consumed by the cranes was lower compared to placebo diet for 4 of the 5 cranes. This could have been due to modest rejection based on taste, or more likely, the reconstitution process and poor binding resulted in the cranes' inability to handle a more fragile pellet. We believe the food consumption results are best explained, however, by what we believe is an increase in food consumption in response to seasonal change. The 4 cranes with greater placebo diet intake did so in the second 5-week period of the study (early fall), and the 1 crane that consumed more experimental diet was the only bird to receive it in the latter period as well, all perhaps reflecting the first stages of migration readiness behavior. Regardless, no cranes experienced significant change in weight or body condition. Additional monitoring, including hematology and blood chemistry analysis, would be of benefit in future trials.

Table 5. Goniometry measurements (in degrees) from each bird's affected leg following 35 days consumption of either a placebo or experimental diet containing a nutraceutical joint supplement.

ID	Leg flexion, placebo diet	Leg flexion, experimental diet	Leg extension, placebo diet	Leg extension, experimental diet
Bubba	145	150	11	8
Rattler	158	163	7	4
Dushenka	157	166	15	15
Kavir	173	175	2	0
Ranjit	120	135	6	11

The fragility of the reconstituted diet was a problem in this study because 2 of the cranes had pre-existing beak malocclusions requiring greater food depths for successful consumption from buckets. A well-bound pellet would have mitigated this issue, but the cranes still appeared to meet their nutritional needs. Feeding the cranes tablets hidden in treats was not an option due to the malocclusions, as well as the overall lack of prior training of these subjects. In well-trained birds without complicating beak injuries, direct dosing using treats may be a viable option (Dierenfeld et al. 2010). Including the NEM® in the original extrusion and pelleting would likely result in a more durable product at delivery.

We noted no acute or systemic adverse effects at the concentration and route of NEM® administered. However, the safety of NEM® cannot be definitely determined due to a lack of hematologic and biochemical data. We are uncertain whether NEM® supplementation was associated with new musculoskeletal conditions diagnosed in 2 of the cranes during the experimental period, though it seems unlikely. The conditions emerged in the contralateral leg to the original, chronically affected leg in each crane. Normally these types of conditions occur secondarily when cranes place undue weight on a good leg while minimizing weight bearing on an affected leg. We hypothesized just the opposite: birds with improved joint function from NEM® supplementation would begin to bear weight in a more balanced manner and be less susceptible to injury or development of secondary musculoskeletal disease. Unfortunately, weight bearing distribution was not assessed in this study. If the birds were in fact still compensating for their chronically injured leg, it is less likely that they had truly improved joint health as a result of the NEM® added to their diet. A full treatment effect also seems less likely with the short duration of the treatment period.

Efficacy

We observed modest improvement in goniometry measurements relative to joint flexion, but not extension, in cranes with an abnormal leg that were provided a nutraceutical joint supplement for 5 weeks. The improvement in abnormal tarsal joint range of motion was approximately 5%. A more thorough comparison to younger individuals of the studied species would provide useful reference data. A longer trial with the same individuals or additional cases would serve to validate this product's potential for mitigating the progression and complications of osteoarthritis and musculoskeletal injuries common to cranes in captive environments.

We did not discern any semi-quantitative change in locomotion behavior in the cranes. The behavior data collected was likely insufficient in frequency and duration to accurately determine the locomotion budget for a given crane and determine an effect of the nutraceutical supplement. Activity budget data is notoriously variable day-to-day, and often highly biased by lack of observation when birds are out of sight. In addition, our observations coincided with a seasonal change that might also have affected activity levels (early fall). We suggest that any future trials include a long-term behavioral assessment as well as direct range of motion assessments within a single prolonged season (e.g., immediately post-breeding to fall) or across an annual cycle.

A primary challenge for further studies will be production of a processed diet containing the nutraceutical that can withstand normal delivery and field conditions encountered when feeding captive cranes. Additionally, full assessment of the therapeutic impact of NEM® will need assessment using multiple methods and over a longer time period. Other options for future trials include testing a therapeutic approach combining the use of NEM® with another product such as an NSAID.

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LITERATURE CITED

Anderson-Mackenzie, J. M., D. J. S. Hulmes, and B. H. Thorp. 1997. Degenerative joint disease in poultry—differences in composition and morphology of articular cartilage are associated with strain susceptibility. Research in Veterinary Science 63:29-33.

Cole, G. A., J. Paul-Murphy, L. Krugner-Higby, J. M. Klauer, S. E. Medlin, N. S. Keuler, and K. K. Sladky. 2009. Analgesic effects of intramuscular administration of meloxicam in Hispaniolan parrots (*Amazona ventralis*) with experimentally induced arthritis. American Journal of Veterinary Research 70:1471-1476.

Curro, T. G., J. A. Langenberg, and J. Paul-Murphy. 1992. A review of lameness in long-legged birds. Pages 265-270 *in* Proceedings of the Association of Avian Veterinarians, 1-5 September 1992, New Orleans, Louisiana, USA.

Dierenfeld, E., D. Baum, L. Hampe, J. Jensen, C. Atwell, and K. Wedekind. 2010. Evaluation of a nutraceutical joint supplement in camels (*Camelus* spp.). Page 37 *in* Proceedings of the 6th European Zoo Nutrition Conference. EAZA Nutrition Group, 29-31 January 2010, Barcelona, Spain.

Eyre, D. R., D. M. Brickley-Parsons, and M. J. Glimcher. 1978. Predominance of type I collagen at the surface of avian articular cartilage. FEBS Letters 85:259-263.

Gabel, R. R., and T. A. Mahan. 1996. Incubation and hatching. Pages 59-76 *in* D. H. Ellis, G. F. Gee, and C. M. Mirande, editors. Cranes: their biology, husbandry, and conservation. National Biological Service, Washington, D.C., and International Crane Foundation, Baraboo, Wisconsin, USA.

Hartup, B. K., J. N. Niemuth, B. Fitzpatrick, M. Fox, and C. Kelley. 2010. Morbidity and mortality of captive whooping cranes at the International Crane Foundation: 1976-2008. Proceedings of the North American Crane Workshop 11:183-185.

Hartup, B. K., and C. A. Schroeder. 2006. Protein electrophoresis in cranes with presumed insect bite hypersensitivity. Veterinary Clinical Pathology 35:226-230.

Novus Nutrition Brands, LLC. 2009. Arenus: steadfast canine, large breed dog health and nutritional supplements. <http://shop.arenus.com/p-24-steadfastcanine-large-breed.aspx#steadfast=tab3>. Accessed 27 Apr 2011.

Olsen G. H., J. W. Carpenter, and J. A. Langenberg. 1996. Medicine and surgery. Pages 137-174 *in* D. H. Ellis, G. F. Gee, and C. M. Mirande, editors. Cranes: their biology, husbandry, and conservation. National Biological Service, Washington, D.C., and International Crane Foundation, Baraboo, Wisconsin, USA.

Wedekind, K. J., I. Middelbos, J. Evans, C. Atwell, and J. Lunnemann. 2010. Efficacy of STEADFAST® EQUINE joint supplement in a chemically-induced osteoarthritis rat model. FASEB Journal (meeting abstract supplement) 24:726.5

TEN-YEAR STATUS OF THE EASTERN MIGRATORY WHOOPING CRANE REINTRODUCTION

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Abstract: From 2001 to 2010, 132 costume-reared juvenile whooping cranes (*Grus americana*) were led by ultralight aircraft from Necedah National Wildlife Refuge (NWR) in central Wisconsin to the Gulf Coast of Florida on their first autumn migration (ultralight-led or UL), and 46 juveniles were released directly on Necedah NWR during autumn of the hatch year (direct autumn release or DAR). Return rate in spring was 90.5% for UL and 69.2% for DAR, the lower value of the latter attributable to 1 cohort with migration problems. Overall population survival 1 year and from 1 to 3 years post-release was 81% and 84%, respectively. Survival 1 year post-release was significantly different between UL (85.1%) and DAR (65.7%) cranes. Since summer 2008, DAR migration and wintering have improved, winter distribution of the population has changed, the migration route of the population has shifted westward, and number of yearlings summering in locations used during spring wandering has increased. Human avoidance problems resulted in 2 birds being removed from the population. As in earlier years, homing to the natal area and prolific pair formation continued (29 of 31 adult pairs have formed in the core reintroduction area), predation continued to be the primary cause of mortality, and parental desertion of nests, especially during the initial (primary) nesting period, continued. During 2005-2010, all 43 of these early nests failed; of 15 late nests or renests, chicks hatched from 8 nests, and 3 chicks fledged. As of 31 March 2011, the population contained a maximum 105 individuals (54 males and 51 females) including 20 adult pairs.

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Key words: direct autumn release, Florida, *Grus americana*, migratory population, reintroduction, reproduction, survival, ultralight aircraft, whooping crane, Wisconsin.

An effort to reintroduce a migratory population of whooping cranes *(Grus americana)* into eastern North America began in 2001 when costume/isolation-reared juveniles were led behind ultralight aircraft from Necedah National Wildlife Refuge (NWR), central Wisconsin, to release on Chassahowitzka NWR on the central Gulf Coast of Florida. Annual releases of cranes by techniques of ultralight-led migration (UL) and direct autumn release (DAR), the latter beginning in 2005, have continued through 2010. The population has been intensively monitored through the course of the reintroduction. Resulting studies have assessed general survival, movements, and reproduction (Urbanek et al. 2005, 2010*a*), habitat selection on summer (Maguire 2008) and winter areas (Fondow 2013), mortality (Cole et al. 2009), winter management and distribution (Urbanek et al. 2010*b*), direct autumn release (Wellington and Urbanek 2010) and corrective translocation (Zimorski and Urbanek 2010) techniques, health (Hartup et al. 2004, 2005), genetics (Converse et al. 2012), and demography (Converse and Urbanek 2010). Progress has been favorable for establishment of the reintroduced population in all subject areas except reproduction, which has experienced consistent nest failure (Urbanek et al. 2010*c*, Converse et al. 2013). This paper provides an overview of the survival, reproduction, and movements of these birds during the first 10 years of the reintroduction.

STUDY AREAS

The core reintroduction area consisted of a large complex of shallow wetlands in Juneau and adjacent counties in central Wisconsin. All ultralight-training sites (2001-2010) and DAR rearing and release sites (2005-2010) were on Necedah NWR (44°04′N, 90°10′W). Juveniles trained to follow ultralight aircraft were led on their first autumn migration to a salt marsh release site on Chassahowitzka NWR (28°44′N, 82°39′W), on the central Gulf Coast of

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Table 1. Current numbers/number of whooping cranes released[a] for each hatch year, reintroduced eastern migratory population, 31 March 2011[b]. UL = Ultralight-led. DAR = Direct autumn release.

	HY2001	HY2002	HY2003	HY2004	HY2005	HY2006	HY2007	HY2008	HY2009	HY2010	Total
UL											
Males	1[c]/4	4/6	6/11	5/10	6/11	0/1	5[c]/9	5/10	9/11	4/4	45/77
Females	1/3	1[d]/10	4/5	2/3	3/8	-	5/7	3/4	8/9	6/6	33/55
Total	2/7	5/16	10/16	7/13	9/19	0/1	10/16	8/14	17/20	10/10	78/132
DAR											
Males				0/1[d]	0/1	1/3	1/3	1/3[d]	2/2	4/7	9/20
Females				-	3/3	0/1	3/7	1/4	6[e]/7	2/4	15/26
Total				0/1	3/4	1/4	4/10	2/7	8/9	6/11	24/46
Wild-hatched and reared											
Total					-	1/1	-	-	-	2/2	3/3
Grand total	2/7	5/16	10/16	7/14	12/23	2/6	14/26	10/21	25/29	18/23	105/181

[a] Number fledged in recruitment from natural reproduction.

[b] Not included are 17 HY2006 UL juveniles that died in a winter pen mortality (2 Feb 2007) and 1 HY2007 female that could not fly and was remanded to permanent captivity.

[c] 1 2-year-old and 1 10-year-old male were transferred to permanent captivity after unresolvable issues due to lack of human avoidance.

[d] Includes 1 male with flight feather problems in 2004 and 1 male with aggression problems in 2008. These 2 individuals were originally reared in ultralight cohorts but were unsuitable for inclusion in the migration by that protocol. They were therefore released in autumn on Necedah NWR. Neither survived to 1 year of age.

[e] 1 yearling female was euthanized because of irrepairable leg injury.

Florida, during each year. A temporary holding site was added in winter 2005-06 on Halpata Tastanaki Preserve (29°02′N, 82°25′W), Southwest Florida Water Management District, Marion County. This was an inland freshwater site 42 km northeast of the winter release site on Chassahowitzka NWR and was used to hold the juveniles until dominant older whooping cranes had cleared the latter site to winter at freshwater inland sites (Urbanek 2010*b*). Beginning in winter 2008-09, a second winter release site was also used at St. Marks NWR (30°06′N, 84°17′W), Wakulla County, in the eastern Florida panhandle.

The reintroduced whooping cranes migrated, for the most part, along a relatively direct route between Wisconsin and wintering areas in the southeastern United States. Most birds wintered in Florida, but some also wintered elsewhere, mainly in Tennessee and South Carolina. Major stopover and winter sites within this route included Jasper-Pulaski Fish and Wildlife Area, Indiana; Goose Pond Fish and Wildlife Area, Greene County, Indiana; Hiwassee Wildlife Refuge, Meigs County, Tennessee; Weiss Lake, Cherokee County, Alabama; Wheeler NWR, Morgan County, Alabama; and Paynes Prairie, Alachua County, Florida. Areas most commonly used by wintering UL birds after their first winter were inland areas of west-central Florida, especially large cattle ranches with associated wetlands (Fondow 2013). Summer, migration, and wintering areas used by the population have been previously described (Urbanek et al. 2005*,* 2010*a*).

METHODS

Eggs were obtained from captive propagation facilities at Patuxent Wildlife Research Center (PWRC), the International Crane Foundation (ICF), Calgary Zoo, Audubon Center for Research of Endangered Species, and San Antonio Zoo. Additionally, eggs were salvaged from abandoned nests on Necedah NWR (Urbanek 2010*c*) and transferred to PWRC or ICF, where all hatching and initial rearing of UL and DAR chicks, respectively, occurred. Details of rearing and release methods have been previously described (Urbanek et al. 2010*a,b*).

Juveniles were costume/isolation-reared (Horwich 1989, Urbanek and Bookhout 1992) according to either UL (Lishman et al. 1997, Duff et al. 2001) or DAR protocols in 2001-2010 and 2005-2010, respectively. Birds of the UL cohorts were led from Necedah NWR in central Wisconsin to the Gulf Coast of Florida on their first autumn migration. Beginning with the 2008 migration, the original route through Indiana, east-

Table 2. Survival of reintroduced migratory whooping cranes 1 year after release[a] (HY2001-2009) and from 1 year after release to age 3 years (HY2001-2007). UL = Ultralight-led. DAR = Direct autumn release.

	1 year after release		1 year after release to age 3 yrs	
	No. alive/no. released	%	No. alive/no. surviving 1 year after release	%
UL				
Males	60/73	82.2	38/44	86.4
Females	43/48[b]	90.0	26/31	83.9
Total	103/121	85.1*[c]	64/75	85.3
DAR				
Males	8/13[d]	61.5	3/4	75.0
Females	15/22	68.2	6/8	75.0
Total	23/35[d]	65.7*	9/12	75.0
All released				
Males	68/86	79.1	41/48	85.4
Females	58/70	82.9	32/39	82.1
Total	126/156	80.8	73/87	83.9

[a] Not included are 17 HY2006 UL juveniles that died in a winter pen mortality event and 1 HY2007 UL female that could not fly and was remanded to permanent captivity.

[b] Excludes a HY2002 female that was euthanized after capture myopathy.

[c] $*P < 0.05$

[d] Includes 2 individuals originally reared in UL cohorts but unsuitable for inclusion in the migration by that protocol. They were later released in autumn on Necedah NWR similar to DAR, although they had not been reared according to the DAR protocol. Neither survived to 1 year of age. Excluding these 2 birds, survival of DAR males and total birds 1 year after release was 8/11 (72.7%) and 23/33 (69.7%), respectively.

central Kentucky and Tennessee, and Georgia was replaced with a more westerly route though Illinois, western Kentucky and Tennessee, and Alabama. Two UL juveniles were initially trained to follow ultralight aircraft but later released similar to DAR birds on Necedah NWR; these individuals are treated as DAR birds in this paper (Table 1). This inclusion contributed to evaluation of the release technique but not to possible effects of rearing method on release outcome. The DAR method depended on the association of the released juveniles with older whooping cranes to guide them on their first autumn migration.

The 18 juveniles of the HY2006 UL cohort (HY = hatch year) were released on Chassahowitzka NWR for 1 night on 20 January 2007 but then kept penned while transient older birds were present at the site until 2 February. During early morning hours on the latter date, a severe storm produced high tides and a direct lightning strike on the penned birds, killing all but 1 juvenile, which escaped (Spalding et al. 2010). The 17 cranes that died during this mortality event were excluded from data summary and analysis.

Differences in survival between UL and DAR cranes were assessed with a 2-sample proportion test with continuity correction (Analytical Software 2008).

RESULTS

Population Size and Survival

During 2001-2010, 178 juveniles were costume/isolation-reared and released: 132 were led by ultralight aircraft from Necedah NWR to the Gulf Coast of Florida on their first autumn migration. The remaining 46 individuals were released directly on Necedah NWR during autumn of the hatch year (DAR) (Table 1). Overall survival of released whooping cranes was 81% (79% for males, 83% for females) 1 year after release and 84% for cranes from 1 year after release until age 3 (Table 2). Survival of both sexes was lower for DAR than UL during the earlier (66 vs. 85%) and later (75 vs. 85%) periods, but the difference was less for the older birds. Survival 1 year after release was significantly different between total individuals of UL (86.0%) and DAR (65.7%) ($Z = 2.32$, $P = 0.0202$) and nearly significantly different between UL (90.0%) and DAR (68.2%) females ($Z = 1.86$, $P = 0.0623$). No other differences between or within the 2 post-release groups were significant.

Of all released individuals plus fledged chicks reared by released birds, 58%, including representatives of all year classes, were extant as of 31 March 2011. The population contained a maximum 105 individuals (54 males and 51 females) including 78 UL, 24 DAR, and 3 wild-hatched and reared cranes (Table 1).

DAR juveniles exhibited a wide range of behavioral scenarios immediately after release, including associating with sandhill cranes and/or older whooping cranes, migrating alone, and mortality (3 killed by predators on northern refuge, 2 killed early in migration by collision with jet landing at airport, and power line collision). However, as the population increased during the course of the study, more whooping crane guide birds were available, especially bachelor males, and all HY2008-2010 DAR juveniles surviving to migrate migrated successfully with them to winter locations.

Mortality

Mortalities were dispersed among sex/age classes at locations within the annual cycle, and the primary cause was predation, amounting to 60% of mortalities that were attributed to a specific cause (Table 3). Excluding 17 juveniles that died in a single weather-related event while penned at the winter release site in 2007 and another that could not fly after release, 74 individuals died from the first release in November 2001 through 31 March 2011. After the 16-month period from late May 2006 through late September 2007, when annual mortality rate in the population was 26.7%, mortality rate reverted to lower levels approximating those observed earlier (Urbanek 2010*a*).

A notable increase in shootings (5 birds confirmed or incidents under investigation) occurred during winter 2010-11. Through October 2007, accounting for all mortalities was complete. Since that time an increasing number of missing birds were not subsequently observed. In Table 3 these were counted as mortalities, some allowance made for probability of detection, after 1 year without observation. Some recent mortalities were also related to infectious disease. An adult female that died in spring 2011 (not included in period covered in Table 3) apparently succumbed to bacterial septicemia due to an intestinal trematode (*Echinoparyphium* sp.) infestation. A prefledged chick also died of airsacculitis and peritonitis resulting from infection by intestinal bacteria in 2010 (National Wildlife Health Center, Diagnostic Services Case Reports 23124 and 23562, 2011).

Table 3. Mortalities (*n* =74) of reintroduced eastern migratory whooping cranes by confirmed or probable causal factor, 2001 through 31 March 2011[a,b]. Location during annual cycle: summer (36), autumn migration (7), winter (20), spring migration (5), unknown (5), capture myopathy (1).

Cause of mortality	Males	Females	Total
Ultralight-led (UL)			
Predation (unidentified predator)[c]	5	6	11
Bobcat predation	5	4	9
Alligator predation	1		1
Eagle predation		2	2
Power line collision[d]	1		1
Gunshot	2	2	4
Trauma (source unknown)	1		1
Epicardial hemorrhage		1	1
Predation of injured bird	1		1
Euthanized (capture myopathy)		1	1
Vehicle collision	1		1
Chronic aspergillosis		1	1
Undetermined[e]	5	2	7
Presumed dead (no carcass recovered)	8	3	11
Total	30	22	52
Direct autumn release (DAR)			
Coyote predation		2	2
Predation (suspected canid)	2	1	3
Bobcat predation	1		1
Alligator predation		2	2
Power line collision	2[f]	2	4[f]
Aircraft collision	1		1
Gunshot	2	2	4
Leg trauma (euthanized)		1	1
Presumed dead (no carcass recovered)	3[f]	1	4[f]
Total	11[f]	11	22[f]
All birds	41	33	74

[a] Does not include 17 HY2007 UL juveniles that died in winter pen mortality event.

[b] Does not include female remanded to captivity because of loss of flight ability.

[c] Includes suspected canid (3).

[d] Includes male found alive but immobile under power line; later died from unrelated cause in captivity.

[e] Carcass recovered, but cause of mortality could not be determined.

[f] 1 individual killed in a power line collision and 1 presumed dead but not recovered were originally reared in UL cohorts but were unsuitable for inclusion in UL migration. They were later released on Necedah NWR similar to DAR although they had not been reared according to the DAR protocol.

Distribution

Released cranes, for the most part, remained in the expected migratory pathway and wintered in Florida or at appropriate locations along the Florida to Wisconsin route. Noteworthy exceptions (discussed below) included wintering areas in South Carolina, presence of birds in the Central Flyway, and birds terminating spring migration east of Lake Michigan. Migration, wintering locations, and movements in the summering area from 2001 to 2008 have been previously described (Urbanek et al. 2005, 2010*a*, 2010*b*).

First year UL:—Released UL cranes began their first spring migration from winter release sites in Florida during 24 March-14 April and with few exceptions (noted below) migrated appropriately back to Central Wisconsin. Typically, these returning yearlings only remained briefly and then moved to various other sites farther south in Wisconsin or occasionally to Minnesota, Iowa, or other areas. This previously unreported pattern has been termed *spring wandering* by the senior author, and will be described in detail in a subsequent paper. With few exceptions these yearlings returned to Necedah NWR and other sites within the core reintroduction area by early July. From 2002 to 2007, these returning yearlings then stayed for the remainder of the summer. Beginning in 2008, yearlings and some 2-year-olds returned to spring wandering locations to summer: 8 in 2008, 12 in 2009, and 15 in 2010 (these values include DAR birds, which demonstrated the same behavior). Spring wandering of adults was rarely observed. Through 2011, all adults established their breeding territories in the core reintroduction area. Most cranes remained in the core until the following autumn migration, although a few returned to previously used spring wandering sites before migrating.

First year DAR:—DAR juveniles migrated unassisted on autumn migration, and the results were variable by cohort. A HY2004 juvenile originally reared as a UL bird but then transferred to DAR followed whooping crane guide birds and wintered at a site with other whooping cranes in Florida. Two HY2005 juveniles wintered together at Hiwassee Wildlife Refuge, Tennessee (1 required retrieval earlier in Kentucky), and 2 others wintered separately with sandhill cranes *(Grus canadensis)* in Florida. All 4 HY2006 juveniles wintered in Florida in 2 groups. Two of the HY2007 birds were killed just after beginning migration; 1 bird migrated to Arkansas, and a group of 6 migrated with no whooping crane or sandhill crane guides directly south to southwestern Illinois. The latter 7 HY2007 birds were retrieved and released on Hiwassee Wildlife Refuge, Tennessee. The eastwardly displaced birds then all migrated in spring to Michigan, where additional retrieval attempts were made. All HY2008-2009 juveniles migrated and wintered successfully with older whooping crane guide birds. DAR birds returning to Wisconsin in spring demonstrated the same homing and spring wandering patterns as UL birds.

First year spring return rates:—For HY2001-2009 juveniles, return rate to central Wisconsin the following spring was 90.5% for UL and 69.2% for DAR. However, return rate of DAR yearlings was highly variable by year, and the lower return rate was due to migration problems (see above) within the HY2007 cohort (Table 4). Return rates were influenced by the previous autumn migration and presence of guide birds. All failures involved spring migration to Lower Michigan and, when possible, were corrected by retrieval and relocation to central Wisconsin (Zimorski and Urbanek 2010).

Birds with long-term dispersal locations outside the core reintroduction area:—Through 2010, approximately 19 birds (5 males, 14 females) had some history (past the yearling autumn) of consistent summering outside the core reintroduction area. Eight of these occurrences involved birds in Michigan. Four females eventually paired with males and returned to establish territories in the core; 2 of these females paired on Hiwassee Wildlife Refuge, Tennessee, 1 returned to the core after 3 years elsewhere with sandhills and then paired with a resident male during spring, and 1 paired as a result of multiple

Table 4. Return rates of yearling whooping cranes to the natal core reintroduction area in central Wisconsin, 2002-2010. Retrieved birds (see footnotes) were released on or near Necedah NWR.

Hatch year	Return rate	
	UL	DAR
2001	5/5	
2002	14/16[a]	
2003	11/16[b]	
2004	13/13	1/1
2005	16/19[c]	3/4[d]
2006	0/0	1/2[e]
2007	14/15	0/6[f]
2008	13/13	4/4[g]
2009	19/19	9/9[g]
Total	105/116	18/26
Percent	90.5	69.2

[a] 1 female retrieved in Ohio.
[b] 3 males and 2 females in Michigan.
[c] 2 males in Michigan (1 retrieved); 1 female migrated with HY2003 female and both were retrieved in New York.
[d] 1 female in Michigan.
[e] 1 male retrieved in Michigan.
[f] 1 male (retrieved) and 5 females (3 retrieved) in Michigan.
[g] Wintered and migrated with older whooping crane guide birds.

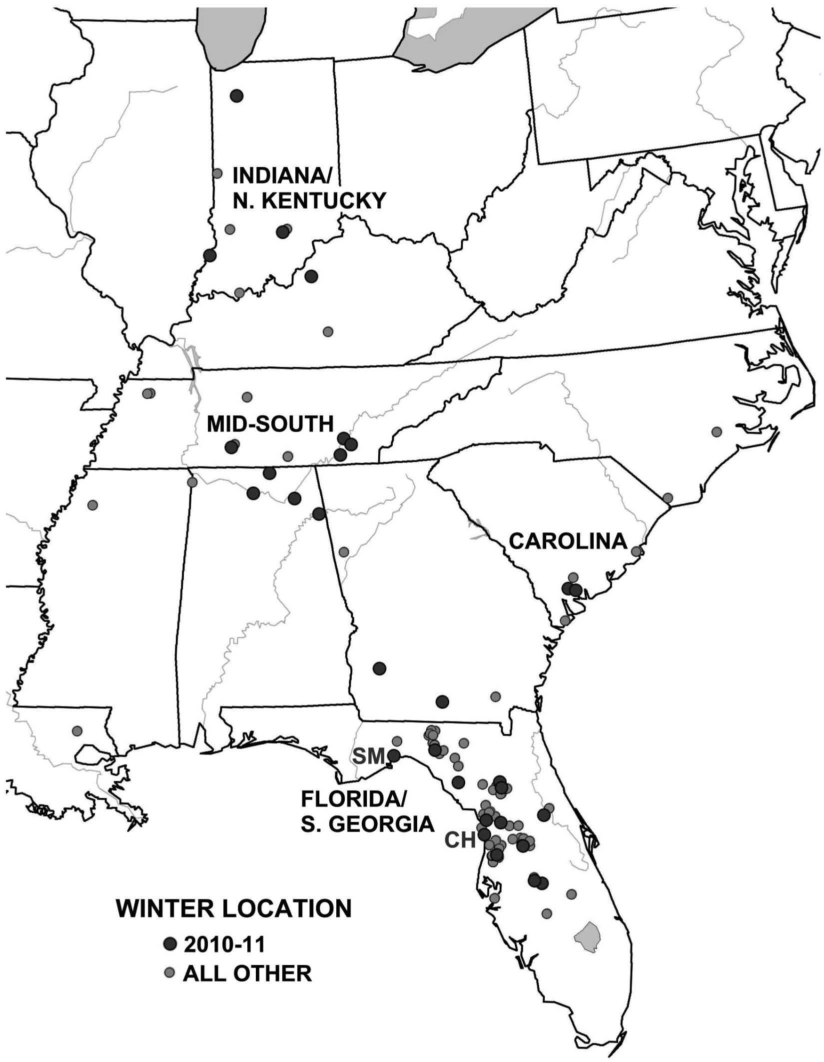

Figure 1. Winter distribution of the reintroduced eastern migratory whooping crane population in 4 geographic areas, 2001-2011. CH = Chassahowitzka NWR. SM = St. Marks NWR.

retrievals. One subadult male that summered at a distant location returned to the core as a 3-year-old.

Winter locations and homing:—Most UL birds originally released on Chassahowitzka NWR returned to that site and then moved to winter at inland freshwater sites upon completion of their first unassisted autumn migration. Subsequent migrations were influenced by association with birds and climate conditions in some years, and some shortstopping occurred. Many adult pairs eventually returned to the same winter area in successive years. Many DAR birds migrated only to the mid-south, where many older adult whooping cranes and sandhill cranes also winter, with Hiwassee Wildlife Refuge being a primary wintering area (Table 5, Fig. 1).

Reproduction

The homing to the natal area and excellent pair formation apparent earlier in the reintroduction have continued in recent years. Of 31 adult pairs occurring in the population through 2010, 29 pairs formed while in the core reintroduction area, mostly on Necedah NWR (Table 6). Except for 1 female from hatch year 2001, all females 4 years of age or older that summered in the core reintroduction area paired with males. Females paired at 3-5 years (see also Urbanek 2010*a*). Males paired at approximately the same time, although several remained unpaired because of limited numbers of females. As of spring 2011, the population contained

Table 5. Winter distribution of reintroduced eastern migratory whooping cranes as typified by location in mid-February (or earlier if mortality occurred during winter), 2003-2011. Does not include juvenile UL birds overwintering on protected release area. Number of total from DAR cranes in parentheses.

Location	2003	2004	2005	2006	2007	2008	2009	2010	2011[a]
Florida	5	19	20 (1)	33 (2)	45 (5)	26 (2)	31 (4)	30 (2)	42 (4)
Georgia					2		4 (2)	3 (1)	9 (7)
South Carolina			7	3	4	4	4	4	4
North Carolina			3	1[e]					
Tennessee			4	7 (2)	4 (3)	18 (10)	21 (8)	13 (6)	14 (4)
Alabama					2	2	7 (1)	6 (2)	19.5 (6.5)
Louisiana					1				
Mississippi								1	
Kentucky								8 (7)	0.5 (0.5)
Indiana					4	1	1	8 (1)	4 (1)
Undetermined		1		1		5	5	5 (1)	9 (3)
Total	5	20	34 (1)	45 (4)	62 (8)	56 (12)	73 (15)	78 (20)	102 (26)

[a] Includes 4 birds counted as wintering in Florida even though their final wintering areas were undetermined. Also includes 1 male counted as wintering in Florida, although he was transferred to permanent captivity in early January. Birds that died were counted as wintering at their mortality sites. Decimals are the result of birds that wintered in more than 1 state.

20 confirmed breeding pairs.

Breeding territories and resulting nests were concentrated in 2 major areas on the southern and northern portions of Necedah NWR with few nests off refuge. Parental desertion of nests continued to result in consistent reproductive failure (Urbanek 2010*c*). During 2005-10, all 43 nests during the initial (primary) nesting period failed. Of 15 late nests or renests, chicks hatched from 8 nests, and 3 chicks fledged (Table 7). The causes of this high nest failure rate are under study. The first DAR females (2) produced eggs for the first time in 2010. Both nested during the later period and incubated full term; however, numbers of DAR individuals are currently too low to provide sufficient data needed to fully evaluate their reproduction.

Table 6. Location and period of breeding pair formation (n = 31), eastern migratory whooping crane population. All pairs formed where concentrations of cranes were present.

Period	No. pairs formed	Location	Circumstances
Mar-May	22[a]	Necedah/core	16 from singles, 6 from triads or quad
Jun-Aug	4	Necedah/core	All from loss of mate
Sep-Nov	3	Necedah/core	1 from loss of mate, 1 after relocation from N.Y.
Dec-Feb	2	Hiwassee, Tenn.	Fall migration or wintering

[a] Includes 1 whooping crane/sandhill crane pair.

Human Avoidance

In general, most released whooping cranes satisfactorily avoided close proximity to humans and human structures. However, because they have been reared in captivity, they can be easily tamed after release if precautions are not taken. The most serious problem sites resulting in habituation of eastern migratory whooping cranes to humans were occurrence at 1) an ethanol plant south of Necedah NWR in 2008-2009, and 2) several human communities adjacent to wetlands in Florida and containing tame non-migratory sandhill cranes, which were sometimes fed by local residents.

Two subadult pairs occupied the grounds of the ethanol plant in spring 2009. They had initially been attracted to spilled corn at this site and were already habituated to humans after wintering at Tooke Lake, a wetland surrounded by residential development in Hernando County, Florida. We solved this problem by removing the dominant male and transferring him to permanent captivity. The female then re-paired on Necedah NWR with a male demonstrating satisfactory human avoidance and adopted his behavior. The other pair then also vacated the site. Another male with a winter territory on or near Chassahowitzka NWR repeatedly returned to nearby Homosassa Springs Wildlife State Park, where he was attracted to a captive female whooping crane, and required relocation on several occasions. We transferred him to permanent

Table 7. Summary of reproduction in eastern migratory whooping population, 2001-2010.

Year	No. nests[a]	Nest type/period	Nest initiation dates	No. days incubation	No. successful nests	No. chicks hatched	No. chicks fledged
2005	2	first	16-19 Apr	1	0	-	-
2006	5	first	5-13 Apr	8-19	0	-	-
	1	renest	23 May	30	1	2	1
2007	4	first	3-19 Apr	2-18	0	-	-
	1	renest	14 May	26[b]	0	-	-
2008	11	first	7-23 Apr	12-29	0	-	-
2009	12	first	2-21 Apr	3-25	0	-	-
	5	renest	13-23 May	4-30	2	2[c]	0
2010	9	first/early	1-5 Apr	3-10	0	-	-
	3	first[e]/late	29 Apr-12 May	30-38[d]	2	2	0
	5[f]	renest	29 Apr-12 May	2-38[d]	3	5[c]	2[c]
Total	58				8	11	3

[a] 1 nest per pair within these nest type/period categories, except for footnote[f] below.
[b] Single infertile egg of sibling pair was abandoned after attempted egg substitution.
[c] 1 chick hatched from egg substituted into nest of infertile pair in each year at 22 days (2009) and 27 days (2010) of incubation. The latter chick fledged.
[d] Single infertile egg in each of 2 nests was removed at 38 days of incubation.
[e] 1 of these nests may have been a renest with actual first nest undetected.
[f] Includes 2 renests by sibling pair (first renest deserted within 2 days).

captivity in January 2011. The female of a pair habituated to humans at Tooke Lake, and to a lesser degree on Necedah NWR, died from gunshot in Indiana during autumn migration 2009. As of March 2011, 6 cranes in the population had a history of intermittent close habituation to humans. This number was reduced from 13 problem birds in 2009.

DISCUSSION

Reintroduced costume-reared whooping cranes have continued to demonstrate successful migration, homing, habitat use, pair formation, and territory establishment. Average annual mortality of white-plumaged whooping cranes in the natural Aransas-Wood Buffalo population (AWBP) was 9.8% during 1938-2010 (B. Johns, Canadian Wildlife Service, unpublished data). Except during a 1.6-month period of excessive mortality (Urbanek 2010*a*), survival of the reintroduced eastern migratory population has generally been comparable. The main cause of mortality, as discussed earlier by Cole et al. 2009, continued to be predation. Because of reduced monitoring since 2008, the number of recovered birds found too decomposed to determine cause of death has also increased. This situation could result in underestimation of importance of some mortality factors such as disease.

Since summer 2008 (Urbanek 2010*a*), the following significant developments in the eastern migratory whooping crane population have occurred: DAR migration has improved as a result of association of juveniles with older whooping cranes. Winter distribution has shifted because of water conditions and climate and addition of a second winter release site. No additional birds have established winter territories in South Carolina. No additional birds have migrated east of Lake Michigan in spring; therefore, need for retrievals was reduced. The migration route of the population has shifted westward, and several new stopover/wintering sites have become established. Number of yearlings summering in locations found during spring wandering has increased as more territories were established by adults on Necedah NWR. Because of reduced monitoring, many missing birds were presumed but not confirmed as mortalities. Human avoidance problems peaked in 2009 but then decreased, and 2 birds were eventually removed from the population because of chronic uncorrectable behavior. Human avoidance problems could rebound in response to current and future land management actions or insufficient monitoring and corrective action. Therefore, efforts to minimize close exposure of whooping cranes to humans and human activity and to resolve situations that may compromise welfare of the population require continued attention.

The following have continued since 2008: Homing to the natal area and pair formation have been excellent.

Most pairs have formed while in the core reintroduction area, mostly on Necedah NWR. Mortality continued to occur at similar rates in seasonal areas occupied, and the primary cause was predation. Parental desertion of nests, especially during the initial (primary) nesting period, continued.

The major problem hindering success of the reintroduction is poor reproduction. Harassment of incubating birds by black flies (*Simulium* spp.) (Urbanek et al. 2010*c*) remains a factor of paramount concern to the welfare of this population. Poor chick survival, which cannot yet be evaluated because of low hatching success, is another factor which could limit the success of this reintroduction and may require attention.

Beginning in 2005, the DAR technique was used as a less expensive and logistically less complicated means to supplement numbers of reintroduced birds. Migration has improved as a result of more consistent association with guide birds. Overall, survival of DAR cranes has generally been lower than that of UL released birds, although not significantly so except for total individuals within 1 year after release (Table 2). However, unlike UL cranes, DAR juveniles are younger when released and not protected in a gentle release pen through their first winter; therefore, additional risk of mortality during this period was not unexpected. The values presented, however, do not include mortalities that occurred during the ultralight-led migrations (6/156 juveniles) before release. In addition, a mortality event affecting an entire cohort of UL birds occurred in February 2007 and resulted in loss of 17/18 members. This group, released for only 1 night on 20 January but then penned thereafter due to transient older cranes present at the pensite, was not included in the UL mortalities in Tables 1-3. With inclusion of these mortalities, the difference in survival between total individuals of UL (74.6%) and DAR (65.7%) 1 year after release was not significant ($Z = 0.85$, $P = 0.3969$). To reduce possibility of a similar catastrophic loss, the wintering UL flock was separated to winter at 2 different release sites beginning in winter 2008-09.

The disadvantage of lack of protection of DAR juveniles during the autumn release period and first autumn migration and winter could possibly be reduced by gentle release (Urbanek and Bookhout 1992) and by increased monitoring to identify and address hazards during their first migration and winter. DAR birds will continue to add significant numbers of cranes to this population, and successful pairing and reproduction comparable to that of UL birds has begun as more of these birds reached breeding age.

MANAGEMENT IMPLICATIONS

Existence of only 1 population of whooping cranes will keep this species endangered and at risk of loss from the wild. Recovery goals for the whooping cranes include establishment of 2 populations in addition to the single natural population. The reintroduction of whooping cranes by the costume-rearing techniques has been successful and should continue until the population becomes self-sustaining. The latter goal, however, will depend on solving the major problem of nest failure.

Costume-reared whooping cranes have proven to be excellent release candidates capable of adapting to natural environments and demonstrating appropriate behaviors in the wild. The technique involving leading birds with ultralight aircraft, including associated protection of the birds through the juvenile period, has been particularly successful. The DAR technique requires greater numbers of birds and time for comparable evaluation but also indicates potential for success. These techniques can play a key role in further management and recovery of this endangered species.

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LITERATURE CITED

Analytical Software. 2008. Statistix 9 user's manual. Analytical Software, Tallahassee, Florida.

Cole, G. A., N. J. Thomas, M. Spalding, R. Stroud, R. P. Urbanek, and B. K. Hartup. 2009. Postmortem evaluation of reintroduced migratory whooping cranes in eastern North America. Journal of Wildlife Diseases 45:29-40.

Converse, S. J., and R. P. Urbanek. 2010. Demography of whooping cranes in the eastern migratory population. Proceedings of the North American Crane Workshop 11:198.

Converse, S. J., J. A. Royle, and R. P. Urbanek. 2012. Bayesian analysis of multi-state data with individual covariates for estimating genetic effects on demography. Journal of Ornithology 152(S2):561-572.

Converse, S. J., J. A. Royle, P. H. Adler, R. P. Urbanek, and J. A. Barzen. 2013. A hierarchical nest survival model integrating incomplete temporally-varying covariates. Ecology and Evolution 3:4439-4447.

Duff, J. W., W. A. Lishman, D. A. Clark, G. F. Gee, and D. H. Ellis. 2001. Results of the first ultralight-led sandhill crane migration in eastern North America. Proceedings of the North American Crane Workshop 8:109-114.

Fondow, L. E. A. 2013. Habitat selection of reintroduced migratory whooping cranes (*Grus americana*) on their wintering range. Thesis, University of Wisconsin, Madison, USA.

Hartup, B. K., G. H. Olsen, N. M. Czekala, J. Paul-Murphy, and J. A. Langenberg. 2004. Levels of fecal corticosterone in sandhill cranes during a human-led migration. Journal of Wildlife Diseases 40:267-272.

Hartup, B. K., G. H. Olsen, and N. M. Czekala. 2005. Fecal corticoid monitoring in whooping cranes (*Grus americana*) undergoing reintroduction. Zoo Biology 24:15-28.

Horwich, R. H. 1989. Use of surrogate parental models and age periods in a successful release of hand-reared sandhill cranes. Zoo Biology 8:379-390.

Lishman, W. A., T. L. Teets, J. W. Duff, W. J. L. Sladen, G. G. Shire, K. M. Goolsby, W. A. Bezner Kerr, and R. P. Urbanek. 1997. A reintroduction technique for migratory birds: leading Canada geese and isolation-reared sandhill cranes with ultralight aircraft. Proceedings of the North American Crane Workshop 7:96-104.

Maguire, K. J. 2008. Habitat selection of reintroduced whooping cranes, *Grus americana*, on their breeding range. Thesis, University of Wisconsin, Madison, USA.

Spalding, M. G., S. Terrell, and W. B. Brooks. 2010. Pathology associated with lightning strike and drowning mortality of whooping cranes in Florida. Proceedings of the North American Crane Workshop 11:215.

Urbanek, R. P., and T. A. Bookhout. 1992. Development of an isolation-rearing/gentle release procedure for reintroducing migratory cranes. Proceedings of the North American Crane Workshop 6:120-130.

Urbanek, R. P., L. E. A. Fondow, C. D. Satyshur, A. D. Lacy, S. E. Zimorski, and M. Wellington. 2005. First cohort of migratory whooping cranes reintroduced to eastern North America: the first year after release. Proceedings of the North American Crane Workshop 9:213-223.

Urbanek, R. P., L. E. A. Fondow, and S. E. Zimorski. 2010*a*. Survival, reproduction, and movements of migratory whooping cranes during the first seven years of reintroduction. Proceedings of the North American Crane Workshop 11:124-132.

Urbanek, R. P., L. E. A. Fondow, S. E. Zimorski, M. A. Wellington, and M. A. Nipper. 2010*b*. Winter release and management of reintroduced migratory whooping cranes *Grus americana*. Bird Conservation International 20:43-54.

Urbanek, R. P., S. E. Zimorski, A. M. Fasoli, and E. K. Szyszkoski. 2010*c*. Nest desertion in a reintroduced population of migratory whooping cranes. Proceedings of the North American Crane Workshop 11:133-141.

Wellington, M. M., and R. P. Urbanek. 2010. The direct autumn release of whooping cranes into the eastern migratory population: a summary of the first three years. Proceedings of the North American Crane Workshop 11:215.

Zimorski, S. E., and R. P. Urbanek. 2010. The role of retrieval and translocation in a reintroduced population of migratory whooping cranes. Proceedings of the North American Crane Workshop 11:216.

AN UPDATE ON MORTALITY OF FLEDGED WHOOPING CRANES IN THE ARANSAS/ WOOD BUFFALO POPULATION

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Abstract: From winter 1950 through spring 2011, 6,364 whooping cranes (*Grus americana*) overwintered at Aransas National Wildlife Refuge, or rarely, elsewhere. Documented winter losses amounted to 105 birds dead or disappeared. About 20% of total losses occurred in the wintering area, where birds spend 5 to 6 months of the year including a few birds that over-summer. Losses of white-plumaged whooping cranes on the summering area in Canada appear to be low with only 3 instances documented. The most significant losses seem to occur in migration and may comprise over 80% of the annual mortality. Migration involves only 17-20% of the annual cycle but is a period when losses are high because birds are exposed to new hazards as they travel through mostly unfamiliar environments. This paper updates a similar account by Lewis et al. (1992) by adding mortality records of the Aransas/Wood Buffalo population (AWBP) from 1987 through 2010 with information on 50 recovered carcasses.

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Key words: Aransas/Wood Buffalo, *Grus americana*, mortality, whooping crane.

Understanding mortality factors of a wildlife population is potentially important for effective management. Several authors have reported on aspects of mortality in whooping cranes (*Grus americana*) of the Aransas/Wood Buffalo population (AWBP). Kuyt (1981) noted that most chick mortality usually occurs during the first 2 weeks of life. Kuyt et al. (1981) and Hunt et al. (1987) described predation of individual juveniles, one of which had avian tuberculosis. In this article we add 24 years of data to update the account by Lewis et al. (1992), which summarized mortality of the AWBP from 1950 to 1987.

METHODS

The winter whooping crane census at Aransas National Wildlife Refuge (NWR) and nearby areas in coastal Texas began in 1938 and has continued through the present (CWS and USFWS 2007). However, aerial counts were infrequent during World War II. Beginning in 1950, after birds first started arriving (mid-October to mid-December) and in spring (mid-March through end of April) as they departed northward, aerial monitoring was generally conducted weekly, weather permitting (Aransas NWR, unpublished data). Mid-winter censuses were conducted 1 or 2 times per month. Starting in 2006, number of census flights done each winter was reduced to 9-12 with emphasis placed on determining the peak flock size.

Since 1966, flights to estimate numbers of nesting pairs in the Canadian nesting grounds have occurred in May. Additionally, searches in June were conducted during 1976-2009 to determine number of young hatched, and in August/September during 1981-1984 and 1997-2011 to determine the number of fledged juveniles. In recent years, up to 25 hours of aerial surveys conducted over 4-5 days in June have counted up to 82% of the flock. A census of the entire breeding area in Wood Buffalo National Park (WBNP) and adjacent areas has never been attempted because the area occupied by whooping cranes, particularly by subadults, is too extensive.

We believe the fall censuses provide a nearly complete count of the arriving wintering population and the spring censuses provide a reasonable estimate of the population alive when spring migration begins. However, the death of subadult cranes at Aransas NWR is difficult to determine because subadult groupings and use areas are variable and carcasses are rarely found. Therefore, the spring estimate is less accurate. Winter mortality estimates are based on the number of dead cranes found plus those recognizable birds that disappeared from Aransas NWR during winter. The estimates of birds initiating spring migration are based on winter mortality estimates minus those birds which remained in Texas coastal habitats throughout summer. To calculate April through November losses of adults and subadults which had migrated in a particular year, the peak number of white-plumaged cranes in Texas in early winter was subtracted from the previous year's combined total of cranes migrating northward and

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surviving cranes summering in Texas.

Records of AWBP carcasses recovered were compiled from the Aransas NWR files. A few birds that had been observed with life-threatening injuries such as a broken leg and which subsequently disappeared without a carcass being found were included. The data set used started in 1950 when regular winter flights were begun at Aransas NWR.

RESULTS

The total of maximum annual winter counts indicates that 6,364 whooping cranes overwintered at Aransas, or rarely elsewhere, from 1950 to 2010 (Table 1). Ninety-eight percent of these cranes survived to migrate northward in spring. Twenty-six birds stayed at Aransas NWR in summer, 3 of which died while summering (Table 1). Winter losses amounted to 105 birds during the 61-year period. The remains of 16 cranes were found in winter, and 89 others disappeared and are presumed to have died in winter. Carcasses recovered included 9 white-plumaged birds and 7 juveniles. Deaths of the 16 recovered individuals are believed due to a combination of disease and/or predation (7), shooting (2), trauma (1), and unknown (6). Juveniles that died often separated from their parents for unknown reasons several days before they died—abnormal behavior believed indicative of disease. Diseases identified were avian tuberculosis and an unknown herpes virus. One case of avian predation was documented, with talon marks consistent with a great horned owl (*Bubo virginianus*) found during necropsy. Other predation was caused by bobcat (*Lynx rufus*), coyote (*Canis latrans*), and American alligator (*Alligator mississippiensis*), but disease was also believed to be involved in at least 3 of those instances. The last known shooting loss during winter occurred in the 1988 winter when a waterfowl hunter shot an adult female near San Jose Island.

Four hundred and thirty-six adults and subadults alive in March at the start of the spring migration disappeared or were found dead from April to November 1950-2010, including 3 over-summering birds which died at Aransas NWR (Table 1). Carcasses were recovered for 29 (6.7%) of the 436 white-plumaged birds that had disappeared between spring and fall. Additionally, 5 juveniles were found dead during fall migration. The most common causes of mortality were collision with power lines and shooting (Figure 1). We also have documentation of an individual colliding with a fence while crossing a small wetland, one being caught in a muskrat trap, one that may have had a heart muscle disease, and one that was hit by a military tanker aircraft taking off from Minot, North Dakota, in June. One of the instances categorized as trauma was from collision with a blunt object where the internal organs were shattered. That bird presumably was either hit by an airplane or died in flight and fell to the ground with great force.

Of the 546 total losses of fledged cranes during 1950-2010, 50 carcasses (9.2%) were recovered, or in a few instances, birds with severe injuries were observed prior to their disappearance that provided clues as to source of mortality (Table 2). Of the 546 losses, 19.8% occurred at Aransas during the 5-6 months the whooping cranes annually spent on the wintering grounds, or in 3 instances birds that over-summered at Aransas. Remains of birds that died were more frequently found at Aransas (18.5%) than during migration or on the nesting grounds (6.8%).

Flights in summer at WBNP indicate that summr (May-Sep) losses of adults and subadults are infrequent in the Park; only 3 carcasses have been found there since 1966. This includes 1 radioed adult found dead in WBNP in summer 2011 that was not included in the 1950-2010 data set. One juvenile (named CANUS) with an injured wing was captured and subsequently survived in captivity for 38 years.

DISCUSSION

Information on when mortality occurs for the AWBP changed very little when 23 years of data (1988-2010) were added to the account by Lewis et al. (1992). Winter losses occurred at about the same rate as that reported in the Lewis paper. Losses north of Aransas NWR when birds are migrating or on the nesting grounds (n = 433) were 80.0% of total mortality, similar to the 81% reported by Lewis et al. (1992). It is probable that mortality on the nesting grounds is underestimated since observations of cranes in the Park are made only during infrequent flights. The general public has no probability of observing cranes in the Park as it remains for the most part impenetrable wilderness. Thus, the probability of recovering a carcass is lower on breeding areas than during migration or winter. One of 4 radioed carcasses recovered disappeared while on the summering area. With only 3 carcasses ever recovered in WBNP compared to 28 in migration, it appears that most of the April to November mortality occurs during migration.

Table 1. Flock size and mortality of the Aransas/Wood Buffalo whooping crane population, 1950-2010.

Winter beginning	White plumaged	Juvenile	Total	Winter losses	Migrating in spring	Number over-summering at Aransas	Over-summer mortality	Total mortality at ANWR	Subadult and adult mortality Apr-Nov	Total recovered carcasses[a]	Total annual mortality Nov-Nov
1950	26	5	31	1	29	1	1	2	9	1	11
1951	20	5	25	2	23			2	4	4	6
1952	19	2	21		21			0	0	0	0
1953	21	3	24		24			0	3	0	3
1954	21	0	21		21			0	1	1	1
1955	20	8	28	1	26	1		1	5	1	6
1956	22	2	24		21	3	1	1	1	1	2
1957	22	4	26		26			0	3	0	3
1958	23	9	32		32			0	1	0	1
1959	31	2	33		31	2		0	3	0	3
1960	30	6	36		36			0	2	0	2
1961	34	5	39	1	38			1	6	1	7
1962	32	0	32	4	28			4	2	0	6
1963	26	7	33	1	32			1	0	1	1
1964	32	10	42		42			0	6	1	6
1965	36	8	44		44			0	6	0	6
1966	38	5	43		43			0	4	0	4
1967	39	9	48	1	47			1	3	2	4
1968	44	6	50		50			0	2	0	2
1969	48	8	56		56			0	5	0	5
1970	51	6	57	1	56			1	2	0	3
1971	54	5	59	1	58			1	12	0	13
1972	46	5	51	1	50			1	3	0	4
1973	47	2	49	1	47	1		1	1	0	2
1974	47	2	49		49			0	0	0	0
1975	49	8	57		57			0	0	0	0
1976	57	12	69		69			0	8	1	8
1977	61	10	71	1	70			1	2	0	3
1978	68	7	75	1	74			1	4	0	5
1979	70	6	76		76			0	4	0	4
1980	72	6	78	1	76	1		1	6	1	7
1981	71	2	73		73			0	6	2	6
1982	67	6	73	2	70	1		2	3	3	5
1983	68	7	75		75			0	4	1	4
1984	71	15	86	2	84			2	3	1	5
1985	81	16	97	1	96			1	7	1	8
1986	89	21	110	1	109			1	0	0	1
1987	109	25	134	3	129	2		3	12	1	15
1988	119	19	138	6	131	1	1	7	5	3	12
1989	126	20	146	4	141	1		4	9	1	13
1990	133	13	146	11	134	1		11	11	2	22
1991	124	8	132	1	131			1	10	1	11
1992	121	15	136		136			0	9	1	9
1993	127	16	143	7	136			7	11	1	18
1994	125	8	133		131	2		0	3	0	3
1995	130	28	158	1	155	2		1	13	1	14
1996	144	16	160		160			0	8	1	8
1997	152	30	182	1	181`			1	16	1	17
1998	165	18	183		183			0	12	0	12
1999	171	17	188	1	186	1		1	16	0	17
2000	171	9	180	6	174			6	13	1	19
2001	161	15	176	2	174			2	5	1	7
2002	169	16	185	1	184			1	15	1	16
2003	169	25	194	1	193			1	10	3	11

Table 1. Continued.

Winter beginning	White plumaged	Juvenile	Total	Winter losses	Migrating in spring	Number over-summering at Aransas	Over-summer mortality	Total mortality at ANWR	Subadult and adult mortality Apr-Nov	Total recovered carcasses[a]	Total annual mortality Nov-Nov
2004	183	34	217	2	214	1		2	25	2	27
2005	190	30	220	6	211	3		6	22	0	28
2006	192	45	237		237			0	10	2	10
2007	227	39	266		266			0	34	0	34
2008	232	38	270	23	245	2		23	5	4	28
2009	242	22	264	1	263			1	3	0	4
2010	238	45	283	4	279			4	25	0	29
Totals	5573	791	6364	105	6233	26	3	108	433	50	541

[a] In a few instances, the carcass was not recovered but mortality was deduced from disappearance of an injured crane.

Table 2. Documented mortalities of the Aransas/Wood Buffalo whooping crane flock, 1950-2010.

Year	Date	Period	Location[a]	Age[b]	Recovered	Cause of death	Comments
1950	Sep	Summer	Burgentine Lake, ANWR	A	Yes	Unknown	"Mac" had been captured in Louisiana and released at ANWR in spring 1950.
1951	Aug	Summer	N. Mullet Bay, ANWR	A	Yes	Unknown	Carcass much decayed
1951	Nov	Winter	Ratama Mill, ANWR	A	Yes	Shot	Shattered joint between femur and tibiotarsus, assumed shot on migration, died at San Antonio Zoo
1951	Dec	Winter	W. St. Charles, ANWR	A	Yes	Trauma	Unknown, missing 1 foot, leg broken at tibiotarsus
1952	Oct	Fall migration	Sharon, Kans.	A	Yes	Unknown	Had dislocated wing, died en route to San Antonio Zoo
1952	Nov	Fall migration	Regina, Sask.	Chick	Yes	Trauma	Injured wing, broken leg, lung conjestion; died
1955	Fall	Fall migration	Sioux Falls, S.D.	WP		Shot	Snow goose hunter (McNulty 1966)
1956	May	Spring migration	Lampass City, Tex.	SA	Yes	Power line	Broken wing tip
1957	Oct	Fall migration	Ketchum, Okla.	WP	No	Trauma	Crippled bird seen, then disappeared
1961	Dec	Winter	Matagorda Island, ANWR		No	Unknown	Ranch foreman discovered carcass (McNulty 1966)
1964	Mar	Winter	ANWR		Yes	Unknown	Bones, feathers, and skin recovered; was 1 of twin chicks; lab detected minute traces of DDT
1965	Nov	Fall migration	Rawlins Cty., Kans.	SA	Yes	Power line	Distribution (3 wire)
1968	Jan	Winter	ANWR	A	Yes	Shot	Shot by goose hunter
1968	Apr	Spring migration	Russell Cty., Kans.	A	Yes	Power line	Distribution (3 wire)
1977	Apr-May	Spring migration	Sask.	A	No	Muskrat trap	Unconfirmed mortality of death in trap
1981	11 Oct	Fall migration	Glaslyn, Sask.	Chick	Yes	Power line	Distribution (1 wire, 9 m), picked up, died later due to injuries
1982	Jun	Spring migration	Minton, S.D.		Yes	Aircraft	Feathers identified on military tanker aircraft
1982	Oct	Fall migration	Oglesby, Tex.	A	Yes	Power line	Distribution (4 wire, <8 m)
1983	Jan	Winter	ANWR	Chick	Yes	Disease, predated	Found dead on M.I.[a], assumed avian tuberculosis (TB) and predation (radioed)

Table 2. Continued.

Year	Date	Period	Location[a]	Age[b]	Recovered	Cause of death	Comments
1983	Jan	Winter	ANWR	Chick	Yes	Disease, predated	Separated, disease similar to avian TB, predated by a coyote (radioed)
1983	May	Spring migration	Edam, Sask.	SA	No	Possibly disease	Unknown, observed by farmer for 1 week, died, possibly disease
1984	Oct	Fall migration	Linton, N.D.	A	Yes	Power line	Male with multiple fractures in wing, captured but later died Jan 1985, aspergillosis, and partial paralysis from running into captive fence during handling
1984	Nov	Winter	ANWR	SA	Yes	Neck trauma	Probable avian predation (radioed)
1986	24 May	Summer	WBNP	A	Yes	Unknown	Male found dead at the nest
1988	Oct	Fall migration	St. Paul, Nebr.	A	Yes	Power line	Distribution (2 wire, 11 m)
1989	Apr	Winter	ANWR	SA	Yes	Avian TB	Avian tuberculosis
1989	3 Jan	Winter	ANWR	A	Yes	Shot	Mistaken for snow goose on San Jose Island
1989	Oct	Fall migration	Nebr.	SA	Yes	Power line	Flew into 2-wire transmission line, found dead
1990	19 Apr	Spring migration	Leoville, Sask.	A	No	Shot	Hunter observed with crane in back of truck at gas station; not convicted because he was “unknowingly” in possession of an endangered species
1991	Apr	Spring migration	Bend, Tex.	A	Yes	Shot	Shot
1991	Jun	Summer	WBNP	WP	Yes	Unknown	Unknown due to decay, not submitted for necropsy
1992	Jan	Winter	ANWR	A	Yes	Unknown	Pile of feathers in burn area
1993	Dec	Winter	ANWR	Chick	Yes	Bobcat predation	Bobcat predation
1996	Mar	Winter	ANWR	Chick	Yes	Disease, predation	Probably not bobcat
1997	Oct	Fall migration	Zelma, Sask.	Chick	Yes	Power line	Dead under a 14.4-kV power line for 1 week
1998	Nov	Fall migration	Quivira NWR, Kans.	A	No	Broken leg	Last seen with broken leg, mate appeared at ANWR without her
2001	Jan	Winter	ANWR	SA	Yes	Unknown	Skull and feathers found
2002	Apr	Spring Migration	De Leon, Tex.	A	Yes	Power line	Power line strike
2003	Nov	Fall Migration	Dallas, Tex.	A	Yes	Shot	Shot
2004	Nov	Fall Migration	Quivira NWR, Kans.	SA	Yes	Shot	Had a leg amputated, died in captivity 9 Nov
2004	Nov	Fall Migration	Quivira NWR, Kans.	SA	Yes	Shot	Second bird had a fractured humerus repaired, died due to complications mid-Nov
2004	Nov	Fall migration	Quivira NWR, Kans.	SA	No	Shot	Shot at, red spot seen on breast, not captured, stayed in area and was last observed in Dec; assumed mortality
2005	Dec	Fall migration	Mo.	Chick	Yes	Bacterium	Bacterium obstructing the larynx
2007	7 Apr	Spring migration	N.D.	A	Yes	Collision	Collision with a blunt object
2007	8 Oct	Fall migration	Sask.	Chick	Yes	Unknown	Scavenged carcass, could not be recovered until spring due to snow cover
2008	Dec	Winter	ANWR	WP	Yes	Starvation, knee	Injured knee and starvation
2009	Jan	Winter	ANWR	Chick	Yes	Predation	Herpes virus and emaciation underlying factors
2009	Feb	Winter	ANWR	Chick	Yes	Disease, predation	Separated, possibly diseased; predation near dugout
2009	Mar	Winter	ANWR	WP	Yes	Unknown	Pile of feathers

[a] ANWR = Aransas National Wildlife Refuge, Cty. = County, M.I. = Matagorda Island, WBNP = Wood Buffalo National Park.
[b] A = Adult, SA = Subadult, WP = White-plumaged.

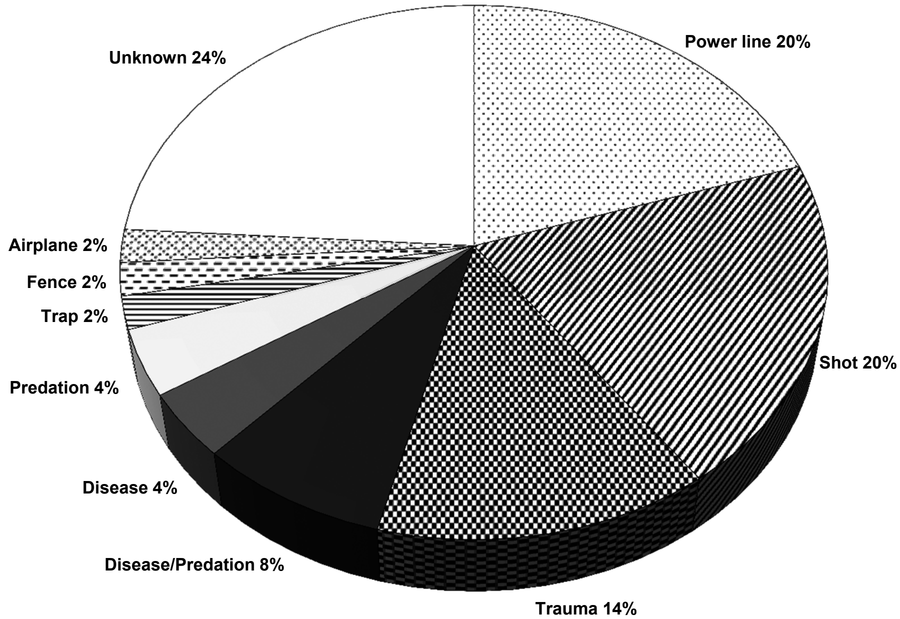

Figure 1. Causes of mortality of 50 carcasses recovered from the Aransas-Wood Buffalo whooping crane flock, 1950-2009.

For an average whooping crane, fall migration takes about 6 weeks, including the staging period in Saskatchewan. Spring migration on average involves about 2-4 weeks. Thus, migration losses occur during a period comprising about 9 weeks (17%) of the annual cycle. Spring and fall migration periods are the periods that should be focused on to further diminish mortality of fledged birds. Such actions are occurring through the Federal-State and Federal-Provincial cooperative plans for protection of whooping cranes (Lewis 1992) and through efforts to diminish collisions with power lines and wind energy developments. However, reducing mortality wherever it occurs benefits the population (CWS and USFWS 2007).

Although the majority of known mortality for the AWBP is split between power lines (n = 10), shootings (10), other trauma (7), and disease often linked with predation (6), carcasses are recovered only 9.2% of the time, leaving the causes for about 90% of mortality as speculative. An ongoing satellite radio telemetry study should allow more unbiased information to be collected on causes and timing of mortality. Also, much more intensive monitoring has occurred on introduced whooping cranes where all such birds are radioed prior to reintroduction.

From the carcasses recovered, the causes of mortality seem different during winter at Aransas compared with the rest of the year. This makes sense since there is little opportunity, with a few exceptions, for collisions with power lines or trauma during the 6 months the birds reside in the coastal salt marsh. Shootings may occur anywhere except in WBNP where human/crane interactions are practically non-existent. Predation on healthy fledged birds seems to be minimal. However, the impact of disease on the flock needs to be investigated further.

Cole et al. (2009) conducted postmortem evaluations on 17 reintroduced migratory whooping cranes in eastern North America from 2001 to 2006. Causes of death included predation (n = 8), trauma (2), capture myopathy (1), and unknown (6). The primary predator was found to be bobcat. Limited roosting habitat or behavior of the naïve captive-raised birds were likely prime factors in predation events. The 2 trauma events were gunshot and power line collision. Infectious disease was not detected in their limited sample.

Predation by bobcats was the primary cause of mortality in nonmigratory whooping cranes in Florida. Whooping cranes were particularly vulnerable during their 44-day flightless molt that occurred every 2-4 years in summer (Spalding et al. 2011). In the early years of the project, juvenile whooping cranes without exposure to roosting ponds in captivity had much higher rates of predation than birds raised in later years with water exposure (Gee et al. 2001). Poor habitat selection (Nesbitt et al. 1997) or limited availability of roosting habitat was found in a majority of the predation events (Cole et al. 2009). Immaturity, lack of predator avoidance training in captivity, and inappropriate habitat selection may put captive-raised cranes at greater risk than wild-raised birds (Spalding et al. 2011). In contrast, predation, except where linked with disease, seems to be relatively uncommon in AWBP whooping cranes. Some mortality in Florida was associated with human activities (crane leg fractured by a golf ball, fishing line wrapped around feet, suspected collision with vehicles) (Folk et al. 2001). Postmortem findings of nonmigratory whooping cranes in Florida include case reports of lead and zinc toxicosis associated with pen construction (Spalding et al. 1997), avian cholera, eastern equine encephalitis, infectious bursal disease, and aspergillosis (Spalding et al. 2004), mycobacteriosis, parasite infections (Spalding 2003), avian tuberculosis and salmonellosis (Stroud et al. 1986), and disseminated visceral coccidiosis (Novilla and Carpenter 2004).

Known causes of mortality in Florida whooping cranes, listed in order from most common to least common, were bobcat predation, power line collision, alligator predation, disease, gunshot, leg fracture, and cattle (Spalding et al. 2011), though the category of missing birds was larger than any other category. Mortality factors for the Florida nonmigratory and eastern migratory flocks seem similar (M. Spalding, University of Florida, unpublished data), with predation mortality of 47% in the migratory flock and 58% for the nonmigratory population (Cole et al. 2009). Traumatic injury accounted for 12% of the mortality in the eastern migratory flock and 7.5% in the Florida nonmigratory flock (Cole et al. 2009).

Causes of death of 24 Rocky Mountain cross-fostered whooping cranes was compiled from necropsy reports (N. Thomas, National Wildlife Health Center, unpublished data). In order of most common to least common, power line and fence collisions (n = 11), disease (4), predation (2), injuries related to capture (2), vehicle collisions (1), and poison (1) were documented. Predation included coyote and golden eagle (*Aquila chrysaetos*) (Windingstad et al. 1981). Diseases included avian tuberculosis and avian cholera (Snyder et al. 1991). Notable was the high incidence of avian tuberculosis (20.8%) compared with much lower rates reported in sandhill cranes (*Grus canadensis*) (0.6%) and waterfowl (0.3%). Rocky Mountain whooping cranes were exposed to large concentrations of geese and sandhill cranes on wintering areas and suffered food shortages as crops grown for the birds were depleted, leading to higher incidence of disease.

Whooping cranes are more susceptible to collision with power lines (Stehn and Wassenich 2008) than sandhill cranes (Brown et al. 1987). Power line mortalities have been documented in all reintroduced whooping crane populations as well as the AWBP, with 49 documented fatal collisions in North America (T. Stehn, U.S. Fish and Wildlife Service, unpublished data). Power lines collisions were the greatest (39.0%) known cause of mortality for fledged whooping cranes in the introduced Rocky Mountain population (Brown et al. 1987). In Florida, males were significantly more vulnerable to power line collisions than females (Spalding et al. 2011).

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LITERATURE CITED

Brown, W. M., R. C. Drewien, and E. G. Bizeau. 1987. Mortality of cranes and waterfowl from power line collisions in the San Luis Valley, Colorado. Pages 128-136 *in* J. C. Lewis, editor. Proceedings of the 1985 crane workshop. Platte River Whooping Crane Maintenance Trust, Grand Island, Nebraska, USA.

Canadian Wildlife Service [CWS] and U.S. Fish and Wildlife Service [USFWS]. 2007. International recovery plan for the whooping crane. Recovery of Nationally Endangered Wildlife (RENEW), Ottawa, Ontario, Canada, and U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Cole, G. A., N. J. Thomas, M. Spalding, R. Stroud, R. P. Urbanek, and B. K. Hartup. 2009. Postmortem evaluation of reintroduced migratory whooping cranes in eastern North America. Journal of Wildlife Diseases 45:29-40.

Folk, M. J., S. A. Nesbitt, and M. G. Spalding. 2001. Interactions of sandhill cranes and whooping cranes with foreign objects in Florida. Proceedings of the North American Crane Workshop 8:195-197.

Gee, G. F., J. M. Nicolich, S. A. Nesbitt, J. S. Hatfield, D. H. Ellis, and G. H. Olsen. 2001. Water conditioning and whooping crane survival after release in Florida. Proceedings of the North American Crane Workshop 8:160-165.

Hunt, H. E., T. V. Stehn, and R. D. Slack. 1987. Whooping crane mortality during the winter of 1982-83. Pages 219-220 *in* J. C. Lewis, editor. Proceedings of the 1985 crane workshop. Platte River Whooping Crane Maintenance Trust, Grand Island, Nebraska, USA.

Kuyt, E. 1981. Clutch size, hatching success, and survival of whooping crane chicks, Wood Buffalo National Park, Canada. Pages 126-129 *in* J. C. Lewis and H. Masatomi, editors. Crane research around the world. International Crane Foundation, Baraboo, Wisconsin, USA.

Kuyt, E., B. E. Johnson, and R. C. Drewien. 1981. A wolf kills a juvenile whooping crane. Blue Jay 39:116-119.

Lewis, J. C. 1992. The contingency plan for federal-state cooperative protection of whooping cranes. Pages 293-300 *in* D. A. Wood, editor. Proceedings of the 1988 North American crane workshop. Florida Game and Fresh Water Fish Commission Nongame Technical Report No. 12, Tallahassee, Florida, USA.

Lewis, J. C., E. Kuyt, K. E. Schwindt, and T. V. Stehn. 1992. Mortality in fledged cranes of the Aransas-Wood Buffalo population. Pages 145-148 *in* D. A. Wood, editor. Proceedings of the 1988 North American crane workshop. Florida Game and Fresh Water Fish Commission Nongame Technical Report No. 12, Tallahassee, Florida, USA.

McNulty, F. 1966. The whooping crane: the bird that defies extinction. E. P. Dutton, New York, New York, USA.

Nesbitt, S. A., M. J. Folk, M. G. Spalding, J. A. Schmidt, S, T, Schwikert, J. M. Nicolich, M. Wellington, J. C. Lewis, and T. H. Logan. 1997. An experimental release of whooping cranes in Florida–the first three years. Proceedings of the North American Crane Workshop 7:79-85.

Novilla, M. N., and J. W. Carpenter. 2004. Pathology and pathogenesis of disseminated visceral coccidiosis in cranes. Avian Pathology 33:275-280.

Snyder, S. B., M. J. Richard, R. C. Drewien, N. Thomas, and J. P. Thilsted. 1991. Diseases of whooping cranes seen during annual migration of the Rocky Mountain flock. Pages 73-79 *in* R. E. Junge, editor. Proceedings of the American Association of Zoo Veterinarians Annual Conference, 28 September-3 October 1991, Calgary, Alberta, Canada.

Spalding, M. G. 2003. Cranes. Pages 702-740 *in* D. J. Forrester and M. G. Spalding, editors. Parasites and diseases of wild birds in Florida. University of Florida Press, Gainesville, USA.

Spalding, M. G., S. A. Nesbitt, M. J. Folk, L. R. McDowell, and M. S. Sepulveda. 1997. Metal consumption by whooping cranes and possible zinc toxicosis. Proceedings of the North American Crane Workshop 7:237-242.

Spalding, M. G., H. S. Sellers, B. K. Hartup, and G. H. Olsen. 2004. Infectious bursal disease virus associated with a wasting syndrome in released whooping cranes in Florida. Page 73 *in* C. K. Bauer, editor. Proceedings of the American Association of Zoo Veterinarians, American Association of Wildlife Veterinarians, and Wildlife Association Disease Joint Conference, 28 August-3 September 2004, San Diego, California, USA.

Spalding, M. G., M. J. Folk, S. A. Nesbitt, and R. Kiltie. 2011. Reproductive health and performance of the Florida flock of introduced whooping cranes. Proceedings of the North American Crane Workshop 11:142-155.

Stehn, T. V., and T. Wassenich. 2008. Whooping crane collisions with power lines: an issue paper. Proceedings of the North American Crane Workshop 10:25-36.

Stroud, R. K., C. O. Thoen, and R. M. Duncan. 1986. Avian tuberculosis and salmonellosis in a whooping crane (*Grus americana*). Journal of Wildlife Diseases 22: 106-110.

Windingstad, R. M., H. E. Stiles, and R. C. Drewien. 1981. Whooping crane preyed upon by golden eagle. Auk 98:393-394.

DISTRIBUTION, DENSITIES, AND ECOLOGY OF SIBERIAN CRANES IN THE KHROMA RIVER REGION OF NORTHERN YAKUTIA IN NORTHEASTERN RUSSIA

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***Abstract**:* The Siberian crane (*Grus leucogeranus*) is the third rarest crane species in the world with a breeding range now centered on 3 core areas and a buffer zone in the arctic of northern Yakutia in northeastern Russia. During 16 July-2 August 2009, we undertook ground surveys within the Khroma River core breeding area, surrounding buffer zone, and lands lying to the west of the known breeding range to estimate densities and determine habitat use and social status of Siberian cranes. A total of 142 Siberian cranes were sighted (including 55 pairs) at 54 locations with 32 cranes (including 13 pairs) sighted outside the currently known breeding range in the lower drainages of the Syalakh and Syuryuktyakh Rivers. After adjusting for a probability of detection of 0.484 (95% CI = 0.281-0.833), Siberian crane densities in the Khroma core area and the buffer zone averaged 0.0921 cranes/km^2 and 0.0363 cranes/km^2, respectively. A majority of cranes (n = 93 [65%]) occurred in complexes of large basin wetlands, with use centered in those having extensive beds of pendant grass (*Arctophila fulva*). Of the 142 cranes seen, 110 (77%) were paired, 21 (15%) were singles, and 11 (8%) were in groups of 3-5**.** The Khroma core supports 1 of 2 large concentrations of breeding Siberian cranes remaining in the wild; therefore, we recommend that consideration be given to designating a nature reserve that would encompass the Khroma core, adjacent buffer zone, and lands to the west (including coastal tundra areas along the lower drainages of the Syalah and Syuryuktyah Rivers). Further research is needed to gain additional insight into Siberian crane distribution and numbers on lands beyond the currently delineated western boundary of the Siberian crane breeding range in the Ust-Yana District of northern Yakutia. Important gaps remain in information needed to effectively guide conservation efforts for the Eastern Population, and recent advances in remote tracking technology offer potential opportunities to help address several key information needs.

PROCEEDING OF THE NORTH AMERICAN CRANE WORKSHOP 12:51–64

Key words: breeding grounds, coastal tundra, crane densities, endangered species, *Grus leucogeranus,* Khroma River, Khroma core, Russia, Siberian crane, social status, surveys, wetland use, Yakutia.

The Siberian crane (*Grus leucogeranus*) is designated as endangered under International Union for the Conservation of Nature (IUCN) guidelines (Meine and Archibald 1996). An estimated 3,000 Siberian cranes remained in the wild in the mid-1990s (Song et al. 1995) including remnant Western and Central populations wintering along the Caspian Sea in Iran and at Keoladeo National Park in India, respectively. However, by fall 2011 only 1 wild bird from the Western Population returned to Iran during fall (S. S. Zadegan, personal communication). Siberian cranes have not returned to traditional wintering grounds in India in recent years (G. Sundar, personal communication). Attempts are underway to restore the Western and Central Populations of Siberian cranes by involving release of hand-reared birds (Y. Markin, personal communication). As a result, the Eastern Population remains the only viable wild population. The Eastern Population winters primarily at Poyang Lake in northern Jiangxi Province, China (Li et al. 2012) and breeds across parts of northern Yakutia in northeastern Russia (Degtyarev and Labutin 1991). Concern for the continued survival of this species is growing, considering the near extirpation of the Central and Western Populations and threats to the Eastern Population from various forms of development, particularly on the species' wintering grounds (Meine and Archibald 1996). Recognition of a need for gaining greater insight into the current breeding distribution and habitat needs of the Eastern Population led to this study.

Historically, Siberian cranes were reported breeding in northern Yakutia beginning in the mid-19th century (Dement'ev et al. 1968). In modern times, Siberian cranes have been found breeding primarily from the Kolyma River Delta west to the vicinity of the Khroma River. In the second half of the 20th century, as aircraft became more widely used for monitoring wildlife populations in arctic Russia, information began to accumulate on breeding distribution of Siberian cranes in northern Yakutia. The most detailed information came from sightings of cranes made during aerial surveys specifically searching for Siberian cranes and incidentally while conducting surveys to determine the status of caribou (*Rangifer tarandus*) and polar [arctic] fox (*Vulpes lagopus*) populations. In the Khroma/Yana Region, distribution of crane sightings was recorded during flights over parts of this region during 1963-1966 (Egorov 1971), 1965, and 1971-1973 (Flint and Kistchinski 1975), 1977 (Perfiliev and Polyakov 1979), 1977-1979 (Flint and Sorokin 1981), and during 1978 (Vshivtsev et al. 1979) (Fig. 1A).

The first published evidence of Siberian cranes existing at high densities in the Khroma core area was reported by Egorov (1971) who referred to 2 isolated core areas used by Siberian cranes in the vicinity of the Khroma River (20,000 km^2) and the Alazeya River (12,000 km^2). The first rough outline of distribution of breeding Siberian cranes across northern Yakutia was prepared by Flint and Kistchinski (1975) using personal observations, published literature, and interviews with people living within this region. Within the Khroma River core, only a small part of lands west of the Khroma River (the focus of current studies) was covered and only 3 instances of nesting were reported, along with a pair not known to have nested and a single bird. Flint and Sorokin (1981), relying on information gained during aerial surveys, identified 3 aggregations: 1) west of the Khroma River on lands south of Lake Soluntakh, 2) west of the Indigirka River across an area of large lakes, and 3) 30-40 km north of the village of Berelekh. Degtyarev and Labutin (1991) pulled together information from the published literature and their own aerial (primarily) and ground surveys from 1978 to 1989 to identify 3 core breeding areas centering on the Khroma, Indigirka, and Alazeya rivers (Fig. 2). Outside each of the 3 core areas, the authors designated a buffer zone where fewer Siberian cranes were thought to exist based on results from aerial surveys in 1980 and 1989 (Fig. 1B) which helped refine the boundaries of the Khroma core area. Of the 3 core breeding areas, the Khroma core is the largest (Degtyarev and Labutin 1991) and least studied with no recent information available on crane distribution, densities, or habitat associations.

Our objectives were to: 1) estimate densities of Siberian cranes occupying the Khroma core and buffer zone in northern Yakutia and compare these data to previous estimates from across the main breeding range, 2) identify wetland habitat types used by cranes within the Khroma core and buffer zone, 3) examine social status of cranes within the Khroma core and the buffer zone, and 4) assess status of Siberian cranes within the lower drainages of the Syalah and Syuryuktyah Rivers including coastal areas which lie outside of the breeding range of Siberian cranes as currently defined for northern Yakutia.

STUDY AREA

Our study area was located in the eastern Ust-Yana District of the Sakha Republic (Yakutia) in the high arctic of northeastern Russia (Fig. 2 [inset showing location within Russia]), approximately 500 km southeast of the Lena River Delta and 200 km east of the Yana River Delta. Our survey route included parts of the Khroma core breeding area, the buffer zone, and lands lying west of the buffer zone which are outside the delineated breeding range (e.g., Neustroevo Station, Fig. 2).

The study area is situated within the arctic coastal plain, and is a non-glaciated, emergent region of the continental shelf with low relief (Bergman et al. 1977). Annual precipitation averages 217 mm and mean January and July temperatures are -37.1ºC and 8.9ºC, respectively (Alisov 1956). Because of the remoteness from the Atlantic Ocean and Pacific Ocean and proximity to the cold Laptev Sea, frost is possible throughout the summer. Perennial permafrost reaches a depth of 500-600 m and the thickness of the frost-free layer in summer reaches 50-75 cm (Karpov 1991). Typical relief features include lakes and other wetland types, rivers, hills (edomas), and large mounds called pingos (bulgannyakh in Yakut language). Edomas are a common feature of the subarctic plains of Eastern Siberia and consist of fossil buried ice underneath a hummocky surface. Bulgannyakhs are mounds of earth up to 70 m in height and 200 m in diameter and formed by ground ice which develops during the winter as temperatures fall (Perfiliev et al. 1991). Slopes bordering lakes and rivers frequently have exposed soils due to collapse of the banks from permafrost melt and solifluction resulting from climate change. Steep eroded banks

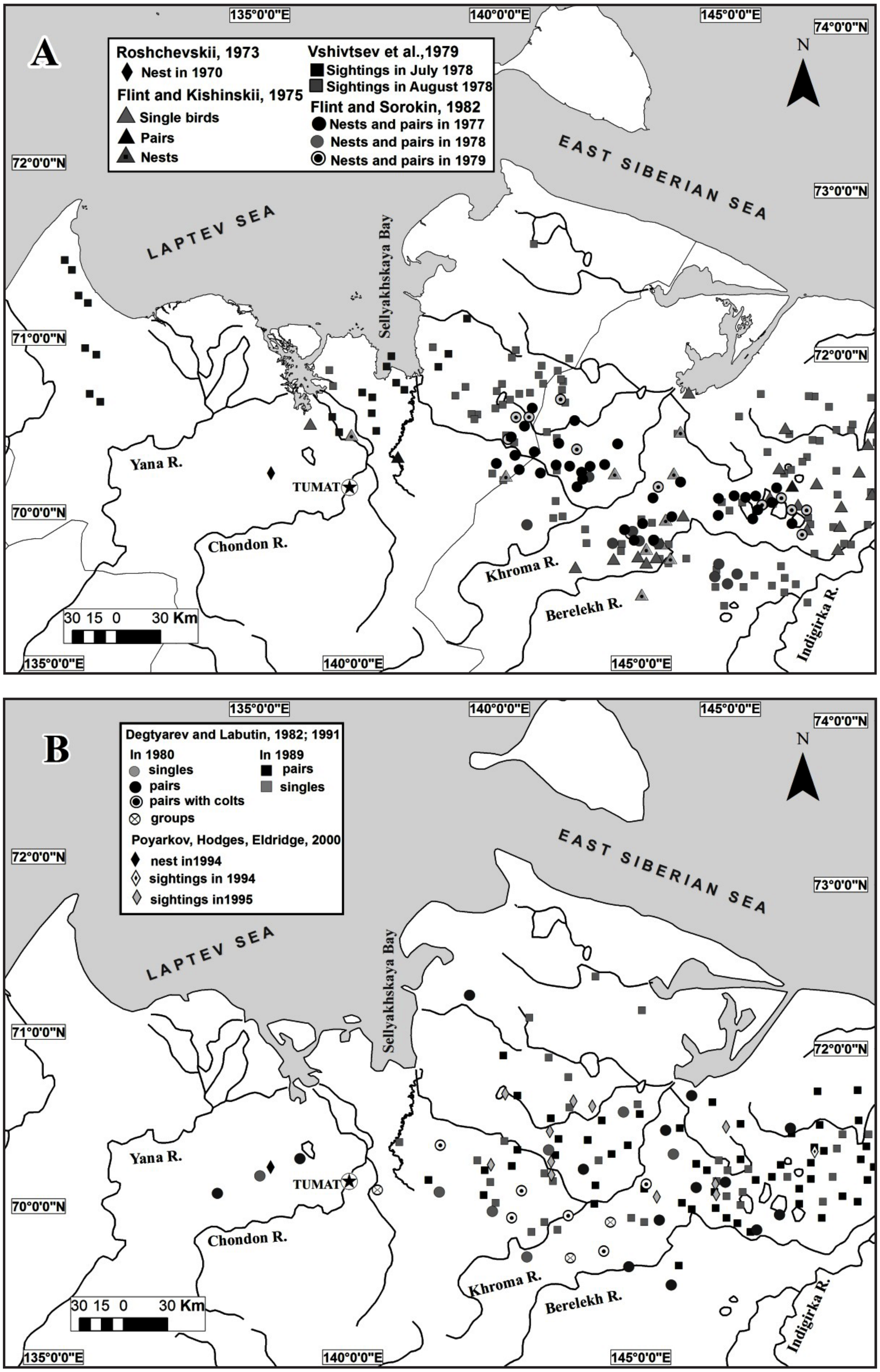

Figure 1. (A) Sightings of Siberian cranes and their nests in the Ust-Yana District of northern Yakutia, Russia, during 1970-1979. (B) Sightings of Siberian cranes in the Ust-Yana District during 1980 and 1989.

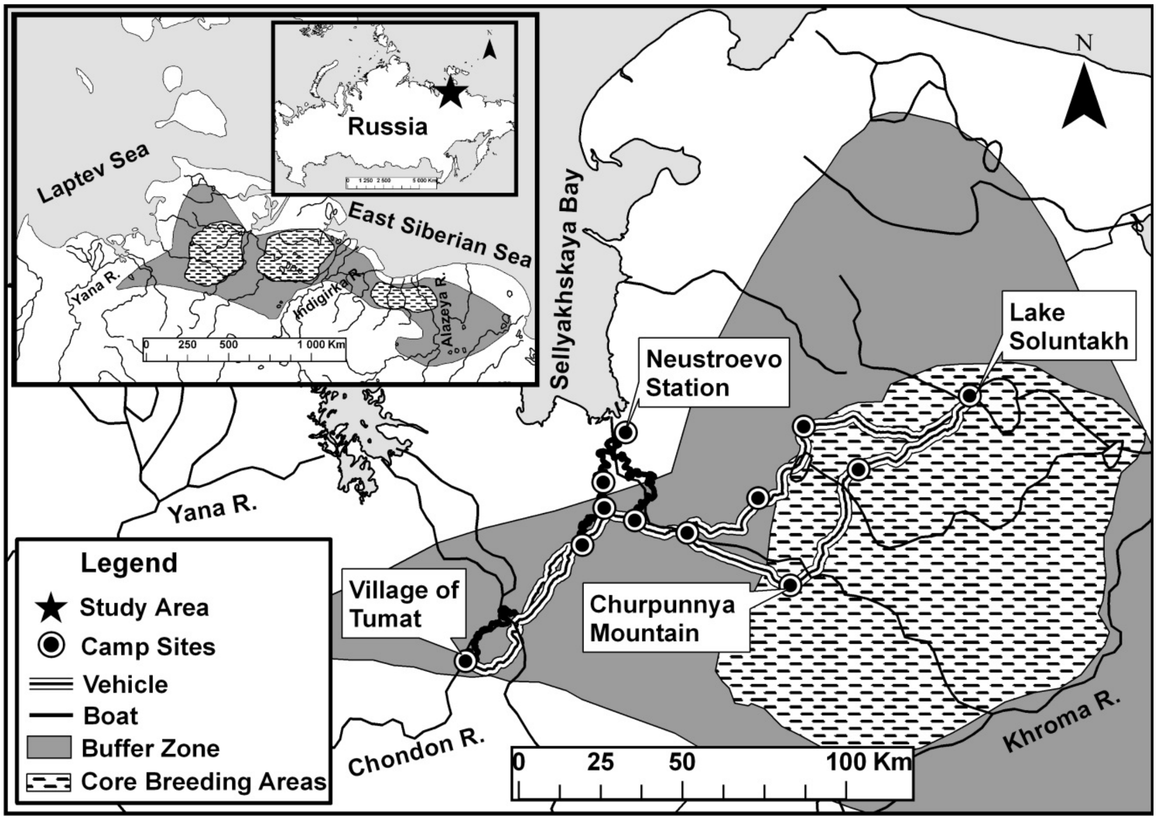

Figure 2. Map showing survey route followed during the current study of Siberian cranes in the Ust-Yana District of northern Yakutia, Russia. Southern edge of survey area was in the taiga/coastal tundra ecotone. The survey route was on the arctic coastal plain and most was located within the coastal tundra. Segments of the survey route crossing the Khroma core, buffer zone, and lands outside of the buffer zone are identified. Insets show the locations of the Khroma, Indigirka, and Alazeya core breeding grounds and buffer zone, and the location of our study area in Russia.

caused by bank collapse contain ledges which in some cases serve as nest sites for birds of prey. Many small rivers on the coastal plain contain channels that are connected with countless lakes resulting in lake-river complexes. River valley lowlands are characterized by an abundance of elongated and crescent-shaped oxbow lakes, which are confined to the floodplains and river terraces of medium and large rivers. Distinctive meteorological characteristics during summer in this region of the tundra are relatively high humidity, frequent fog and drizzling rain, which saturates shallow permafrost tundra soils (Desyatkin et al. 2009).

The dominant plant species in the uplands of the study area are cotton grasses (*Eriophorum vaginatum* and *E. angustifolium*) with an understory of dwarf birch (*Betula exilis*), labrador tea (*Ledum decumbers*), and numerous species of sphagnum moss (*Sphagnum* spp.). Narrow strips of willow (*Salix* spp.) occur on the lower slopes of edomas and on banks and along shores of rivers and some lakes and reach a maximum height to ~1 m. The southern edge of the study area lies within the taiga/tundra ecotone and is characterized by sparse stands of stunted larch (*Larix cajanderi*, *L. gmelinii*) which form the overstory. The vegetation understory of the taiga-forest ecotone consists of most of the same dominant plants as occur in the coastal tundra.

Several wetland types on our study area were similar to those occurring on the arctic coastal plain of Alaska and were classified using the wetland classification system developed by Bergman et al. (1977) for that region. The Bergman wetland classification system was used previously to classify wetland habitats on the Indigirka River Delta (see Pearse et al. 1998). Class II wetlands were broadly distributed across the study area and consisted of shallow depressions that varied widely in size and were dominated by *Carex concolor* and *C. chordorrhiza* sedges. Class III wetlands were relatively small in size with centers dominated by pendant grass (*Arctophila fulva*) and bordered by a zone of *Carex aquatilus*. Class IV ponds were relatively small with deep, open centers surrounded by a zone of pendant grass. Class V wetlands were large, deep lakes, with several on the study area being elongate with the long axis oriented 10 to 15 degrees west of true north. Regularity in basin orientation results from a system of circulating currents set up in the lakes by prevailing northeasterly winds (Carson and Hussey 1962). Complexes of large relatively shallow basins, with 1 or more central zones vegetated by stands of pendant grass interspersed with open water and bordered by stands of *Carex aquatilus,* occurred widely across the study area.

Coastal wetlands ranged from lagoons confluent with the sea to ponds periodically inundated by high wind tides. Riverine wetlands were widely distributed on our study area where large and small rivers crossed the landscape. The Syalyakh and Syuryuktyakh Rivers from which we conducted crane surveys by boat contained low terraces of alluvial origin that supported extensive wetland habitat ranging from tundra bogs to pendant grass swamps (Perfiliev et al. 1991). Bottoms of small river valleys of alluvial origin also contained sedge (*Carex* spp.), tundra bogs on floodplains, and low terraces along with pendant grass swamps.

Siberian cranes shared the study area with numerous other species of water birds. Waterfowl species we observed included whooper swan (*Cygnus cygnus*), Bewick's swan (*Cygnus bewickii*), bean goose (*Anser fabalis*), lesser white-fronted goose (*Anser erythyropus*), greater white-fronted goose (*Anser albifrons*), black brant (*Branta nigricans*), king eider (*Somateria spectabilis*), long-tailed duck (*Clangula hyemalis*), pintail (*Anas acuta*), common teal (*Anas crecca*), Eurasian wigeon (*Anas penelope*), greater scaup (*Aythya marila*), and Baikal teal (*Anas formosa*). Bean geese were the most common waterfowl species we encountered along the survey route with most other species being present in relatively low numbers. Hunters we interviewed stated spectacled eider (*Somateria fisheri*) and Steller's eider (*Polystica stelleri)* occur in low numbers on the study area, but we did not observe these species (also see Hodges and Eldridge 1995). Siberian cranes shared the study area with sandhill cranes (*Grus canadensis*) which occur in low densities (G. Krapu, unpublished data). Three species of loons (*Gavia* spp.), numerous species of shorebirds, 3 species of jaegers (*Storcorarius* spp.), and several species of gulls also were present.

METHODS

To determine Siberian crane distribution, estimate density, and identify social status, surveys were conducted by amphibious vehicle (total distance traveled = 460 km) and boat (125 km) during 16 July-2 August 2009. The survey route began at the village of Tumat near the northern edge of the forest tundra ecotone (Fig. 2). About 20 km north of the village and extending to the coast, the landscape is coastal tundra. From Tumat, the survey route first proceeded toward Nuestroevo Station near Sellyakhskaya Bay on the Laptev Sea, then east to Lake Soluntakh, and from there southwest toward Churpunnya Mountain, and then finally west and south back to Tumat (Fig. 2).

To allow the driver of the amphibious vehicle to stay on the designated survey route, coordinates of the planned route were programmed into 2 Delorme GPS units in advance of field work. Landscape imagery of the arctic coastal plain along the survey route was programmed into each GPS unit before the expedition to provide crane surveyors with an aerial view of the landscape outward from the vehicle to a distance of 8 km. This width of imagery provided crane surveyors with detailed knowledge of the surrounding landscape and allowed crane locations to be plotted with greater precision. Plastic laminated NASA images of the study area were carried during surveys and crane locations were plotted at appropriate locations as a backup in the event of failure or loss of the GPS units.

Siberian cranes were often first sighted with binoculars. Confirmation that species identification was correct occurred by observation of each individual through the lens of a 60× Bausch and Lomb spotting scope. Whooper and Bewick's swans nest at low densities across the study area which made higher magnification necessary to verify correct species identification especially at long distances. We frequently stopped to scan the landscape from the highest elevations available (e.g., standing on top of the vehicle or other elevated sites such as edomas) to maximize opportunities for sighting cranes present along the transect routes.

The land survey route crossed parts of both the Khroma River core area and buffer zone (Fig. 2) delineated by Degtyarev and Labutin (1991). The survey route was divided into transects, defined by the section of the survey route driven each day. The Khroma core and buffer zone contained 5 and 9 transects totaling 149.8 and 240.9 km, respectively. Boat surveys were conducted adjacent to lower parts of the Syalakh and Syuryuktyakh Rivers where terrain prevented crane surveys by tracked vehicle. During boat surveys, cranes on wetlands adjacent to the river channel were visible only during stops where observers could climb on top of elevated river banks bordering the river. River stops to search for cranes generally were made where large wetlands bordered the river and elevated river banks offered an opportunity for viewing across extensive wetland habitat. The boat survey method was effective in locating cranes on major wetlands along rivers, but cranes may have been missed in areas adjacent to stretches of river where no elevated viewing sites were available. As a result, we did not attempt to estimate crane densities for landscapes where surveys were conducted only by boat.

Density estimates of Siberian cranes for the Khroma core and buffer area were computed as the number of individuals per km^2 using distance sampling methods (Buckland et al. 2001). When a crane was sighted, the location of the crane was plotted on the base map of the study site which had been uploaded to the screen of the DeLorme GPS unit and the distance from the vehicle to the crane (in km) was computed by the GPS unit. At the point on the transect route where the line from the vehicle to the crane was perpendicular to the first line of sight from vehicle to crane location, the distance from the vehicle to the crane was also computed. These measurements were used to estimate probability of crane detection during surveys to provide a more reliable estimate of crane density along the survey route than if we had assumed all cranes were sighted. Six models suggested by Buckland et al. (2001; models: half normal key with cosine adjustments, half normal key with Hermite polynomial adjustments, uniform key with cosine adjustments, uniform key with simple polynomial adjustments, hazard-rate key with cosine adjustments, and hazard-rate key with simple polynomial adjustments) were used for modeling the detection function in Distance 5.0 (Thomas et al. 2010). Akaike's Information Criterion (AIC) was used to evaluate the suitability of these 6 models; if multiple models found suitable, model averaging techniques were used to compute all estimates (Burnham and Anderson 2002). Since cranes were observed in clusters, the density of crane clusters was first computed and then the density of cranes was computed as the density of clusters times the average cluster size. A combined density estimate of cranes for the Khroma core and buffer zone was computed as a weighted average of these 2 estimates, using the total transect length surveyed (in km) as the weight. Following Buckland et al. (2001), we truncated the longest 10% of the distances of observations, resulting in a truncation width of 4,188.9 meters.

Wetland types used by Siberian cranes were identified after taking into consideration depth, size, and vegetation using the wetland classification system of Bergman et al. (1977), developed for the arctic coastal plain of Alaska, or where appropriate, wetlands were classified using the landscape classification developed for northern Yakutia by Fedorov et al. (1989). Siberian cranes also were recorded by their social status, i.e., as pairs, singles, and groups (3+ cranes). Supplemental information on status of Siberian cranes on the study area was obtained from interviews with hunters, fishermen, and reindeer herders encountered during crane surveys or during time spent at the village of Tumat.

We evaluated whether density of Siberian cranes found on transects in the Khroma core was representative of the entire Khroma core by examining if the habitat within the survey route was representative of the habitat outside the survey route. Forty random points were selected from within the survey route and 60 random points were selected from outside the survey route, in both the Khroma core and buffer zone. The survey route was defined as the width of 5.6 km on either side of the vehicle path. For each of these points, the habitat composition (% wetland, % open water, and % upland) was identified within 1, 2, 3, 4, 5, and 6-km radii from each point. Landsat imagery of the Khroma core and buffer zone provided the baseline information used to assess habitat composition. To evaluate whether our crane density estimates within the survey route could be used to provide a reliable estimate of the number of Siberian cranes present across the entire Khroma core and buffer zone, we compared the habitat composition of the random points within the survey route to the random points outside of the survey route across the entire Khroma core and buffer zone. We used histograms, empirical distribution plots and Kolmogorov-Smirnov's test to determine if the distribution of each composition variable was the same inside and outside the survey route.

RESULTS

Weather conditions were suitable for conducting surveys on 18 of the 20 survey days. Snowfall during surveys was limited to flurries on the evening of 20 July, and the snow melted soon after falling. The winter snow accumulation had melted completely by the date of our arrival on the study area, eliminating a potential major limitation to sighting large white birds on the tundra landscape.

Of the 142 cranes surveyed, 110 (77%) were paired, 21 (15%) were singles, and 11 (8%) birds were in groups of 3-5 (Table 1). The pair/single crane ratio averaged 2.6:1 across the Khroma River core area, the buffer zone, and outside the breeding range (Table 1). The pair to single ratio in the Khroma core and buffer zone averaged 2.8:1 and 1.8:1, respectively. No flightless young were sighted during surveys. Some of the paired adults exhibited behaviors suggesting they may have been accompanied by colts, but confirmation was not possible. Interviews with local reindeer herders, hunters, and fishermen along the survey route indicated that Siberian cranes have occurred on the study area for as long as they could remember with adult pairs often being accompanied by colts.

Nineteen crane clusters (n = 36 birds) were sighted on the 9 transects located in the buffer zone, and 39 clusters (n = 69 birds) were seen on the 5 transects of the Khroma core area. Thirty-two cranes, including 13 pairs, were sighted outside of the known breeding range during boat surveys in the lower drainages of the Syalakh and Syuryuktyah Rivers. Eleven cranes were recorded, including 4 pairs, on a large coastal wetland at the mouth of the Syalakh River adjacent to Sellyakhskaya Bay of the Laptev Sea (Fig. 3). Though cranes were widely distributed throughout the coastal tundra area (Fig. 3), none were seen on transects within the taiga/tundra ecotone. Crane clusters consisted of 1-5 birds with an average size of 1.8 (SE = 0.1) cranes per cluster.

Table 1. Social status of Siberian cranes sighted along transects on the Khroma River core breeding area, the buffer zone surrounding the Khroma River core breeding area (see Degtyarev and Labutin 1991), and lands lying to the west of the delineated breeding range in the Ust-Yana District of northern Yakutia. Percentages of Siberian cranes are listed by social status. Number of cranes in each social status category is listed in parentheses.

Crane social status	Khroma River core breeding area	Khroma River buffer area	Outside known breeding range	Total
Pairs	28 (56)	14 (28)	13 (26)	55 (110)
Singles	10	8	3	21 (21)
Ratio (pairs/singles)	2.8:1	1.8:1	4.3:1	2.6:1
Groups (3-5)	1(3)	1(5)	1(3)	3 (11)
Totals	69	41	32	142

Table 2. Densities of clusters and individual Siberian cranes on the Tamut study area in the eastern Ust-Yana District of northern Yakutia after adjustment for probability of detection. Ground surveys were conducted during 16 July-2 August 2009.

Area	Density of clusters (no./km^2)	Density of individuals (no./km^2)	95% CI
Buffer	0.0202	0.0363	(0.0150-0.0877)
Khroma core	0.0513	0.0921	(0.0350-0.2429)
Overall	0.0321	0.0577	(0.0256-0.1300)

All 6 models considered for modeling the detection function fit well (all ΔAIC < 2). Therefore, all estimates given are model averaged estimates using all 6 models. The estimated probability (P) of detection of Siberian crane clusters was 0.48 (95% CI = 0.281-0.833, Fig. 4). Siberian crane densities in the Khroma core and buffer zone were estimated to be 0.09 cranes/km^2 and 0.04 cranes/km^2, respectively (Table 2). After accounting for probability of detection, crane density averaged 0.06 cranes/km^2 across both the Khroma core and buffer zone. We did not extrapolate our findings to estimate total number of cranes for the entire Khroma core because the proportion of the landscape in preferred crane habitat observed within the survey route was lower than that proportion outside the survey route. Conversely, preferred crane habitat formed a higher proportion of the habitat within the transect area of the buffer zone than in the non-surveyed part of the buffer zone.

Siberian cranes in the coastal tundra zone were most often associated with complexes of often interconnected large wetlands (Table 3). Siberian cranes typically occurred in the central zone of large wetland basins, low terrace wetlands adjacent to the Syalah and Syuryuktyah Rivers, and to a lesser extent, wetlands located in valleys of small rivers. Eleven cranes, including 4 pairs were observed in 1 of 2 Class VIII coastal wetlands that bordered Sellyahkskaya Bay (near the Nuestroevo Station, Fig. 3 and Table 3). The largest wetland occupied by Siberian cranes along the coast was approximately 1,000 ha. In wetland

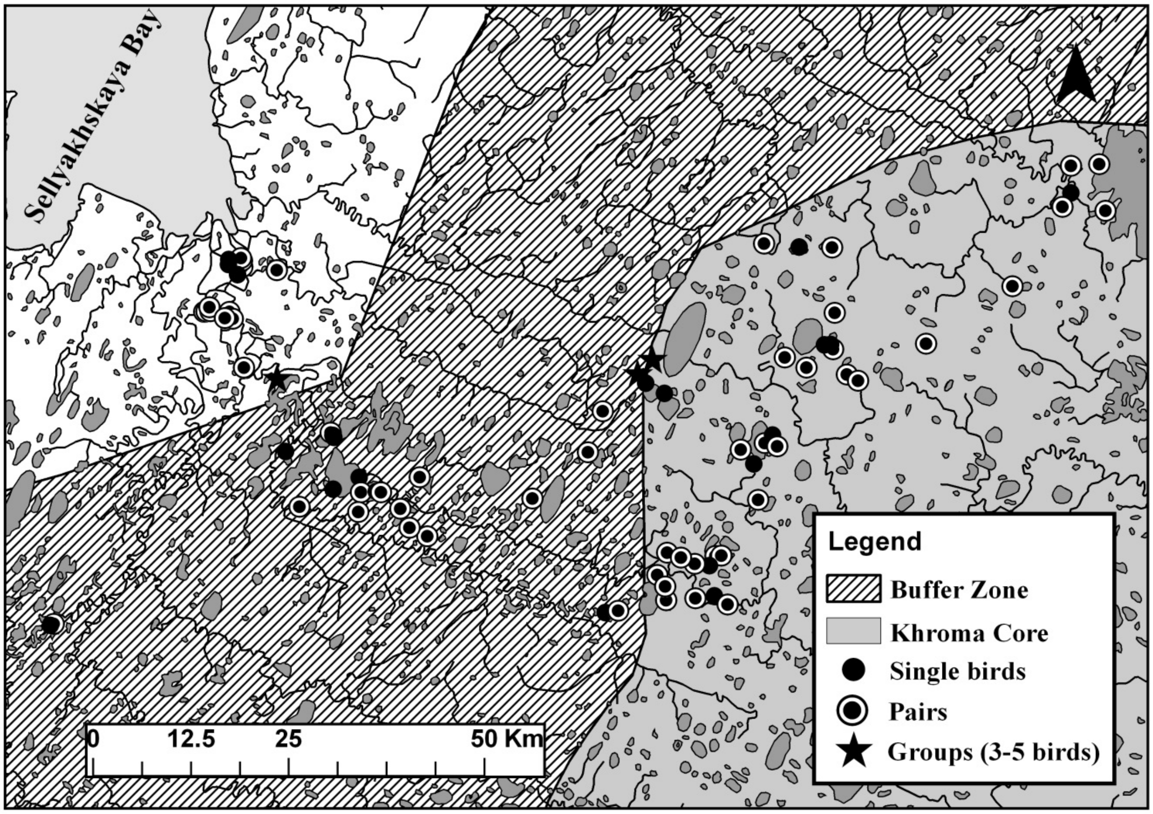

Figure 3. Distribution of sightings of Siberian cranes in the western part of the Khroma core, buffer zone, and to the west of the buffer zone during surveys conducted 16 July-2 August 2009 in the Ust -Yana District of northern Yakutia, Russia.

types occupied, Siberian cranes were most often found in stands of pendant grass surrounded by open water. Although large temporary wetlands dominated by *Carex* spp. were widespread on the study area, Siberian cranes generally avoided these habitats. Only 1 of the 142 cranes (0.7%) was observed on a non-wetland site.

DISCUSSION

Breeding Distribution and Densities

Siberian cranes were a common species within transects located in the coastal tundra zone of the Ust-Yana District. Distribution of Siberian cranes we observed suggests some changes in breeding distribution when compared to the distribution reported by Flint and Kistchinski (1981), who did not find Siberian crane nesting on the arctic tundra lowlands of river deltas near the sea, on river floodplains, or on uplands. We similarly did not find Siberian cranes in the uplands. However, we found breeding pairs to be relatively common in large wetlands on arctic tundra north of the forest tundra ecotone, along with significant numbers of pairs occurring in wetlands located on river floodplains near the sea, and on a large coastal wetland. No previous records have been reported for Siberian crane pairs occupying coastal wetlands in northern Yakutia (A. G. Sorokin, personal communication). Inland from the coast, a few sightings of Siberian cranes had been previously reported west of the designated breeding range including 2 nesting records: a nest found in 1970 along the lower reaches of the Chondron River (Fig. 1A, Flint and Kistchinski 1981) and a second nest found on 26 June 1994 (Fig. 1A, Poyarkov et al. 2000). A pair with a colt was sighted west of the Sellyakh River in 1980 (Degtyarev and Labutin 1991). Other large wetlands we did not visit outside the delineated breeding range in the same general area likely also supported Siberian cranes. Presence of numerous breeding pairs in the areas described suggests the breeding range be extended about 20-25 km northwest from the currently

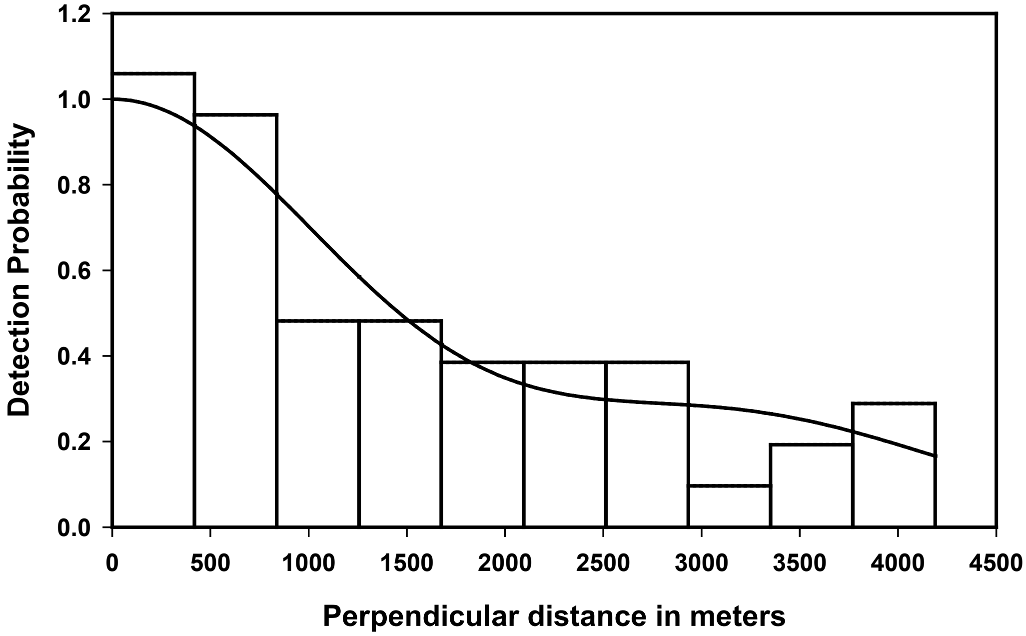

Figure 4. Probability of a Siberian crane being detected based on the model fit with a half normal key function and cosine adjustment. Six models with varying key functions and adjustments to model the detection function were considered and fit using Distance 5.0 (Thomas et al. 2010). The model fit for the other 5 models considered were similar to that displayed here. Density estimates were computed by model averaging estimates from these 6 models. The model averaged estimate of the probability of detection (*P*) is 0.484 (CI: 0.281-0.883).

designated range boundary (Degtyarev and Labutin 1991).

Distribution differences of Siberian cranes in the Khroma region noted between our study and Flint and Kistchinski (1981) suggest birds have moved into wetland habitat closer to the Laptev Sea over the past 40 years, and this shift may have been linked to climate change. Our inspection of meteorological data collected from this region over the past 70 years shows a major lengthening of the ice-free period and growing season in this region as ambient temperatures have increased (G. Krapu, unpublished data). An earlier and more extensive melting of the polar ice pack of the Laptev Sea in recent decades has caused the climate along the coast to moderate, creating conditions more conducive to crane breeding. Climate change may also pose increased risks to Siberian cranes due to modifications in the tundra landscape and increased weather unpredictability (Pshennikov and Germogenov 2001). Population growth may have contributed to higher than

Table 3. Habitat use by 142 Siberian cranes sighted along transects in the Ust-Yana Region of northern Yakutia during 16 July-2 August 2009.

Wetland type	No. cranes	%	Pairs	Singles	Groups
Complexes of large wetlands	93 (38)[a]	65	37	11	2 [3, 5]
Low terrace[b]	21 (5)	15	10	1	0
Small valley[b]	14 (18)	10	4	3	1 [3]
Coastal (VIII)[c]	11 (1)	8	4	3	0
Other (flying, upland)	3 (0)	2	0	3	0
Totals	142 (62)	100	55	21	3

[a] Number of wetlands by wetland type used by cranes listed in parentheses.
[b] Permafrost landscape classification by Fedorov et al. (1989).
[c] Wetland classification of Bergman et al. (1977).

expected crane densities in the Khroma core and buffer zone.

Aerial surveys of Siberian cranes undertaken prior to 1980 on their main breeding grounds in northern Yakutia produced Siberian crane density estimates much lower (Table 4) than we found on our study area (Table 2). However, Degtyarev and Labutin (1991) based on work that began in 1980 reported average densities as high as 0.038 cranes/km^2 on the Alazeya core (1985), 0.025 cranes/km^2 on the Indigirka core (1985), and 0.028 cranes/km^2 for the Khroma core, estimates that more closely approached crane densities gained during this study. Hodges and Eldridge (1995) from aerial surveys of a 43,300 km^2 area between the western edge of the Indigirka Delta to about the western edge of the Khroma core estimated a Siberian crane density of 0.023 cranes/km^2. Their survey route included areas outside the Khroma and Indigirka cores and buffers, and when crane density was estimated only for the southern half (21,650 km^2 area) of their surveyed area where all 10 Siberian cranes were sighted, crane density increased to 0.049 cranes/km^2, which approaches our estimate of 0.058 cranes/km^2 for the area we surveyed. Higher densities of Siberian cranes reported by Degtyarev and Labutin (1991), Hodges and Eldridge (1995), and this study when compared to pre-1980 surveys might reflect growth in the Eastern Population of Siberian cranes over the past 30 years, but differences in methods used and areas covered prevent a direct comparison.

We found evidence that sufficient breeding occurs beyond the boundaries of the delineated breeding range on the west edge to recommend this area be included within the breeding range probably through expansion of the buffer zone. The low densities obtained from aerial surveys of the Yakutia breeding grounds prior to 1980 may reflect, in part, less attention given to sampling methods and probability of detection than during the 1980s (Degtyarev and Labutin 1991), 1990s (Hodges and Eldridge 1995), and the current study. Results from our survey, when compared to previous findings, suggest ground surveys provide a reasonable alternative method for estimating crane densities on areas surveyed within cores and the buffer zone in northern Yakutia. However, the wide distribution of lakes and other wetlands in the Khroma region make ground travel difficult, reducing ability to obtain a sample of lands representative of the core area or the buffer zone limiting the area of inference to lands surveyed.

Habitat Use

Siberian cranes (especially pairs) were observed using large basin, river terrace, and small valley wetlands (Table 3) and occurred principally in extensive stands of pendant grass where present in central parts of wetlands. At Kytalyk Nature Reserve, Siberian cranes also utilized large wetlands (see Watanabe 2006, Fig. 5), and all 3 nests that were located were in *Carex* spp. Our surveys were conducted after the nesting period and we did not search for or locate nests, but because of the close affinity to pendant grass beds, we suspect most nesting on our study area occurred in this cover type.

Large relatively shallow wetlands with extensive stands of pendant grass allow Siberian cranes to nest over water at considerable distances from shore which likely

Table 4. Estimated numbers of Siberian cranes in the main breeding areas in northern Yakutia, 1957-1980, based on indicated studies.

Information source	Period	Area of main habitat (km^2)	Density (no./km^2)
Vorobyov (1963)	1957-1960		400-500
Uspenski et al. (1962)	1960	2,500-3,000	1,000-1,400
Egorov (1965)	1963	20,000	900
Egorov (1971)	1963-1964, 1966	32,000	1,500
Flint and Kistchinski (1975)	1971	130,000[a] (30,000)[b]	300 (0.0051)
Flint and Sorokin (1982)[a,b]	1977-80		250-300
Perfiliev (1965)	1960-1962		600-700
Perfiliev and Polyakov (1979)	1975, 1977	130,000[a] (30,000)[b]	700 (0.007)
Vshivtsev et al. (1979)	1978	>130,000[a] (51,000)[b]	325 (0.0058)
Labutin et al. (1982)	1980	65,560[a]	433 (0.0075)

[a] Total area of distribution of the main part of the Siberian crane population.
[b] Regular nesting area of the Siberian crane population.

helps to deter mammalian predators from destroying nests while also providing suitable foraging habitat. Most cranes we observed were foraging in pendant grass stands but at distances too great to determine foods being taken. Polar (arctic) fox, the primary mammalian predator on the study area, generally avoid having to travel long distances over water to reach nests of species nesting in wetlands (Vorobyov 1963). Siberian crane nests typically are located in 25-60 cm of water (Vorobyov 1963, Flint and Kistchinski 1975) although nests can occur at more shallow depths. For example, Watanabe (2006) recorded an average water depth of 10.5 cm at Siberian crane nests (n = 3) on his study area in the Kytalyk Nature Reserve. Wetlands used by Siberian cranes on our study area were shared with 3 species of jaegers and several species of gulls, all potential egg or young chick predators. As a result, crane eggs or newly hatched young become highly vulnerable if left unattended; such losses are likely low as Siberian cranes generally do not leave nests unattended (Flint and Kistchinski 1975). Adults are seldom captured by predators, and from interviews with people living in the region, Siberian cranes appear to rarely be shot or otherwise taken by humans.

Social Status of Siberian Cranes

Pairs accounted for 77% of the birds we surveyed (Table 1) compared to 80% of birds observed in 1973 on Yakut breeding areas by Flint and Kistchinski (1981). Flint and Kistchinski (1981) concluded that only 62% of pairs were territorial and half of the territorial birds actually nested. Degtyarev and Labutin (1999) and Pshennikov and Germogenov (2000) found 4.3-64.5% (mean = 34.6, SD = 18.5) of pairs sighted actually nested across 9 years of data collection. Comparing results from Flint and Kistchinski (1981) to our study area would mean that of the 55 pairs we surveyed, only 34 pairs would have been territorial, of which about half (n = 17 pairs) would have nested. We did not have an opportunity to study individual pairs for a sufficient length of time to confirm whether pairs were territorial or nesting occurred. According to Flint and Kistchinski (1981), about 34% of Siberian cranes on the Yakut breeding grounds they studied were 3 years old and 42% were 4+ years old. Single birds which represented 15% of the birds on our study area generally are 1 or 2 years old (Flint and Kistchinski 1981). Groups of 3 or more consisted of unmated birds.

Research Needs

Detailed knowledge of the distribution, density, and habitat use on breeding grounds of Siberian cranes in northern Yakutia continues to be an important research need that will help guide future habitat protection efforts. Further research will be needed to determine extent of expansion in breeding range boundaries, particularly along the western edge of the breeding range. Obtaining a more comprehensive understanding of Siberian crane distribution and habitat use on the breeding grounds, staging areas, or wintering grounds, along with gaining better insight into the effect of climate change, and other factors on annual productivity in the Eastern Population has become more feasible with recent advances in satellite telemetry technology. It is now possible to monitor sites used by tagged cranes on a daily basis throughout the annual cycle, allowing a comprehensive assessment of sites used in meeting Siberian crane needs. Solar-powered transmitters are being used to collect similar types of data on the endangered whooping crane (*Grus americana*) in North America, where only about 300 individuals remain in the wild Aransas-Wood Buffalo flock (G. Krapu, unpublished data). The improved ability to obtain detailed information on distribution of tagged individuals throughout the annual cycle, including daily activity movements, also would be useful when deciding when and where to conduct aerial and ground population surveys of Siberian cranes.

Conservation Issues

The large number and high density of Siberian cranes we encountered during surveys of the Khroma core and the high ratio of pairs among cranes sighted on the Khroma core are of special significance in light of the endangered status of this species. The Khroma and Indigirka cores are the largest (Fig. 2) and most important breeding grounds of the Siberian crane remaining in the world. The high densities of Siberian cranes observed on the Khroma core, buffer zone, and adjacent area reflect that wetland habitats present are exceptionally productive and well suited to meeting the birds' needs. We recommend that consideration be given to providing formal protection through establishing a nature preserve on a major portion of lands lying between the east bank of the Syalakh River and the western boundary of Kytalyk Nature Reserve and from the south boundary of

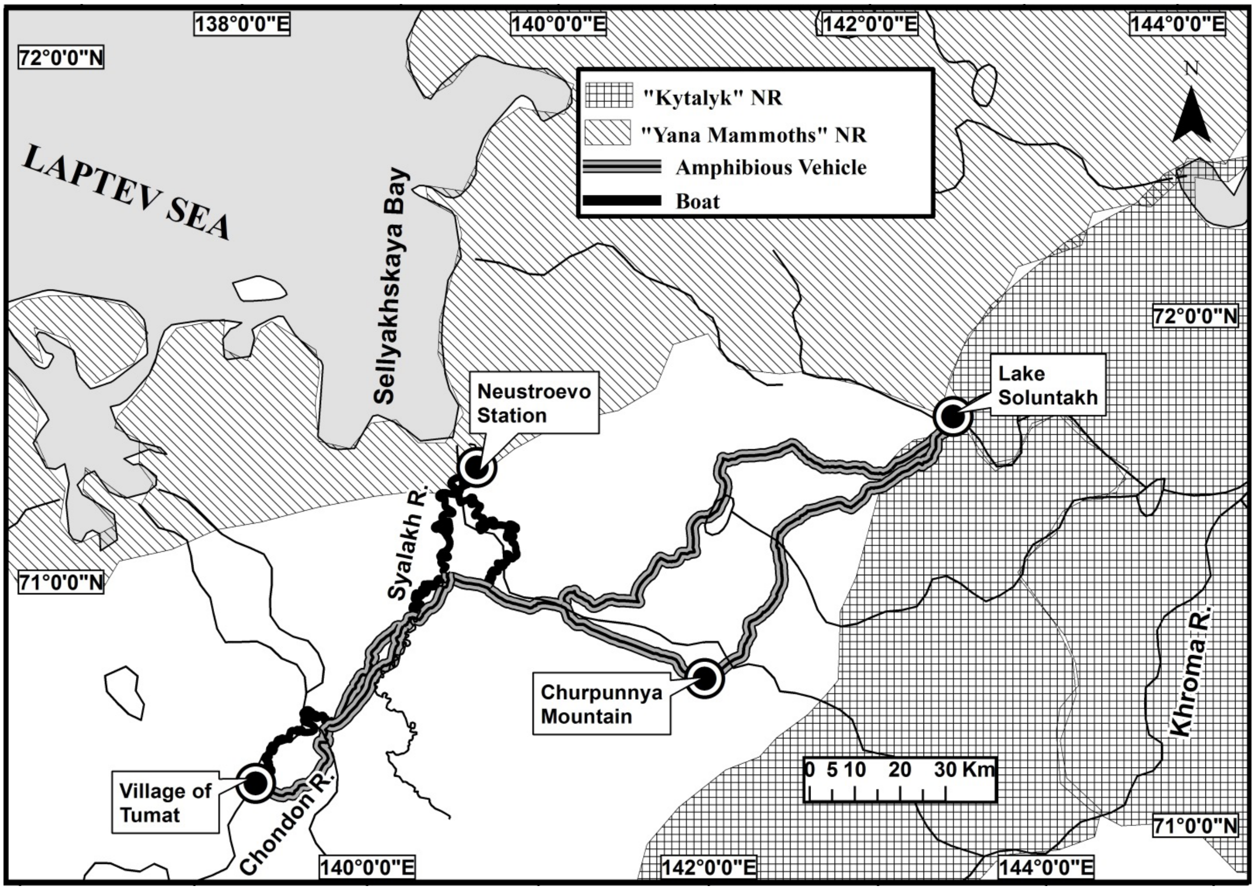

Figure 5. Location of our study area between Kytalyk Nature Reserve and Yana Mammoths Nature Reserve in the eastern Ust-Yana District in northern Yakutia, Russia. The authors propose a nature reserve be established to protect key breeding habitat of Siberian cranes that currently remains unprotected between the existing nature reserves.

Mammoths Nature Reserve to the southern boundary of the Khroma core and adjacent buffer zone (Fig. 5). This reserve would focus on currently unprotected parts of the Khroma core, adjacent buffer zone, and lands lying to the west of the designated breeding range and would represent a major step ensuring the protection of a key breeding ground of the Eastern Population of Siberian cranes. These lands also serve as important breeding and staging sites for numerous species of Eurasian shorebirds and waterfowl.

Our study area lies within a part of the eastern arctic of Asia that was not glaciated, was grassland steppe throughout the Pleistocene Epoch, and in the absence of continental glaciers was populated by woolly mammoths (*Mammuthus primigenius*) and numerous other large prehistoric mammals which flourished for much of the last million years (Hopkins et al. 1982). Mammoth bones and carcasses are widespread in this region along with the remains of other species of prehistoric mammals adding to the significance of the natural history of the study area. With the remains of mammoths present and their tusks valuable, tracked vehicles are being used to search for mammoth tusks leaving deep ruts particularly in or near wetlands and causing damage to the fragile tundra environment. Failure to limit tracked vehicle traffic on the tundra during the period when the surface is not frozen is likely to lead to severe erosion and washouts as water accumulates in the tracks and permeates downward as the permafrost melts. To the extent feasible, use of vehicle types that destroy the tundra vegetation exposing the tundra soils should be avoided particularly during the months when surface soils are not frozen.

The wilderness character of the study area along with the well-being of wildlife populations inhabiting the region studied would be enhanced by a cleanup of the abandoned tin mine on Churpunnya Mountain. This privately-owned mine had gone bankrupt and had been abandoned a few months prior to our arrival at the site in late July 2009. Discarded equipment and other debris from the mining operation were strewn over a large area on the northeast slope of the mountain. Polluted water contained in holding ponds in the mined area poses a potential threat to cranes and other wildlife living in the area should this water drain into wetlands located north and east of the site. In 2 instances, single Siberian cranes had been found dead in the vicinity of Churpunnya Mountain in years just preceding our visit (Y. P. Stoyan, personal communication). Ten Siberian cranes (5 pairs) were observed from the north slope of the mountain, reflecting the area supports a high density of this species. One potential option in conjunction with a cleanup would be to establish a biological research station at this site focusing on studies of tundra-nesting Siberian cranes and other wildlife indigenous to this region. The site would be well suited for studies evaluating effects of climate change on the biota of this region.

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LITERATURE CITED

Alisov, B. P. 1956. Climate of USSR. Moscow State University Press, Moscow, Russia.

Bergman, R. D., R. L. Howard, K. F. Abraham, and M. W. Weller. 1977. Water birds and their wetland resources in relation to oil development at Storkersen Point, Alaska. U.S. Fish and Wildlife Service Resource Publication 129, Washington, D.C., USA.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling–estimating abundance of biological populations. Oxford University Press, New York, New York, USA.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, New York, USA.

Carson, C. E., and K. M. Hussey. 1962. The oriented lakes of arctic Alaska. Journal of Geology 79:417-439.

Degtyarev, A. G., and Y. V. Labutin. 1991. Siberian crane in Yakutia: range, migration, and numbers. Zoological Journal 70:63-74.

Degtyarev, A. G., and Y. V. Labutin. 1999. On the reproduction of the white crane, *Grus leucogeranus* (Gruiformes, Gruidae), Yakutia. Zoological Journal 78:1210-1217.

Dement'ev, G. P., R. N. Meklenburtsev, A. M. Sudilovskaya, and E. P. Spangenberg. 1968. Birds of the Soviet Union. Volume 2. Published for Smithsonian Institution and National Science Foundation, Washington, D.C., USA, by Israel Program for Scientific Translations, Jerusalem.

Desyatkin, R. V., M. V. Okoneshnikova, and A. R. Desyatkin. 2009. Soils of Yakutia, Russia. Academy of Sciences, Siberian Division, Institute of Biological Problems of the Permafrost Zone, Yakutsk, Russia.

Egorov, O. V. 1965. Status of populations of waterfowl and some other birds in the Delta of the Lena and Yana-Indigirka tundra based on aerial surveys. Pages 124-127 *in* Nature of Yakutia and its protection. Yakutsk, Russia.

Egorov, O. V. 1971. New data on the distribution and number of Siberian crane in Yakutia. Pages 224-226 *in* Proceedings of the fifth republic meeting on environmental protection of Yakutia. East Siberian Publishing House, Nature Protection of Yakutia, Irkutsk, Russia.

Fedorov, A. N., T. A. Botulu, S. P. Varlamov, I. S. Vasiliev, S. P. Gribanova, I. V. Dorofeev, I. V. Klimovsky, V. V. Samsonova, and P. A. Soloviev. 1989. Permafrost landscapes of Yakutia. GUGK, Novosibirsk, Russia.

Flint, V. E., and A. A. Kistchinski. 1975. The Siberian crane (*Grus leucogeranus* Pallas, 1773) in Yakutia. Zoological Journal 44:1197-1212.

Flint, V. E., and A. A. Kistchinski. 1981. The Siberian crane in Yakutia. Pages 136-145 *in* J. C. Lewis and H. Masatomi, editors. Crane research around the world. International Crane Foundation, Baraboo, Wisconsin, USA.

Flint, V. E., and A. G. Sorokin. 1981. The biology of the Siberian crane (sterkh) in Yakutia. Pages 60–65 *in* N. M. Litvinenko and I. A. Neufeldt, editors. Cranes of east Asia. Academy of Sciences of the USSR, Vladivostok, Russia.

Flint, V. E., and A. G. Sorokin. 1982*a*. On the biology of the Siberian crane. Pages 103-112 *in* Y. V. Labutin, editor. Migration and ecology of birds in Siberia. Nauka, Novosibirsk, Russia.

Flint, V. E., and A. G. Sorokin. 1982*b*. The modern status of the Yakut population of Siberian white crane. Pages 60-65 *in* N. M. Litvinenko and I. Neufeldt, editors. Cranes of east Asia. Academy of Sciences of the USSR, Vladivostok, Russia.

Hodges, J. I., and W. D. Eldridge. 1995. Aerial waterfowl surveys near the arctic coast of eastern Russia. 1995. Unpublished report, Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Anchorage, Alaska, USA.

Hopkins, D. M., J. V. Mathews, Jr., C. E. Schweger, and S. B. Young. 1982. Paleoecology of Berengia. Academic Press, New York, New York, USA.

Karpov, N. S. 1991. Effect of reindeer grazing on the grassland vegetation of subarctic tundras of Yakutia. Yakutsk Research Center, Yakutsk, Russia.

Labutin, Y. V., A. G. Degtyarev, and V. P. Larionov. 1982. Distribution and abundance of cranes in north-eastern Yakutia. Pages 66-69 *in* N. M. Litvinenko and I. A. Neufeldt, editors. Cranes of east Asia. Academy of Sciences of the USSR, Vladivostok, Russia.

Li, F., G. Liu, J. Wu, N. Zeng, J. Harris, and J. Jin, editors. 2012. Ecological study of wetlands and water birds at Poyang Lake. Popular Science Press, Beijing, China.

Meine, C. D., and G. W. Archibald, editors. 1996. The cranes: status survey and conservation action plan. International Union for the Conservation of Nature, Gland, Switzerland.

Pearse, J. M., D. Esler, and A. G. Degtyarev. 1998. Birds of the Indigirka Delta, Russia: historical and biogeographic comparisons. Arctic 51:361-370.

Perfiliev, V. I. 1965. The white crane and its preservation in Yakutia. Pages 99-112 *in* Yakutia's nature and its preservation. Yakutsk Book Publisher,Yakutsk, Russia.

Perfiliev, V. I., and A. V. Polyakov. 1979. On the present distribution and population status of the Siberian crane in Yakutia. Pages 45-51 *in* M. V. Popov, F. N. Kirillov, and V. F. Volzin, editors. Protection and rational use of wildlife and natural environment of Yakutia. Proceedings of the VIII National Workshop on Conservation of Yakutia, Yakutsk, Russia.

Perfiliev, V. I., L. V. Teterina, and N. S. Karpov. 1991. The vegetative cover of the tundra zone of Yakutia. Yakut Science Center, USSR Academy of Sciences, Russia.

Poyarkov, N. D., J. I. Hodges, and W. D. Eldridge. 2000. Atlas of the distribution of birds in the coastal tundra of northeast Asia (based on aerial surveys 1993-1995). Biodiversity Conservation Center–2000.

Pshennikov, A. E., and N. I. Germogenov. 2001. Some aspects of Siberian crane ecology in Yakutia related to the global climate change. Pages 114-117 *in* B. Ivanov and T. Maximov, editors. Role of permafrost ecosystems in global climate change: Proceedings of International Conference, Yakutsk, Russia.

Song, X., Z. Jinsheng, and H. Xiangyu. 1995. Crane and stork counts and conservation measures at Poyang Lake Nature Reserve. Pages 73-80 *in* C. H. Halvorson, J. T. Harris, and S. M. Smirenski, editors. Cranes and storks of the Amur River, China. Arts Literature Publishers, Moscow, Russia.

Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5-14.

Uspenski, S. M., R. L. Beme, S. G. Priklonsky, and V. N. Vekhov. 1962. Birds of northeastern Yakutia. Ornithology 4:64-86.

Vorobyov, K. A. 1963. Birds of Yakutia. USSR Academy of Science Publishing House, Moscow, Russia.

Vshivtsev, V. P., B. M. Pavlov, B. V. Novikov, and L. A. Kolpashchikov. 1979. Aerial survey of Siberian cranes in Yakutia. Pages 69-71 *in* Migration and ecology of birds in Siberia. Abstracts of Ornithological Conference, Yakutsk, Russia.

Watanabe, T. 2006. Comparative breeding ecology of lesser sandhill cranes (*Grus canadensis canadensis*) and Siberian cranes (*G. leucogeranus*) in eastern Siberia. Dissertation. Texas A&M University, College Station, USA.

SANDHILL CRANE COLLISIONS WITH WIND TURBINES IN TEXAS

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The High Plains of the United States have been experiencing a large increase in wind energy generation sites with the American Wind Energy Association reporting an increase across America from 10 total installed gigawatts in 2006 to 60 total installed gigawatts in 2012. (American Wind Energy Association 2012). The High Plains also coincides with the Central Flyway in North America which is used by numerous bird species during migration, some with large bodies and high wing loading including the sandhill cranes (*Grus canandensis*), whooping cranes (*G. americana*), and waterfowl. Species such as these tend to be more vulnerable to mortality from strikes with structures due to reduced maneuverability (Bevenger 1998). Texas is currently 1 of the top 5 producers of wind power generation, and installation of wind power is expected to increase due to its high wind capabilities (American Wind Energy Association 2012).

Eighty percent of the midcontinent sandhill crane population migrates to northwestern Texas every winter (Iverson et al. 1985), and the entire wild North American whooping crane population migrates through northern Texas to winter along the coast of the Gulf of Mexico (Stehn 2010). More wind turbines on the landscape may put these populations of cranes at risk for increased turbine collisions.

Previous research shows that sandhill cranes and whooping cranes use their migratory staging habitat in a similar manner (Kauffeld 1981, Armbruster 1990). Sandhill cranes may be an appropriate surrogate to study for the potential impacts of wind energy on whooping cranes during migration, and possibly during the winter. Cranes will increasingly come into contact with this infrastructure as the number of wind turbines and associated structures expands across the landscape. Cranes are susceptible to mortality from colliding with power lines and other large obstacles (Windingstad 1988, Brown and Drewien 1995, Bevanger 1998). As part of a larger study evaluating crane behavior in response to wind turbines, we documented sandhill crane mortality from contact with wind turbines in the southern High Plains of Texas. We recorded weather conditions and time of day. This information can be used as a basis for further study of crane mortality risk around wind energy infrastructure.

We recorded sandhill crane presence and behavior in Carson, Floyd, Crosby, and Dickens counties during winters (Oct-Feb) 2009-10 and 2010-11. This area is flat (elevation range 1,000 to 1,500 m) with scattered playa wetlands in a large agricultural region producing corn, milo (sorghum), cotton, and winter wheat. Cranes use this area during migration and part of winter, foraging in agricultural areas and roosting at night in playas.

We surveyed the area using 174 km of road transects. The Texas panhandle is extremely flat with few visual obstructions, and flocks of cranes could often be spotted from more than a kilometer away. Transect surveys were designed for detection of crane flocks and to sample behavior. We recorded time and weather conditions including air temperature, wind speed, relative humidity with a handheld Kestrel 3000 wind and weather meter (Nielson-Kellerman Kestrel Meters, Champlain, NY), cloud cover, and precipitation.

We documented a sandhill crane strike at the Llano Estacado wind farm (UTM zone 14S, 297542E, 3924893N; 35° 26′ 48.9″N, 101° 13′ 50.5″W) on 23 November 2009 at 1000 hours (DST, CTZ). The observer was approximately 350 m away from the impact when it occurred. It was 12.8°C, relative humidity 80%, and foggy with 90% cloud cover. Visibility was limited (<200 m). Winds averaged 13.2 km/hr, gusting to 19.9 km/hr.

The second strike occurred at the Pantex Wind Farm (UTM zone 14S, 268556E, 3919797N; 35° 26′ 40.9″N, 101° 32 ′ 54.1″W) on 24 November 2010 at 0930 hours. The observer was approximately 700 m away from the impact. The impact occurred approximately 800 m from a consistently used roosting playa for cranes and geese (Oct and Nov 2010). It was 9.4°C, relative humidity 64%, with 40% cloud cover. Visibility was limited (<200 m). Winds averaged 10.9 km/hr, gusting to 21.6 km/hr. Both impacts were directly witnessed by the surveyor.

These impacts occurred in foraging and roosting areas of sandhill cranes during their migration and

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wintering. There are a number of factors besides body mass and wing loading (Bevanger 1998) that may increase crane susceptibility to mortality from wind turbine strike. Good turbine locations and migratory corridors tend to occur in the same areas because of favorable wind conditions (Sugimoto and Matsuda 2011). Wind farms in areas that are used regularly by large numbers of species for feeding and roosting on migratory routes, or local flight routes between foraging and roosting areas, present a greater risk to the species that occupy the area (Drewitt and Langston 2008, Everaert and Stienen 2006). Gregarious species, such as the sandhill crane, seem to be more prone to collisions, due to greater concentrations of birds and lower levels of attention shown when following a lead bird (Pettersson 2005). Birds which make local movements between roosting and foraging sites tend to fly at a lower altitude than migrating birds, which also increases the susceptibility of collisions (Drewitt and Langston 2008).

Visibility likely had a role in the crane strikes we witnessed. Birds which habitually fly at dawn and dusk between foraging and roosting sites, such as the sandhill crane, are less likely to detect the wind turbines (Larsen and Clausen 2002). Some suggest that crane flight speed is so slow that they may be able to detect and avoid turbines (Cooper 2006, McCarthy 2009). Our observations suggest this may not be the case during poor weather conditions. Inclement weather patterns that reduce visibility may increase the frequency of turbine strikes (Drewitt and Langstron 2008, Martin 2011). Furthermore, many birds do not have a high visual acuity directly in front of them (Martin 2011), likely further exacerbating the problem.

Time of year may have been a factor in the mortalities we recorded as well (Bevanger 1998). Others have documented larger numbers of bird strikes during fall migration as compared to other times of the year (Faanes 1987, Crawford and Engstrom 2001). During this time of year, migratory birds may be more unfamiliar with their environment, increasing the risk of mortality from obstacles (Drewitt and Langstron 2008).

These are observations that occurred during sampling for other objectives and therefore underrepresented the potential for cranes striking turbines. Intensive sampling for mortalities was not conducted, so we cannot calculate the mortality on a per-turbine or per-wind farm approach. Consulting documents state that turbines are not a large risk for cranes. Our observations suggest that turbine mortality surveys for cranes in the migratory and wintering habitat should be conducted, and we recommend further research assessing the frequency of collisions for both sandhill cranes and whooping cranes which use habitat during migration in a similar manner (Kauffeld 1981, Armbruster 1990).

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LITERATURE CITED

American Wind Energy Association. 2012. AWEA U.S. wind industry annual market report: year ending 2012. American Wind Energy Association, Washington, D.C., USA.

Armbruster, M. J. 1990. Characterization of habitat used by whooping cranes during migration. U.S. Fish and Wildlife Service Biological Report 90(4):1-16.

Bevanger, K. 1998. Biological and conservation aspects of bird mortality caused by electricity power lines: a review. Biological Conservation 86:67–76.

Brown W. M., and R. C. Drewien. 1995. Evaluation of two power line markers to reduce crane and waterfowl collision mortality. Wildlife Society Bulletin 23:217-227.

Cooper, J. M. 2006. Sandhill crane breeding on northern Vancouver Island, British Columbia. Northwestern Naturalist 87:146-149.

Crawford, R. L., and R. T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. Journal of Field Ornithology 72:380–388.

Drewitt, A. L., and R. H. W Langston. 2008. Collision effects of wind-power generators and other obstacles on birds. Annals of the New York Academy of Sciences 1134:233–266.

Everaert, J., and E. W Stienen. 2006. Impact of wind turbines on birds in Zeebrugge (Belgium): significant effect on breeding tern colony due to collisions. Biodiversity and Conservation 16:3345-3359.

Faanes, C. A. 1987. Bird behavior and mortality in relation to power lines in prairie habitats. U.S. Fish and Wildlife Service Technical Report 7, Washington, D.C., USA.

Iverson, G. C., and Tacha, T. C. 1985. Habitat use by sandhill cranes wintering in western Texas. Journal of Wildlife Management 49:250-254.

Kauffeld, J. D. 1982. Management of migratory crane habitat on Alamosa and Monte Vista National Wildlife Refuges. Pages 117-121 *in* J. C. Lewis, editor. Proceedings of the 1981 crane workshop. National Audubon Society, Tavernier, Florida, USA.

Larsen, J. K, and Clausen, P. 2002. Potential wind park impacts on whooper swans in winter: the risk of collision. Waterbirds 25:327-330.

Martin G. R. 2011. Understanding bird collisions with man-made objects: a sensory ecology approach. Ibis 153:239-254.

McCarthy, M. 2009. Predicting impacts of the Stockyard Hill windfarm on the Victorian brolga population. Final Report, Applied Environmental Decision Analysis, Commonwealth Environment Research Facility, University of Melbourne, Australia.

Pettersson, J. 2005. The impact of offshore wind farms on bird life in southern Kalmar Sound, Sweden: a final report based on studies 1999-2003. Report for the Swedish Energy Agency. Lund University, Lund, Sweden.

Sugimoto, H., and H. Matsuda. 2011. Collision risk of white-fronted geese with wind turbines. Ornithological Science 10:61-71.

Stehn, T. 2010. Species status and fact sheet: whooping crane. <http://www.fws.gov/northflorida/WhoopingCrane/whoopingcrane-fact-2001.htm>. Accessed 11 Sep 2011.

Windingstad, R. M. 1988. Nonhunting mortality in sandhill cranes. Journal of Wildlife Management 53:260-263.

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CHROMIC AND IRON OXIDES AS FECAL MARKERS TO IDENTIFY INDIVIDUAL WHOOPING CRANES

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The whooping crane (*Grus americana*) is listed as endangered under the IUCN Red List, the United States Endangered Species Act, and the Canadian Species at Risk Act (BirdLife International 2012, CWS and USFWS 2007). A major focus of recovery efforts for this endangered species is reintroduction to establish new populations (CWS and USFWS 2007). Captive populations are critical as a source of individuals for reintroduction efforts and also serve as insurance populations. Currently, there are a total of 157 whooping cranes held in captive breeding centers across North America, with the largest at the USGS Patuxent Wildlife Research Center (PWRC) in Laurel, Maryland. Birds produced in this facility are currently being released as part of efforts to establish the Eastern Migratory Population (EMP, Urbanek et al. 2005) and in an effort to establish a non-migratory population in Louisiana. In the past decade, PWRC has produced and released annually an average of 18 birds into the wild; however, reproductive performance of birds at this facility is lower than desired. PWRC had a 60% fertility rate for eggs laid from 2000 through 2010 (J. N. Chandler, personal communication, 2011). Furthermore, reproductive onset in this captive population appears to be delayed compared to wild populations. In wild populations, reproductive onset (production of sperm and eggs) normally occurs ~5 years of age in both males and females, ~2 years after initial pair formation occurs (Ellis et al., 1996), while some females in the EMP have laid eggs earlier than 5 years of age (Converse et al. 2011). However, PWRC females in some cases do not start to lay eggs until 7 years of age (Mirande et al. 1996). Currently, the PWRC population consists of a total of 74 whooping cranes, including 22 pairs. Six of these pairs (27%) are consistently infertile (i.e., no production of fertile eggs) and 3 other pairs (14%) have low fertility (30-45% fertility in eggs laid), which is variable from year to year. Six pairs (27%) are recently formed and have not produced eggs, and so have unknown fertility. This leaves only 7 pairs (33%) which contribute maximally to PWRC's chick production (J. N. Chandler, personal communication, 2011). Because of the challenges occurring within this captive colony, PWRC and Smithsonian National Zoo have initiated a joint research project to identify potential underlying causes of poor reproduction in captive whooping cranes.

One method critical to this research is non-invasive hormone monitoring, which has been used in a variety of studies focused on examining basic animal biology, health, and reproduction, as well as physiological responses of animals to captive management. Hormone metabolite concentrations can be sampled in a variety of materials including feces, urine, hair, feathers, and saliva (Brown 2008, Brown et al. 2001, Holt et al. 2003, Lobato et al. 2010, Moore et al. 1984, Wielebnowski et al. 2002). In the giant panda (*Ailuropoda melanoleuca*) hormone metabolites have been monitored in urine samples in order to understand the timing of estrus and ovulation, which aids in planning animal introductions and artificial inseminations (Moore et al. 1984). In the clouded leopard (*Neofelis nebulosa*) fecal hormone sampling has helped researchers understand relationships between aspects of enclosure design and location and stress responses (Wielebnowski et al. 2002).

Already used in a variety of wild mammal species in both *ex situ* and *in situ* studies, non-invasive hormone monitoring is also gradually being adapted to birds. Most avian hormone studies to date have utilized blood sampling (Angelier and Chastel 2009, Angelier et al. 2009, Angelier et al. 2006, Bluhm et al. 1983), a process which has been shown to cause stress (Gratto-Trevor et al. 1991). Studies have validated the effectiveness and feasibility of non-invasive hormone monitoring in some bird species. Ludders et al. (2001) showed that serum corticosterone patterns were similar to those in fecal samples collected from the same bird in Florida sandhill cranes (*Grus canadensis pratensis*). Stanley et al. (2007) validated reproductive steroid hormone assays for both golden eagles (*Aquila chrysaetos*) and peregrine falcons (*Falco peregrinus*) housed in a captive setting. To date, non-invasive hormone monitoring has not been used to assess gonadal activity and little work has been done assessing adrenal activity and function in whooping cranes. Ongoing data collection at PWRC is one of the first efforts to use non-invasive hormone monitoring in an attempt to understand whooping crane reproductive biology.

The first critical step in this work was to establish a method to identify fecal samples from an individual bird within a breeding pair. Trials with different types of food dyes in varying amounts were unsuccessful. In the present study, we determined the feasibility of using chromic oxide (Cr_2O_3) and iron oxide (Fe_2O_3) as fecal markers. Both chromic oxide and iron oxide were obtained from Prince Agri Products, Inc. (Quincy, IL). These dyes have been used in nutritional studies in a variety of species, including chickens, ducks, cows, horses, and humans, especially in studies that involve more than 1 feeding trial or those aiming to assess the digestibility of a food item (Schurch et al. 1950). Both are non-biological, insoluble compounds which, when ingested, are not absorbed by the digestive system (Dansky and Hill 1952, Schurch et al. 1950). Instead, they pass directly through the digestive tract and subsequently color the animal's feces.

In our first trial, cranes housed individually in outdoor pens were given smelt (*Osmerus mordax mordax*) containing a capsule filled with 450 mg green chromic oxide (n = 5 birds) or yellow (n = 5), red (n = 4), orange (n = 3), or black (n = 3) iron oxide. The appearance of color in the feces was visually determined 8 hours later, with color intensity judged on a scale of 0 to 3, with 3 indicating intense color and 0 indicating no visible color. Visibility was determined in the field, where subsequent endocrine studies will take place, because it is important to know which color would be easiest to find where vegetation and other factors obscure sample visibility. Chromic oxide in green, and iron oxide in orange, red, and black (but not yellow) were visible in feces (green = 3; red = 2; black = 1.5; orange = 1; and yellow = 0).

In a second trial, we assessed the time required until chromic oxide could be observed post-feeding. Four whooping cranes were housed individually in indoor pens (Fig. 1) and fed smelt containing 230 mg of green chromic oxide. The pens were checked every 30 minutes until first appearance of the dye in the feces, and then every hour until the end of the day (8 hr post feeding). At the beginning of day 2 (24 hr post-feeding), the pens were cleared of all feces to ensure that any subsequent samples which showed a presence of chromic oxide were fresh samples. The marker first appeared on average (± SE) 1.5 ± 0.2 hours after feeding and remained detectable until 27.7 ± 0.2 hours for a total duration of 26.2 ± 0.2 hours. Therefore, use of chromic oxide allows for a flexible collection interval and increased chance of finding an individual's fecal samples. We observed no adverse consequences of feeding either substance, as fecal production (size, consistency, and overall number of fecals) appeared normal.

Finally, it was necessary to verify that chromic oxide and iron oxide would not interfere with hormone assay performance. Feces were collected daily at 0730 hours for 5 days from 3 male and 3 female whooping

Figure 1. Indoor pens where cranes were housed for trial 2. Small pens with wood shavings used as bedding allowed easy detection and identification of dyed samples.

crane adults, housed individually. On the afternoon of the second day (Day 2) each crane was given smelt containing a capsule filled with 230 mg of either green chromic oxide (females) or red iron oxide (males) so that the fecal samples collected on the morning of Day 3 were dyed. Samples were extracted with a modified dry shaking extraction using 70% ethanol (Brown 2008). Once extracted, all samples were assessed for corticosterone using a RIA kit (MP Biomedicals, Solon, OH; Fig. 2a). Female samples were also evaluated for progestagen metabolites using an enzyme immunoassay (EIA, monoclonal pregnane CL425; Fig. 2b), and male samples were also examined for testosterone using an EIA (polyclonal R156/7; Fig. 2c). Antibodies for protestagen and testosterone EIAs were obtained from C. Munro (University of California, Davis, CA). Hormone metabolite concentrations remained constant over the collection period (Fig. 2), providing no evidence that either colorant interfered with the evaluation of excreted hormones. The only individual that showed a significant difference between the Day 3 sample and the other collected samples, using a standard z score, was the corticosterone value for female crane number F2.

In summary, our findings indicate that both chromic oxide and iron oxide can be used as fecal markers for non-invasive hormone monitoring. This method will aid ongoing studies aimed at advancing the understanding of reproductive endocrinology and underlying causes of poor reproduction in captive whooping cranes. Studies are in progress to evaluate hormone metabolite concentrations and patterns in male and female whooping cranes during the breeding season. The method will be easily transferrable to a host of other avian species aiding in their conservation and captive management.

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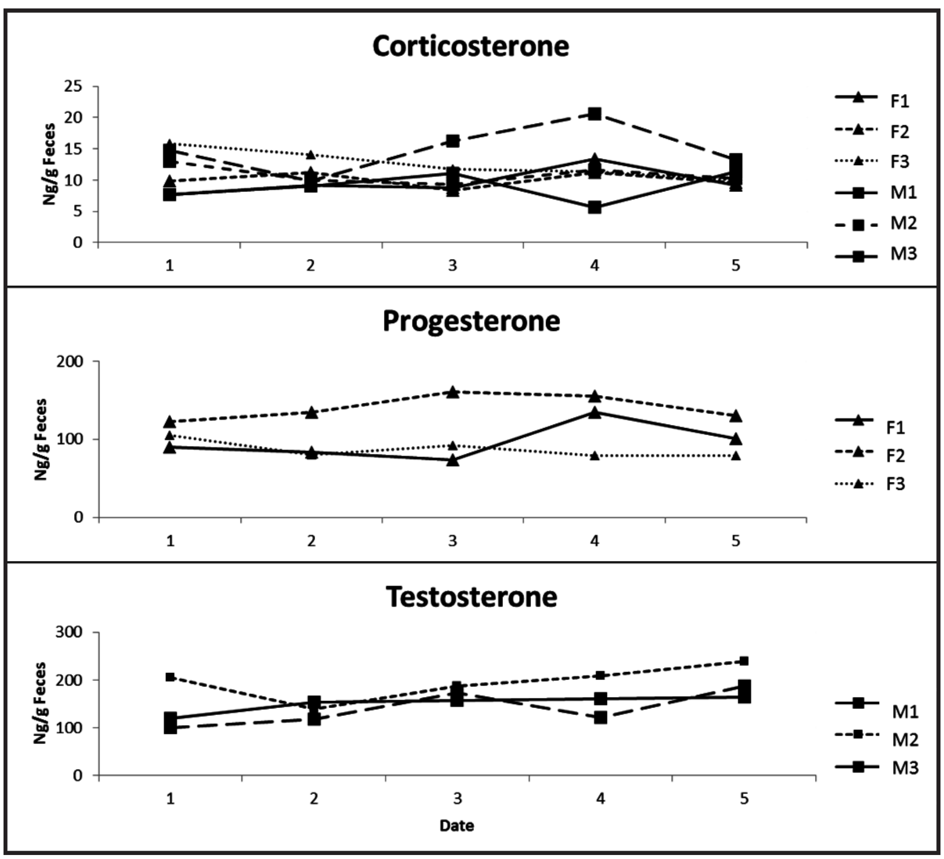

Figure 2. Metabolite concentrations assessed during a 5-day period in 6 adult whooping cranes. M indicates males (*n* = 3) and F designates females (*n* = 3). Sample collected on Day 3 contained fecal marker: iron oxide for males and chromic oxide for females.

oxide in her own poultry nutrition research and was instrumental to the idea to use this substance as a fecal marker for this species. We would also like to thank everyone on the USGS PWRC crane crew and vet staff for all of their help. N. Presley, S. Putman, and N. Parker of Smithsonian's Conservation Biology Institute Endocrine Lab were extremely helpful with mentorship and training on each of the hormone assays. Support for this project was provided by Morris Animal Foundation. All methods and animal use were approved by both the Smithsonian and USGS Patuxent Animal Care and Use Committees.

LITERATURE CITED

Angelier, F., and O. Chastel. 2009. Stress, prolactin and parental investment in birds: a review. General and Comparitive Endocrinology 163:142-148.

Angelier, F., C. Clement-Chastel, J. Weicker, G. W. Gabrielsen, and O. Chastel. 2009. How does corticosterone affect parental behaviour and reproductive success? A study of prolactin in black-legged kittiwakes. Functional Ecology 23:784-793.

Angelier, F., S. A. Shaffer, H. Weirmerskirch, and O. Chastel. 2006. Effect of age, breeding experience and senescence on corticosterone and prolactin levels in a long-lived seabird: The wondering albatross. General and Comparative Endocrinology 149:1-9.

BirdLife International. 2012. *Grus americana*. *In* IUCN 2013. IUCN red list of threatened species. Version 2013.2. <http://www.iucnredlist.org/details/22692156/0>. Accessed 28 Feb 2014.

Bluhm, C. K., R. E. Phillips, and W. H. Burke. 1983. Serum levels of luteinizing hormone, prolactin, estradiol and progesterone in laying and nonlaying mallards (*Anas platyrhynchos*). Biology of Reproduction 28:295-305.

Brown, J. L. 2008. Wildlife endocrinology manual. CRC Endocrine Research Laboratory, Smithsonian National Zoological Park, Conservation and Research Center, Washington, D.C., USA.

Brown, J. L., A. C. Bellen, M. Fouraker, D. E. Wildt, and T. L. Roth. 2001. Comparative analysis of gonadal and adrenal activity in the black and white rhinoceros in North America by non-invasive hormone monitoring. Zoo Biology 20:463-448.

Canadian Wildlife Service [CWS] and U.S. Fish and Wildlife Service [USFWS]. 2007. International recovery plan for the whooping crane. Recovery of Nationally Endangered Wildlife (RENEW), Ottawa, Ontario, Canada, and U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Converse, S. J., J. A. Royal, and R. P. Urbanek. 2011. Bayesian analysis of multi-state data with individual covariates for estimating genetic effects on demography. Journal of Ornithology 152:561-572.

Dansky, L. M., and F. W. Hill. 1952. Application of the chromic oxide indicator balance studies with growing chickens. Journal of Nutrition 47:449-458.

Gratto-Trevor, C. L., L. W. Oring, and A. J. Fivizzani. 1991. Effects of blood sampling stress on hormone levels in the semipalmated sandpiper. Journal of Field Ornithology 62:19-27.

Holt W. V., A. R. Pickard, J. C. Rodger, and D. E. Wildt, editors. 2003. Reproductive science and integrated conservation. Cambridge University Press, New York, New York, USA.

Lobato, E., J. Moreno, S. Merion, J. Morales, G. Tomas, J. Martinez, R. Vasquez, A. Kuchar, E. Mostl, and J. Osonro. 2010. Arrival date and territorial behavior are associated with corticosterone metabolite levels in a migratory bird. Journal of Ornithology 151:587-597.

Ludders, J. W., J. A. Langenberg, N. M. Czekala, and H. N. Erb. 2001. Fecal corticosterone reflects serum corticosterone in Florida sandhill cranes. Journal of Wildlife Diseases 37:646-652.

Mirande, C. M., G. F. Gee, A. Burke, and P. Whitlock. Egg and semen production. Pages 45-57 in D. H. Ellis, G. F. Gee, and C. M. Mirande, editors. Cranes: their biology, husbandry, and conservation. National Biological Service, Washington, D.C., and International Crane Foundation, Baraboo, Wisconsin, USA.

Moore, H. D. M., M. Bush, M. Celma, A. L. Garcia, T. D. Hartman, J. P. Hearn, J. K. Hodges, D. M. Jones, J. A. Knight, L. Monsalve, and D. E. Wildt. 1984. Artificial insemination in the giant panda (*Aliuropoda melanoleaca*). Journal of Zoology 203:269-278.

Schurch, A., L. Llyod, and E. Crampton, E. 1950. The use of chromic oxide as an index for determining the digestibility of a diet. The Journal of Nutrition 41:629-636.

Stanley, A. M., J. M. Blanco, A. M. Dufty, Jr., D. E. Wildt, and S. L. Monfort. 2007. Fecal steroid monitoring for assessing gonadal and adrenal activity in the golden eagle and peregrine falcon. Journal of Comparative Physiology B 177:609-622.

Urbanek, R. P., L. E. A. Fondow, C. D. Satyshur, A. E. Lacy, S. E. Zimorski, and M. Wellington. 2005. First cohort of migratory whooping cranes reintroduced to eastern

North America: the first year after release. Proceedings of the North American Crane Workshop 9:213-223.

Wielebnowski, N. C., N. Fletchall, K. Carlstead, J. M. Busso, and J. L. Brown, J. L. 2002. Noninvasive assesment of adrenal activity associated with husbandry and behavioral factors in the North American clouded leopard population. Zoo Biology 21:77-98.

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Key words: chromic oxide, fecal marker, hormone monitoring, iron oxide, whooping crane.

TYLOSIN TARTRATE PROMOTES RESOLUTION OF INSECT BITE HYPERSENSITIVITY REACTIONS IN CAPTIVE CRANES

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Previous research has described significant serum protein electrophoretic changes associated with intense periocular swelling in several crane species, typical of Type I hypersensitivity reactions, and thought to be the result of insect bites (Hartup and Schroeder 2006). We reviewed medical records for treatment plans and outcomes from 58 cases of insect hypersensitivity reactions observed in a diverse collection of captive cranes at the International Crane Foundation, Baraboo, Wisconsin. The purpose of this study was to fully describe the epidemiological and clinical characteristics of these cases, and determine the efficacy of treatment of these cases with tylosin tartrate, a macrolide antibiotic.

The mean annual number of cases (± SD) between 2000 and 2011 was 4.8 ± 2.9, and ranged from 1 to 11 cases per year (no cases were found prior to 2000). Cases occurred April to September, but peaked in June (n = 31). Twenty-four cases (41%) occurred in 1 quadrant of the off-exhibit breeding facility. Cases were observed in 6 species present at the facility. The largest number of cases occurred in whooping cranes (*Grus americana*) (n = 24, 41%), followed by Siberian cranes (*G. leucogeranus*) (n = 17, 29%). Forty-eight cranes were affected once, 9 cranes were affected twice, and 1 crane was similarly affected 3 times. Forty-one females (71%) and 17 males (29%) were affected. Female cranes were diagnosed with hypersensitivity reactions more than twice as often as males (odds ratio = 2.41, 95% confidence interval 1.05-5.58; χ^2 = 5.19, P = 0.02). The affected cranes ranged in age from 9 days to 33 years old; there was no apparent age predilection.

Clinical signs included unilateral periocular swelling (n = 58, 100%), oculonasal discharge (n = 29, 50%), conjunctivitis (n = 19, 33%), blepharitis (n = 12, 21%), or a punctate wound with or without an attached insect exoskeleton remnant (n = 10, 17%). Cases ranged in severity from mild (minimal periocular swelling only, n = 7, 12%), to moderate (modest periocular swelling with up to 1 additional sign, n = 35, 60%), to severe (large periocular swelling with 1 or more additional signs, n = 16, 28%).

Treatment regimens included non-steroidal anti-inflammatory drugs (NSAIDs, including ketoprofen, carprofen, piroxicam, meloxicam), topical antibiotic ophthalmic ointment with or without hydrocortisone, systemic antibiotics (enrofloxacin, tylosin tartrate), or no treatment. There was no to minimal clinical improvement observed in cases where an NSAID, topical ophthalmic ointment or enrofloxacin were used. Cases typically resolved in 18-29 days when these drugs were used alone or in combination. By comparison, the mean time to resolution of clinical signs was 20 ± 6.8 days in 3 cases where no drugs were used. The mean duration of clinical signs decreased significantly in cases where tylosin tartrate was administered (13.0 ± 8.3 days), either alone or in conjunction with another drug, compared to cases where no tylosin was used (25.2 ± 11.2 days, t = 4.2, P < 0.001). The mean duration of clinical signs was 9.9 ± 5.4 days in 15 cranes that received tylosin tartrate and no other drug.

Tylosin tartrate produced a significant clinical benefit in these cases, typically shortening the duration of signs of hypersensitivity reactions in cranes by 1 to 2 weeks. The drug is easily delivered in drinking water and may provide a prophylaxis to bacterial infection in these cases. We speculate that modulation of inflammatory mediators and cytokines is responsible for the improvements in clinical signs after treatment with tylosin tartrate. *In vitro* and *in vivo* studies in mammals show macrolide antibiotics such as tylosin modify the host immune and inflammatory responses (Cao et al. 2006). Further work is needed to determine the range of pest species that incite hypersensitivity reactions in cranes, to examine whether affected cranes have lowered breeding success, and to investigate possible prevention strategies.

LITERATURE CITED

Cao, X. Y., M. Dong, J. Z. Shen, B. B. Wu, C. M. Wu, X. D. Du, Z. Wang, Y. T. Qi, and B. Y. Li. 2006. Tilmicosin and tylosin have anti-inflammatory properties via modulation of COX-2 and iNOS gene expression and production of cytokines in LPS-induced macrophages and monocytes. International Journal of Antimicrobial Agents 27:431–438.

Hartup, B. K., and C. A. Schroeder. 2006. Protein electrophoresis in cranes with presumed insect bite hypersensitivity. Veterinary Clinical Pathology 35:226-230.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12: 73-74

Key words: cranes, hypersensitivity, insect bite, treatment, tylosin tartrate.

OBSERVATIONS OF MOLT IN REINTRODUCED WHOOPING CRANES

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Whooping cranes (*Grus americana*, WHCR) complete a full flightless molt of primary flight feathers every 2-3 years. The flightless period may represent an important component of the annual cycle; however, molt patterns in WHCR are poorly understood. WHCR undergo a flightless period following ecdysis (feather loss) making them more vulnerable to predation threats, and likely changing their habitat selection from open wetlands to areas with a higher concentration of cover. Studies of molt in wild birds can then be compared to associated habitat needs at that critical time and inform the selection of future release sites elsewhere.

In 2011, 6 reintroduced Eastern Migratory Population (EMP) WHCR were identified as molting in and around Necedah NWR. Initially, secretive behavior and/or limited movement by the birds indicated possible molt; this was followed by visual confirmation through observing a wing flap so that presence/absence of remiges could be noted. Birds confirmed to be molting were WCEP IDs 29-09, 4-08, 13-02 and mate 18-02, and 12-02 and mate 19-04. The latter pair was confirmed to be molting only through the collection of 34 (of a maximum of 40) primary feathers on the pair's territory.

For the WCEP birds, all were confirmed to be molting within 6 days of each other during the first week of July. Each bird's primaries were observed to be approximately 25% emerged or less, placing the start date of molt for all 6 birds within 1 week of each other, around the first week of June. Two breeding pairs, 1 of same age (9 yr) and 1 2 years apart (7 and 9 yr), both molted simultaneously. Two other birds (not paired or breeding) confirmed in molt were 2 and 3 years old, respectively.

The long-term records of captive WHCR at the International Crane Foundation (ICF) offer a valuable opportunity to examine feather loss throughout their many life stages. A review of daily husbandry records from captive WHCR at ICF (1990-2010) showed that initiation of feather loss for females preceded that of males. Females began molting as early as 31 March with the latest primary feather loss in late July, whereas the earliest date for males was 22 April and lasted until late summer (M. Levenhagen and M. Wellington, ICF, unpublished data). Contrary to findings in captive birds, of the 6 WCEP birds confirmed to be molting in 2011, both males and females appeared to initiate molt concurrently. Simultaneous molt within pairs is consistent with Florida sandhill cranes (*G. canadensis pratensis*), where there was no difference between the remigial molt of first year, second year, and adult birds (Nesbitt and Schwikert 2008). Sandhill cranes do not become flightless, however. The molting phase of a WHCR can be a vulnerable time presenting unique behavioral and environmental constraints. As efforts to reintroduce this species into the Eastern Flyway continue, understanding this phase is potentially vital to a successful reintroduction.

LITERATURE CITED

Nesbitt, S. A., and S. T. Schwikert. 2008. Timing of molt in Florida sandhill cranes. Proceedings of the North American Crane Workshop 10:125–127.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:75

Key words: Eastern Migratory Population, flightless period, *Grus americana*, molt, whooping crane.

THE HISTORY AND REINTRODUCTION OF WHOOPING CRANES AT WHITE LAKE WETLANDS CONSERVATION AREA, LOUISIANA

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On 16 February 2011, whooping cranes (*Grus americana*) were reintroduced in the wetlands of southwest Louisiana, after an absence of 61 years. This brief communication provides background on the historical presence of whooping cranes in this region, describes the long road to reintroduction, presents observations from the reintroduction's first day, and offers thoughts on its future prospects.

On 15 May 1939, biologist John J. Lynch of the U.S. Fish and Wildlife Service observed 13 whooping cranes in the remote freshwater marsh north of White Lake in Vermilion Parish, Louisiana. He not only confirmed what local residents and trappers had long known (Drewien et al. 2001, Gomez et al. 2005), but he was also viewing a native Louisiana species in its twilight.

According to Robert P. Allen (1952), whooping cranes had once flourished in southwest Louisiana. Migratory cranes wintered on the tallgrass prairies of the Pleistocene Prairie Terrace at the northern edge of the coastal plain, as well as in the adjacent Chenier Plain wetlands, using the region's brackish and saltwater marshes and chenier ridges. Large-scale conversion of the prairies to commercial rice production in the late 19th century, followed by canal construction and the resultant enhanced access to the marshes in the early 20th century, increased the vulnerability of whooping cranes to hunting and disturbance. The last report of the species on the Louisiana prairies dates from 1918, while reports of cranes in the salt and brackish marshes end in the early 1940s. Only in the region of the still relatively isolated freshwater marsh north of White Lake did sightings continue, and area residents and trappers insisted that *la grue blanche* (the white crane) was not only resident year-round, but was also nesting and raising young in the vast *Panicum hemitomon* marsh (Allen 1952, Gomez 1992).

John Lynch's interviews with these local residents and trappers led to the biologist's 1939 flight over the White Lake marsh, during which he observed 13 whooping cranes: 11 adults and 2 juveniles. He described the latter as "young-of-the-year, about one-third grown" (Lynch 1984:38). Lynch's record of the sighting (Drewien et al. 2001), as well as his interviews with residents and trappers (Gomez et al. 2005), provided the scientific community, including Allen, with primary information on whooping cranes in the White Lake marsh, describing the Louisiana non-migratory population's habitat and behavior and documenting its breeding.

The following year, on 7 August 1940, a hurricane and its accompanying heavy rains flooded the region and scattered the White Lake flock; only 6 of the birds returned. By 1947, a single Louisiana crane remained, and on 11 March 1950 this lone bird, dubbed "Mac," was chased by helicopter, captured, and transported to Aransas National Wildlife Refuge in Texas, where it died 6 months later (Van Pelt 1950, McNulty 1966, Doughty 1989).

As whooping crane numbers, then precipitously low, rose during the ensuing decades in response to increased protection of the birds and their habitat, including their listing under the federal Endangered Species Act of 1973 (Doughty 1989), the desire to reintroduce whooping cranes into their former Louisiana range surfaced. In 1977, Dr. George Archibald, co-founder of the International Crane Foundation, and John Allender of the Audubon Park Zoo in New Orleans proposed such a reintroduction into the cranes' historic range (Allender and Archibald 1977). The proposal to reintroduce an endangered species in coastal Louisiana, however, met with skepticism from the U.S. Fish and Wildlife Service (USFWS), along with strong opposition from the Louisiana Wild Life and Fisheries Commission (predecessor of the Louisiana Department of Wildlife and Fisheries [LDWF]). The Commission expressed concern for the future of the fur trapping industry, which was booming during the decade of the 1970s with an average yearly value of $11.84 million, as well as likely interference with waterfowl hunting, also a deeply rooted cultural and economic mainstay (Gomez 1992, 1998, 2001). Without local and federal agency support, the proposal failed to gain acceptance, and the hope of reintroducing whooping cranes in Louisiana languished for more than a decade.

By the early 1990s, however, attitudes in Louisiana had begun to change (Gomez 1992). The trapping

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industry, now in decline, was less an economic force in the state, and waterfowl hunter compliance with regulations had increased (Gomez 1998). Perhaps most importantly, the Endangered Species Act had been modified in 1982 to include Section 10 (j), providing for the reintroduction of "Nonessential Experimental Populations" of endangered species and allowing greater flexibility of land use, since no "critical habitat" designation would be required. With such a provision in place, coastal Louisiana's waterfowl hunting, fur and alligator trapping, rice farming, cattle ranching, and other traditional practices could continue, despite the presence of reintroduced whooping cranes.

Official consideration of Louisiana as a potential reintroduction site proceeded cautiously during the 1990s and 2000s. Early action in this period included the search for a wintering site for a new experimental population of migratory whooping cranes in the eastern United States, in which 5 Louisiana sites were considered but none was chosen, due to their proximity to the migration route of the Aransas-Wood Buffalo population (Cannon 1998); formation at the request of G. Archibald in 2001 of the Louisiana Crane Study Group/Louisiana Crane Working Group to develop a list of contacts in Louisiana and to facilitate research and information gathering necessary for assessing the state's potential as a reintroduction site; development of a whooping crane breeding program at the Audubon Nature Institute's Audubon Center for Research on Endangered Species (ACRES) and Species Survival Center in New Orleans; and continued historical research and publication on the White Lake population (Drewien et al. 2001, Gomez et al. 2005). John Lynch's daughter Mary Lynch Courville aided this historical research by making her father's notes and letters available; they provided detail on marsh vegetation and on whooping crane habitat use, nesting, and other behavior.

With renewed interest in Louisiana came repeated visits and aerial inspections of the state's southwestern marshes by Canada-U.S. Whooping Crane Recovery Team (WCRT) leader Tom Stehn, as well as by G. Archibald and additional WCRT members. The WCRT held 2 meetings in Louisiana; the first took place in the New Orleans area (Belle Chasse) at ACRES in January 2001. The second, in Lafayette in February 2007, included field trips to 2 areas under consideration as possible reintroduction sites: White Lake Wetlands Conservation Area (WCA) and Marsh Island State Wildlife Refuge, both owned by the State of Louisiana and administered by LDWF.

Central Louisiana conservation activist Sara Simmonds' recruitment of wildlife biologist Dr. Sammy King of Louisiana State University (LSU)'s Cooperative Wildlife Research Unit and U.S. Geological Survey (USGS) in 2004 proved instrumental in catalyzing research projects requested by the WCRT. This research included King's documentation of migration routes of sandhill cranes (*Grus canadensis*) wintering in southwest and central Louisiana (King et al. 2010), LSU doctoral candidate Sung-Ryong Kang's study of whooping crane food availability in the White Lake marsh (directed by King), and LDWF biologist Jeb Linscombe's study of marsh water levels on the White Lake WCA.

The Louisiana Whooping Crane Partnership, an agency-level organization led by S. King and LDWF's Phil Bowman, held its inaugural meeting at ACRES in May 2008. After Bowman's retirement, successor Bob Love enthusiastically championed the idea of returning a native species to the state. In August 2009 LDWF began to develop a plan for a potential whooping crane reintroduction in Louisiana; these efforts gained approval from the WCRT in April 2010 (Zimorski 2011).

As a result of all these activities, combined with ongoing discussion among the WCRT, USGS's Patuxent Wildlife Research Center, International Crane Foundation, ACRES, USFWS, and LDWF, a formal proposal to reintroduce a non-migratory, nonessential experimental population of whooping cranes in the marshes of the White Lake WCA in southwest Louisiana at last coalesced and was published in the Federal Register in August 2010 (U.S. Department of the Interior, Fish and Wildlife Service 2010). Thanks to the cooperative work of these groups, and to the persistent and multifaceted efforts of LDWF administrators Bob Love and Buddy Baker; Rockefeller State Wildlife Refuge staff and biologists Tom Hess, Jeb Linscombe, Carrie Salyers, and Sara Zimorski; LSU researchers S. King, S. Kang, and Tandi Perkins; and the White Lake WCA crew headed by manager K. Wayne Sweeney and foreman Roger Cormier, the proposal gained traction in Louisiana and moved toward fruition.

Public hearings in Gueydan (near White Lake WCA) and Baton Rouge in September 2010 gleaned public comment on the reintroduction proposal and draft environmental assessment; most comments were strongly supportive of returning native whooping cranes to the state's coastal wetlands. Comments that expressed concern focused primarily on habitat quality, and these were researched and satisfactorily addressed by LDWF and USFWS. In February 2011 the Final Rule establishing the Nonessential Experimental Population of Endangered Whooping Cranes in Southwestern Louisiana, written by Bill Brooks and Deborah Fuller of USFWS (Region 4), was published in the Federal Register (U.S. Department of the Interior, Fish and Wildlife Service 2011). The Final Rule includes additional details on many of these mileposts on the long road to reintroduction.

More than 2 decades of effort and 3 decades of desire culminated with the arrival of 10 juvenile whooping cranes at the White Lake (Florence) Landing south of Gueydan in Vermilion Parish, Louisiana, at approximately 1530 hours on 16 February 2011. The chicks (7 females and 3 males) had been hatched in late May and early June 2010 at USGS's Patuxent Wildlife Research Center (WRC) near Laurel, Maryland, from eggs laid at 3 captive breeding facilities (Patuxent WRC, Calgary Zoo, and Audubon Species Survival Center) and from an egg laid on Necedah National Wildlife Refuge in Wisconsin (Puckett and Whitehead 2011). The costume-reared chicks, each loaded in a wooden crate, had flown from Maryland on a Cessna Caravan single turboprop plane provided by Windway Corporation. After landing at Jennings, Louisiana, just after 1430 hours, the birds were unloaded and driven south to the landing by LDWF staff and administrators. There the White Lake crew, Rockefeller Refuge biologists, and several guests awaited the cranes and their entourage. C. Salyers' sign spoke for us all: it read "Welcome Back to Louisiana."

In silence, the birds' crates were carefully removed from their cargo trailer and carried to a waiting boat, which transported them south along the Florence Canal to the reintroduction site on White Lake WCA, arriving just before 1630 hours. On the sliver of levee between canal and marsh, LDWF staff donned crane costumes (made by a local seamstress who volunteered her talents in support of the project), met for a final whispered meeting, and began the reintroduction. After health checks, each whooping crane was hand-carried to the acclimation pen, which is located in the "refuge" unit of the 28,722-ha (71,000-acre) White Lake WCA. The pen is a large oval enclosure that consists of an outer pen of 0.6 ha (1.5 acres) and an inner, top-netted pen of 21-m radius designed to protect the young cranes from predators.

From the time the first reintroduced Louisiana whooping crane "touched down" in the inner pen at approximately 1700 hours until the last of the 10 birds' toes met the wet mud of the marsh an hour later, LDWF staff worked carefully and efficiently to transfer the birds to their new, yet ancient, home. All present sensed the historic magnitude of the occasion, and as the sun set over the marsh, our mutual feeling upon seeing 10 whooping cranes drinking, preening, and beginning to explore their surroundings was one of satisfaction, joy, and hope.

Several weeks later, on 14 March 2011, the cranes were released from the inner pen and allowed to fly freely. After observing the Louisiana cranes in early April, George Archibald wrote "I had the feeling that the cranes are in their element, that they have the genetic resources to respond in the proper manner to the elements of that fabulous ecosystem, that they are going to do it and flourish without that much help from humans." (G. Archibald, personal communication). These optimistic words echo the sentiments of the reintroduction's Louisiana supporters.

The experiment, of course, is just beginning, and there is much to be learned. LDWF biologists and their research affiliates will continue this story, hopefully for many years to come.

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LITERATURE CITED

Allen, R. P. 1952. The whooping crane. National Audubon Society Research Report 3, New York, New York, USA.

Allender, J., and G. Archibald. 1977. The preliminary proposal regarding the reestablishing of resident whooping cranes in Louisiana. Unpublished report, Audubon Park Zoological Garden, New Orleans, Louisiana, USA.

Cannon, J. R. 1998. Whooping crane wintering sites study. Final Report to Canadian-United States Whooping Crane Recovery Team, Calgary, Alberta, Canada.

Doughty, R. W. 1989. Return of the whooping crane. University of Texas Press, Austin, USA.

Drewien, R. C., J. Tautin, M. L. Courville, and G. M. Gomez. 2001. Whooping cranes breeding at White Lake, Louisiana, 1939: observations by John J. Lynch, U.S. Bureau of Biological Survey. Proceedings of the North American Crane Workshop 8:24-30.

Gomez, G. M. 1992. Whooping cranes in southwest Louisiana: history and human attitudes. Proceedings of the North American Crane Workshop 6:19-23.

Gomez, G. M. 1998. A wetland biography: seasons on Louisiana's Chenier Plain. University of Texas Press, Austin, USA.

Gomez, G. M. 2001. Whooping cranes in southwest Louisiana. Journal of Louisiana Ornithology 5:33-45.

Gomez, G. M., R. C. Drewien, and M. L. Courville. 2005. Historical notes on whooping cranes at White Lake, Louisiana: the John J. Lynch interviews, 1947-1948. Proceedings of the North American Crane Workshop 9:111-116.

King, S. L., A. R. Pierce, K. R. Hersey, and N. Winstead. 2010. Migration patterns and movements of sandhill cranes wintering in central and southwestern Louisiana. Proceedings of the North American Crane Workshop 11:57-61.

Lynch, J. J. 1984. A field biologist. Pages 35-40 *in* A. S. Hawkins, R. C. Hanson, H. K. Nelson, and H. M. Reeves, editors. Flyways: pioneering waterfowl management in North America. U.S. Fish and Wildlife Service, Washington, D.C., USA.

McNulty, F. 1966. The whooping crane: the bird that defies extinction. E. P. Dutton, New York, New York, USA.

Puckett, C. and M. Whitehead. 2011. Bios for the birds: USGS-raised whooping crane chicks leave the nest. Press release. 22 February 2011. U.S. Geological Survey, Reston, Virginia, USA.

U.S. Department of the Interior, Fish and Wildlife Service. 2010. Proposed Rule. Establishment of a nonessential experimental population of endangered whooping cranes in southwestern Louisiana. Federal Register 75:51223-51237.

U.S. Department of the Interior, Fish and Wildlife Service. 2011. Final Rule. Establishment of a nonessential experimental population of endangered whooping cranes in southwestern Louisiana. Federal Register 76:6066-6082.

Van Pelt, A. 1950. Louisiana's lone "whooper" captured. Louisiana Conservationist 2:22,25.

Zimorski, S. 2011. Whooping cranes return to Louisiana. ICF [International Crane Foundation] Bugle 37(2):8.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:76-79

Key words: Louisiana, reintroduction, White Lake, whooping crane.

ASSESSMENT OF THE EASTERN POPULATION GREATER SANDHILL CRANE FALL SURVEY, 1979-2009

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Abstract: The Eastern Population of sandhill cranes (*Grus canadensis tabida*) has been monitored since 1979 with a ground-based survey that involves counting cranes at staging areas throughout their fall migratory range. The fall count suggests the Eastern Population is rapidly increasing, and recently a management plan was developed that includes provisions for harvesting cranes. We analyzed the fall survey data and compared results to the Breeding Bird Survey and Christmas Bird Count to assess a) the population trajectory of eastern cranes, and b) whether the fall survey is adequate to establish harvest limits in the Mississippi and Atlantic flyways. All 3 surveys indicate the Eastern Population has increased 3.4-10.0% annually. The fall survey seemed adequate for tracking population change but did not portray the geographic expansion of the population as well as either the Breeding Bird Survey or Christmas Bird Count. The fall survey lacks statistical rigor and could be improved by revising criteria for site selection, standardizing protocols, and adjusting for counting bias. An aerial survey similar to that used for Midcontinental sandhill cranes could replace the existing fall survey and provide more reliable results but would be expensive to implement and maintain. The Christmas Bird Count is an unattractive alternative to the fall survey because Eastern Population cranes cannot be distinguished from the resident Florida population. The Breeding Bird Survey, in contrast, can distinguish and account for both range expansion and varying density within the breeding range, has a long-term history and standardized protocols, and would involve minimal additional cost.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:80

Key words: Eastern Population, fall survey, *Grus canadensis tabida*, sandhill crane.

FACTORS INFLUENCING GREATER SANDHILL CRANE NEST SUCCESS IN NEVADA

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Abstract: The Lower Colorado River Valley population of greater sandhill cranes (*Grus canadensis tabida*) that nests primarily in northeastern Nevada, is the smallest population of migratory sandhill cranes and has the lowest reported recruitment rate (4.8%) of any crane population in North America. No studies exist that have estimated demographic parameters for this population. Accurate parameter estimates are vital to management of this population. To identify factors limiting recruitment in this population, we monitored 160 greater sandhill crane nests in northeast Nevada during 2009-2010. We used maximum likelihood based approaches in Program Mark to assess models of nest survival and estimate parameters. We estimated daily survival rates from the best supported model corresponding to Mayfield nest success of 36 and 29% for 2009 and 2010, respectively. We found the best supported model describing nest success contained the explanatory variables, year, water depth, vegetation height, and a trend in daily nest survival over a 30-day nesting cycle. Water depth and vegetation height had a significant positive impact on daily survival rates. We found key factors limiting greater sandhill crane nest success may also have the greatest potential for management to improve recruitment. We suggest that landowners reduce rate of water withdrawal and protect areas of dense vegetation.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:80

Key words: *Grus canadensis tabida*, Lower Colorado River Valley population, nest success, Nevada, sandhill crane.

INFLUENCE OF FOOD AND PREDATOR ABUNDANCE ON STRESS LEVELS OF SANDHILL CRANES WINTERING IN NORTHERN MEXICO

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Abstract: Intense and prolonged stress among birds affects survival and productivity. Stress levels, measured as levels of corticosterone hormones, may be influenced by food resources and predator recognition. However, few studies have explored the effects of such conditions on stress in wild birds. We evaluated the relationship between food and predator abundance on stress levels of sandhill cranes (*Grus canadensis*) wintering in wetlands in Northern Mexico during 2 winters, 2007-08 and 2008-09. Corticosterone was measured from fecal samples using an Enzyme Immunoassay (EIA). Cranes wintering in wetlands with low food abundance had higher levels of corticosterone ($\bar{x}$ = 1149.0 ± 328.0 SE), than those in areas with high food ($\bar{x}$ = 99.3 ± 3.4 SE). Cranes wintering in wetlands with high predator abundance showed higher levels of corticosterone ($\bar{x}$ = 1953.0 ± 373.0 SE) versus those in wetlands with low predator abundance ($\bar{x}$ = 116.7 ± 6.2 SE). Our results demonstrate the influence of 2 key environmental factors on stress among wild birds and represent the first account of such influences in cranes.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:81

Key words: corticosterone, food resources, *Grus canadensis*, Northern Mexico, predator abundance, sandhill crane, stress.

A SUSTAINABLE SOLUTION FOR CROP DAMAGE BY CRANES AND OTHER BIRD SPECIES TO PLANTED SEED

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Abstract: Our objectives were to determine if sandhill cranes (*Grus canadensis tabida*) selected emerging corn within and between anthraquinone-treated or non-treated fields, and then to evaluate the efficacy of chemical deterrent methods. We studied the location, habitat, number and behavior of cranes in a 6,500-ha study area during 2006-2009 in south-central Wisconsin. Cranes used corn fields when they were vulnerable to damage (corn emerging day 1-17) more than non-vulnerable corn (emerging day 18-35, $F = 4.39$, $P = 0.04$). Within the period of corn vulnerability to crane damage, no damage to emerging seedlings occurred in treated fields while most non-treated fields were damaged extensively ($F = 45.0$, $P < 0.001$). Crane numbers in treated fields, however, did not differ from cranes using non-treated fields ($F = 0.009$, $P = 0.92$). When in non-treated fields, crane numbers correlated inversely with corn seedling density ($R^2 = 0.84$) but were uncorrelated with seedling density in treated fields ($R^2 = 0.03$). While cranes generally prefer emerging cornfields (i.e., between field selection), the treatment of planted corn *within* a field effectively reduced damage. Unlike other abatement methods, seed treatments reduce damage to germinating corn without affecting crane distribution. Measuring preference at both scales of selection identified key ecological constraints that damage control activities must incorporate to design successful abatement protocols. Most importantly, this technique has been deployed by individual landowners statewide in relation to crane distribution at an ecologically significant scale. Over 57,000 acres of corn were treated in Wisconsin during 2010 alone.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:81

Key words: anthraquinone, chemical deterrent, corn, crop damage, *Grus canadensis*, sandhill crane, Wisconsin.

MODELLING THE EFFECT OF LANDSCAPE AND ENVIRONMENTAL FACTORS ON SANDHILL CRANE DISTRIBUTION IN THE CENTRAL PLATTE RIVER VALLEY OF NEBRASKA

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Abstract: Each spring, most of the midcontinent population of sandhill cranes (*Grus canadensis*) stage in the Central Platte River Valley (CPRV) in Nebraska due to its importance in their annual cycle. The purpose of this study was to model the landscape and environmental factors effecting observed habitat use by cranes. Habitat use models were developed and ranked using Bayesian Information Criteria (BIC) and discriminated using the Receiver Operating Characteristic (ROC) curve. This study suggests cranes show a high preference for alfalfa fields as feeding habitat, but preferences for corn and sorghum fields are similar. Soybean fields were less likely to be used than both corn and sorghum, while winter wheat was the least likely row crop used for feeding. Cranes also showed a low preference for grassland habitats, however, this is likely due to limited grassland availability in the survey area and sampling protocol. The location of these habitats was also an important factor influencing crane use. Habitat use was greatest within bridge segments 2 to 7 and 9, but use decreased as distance from the river increased. Bridge segments 1 and 8 were used similarly, while bridge segments 10 and 11 had the lowest likelihood of use. Overall, it is evident cranes have a higher preference for certain habitats in certain areas. Models developed in this study provide baseline data with a practical use to directly valuate land for cranes within the CPRV, locate areas with the potential to support cranes, and develop management plans for areas currently used.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:82

Key words: Central Platte River Valley, *Grus canadensis*, habitat, landscape, Nebraska, sandhill crane.

DIFFERENCES IN HABITAT USE BY WHOOPING CRANES OBSERVED IN NATURAL AND URBAN AREAS OF TEXAS DURING WINTER 2009-2010

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Abstract: Since 1938 the wild whooping crane (*Grus americana*) population has grown from 18 individuals. Although population growth occurred, available habitat for cranes has decreased, especially on wintering grounds. In response, some cranes now use urban areas in addition to natural winter habitat. Typical winter habitat in natural areas includes bay, marsh, and upland habitats; however, in urban areas these differ from those in natural areas. In urban areas, bay and marsh habitats are reduced and upland habitat includes agricultural fields or private yards where corn feeders are often present. Currently, research is needed to determine habitat use and potential negative threats for cranes frequenting urban areas compared to cranes using natural areas. Here we examine habitat use by whooping cranes in urban and natural areas near Aransas National Wildlife Refuge (ANWR), Texas. Behavioral observations of whooping cranes were collected in natural and urban areas during winter 2009-10. We recorded observations in natural areas (n = 112 observations) and in urban areas (n = 99 observations). Family groups (2 white birds and 1 brown juvenile), adult and/or sub-adult groups (3 or more white individuals), pairs (2 white individuals) and single animals were observed in both areas. In natural areas we observed birds in marsh (n = 91 observations), upland (n = 16 observations), and bay habitats (n = 5 observations), although access to the bay within ANWR was limited. In urban habitats we observed birds in upland (n = 51 observations), marsh (n = 31 observations) and bay habitats (n = 17 observations). Thus, preliminary analysis suggests whooping crane habitat use differs between urban and natural areas.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:82

Key words: Aransas, *Grus americana*, habitat use, urban areas, whooping crane.

MEASURING FECAL CORTICOSTERONE IN WILD WHOOPING CRANES

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Abstract: Non-invasive measures of hormones in animals can be a useful tool for understanding physiological mechanisms that may lead to changes in behavior, survival, and reproduction. Specifically, measures of fecal corticosterone metabolites (CORT), the primary stress hormone in birds, have been correlated with environmental changes, such as food abundance, habitat alteration, and human disturbance. In this study we provide the first measure of fecal CORT for individuals from the wild population of whooping cranes (*Grus americana*). Habitat alteration and urbanization on the wintering grounds are major threats to the wild population of whooping cranes, thus it is important to determine a possible method to assess physiological health of the population using a non-invasive technique. During winter 2009-10, fresh fecal samples (n = 32) (i.e., less than 1 hour old) were collected from accessible areas where whooping cranes were observed within and around Aransas National Wildlife Refuge, Texas. We used an ethanol extraction to isolate endogenous CORT from fecal samples. The enzyme-immuno-assay (EIA) was validated by showing parallel immunoactivity of endogenous CORT to that of the assay standards. Fecal CORT was measureable in wild whooping cranes where mean CORT concentration was 2.14 ng/g feces (± 1.96 SD). Measures of fecal CORT ranged from 7.08 to 0.16 ng/g feces, although there was no significant difference between samples collected from different locations ($F_{8,23} = 0.898$, $P = 0.534$). Future studies will determine whether measures of fecal CORT vary with respect to foraging behavior and structure of whooping crane social groups.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:83

Key words: Aransas, fecal corticosterone, *Grus americana*, whooping crane, wild population.

POTENTIAL IMPACT OF CLIMATE CHANGE SCENARIOS ON WHOOPING CRANES

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Abstract: The whooping crane (*Grus americana*), a rare and critically endangered species, is wetland dependent throughout its life cycle. The whooping crane's small population size, limited distribution, and wetland habitat requirements make it vulnerable to potential climate changes. Climate change predictions suggest overall temperature increases and significant changes in precipitation regimes throughout North America. At the individual level temperature changes should have neutral to positive effects on thermoregulation and overall energy expenditure throughout the whooping crane's range. In the breeding grounds, earlier snow melt and increasing temperatures should improve food resources. However, increased precipitation and more extreme rainfall events could impact chick survival if rainfall occurs during hatching. Increased precipitation may also alter fire regimes leading to increased woody plant abundance thus reducing nesting habitat quality. During winter, higher temperatures will lead to a northward shifting of freeze line which will decrease habitat quality via invasion of black mangrove (*Avicennia germinans*). Large portions of current winter habitat may be lost if predicted sea level changes occur. Stopover wetland availability during migration may decrease due to drier conditions in the Great Plains. Current and future conservation actions should be planned in light of not only current needs but also considering future expectations.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:83

Key words: climate change, *Grus americana*, whooping crane.

WHOOPING CRANE MIGRATION THROUGH THE GREAT PLAINS: CONSERVATION ISSUES

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Abstract: The whooping crane (*Grus americana*) is a critically endangered species with less than 300 individuals left in the wild. Whooping cranes breed in Wood Buffalo National Park in Canada and winter along the Texas coast at Aransas National Wildlife Refuge and surrounding areas. Whooping cranes migrate south every fall and north every spring through the Great Plains. Whooping cranes use shallow wetlands as stopover roost sites while in migration. Information gathered to date via several sources has defined the migratory route and has allowed for identification of important stopover areas which will be presented. Only 4 migratory stopover sites have been designated as critical habitat for whooping in the entire migratory corridor. Therefore, a significant gap remains in regards to protection of migratory stopover areas for whooping cranes. The migration period is the time of the yearly cycle during which most of the whooping crane mortality occurs and is the period of most concern from a conservation standpoint. Issues of conservation concern during migration include high mortality, stopover habitat loss, lack of protection of important stopover areas, and potential future conflicts with renewable energy source infrastructure. The identification and characterization of stopover areas is of critical concern and some suggestions are made for their evaluation, categorization, and prioritization for protection.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:84

Key words: Great Plains, *Grus americana*, migration, stopover areas, whooping crane.

VIDEO SURVEILLANCE OF NESTING WHOOPING CRANES

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Abstract: From 1995 to 2010 we monitored 81 whooping crane (*Grus americana*) nests; of those, only 37 chicks hatched and 11 fledged. It often was not apparent why nests failed and it was not practical to conduct labor-intensive observations at nests; therefore we collected behavioral data using video surveillance cameras at 15 nests from 2000 to 2009. Seven of 15 nests were successful in hatching chicks, while the remaining nests failed during the incubation period. Overall, 1,537.5 and 1,023.5 hours of incubation recordings were examined for successful and failed nests, respectively. No differences were detected in mean incubation bouts (time consecutively sitting on eggs) between successful and failed nests at similar stages in the incubation cycle, suggesting incubation behavior was not the sole cause of nest failure. Average time spent not incubating, however, was significantly different on 4 of 6 days. At failed nests, birds returned to the nest to incubate less frequently due to drought conditions and/or disturbances; likewise, pairs at failed nests appeared to exchange incubation duties infrequently and did not share the duties equally. Among successful nests, mean incubation bouts were 32.5 minutes, although there was a decreasing trend throughout the incubation period. When not sitting on eggs, adults spent on average 1.4 minutes turning the eggs and the mean time neither adult was on nest platform was 1.5 minutes. Video surveillance is a valuable tool for the efficient gathering of behavioral data at whooping crane nests.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:84

Key words: *Grus americana*, incubation, nests, video surveillance, whooping crane.

COPULATION OF NON-MIGRATORY WHOOPING CRANES IN FLORIDA

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Abstract: Information on copulatory behavior and timing before egg laying is poorly known in wild whooping cranes (*Grus americana*). We monitored 10 crane pairs for breeding behavior prior to and during the 2010 breeding season to document timing of copulations and pre- and post-copulatory behavior. We observed pairs at different times of the day and under differing weather conditions to determine if copulations were more frequent during certain daylight hours or during precipitation. Monitoring began 111 days prior to the start of incubation for the first nest of the season. Pairs were observed for 125.78 hours (mean = 75 min) during 100 observation periods; 17 observation periods occurred on days with precipitation. Three copulations were observed, 2 by the same pair and another by unpaired individuals. The copulations by the same pair occurred 9 and 18 days prior to incubation. The third observation was an extra-pair copulation, first ever documented for the species, which occurred between a paired female and lone male. This copulation occurred 3 days after the female's 20-day-old chick was depredated. No copulations were observed on days with precipitation. Due to a low number of copulations, opportunistic accounts (n = 18) within this population also were examined and showed whooping cranes copulate up to 62 days prior to incubation and between 0610 and 1345 hours EST. Our data suggest copulations occur on days without precipitation between early morning and early afternoon hours. Moreover, although cranes are a long-lived, monogamous species, extra-pair copulations do occur.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:85

Key words: copulation, copulatory behavior, Florida, *Grus americana*, incubation, non-migratory, whooping crane.

USING ECOREGIONS TO QUANTIFY CHANGES IN BREEDING SANDHILL CRANE DENSITIES FOR WISCONSIN

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Abstract: To better understand the dynamics of breeding sandhill crane (*Grus canadensis*) densities, we used Annual Midwest Crane Count (AMCC) data and U.S. EPA Ecoregions within Wisconsin to describe potential breeding distribution changes. Crane Count is a long-term citizen science program aimed at providing an estimation of crane densities in Wisconsin through a spring census. We used both the number of pairs (representative of potential productivity) and the total number of cranes (representative of overall crane use) counted per site. Ecoregions, in addition to providing a broad intrinsic descriptor of habitats, have the advantage of providing a more accurate representation of the parts of the landscape that may be relevant to cranes. Though the overall population of sandhill cranes in the state is still increasing, it is not changing uniformly among ecoregions. Crane densities and pair densities increased in several northwestern ecoregions of the state, but densities in the southcentral ecoregions, which hold the highest concentration of cranes, did not change; 1 ecoregion even indicated a significant decline in the number of pairs. The feature common to the regions that show an increase in cranes is a high abundance of lakes; the only ecoregion showing a decrease in cranes is specifically mentioned as having a lower density of lakes than its surrounding regions, evidence that cranes may be adapting to marginal habitats as more characteristic habitats become fully occupied. Ecoregions appear to describe population change in Wisconsin better than political boundaries; future work will include extended areas of the Midwest covered by the AMCC.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:85

Key words: Crane Count, densities, ecoregions, *Grus canadensis*, sandhill crane, Wisconsin.

STATUS OF THE FLORIDA RESIDENT FLOCK OF WHOOPING CRANES

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Abstract: As of 15 January 2011 we are continuing to monitor the remaining 21 (12 females, 9 males) whooping cranes (*Grus americana*) in the reintroduced Florida population. Most birds currently are paired (8 pairs) facilitating continued research on their breeding challenges. Last breeding season we conducted a pilot study to determine the efficacy of using artificial eggs containing temperature loggers to measure incubation temperature in nests of whooping and Florida sandhill (*G. canadensis pratensis*) cranes. The technique will be used to compare incubation temperature and behavior between successful vs. unsuccessful nests and between sandhill and whooping cranes. A single artificial egg was placed into the nests of 5 whooping cranes and 1 sandhill crane, the first time the procedure has been done with any wild crane species. All pairs accepted and incubated the artificial eggs. The most important finding from preliminary examination of plots of incubation temperature showed that in 4 whooping crane nests there was a single large downward spike in incubation temperature that occurred on 1 night. Amount of time off the eggs ranged from 3.12 to 15.30 hours during which the eggs dropped up to 23°C (41°F) below mean incubation temperature (for the period data was recorded). Unusually long lapses in incubation likely affect the hatchability of eggs. This spring we will deploy cameras capable of night-vision near nests to determine the cause of these lapses in incubation. We also will continue to deploy artificial eggs into nests to collect data on incubation temperature.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:86

Key words: artificial eggs, Florida, *Grus americana*, incubation temperature, reintroduced population, whooping cranes.

HISTORICAL BREEDING, STOPOVER, AND WINTERING DISTRIBUTIONS OF A WHOOPING CRANE FAMILY

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Abstract: Between 1977 and 1988, 134 whooping cranes (*Grus americana*) were banded in Canada's Wood Buffalo National Park (WBNP). The historical information collected from 4 banded cranes that hatched from the same nest, at NY-1 (nesting area Nyarling 1), allowed us to track the history of a multi-generation family of whooping cranes. Nine offspring were banded, and 7 other banded cranes were related to them. Thirty years of historical records showed 59 unbanded individuals exhibiting bonds to the banded family. In total, 79 cranes related to the same unbanded nesting pair were reported at WBNP, wintering ground in Aransas National Wildlife Refuge (ANWR), Texas, and along the Central Flyway during migrations. We integrated this information to build a whooping crane family tree, which represents all familial relationships among them up to 4 generations, the number of mates and offspring, years of hatch and death, and other behavioral information. Spatial and temporal information from this family shows the historical distribution and dispersion pattern of winter territories and nesting areas by all descendents of the same family, and site fidelity was shown by males. Nests were established in the Sass River and Klewi nesting areas, and wintering territories were held in Matagorda Island and San Jose within ANWR. Banded family members tended to use the same stopovers repeatedly along the Central Flyway, some of which are not now classified as critical habitat. Evidences of potential inbreeding, adoption, and migration as "extended" family units were obtained. Nesting success and failure synchronicity was observed among family members.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:87

Key words: Aransas, family, *Grus americana*, historical distribution, whooping cranes, Wood Buffalo National Park.

GIS DATABASE DESIGN FOR ANALYSIS OF SUB-SAHARAN AFRICAN CRANE RESEARCH

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Abstract: Much of Sub-Saharan Africa is geographically complex due to significant seasonal differences in precipitation, short- and long-term climate variability, and a diverse cultural and political make-up. Avian responses to dynamic natural systems and ecologists› needs to communicate cross-culturally make it challenging for researchers to accurately map and assess crane populations. The project presented is part of an on-going study geared toward understanding the distribution of Sub-Saharan Africa's 4 crane species (*Balearica pavonina, Balearica regulorum, Bugeranus carunculatus, Anthropoides paradisea)* and where cranes are in need of protection. The objectives of this project were to 1) develop a GIS data layer that depicts Sub-Saharan African crane research, 2) review the data layer for information about crane populations, and 3) find spatial gaps in research. We investigated approximately 300 refereed journal articles and other published literature including technical documents from the International Crane Foundation and the African Endangered Wildlife Trust. We found it challenging to obtain other published information and even more challenging to find spatial information in published records. Analysis of the database revealed that patterns of crane populations are closely linked to the research conducted by only a few researchers that publish most regularly. In addition, most information published involved only 2 of the 4 crane species (*Bugeranus carunculatus and A. paradisea).* Presented are the details of the data layer and fields constructed, results of the data analysis to date, and plans for continuation of the project.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:88

Key words: African cranes, GIS database, Sub-Saharan.

THE EFFECT OF WEATHER ON PRODUCTIVITY IN A GREATER SANDHILL CRANE POPULATION IN SOUTH CENTRAL WISCONSIN

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Abstract: Since 1991 the International Crane Foundation has been marking greater sandhill crane (*Grus canadensis tabida*) breeding pairs and juveniles in a dense population in south central Wisconsin. Currently, 389 individuals have been marked on private lands within a study area of 6,800 ha. In this analysis we focus on the effect of weather on yearly productivity (number of chicks fledged/territory) of marked territorial pairs from 1993 to 2010. Prior to 1993 the number of marked territories was <13 and too small for analysis. Over 18 years, 84 total territories were marked with an average of 40.17 (range = 13-60) territories observed per year. Marked individuals persisted on territories 1-18 years (mean = 8.43). The average productivity was 0.32 chicks fledged per year per territory, with yearly variability ranging from 0.14 to 0.47. Many climatological factors might cause this variation in productivity of greater sandhill cranes. In this study we will show how some specific weather events (snowfall during the previous winter and precipitation, Palmer Drought Severity Index [PDSI], and temperature during the breeding season) influence territory productivity of this dense breeding population.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:88

Key words: greater sandhill crane, *Grus canadensis tabida*, productivity, weather, Wisconsin.

THE USE OF SATELLITE TELEMETRY TO EVALUATE MIGRATION CHRONOLOGY AND BREEDING, MIGRATORY, AND WINTERING DISTRIBUTION OF THE EASTERN POPULATION OF SANDHILL CRANES

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***Abstract*:** The Eastern Population (EP) of sandhill cranes (*Grus canadensis*) is rapidly expanding in size and geographic range. The core of the EP's breeding range spans much of Wisconsin and Michigan in the United States, and most of Ontario in Canada; however, the EP has expanded in all directions as the population has continued to grow. As a result, little is known about the geographic extent of the breeding, migratory, and wintering range of EP cranes as well as migratory chronology and use of primary staging areas. In December 2009, we began trapping EP cranes and deploying solar-powered Global Positioning System satellite transmitters to assess spatial and temporal variation in annual movements. To date, we have trapped and attached transmitters (n = 30) at Manitoulin Island, Ontario; Jasper-Pulaski Fish and Wildlife Area, Jasper and Pulaski Counties, Indiana; and Hiwassee Wildlife Refuge, Meigs County, Tennessee. GPS data are currently being received from CLS America Inc., Maryland, translated by software developed by North Star Science and Technology, Virginia, and analyzed using Environment System Research Institute (ESRI) ArcGIS software. In 2011, preliminary data show that 1 crane remains in Indiana, 1 in Kentucky, 12 in Tennessee, 2 in Georgia, and the remainder in Florida. These data provide the first comprehensive representation of the annual habitats that EP cranes frequent. While subsequent seasons of data collection will provide more robust estimates of range boundaries, these initial data remain particularly pertinent due to the unknown nature of the EP in general.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:89

Key words: Eastern Population, *Grus canadensis*, migration, sandhill cranes, satellite telemetry.

HABITAT USE, MIGRATORY BEHAVIOUR, AND VITAL RATES OF SANDHILL CRANES ON THE NORTH SHORE OF LAKE HURON, ONTARIO

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Abstract: The Eastern Population (EP) of sandhill cranes (*Grus canadensis*) has increased substantially within the last 30 years. In Ontario, numbers have increased from occasional sightings in the early 1980s to nearly 9,000 birds during fall migration in 2009. This rapidly expanding population is now causing agricultural damage, but conservation and management are constrained by the fact that little is known about crane habitat use and migratory movements in Ontario. During July and August 2010, cranes (n = 9) were captured on Manitoulin Island, Ontario, at baited rocket net sites and fitted with solar-powered GPS transmitters. From July to October 2010, age-ratio data were collected and used as an index to fall recruitment (productivity: proportion of juvenile birds). Data from July and August represent southern breeding birds (local), whereas those from September and October represent northern breeding birds (migrant). Lastly, weekly roost surveys were conducted at focal roost sites (n = 6) to determine how roost site characteristics contribute to variation in levels of use (i.e., number of birds). Preliminary results suggest that most local marked birds (n = 6) departed the study area prior to the peak in fall migration (i.e., local birds departed earlier). Marked birds travelled west along Manitoulin Island and south through central Michigan to wintering grounds in southern Florida. In addition, local birds showed lower productivity (mean ± SE) than migrants (n = 889; 8.8 ± 0.41, and n = 4,674; 15.0 ± 0.66, respectively). These preliminary data will provide a basis for future management decisions.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:89

Key words: Eastern Population, *Grus canadensis*, habitat use, Manitoulin Island, Ontario, sandhill cranes.

SEASONAL FECAL CORTICOSTERONE MEASUREMENTS IN WISCONSIN SANDHILL CRANES

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Abstract: Corticosterone is the primary glucocorticoid hormone released by the adrenal gland in birds. Levels of corticosterone exhibit diurnal and seasonal variation, as well as fluctuate under stressful conditions. From May to November 2008 and March to May 2009, fresh fecal samples were collected biweekly at a sandhill crane (*Grus canadensis*) roost on the Wisconsin River near Briggsville, Wisconsin. The birds were visually healthy and in either non-breeding/non-migratory or migratory condition. Fecal samples were analyzed by radio-immunoassay to measure corticosterone. The overall mean corticosterone concentration observed was 13.69 ± 0.83 (SE) ng/g. Corticosterone concentrations varied across collection dates ($F = 8.15$, $P < 0.01$) and season ($F = 11.04$, $P < 0.01$). The mean corticosterone concentration during spring migration was greater than the other 4 seasons ($P < 0.01$). The mean corticosterone concentration during summer was greater than during fall staging ($P = 0.02$). Corticosterone concentrations tended to increase during fall migration compared to the fall staging season ($P = 0.05$). Peaks in corticosterone during spring and fall migratory periods were consistent with similar elevations known from other birds, as well as coincided with colder temperatures known to influence corticosterone levels. Our study provides a preliminary understanding of seasonal baseline corticosterone levels in a well described, healthy, free-ranging crane population. We successfully used a non-invasive sampling scheme that may find applicability to conservation assessments of threatened crane populations.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:90

Key words: corticosterone, *Grus canadensis*, hormone, monitoring, radio-immunoassay.

POPULATION GENETIC STRUCTURE OF THE EASTERN FLYWAY POPULATION OF SANDHILL CRANES

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Abstract: The Eastern Flyway Population (EFP) of sandhill cranes (*Grus canadensis*) suffered a demographic bottleneck in the 1930s. Currently, this population is growing both in population number and geographic range through diffusion from local concentrations that survived the population bottleneck. To determine how these concentrations were historically connected as well as potential source populations for re-colonized areas, we employed Amplified Fragment Length Polymorphisms (AFLP) to determine population genetic structure. DNA samples were collected from 9 areas throughout the range of the EFP. These samples were compared to DNA collected from the Mid-Continent Population (MCP), Central Valley Population (CVP), Pacific Flyway Population (PFP), and non-migratory Florida Population. Within the EFP, there was definite hierarchical structure (average pairwise Fst = 0.1795). Rather than following an isolation-by-distance model, the concentrations were structured based on latitudinal similarity. Concentrations in southern Michigan were clustered together and most similar to a cluster formed by concentrations in south-central Wisconsin and northern Illinois. Concentrations in northwest Wisconsin, Michigan's Upper Peninsula, and southeastern Ontario were also clustered together. Concentrations in central Wisconsin and eastern Minnesota were outliers, but still within the overall cluster of the EFP. The EFP cluster was most closely related to the MCP, the CVP and PFP formed their own cluster, and Florida constituted an outgroup. This latitudinal stratification is interesting considering the belief that Lake Michigan and dense forests in northern Wisconsin serve as barriers to gene flow. Understanding population genetic structure and interactions between these concentrations can be useful in directing management scenarios for the EFP.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:90

Key words: AFLP, bottleneck, Eastern Flyway Population, *Grus canadensis*, population genetic structure, sandhill cranes.

EVALUATION OF THE GENETIC MANAGEMENT OF THE ENDANGERED MISSISSIPPI SANDHILL CRANE

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Abstract: The minimization of kinship in captive populations can be achieved through the use of pedigree information. Pedigree knowledge alone, however, is not sufficient if pedigree information is missing, questionable, or when the founders of the captive population are related to one another. If this is the case, higher levels of inbreeding and lower levels of genetic diversity may be present in the captive population than those calculated by pedigree analyses alone. In this study, we analyzed the genetic status of the critically endangered Mississippi sandhill crane (*Grus canadensis pulla)* using studbook data from the U.S. Fish and Wildlife Service managed captive breeding and release program. In addition to traditional pedigree analyses, we used microsatellite DNA data to provide information on shared founder genotypes, allowing for refined analysis of genetic variation in the population, and providing a new DNA-based studbook pedigree that will assist in the genetic management of the Mississippi sandhill crane population. The genetic variation observed in the Mississippi sandhill crane was then contrasted with the variation observed for Florida sandhill cranes (*G. c. pratensis*). Results show far less variation in the Mississippi population and suggest that while gene flow no longer occurs between the 2 populations, the introduction of cranes from the Florida population would increase the genetic diversity of the Mississippi sandhill crane population.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:91

Key words: genetic management, *Grus canadensis pulla*, microsatellite DNA, Mississippi sandhill crane, pedigree.

MISSISSIPPI SANDHILL CRANE UPDATE 2009-2010

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Abstract: The Mississippi sandhill crane (*Grus canadensis pulla*) is an endangered non-migratory subspecies found on and near the Mississippi Sandhill Crane National Wildlife Refuge in southeastern Mississippi. We continued conservation efforts for the recovery of this population in 2009-2010. To maintain open savanna, we burned 7,600 acres including 76% during the growing season. To restore open savanna, 1,109 acres of woody vegetation were removed using mechanical methods. To bolster the population, we released 19 captive-reared juveniles in 2008-09, and 15 in 2009-10. To protect cranes, nests, and young, we conducted 2,672 trap-nights in 2009, removing 11 large predators and 21 raccoons (*Procyon lotor*). In 2010, contractors conducted 4,954 trap-nights, removing 50 large predators and 98 raccoons. Crane and habitat monitoring assessed life history parameters including radio-tracking, visual observations, and an annual nest census. We collected 3,274 observation records including 1,124 radio-fixes. We captured 6 AHY cranes to band or replace worn or nonfunctional radio-transmitters, all using toe nooses. We discovered 20 AHY carcasses. Of 18 with known or suspected causes of death, 61% were due to predation and 39% to trauma. There were 31 nests in 2009 and 29 in 2010, with 5 total fledglings. The use of 0.4-ha nest barriers showed promise in increasing productivity. The population remained stable at 100-110 cranes.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:91

Key words: *Grus canadensis pulla*, Mississippi sandhill crane, National Wildlife Refuge, update.

USE OF INDIAN TOE NOOSES TO CAPTURE MISSISSIPPI SANDHILL CRANES

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Abstract: In 1998 master bird trapper Ali Hussain traveled to Mississippi to demonstrate traditional trapping techniques including the clap trap, norbans, and toe nooses. Hussain is the last of a tribe of bird trappers from Bihar. He caught over 500 species of birds using their traditional methods with local materials. Each toe noose consists of a 10-cm diameter fishing line loop tied to a 4-mm thick, 6-cm tall support stick. Each noose line consists of 80-120 nooses tied in series. One or multiple noose lines were deployed around bait or in known walking areas to passively capture 1 to 3 target Mississippi sandhill cranes (*Grus canadensis pulla*). We captured 76 AHY cranes using nooses. Since 2005, nooses accounted for 86% of captures. There were no known injuries related to the use of nooses. We recommend nooses as an effective passive capture technique.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:92

Key words: capture technique, *Grus canadensis pulla*, Mississippi sandhill crane, toe noose.

EFFECT OF REARING TECHNIQUE ON AGE OF FIRST REPRODUCTION OF RELEASED MISSISSIPPI SANDHILL CRANES

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Abstract: By the 1970s, there were only 30-35 Mississippi sandhill cranes (*Grus canadensis pulla*) in the wild. To bolster the population of this endangered non-migratory subspecies, 456 captive-reared juveniles were released onto the Mississippi Sandhill Crane National Wildlife Refuge (refuge) from 1981 to 2011 in the largest crane augmentation to date. Both hand and parent-reared cranes were released using an acclimated technique developed for the refuge. Here we continue an earlier comparison in survival between hand and parent-reared cranes to assess age of first reproduction between the 2 rearing techniques. We included 114 nests between 1985 and 2010 involving 53 hand-reared (HR), 54 parent-reared (PR), and 7 wild-hatched cranes. The mean age of first egg was 5.9 years for HR and 5.5 for PR ($P = 0.29$). The mean age at first hatch ($n = 85$) was 6.6 years, with a range of 3-17. Only 24 nests fledged a chick and there was no difference ($P = 0.26$) in mean number fledged/years active nest between HR (0.27) and PR (0.36) cranes. However, in nests with at least 1 wild-hatched adult, recruitment was twice as high as nests where both adults were captive-reared. This may suggest challenges for success in re-introduction versus supplementation efforts.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:92

Key words: *Grus canadensis pulla*, hand-reared, Mississippi sandhill crane, parent-reared, rearing technique, reproduction.

ANNUAL RECRUITMENT AND BROOD SIZE OF GREATER SANDHILL CRANES IN MICHIGAN

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Abstract: Documenting long-range recruitment rates is important for understanding population fluctuations and trends of the Eastern Population of greater sandhill cranes (*Grus canadensis tabida),* especially now that hunting is proposed for this population. Counts of cranes in juvenile or adult plumage were made in south central Michigan fields. Brood size was recorded 15 August through September, 1988-2010. Recruitment was estimated from age ratio (juveniles/total cranes × 100) counts of all cranes sampled 15 August through November, 2003-2010. Mean annual recruitment rate weighted by year was estimated at 11.0 ± 2.0 (SE) juveniles based on a sample of 12,057 cranes. During the pre-staging period (15 Aug-Sep) recruitment was estimated to be 10.5 ± 2.4 compared to the staging period (Oct-Nov) recruitment rate of 11.6 ± 2.1. The mean brood size weighted by years for 407 pairs with young was 1.30 ± 0.14 young/pair with 71% of the pairs fledging 1 young, 29% 2 young, and 0.2% fledged 3 young. The annual percentage of broods with >1 young was positively correlated with annual fall age ratios ($r = 0.99$, $P < 0.01$) during 2003-2010.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:93

Key words: brood size, Eastern Population, greater sandhill cranes, *Grus canadensis tabida*, recruitment.

GENETIC INFLUENCES ON FERTILITY AND LONGEVITY IN THE CAPTIVE BREEDING POPULATION OF THE MISSISSIPPI SANDHILL CRANE

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Abstract: Data from the studbook for the captive breeding population of the Mississippi sandhill crane (*Grus canadensis pulla*) was analyzed to determine if genetic factors influenced the fertility of eggs and survival of hatched individuals. A total of 19 sires and 23 dams were represented by enough offspring for analysis. Egg fertility was generally high among both sires and dams, although a few sires produced few or no fertile eggs. This is likely not representative of the true variability in fertility, as low fertility individuals were quickly excluded from the breeding program. Longevity was highly variable, with mean longevity of offspring reaching a maximum of 6.7 years for 1 sire. However, 2 sires and 1 dam produced offspring surviving less than 1 year on average. The results suggest that genetic factors may influence the life history traits of captive-bred individuals. A quantitative genetic analysis to estimate heritability of life history traits is currently underway.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:93

Key words: captive breeding, fertility, genetic factors, *Grus canadensis pulla*, longevity, Mississippi sandhill crane.

MOVEMENTS AND HOME RANGE SIZE OF GREATER AND LESSER SANDHILL CRANES WINTERING IN CENTRAL CALIFORNIA

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Abstract: We assessed landscape use of sandhill cranes (*Grus canadensis)* wintering in the Sacramento-San Joaquin Delta region of California and compare movement patterns of sympatric greater (*G. c. tabida)* and lesser sandhill cranes (*G. c. canadensis*). State-threatened greaters showed stronger fidelity to wintering sites and moved between discrete wintering areas less frequently as 8% of the greaters used more than 1 wintering region compared to 43% of the lessers. Average flight movements (commuting distance) between night roost sites and feeding areas were about half the distance for greater sandhill cranes (2.1 km) compared to lesser sandhill cranes (5.0 km), and winter home ranges were nearly one-ninth the size (2.2 km^2). These results have application for conservation of wintering cranes at a landscape scale, and we recommend that habitat protection and restoration for the threatened greater subspecies be prioritized for areas within 2 km of existing traditional roost sites to ensure a high probability of use. In addition, providing new roost sites towards the edge of the current range of greater sandhill cranes will allow them access to additional agricultural fields and will possibly increase the carrying capacity of their winter range. Conservation of habitat for lessers could take a broader landscape approach, with a focus on sites within 5 km of roost sites.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:94

Key words: California, greater sandhill cranes, *Grus canadensis* canadensis, *Grus canadensis tabida*, lesser sandhill cranes, movements, Sacramento-San Joaquin Delta, wintering.

HEALTH MANAGEMENT FOR REINTRODUCED WHOOPING CRANES IN WISCONSIN 2005-2010: DIRECT AUTUMN RELEASE

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Abstract: Between 2005 and 2010, 63 (27 male, 36 female) costume-reared whooping cranes (*Grus americana*) were assigned to the Direct Autumn Release project of the Whooping Crane Eastern Partnership for intended release in October of their hatch year. Regular preventive health screening and pre-release evaluations were used to maximize survival and fitness prior to release and to minimize transfer of potential disease agents to native habitats. A total of 44 clinically normal birds were released at the Necedah NWR in central Wisconsin following extensive hematological, blood biochemical, toxicological, serological, parasitological, and microbiological evaluation. Instances of morbidity during captivity were categorized by primary body system affected (in descending order of occurrence): musculoskeletal, respiratory, systemic, integumentary, gastrointestinal, oral, and ocular. Musculoskeletal abnormalities included linear limb rotation, angular limb deformity, carpometacarpal rotation (angel wing), muscle rupture, and fracture. Five birds were removed from the project prior to scheduled release, all for musculoskeletal abnormalities that prevented normal function. Fourteen birds died or were euthanized prior to release; pre-release mortality was attributed to developmental abnormality, predation, trauma or infectious disease. Cases of infectious disease were dominated by chronic respiratory aspergillosis ($n = 7$). Post-release mortality was caused by predation and trauma; no evidence of infectious disease of captive origin was detected. The data collected from this project have helped produce a picture of captive whooping crane flock health, provided hematological and biochemical reference ranges, elucidated the main causes of project morbidity and mortality, and should aid in evaluating management factors impacting pre- and post-release success.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:94

Key words: aspergillosis, *Grus americana*, health management, pathogen transfer, preventive medicine.

LANDSCAPE USE AND MOVEMENTS OF SANDHILL CRANES USING THE HORICON MARSH, WISCONSIN, DURING FALL ROOSTING AND STAGING

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Abstract: The Horicon Marsh in southeastern Wisconsin is the largest cattail (*Typha latifolia*) marsh in the lower 48 states, providing important habitat for sandhill cranes (*Grus canadensis*) during fall roosting and migration staging. Adjacent agricultural fields, small wetlands, and grasslands offer essential food resources. Eighty-six commercial wind turbines have been erected 3.2 km northeast of the marsh in areas cranes are known to use. We studied crane movements across this landscape in fall 2009 and 2010 to assess the risk of turbine encounters and habitat avoidance associated with wind energy development. Timing of flights to and from the roost were predictable with sunlight, but shifted slightly during inclement weather. Foraging cranes primarily were found in harvested corn and soybean fields, although cranes habitually used certain areas regardless of crop type. Over 70% of observations were within 3.2 km of the refuge boundary. Using portable marine radar, we observed that cranes flew lower than 250 m, directly to and from the refuge at about 53 km/hour. Flight directions were mostly east-west in 2009 and more variable in 2010. In 2009 fewer fields were available because very wet weather greatly delayed harvest, whereas 2010 harvest was 30% ahead of normal due to dry conditions. Furthermore, the location of the main roost was static in 2009, and in 2010 the main roost moved several hundred meters north after an extreme windstorm during late October 2010. Cranes seem to perceive and avoid turbine rotors but were rarely found in fields with turbines.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:95

Key words: *Grus canadensis*, Horicon Marsh, migration staging, sandhill cranes, wind turbines, Wisconsin.

THE ROLE OF THE CENTRAL PLATTE RIVER VALLEY TO THE MIDCONTINENT POPULATION OF SANDHILL CRANES IN THE 21ST CENTURY

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Abstract: The Midcontinent Population (MCP) of sandhill cranes (*Grus canadensis*) is the largest and most wide ranging population of cranes in the world with major breeding grounds located on 2 continents and 3 nations. I examine underlying factors that have led to development of this exceptionally strong spring staging tradition in the Central Platte River Valley (CPRV), describe temporal and spatial aspects of use by each subspecies and subpopulation, and evaluate factors that are limiting crane use. Cranes have successfully adapted to massive habitat change in the CPRV over the past 70 years and continue to be challenged by new developments which I will address. Aided by new technology, I follow the cranes throughout the annual cycle, identifying major breeding grounds, key spring and fall stopovers, and wintering areas, along with key habitat resources supporting the MCP. We have documented a much larger number and wider breeding distribution of sandhill cranes in northern Russia than previously thought, and I will describe a 2009 expedition that led to the discovery of the species breeding westward to near the Lena River Delta. The focus will be primarily on research results having important implication to sandhill crane management. Although the trajectory of MCP growth over the past 70 years reflects a major conservation success story, climate change, energy development, and intensification of agriculture could pose potential long-term threats to the Population which I will discuss. [Plenary presentation at opening of Workshop]

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:96

Key words: Central Platte River Valley, *Grus canadensis*, Midcontinent Population, Russia, sandhill cranes.

IMPLEMENTATION OF THE WHOOPING CRANE MONITORING PROTOCOL ALONG THE PLATTE RIVER, NEBRASKA

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Abstract: Assessment Impact Monitoring Environmental Consultants (AIM) was contracted by the Platte River Recovery Implementation Program to implement the protocol entitled *Monitoring Whooping Crane Migrational Habitat Use in the Central Platte River Valley* during the spring (21 Mar-29 Apr) and fall (9 Oct-10 Nov) migrations. During 2001-2011, we aerially surveyed a 145-km (90-mile) stretch of the Platte River from Lexington to Chapman near sunrise. In any given survey 62-94% of the scheduled flights were completed. Of transects scheduled, 2,163 of 2,920 (74%) were flown covering about 156,646 survey km (97,335 miles). A total of 167 individual whooping cranes (*Grus americana*) was documented (135 adults: 32 chicks). The frequency of sightings was: FO = 0.09 (0.1-0.35) sightings per transect and 1 sighting per 760 km flown. The largest group = 11; most seen in a migration = 36; most crane-use days = 121 days. There were 738 crane-use days (spring = 407; fall = 331). From 0.5% to 13% (mean = 4%) of the population stopped along the Platte River. Totals of 750 hours of time-budget and 897 hours of habitat use data were collected. Diurnal activities ranged from 0 to 10.3 km from nocturnal roost sites. Over 67% of diurnal habitat use was corn, river was 19%, and lowland grass was about 2%. Corn was used nearly 2.5 times more in spring than fall, and river was used 9 times more in fall than spring. Length of stay for a group was 2-26 days.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:96

Key words: *Grus americana*, migration, monitoring protocol, Platte River Recovery Implementation Program, Platte River Valley, whooping crane.

NEW RECORDS OF WINTERING GROUNDS FOR SANDHILL CRANES IN MEXICO

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Abstract: Although the sandhill crane (*Grus canadensis*) is considered a threatened species in Mexico, there is no detailed information on its present winter distribution and on the description of wetlands where cranes had not been previously recorded. This information would be important for making decisions for management and conservation plans. Our objectives were to update current range and identify new wintering areas for the sandhill crane in Mexico and to characterize wetlands where they roost in winter. Wetlands were surveyed by ground (52) and by air (83) covering the Chihuahuan Desert in the states of Chihuahua, Coahuila, Nuevo Leon, Durango, San Luis Potosi, Zacatecas, and Guanajuato. Sandhill cranes were recorded in 31 wetlands of which 13 were new location records for Mexico and extended the present distribution 237 km farther south. All wetlands have human activities surrounding them and some are near urban centers, which give insights about the threats that wetlands are facing at present. Studies to assess the wintering areas and sandhill crane migratory pathways are important, not just for conservation of the cranes, but also to protect other species that depend on the desert wetlands in northern Mexico.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:97

Key words: *Grus canadensis*, Mexico, sandhill crane, wintering areas.

SANDHILL CRANES BREEDING IN NEW ENGLAND: AN UPDATE

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Abstract: Sandhill cranes (*Grus canadensis*) breeding in New England have slowly increased in abundance and distribution since the first documented nesting in Maine in 2000. At least 6 territorial or nesting pairs were present at 6 sites in Maine in 2010, and single pairs nested in 2009 and 2010 at single sites in Massachusetts and Vermont where nesting has occurred since at least 2007. Of 23 nests observed in 9 wetlands in Maine, Massachusetts, and Vermont between 2001 and 2010, 6 were in lakeside marshes, 5 were in riverine marshes, 8 were in lakeside fens or bogs, and 4 were in beaver-impounded palustrine marshes. Dominant vegetation within 5 m of nests was either cattail (*Typha* spp.), or varying proportions of sedges (*Carex* spp.), leatherleaf (*Chamaedaphne calyculata*), sweetgale (*Myrica gale*), and sphagnum. Wetlands used for nesting ranged in area from 2 to 200 ha. Measures of pH within 50 m of nests ranged from 4.8 to 9.7. At least 22 of 29 (76%) nest attempts between 2000 and 2010 hatched 1 or 2 eggs. In at least 14 instances, chicks survived to at least 8 weeks of age, including 5 2-chick broods. Chick survival was higher for pairs nesting and raising chicks on large, open wetlands along edges of lakes and rivers than for pairs at smaller palustrine wetlands. Reports of sandhill cranes in all 6 New England states have increased in frequency over the past 2 decades. Observed patterns of habitat use suggest that New England can support a large and widely distributed breeding population of sandhill cranes.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:97

Key words: breeding, *Grus canadensis*, New England, sandhill cranes.

EFFECTS OF WIND FARMS ON WINTERING SANDHILL CRANES IN THE SOUTHERN HIGH PLAINS OF TEXAS

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Abstract: Texas has been shown to have a superior annual capacity for wind power and this capacity has led to the erection of multiple wind farms across Texas with many more facilities planned. Wind energy is vital for a shift to carbon-emission free energy, however there has been relatively little research investigating the effect of wind farms as disturbance factors across the landscape. This project examines how wind energy infrastructure affects sandhill crane (*Grus canadensis*) behavior including landscape level habitat uses. Sandhill cranes are known to avoid human disturbance, and wind farms have been shown to render surrounding habitat of up to 1 km unsuitable through direct effects (destroying habitat) and indirect effects on bird behavior (avoidance). We examined the distribution of cranes at multiple wind farms in the southern High Plains of Texas. We evaluated the effects wind farms have on roost occupancy, habitat use, and crane behavior by comparing areas with wind turbines to those without for presence of cranes at roosting sites and behavior of cranes at foraging sites. Preliminary findings showed that cranes were found less likely to forage within 2 km of the wind farms and exhibited a clumped distribution when found near wind farms. Additionally, cranes foraging within 2 km of the wind farms spent more of their time being vigilant and less time loafing than the cranes outside the 2 kilometers. These findings, along with further analysis, can be used to predict areas of avoidance and help preserve important crane habitat in a rapidly developing landscape.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:98

Key words: *Grus canadensis*, High Plains, New England, sandhill crane, Texas, wind farms.

TERRITORY HISTORIES OF FLORIDA SANDHILL CRANES: 1980-2006

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Abstract: Fifteen nesting territories of Florida sandhill cranes (*Grus canadensis pratensis*) were monitored for a total of 132.3 crane nesting years during the 1980s and 1990s. During this time 105 nesting attempts produced 34 fledged chicks; there were 26 mate changes among the pairs. Seven territories were abandoned by the original pair but were reoccupied by another pair, sometimes after an interval of only a few days. Territory boundaries remained unchanged during the nearly 20 years we observed these territories. Rapid repairing following death or divorce or the quick occupation of an abandoned territory by another pair are likely reasons we found the boundaries of the 15 territories to be more constant than individual pair membership. We revisited the 15 longest monitored territories in fall 2005 and during the 2006 nesting season. Seven of the territories appeared to have a sufficient amount of the wetland and upland habitat needed to support a nesting pair of cranes, and 6 of them were occupied during the 2006 nesting season. The remaining 8 territories appeared to be unusable; 6 had upland foraging habitat but no suitable nesting habitat, in 1 both wetland and upland foraging habitats were overgrown, and in the other, upland foraging habitat had been converted to a series of small fenced paddocks.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:98

Key words: *Grus canadensis* pratensis, Florida sandhill crane, territory histories.

UPDATED EASTERN SANDHILL CRANE RANGE MAPS

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Abstract: The breeding, wintering, and migrating range of the Eastern Migratory Population (EMP) of greater sandhill cranes (*Grus canadensis tabida*) is located within the Mississippi and Atlantic Flyways. Historically, the majority of the EMP bred across the Great Lakes Region (primarily Wisconsin and Michigan) and wintered in southern Georgia and Florida. The population is currently expanding and re-colonizing former breeding and wintering areas. We attempt to delineate the expansion of the EMP by developing an updated breeding and wintering range map for the subspecies. Christmas Bird Count (CBC) data from 2006 to 2010 was used to determine the current status and migratory trends of bird populations during the winter season. The North American Breeding Bird Survey (BBS) from 2000 to 2010 was used to describe breeding areas. Data sets were sorted by location and mapped by density. The majority of the winter distribution of EMP cranes (86%) winter in Alabama, Georgia, Florida, and Tennessee. Smaller concentrations of birds are expanding their wintering ranges east into the Carolinas and west into Mississippi and Louisiana. More and more EMP birds are also remaining later in more northerly areas of the wintering range (Michigan, Ontario, Wisconsin). BBS data confirm that the breeding range has expanded to include many northeastern and midwest states and Maritime Canadian provinces. Accurately measuring the expansion of this subspecies population is an important step in fine-tuning future management plans.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:99

Key words: Eastern Migratory Population, expansion, greater sandhill cranes, *Grus canadensis tabida*, range.

HEMATOLOGY AND SERUM CHEMISTRY RESULTS FROM EXPERIMENTAL EXPOSURE OF SANDHILL CRANES TO WEST NILE VIRUS

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Abstract: West Nile virus is a deadly virus for young cranes. In testing 2 different vaccines on both adult and juvenile sandhill cranes (*Grus canadensis*), we discovered that some blood parameters are altered by exposure to the virus. White blood cell counts were the most obvious and may be used as an indicator of West Nile virus exposure in cranes. Other hematology and serum chemistry results were studied and only hematocrit, percent heterophils, and percent lymphocytes were of interest, along with the already published information on titers encountered in experimental infections. Clinical pathology results showed challenged cranes, whether vaccinated or not, had a decrease in their hematocrits and an elevation of 2.5-fold in their white blood cell counts as compared to unchallenged control sandhill cranes. No differences were apparent in the differential counts of heterophils and lymphocytes. Our work would suggest that a combination of white blood cell counts and antibody titers can be used to diagnose and assess the severity of West Nile virus infections in cranes.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:99

Key words: flavivirus, *Grus canadensis*, hematocrit, hematology, sandhill crane, WBC, West Nile virus, white blood cell count.

PHOTOPERIOD AND NESTING PHENOLOGY OF WHOOPING CRANES AT TWO CAPTIVE FACILITIES

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Abstract: Increasing daylight is known to be a breeding stimulus in many avian species breeding in northern latitudes. This is thought to be true for cranes that breed in such latitudes including the whooping crane (*Grus americana*). For this reason, the captive breeding centers use artificial light to lengthen daylight hours, but no study has been done to examine the effect of such lighting on the reproductive season. We examined the past light cycles and breeding season results from whooping crane pairs at USGS Patuxent Wildlife Research Center and the International Crane Foundation (ICF). At Patuxent 2 lights were used to produce light of 170 lux in the pens. On average, photoperiod lights were turned on 17 February (range 11-24 Feb). With 2 lights per pen, whooping cranes laid their first egg on average 10 days earlier than when 1 light was used and 16 days earlier than when no lights were used. At ICF the difference between lights on a pen and no lights was only 8 days difference in first lay dates, but still this was statistically significant.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:100

Key words: artificial light, captive breeding, *Grus americana*, photoperiod, whooping crane.

PROTOCOL AND RESULTS FROM THE FIRST SEASON OF CAPTIVE REARING WHOOPING CRANES FOR A NON-MIGRATORY RELEASE IN LOUISIANA

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Abstract: During 2010 we successfully reared 10 whooping cranes (*Grus americana*) for a non-migratory release at White Lake Wetlands Conservation Area, Louisiana. The last wild whooping crane in the flock that inhabited that area was captured in 1950. Once in private corporate hands, the area is currently owned and managed by the Louisiana Department of Wildlife and Fisheries. That organization, along with Louisiana State University, USGS Louisiana Cooperative Fish and Wildlife Unit. and USGS Patuxent Wildlife Research Center (PWRC) partnered to arrange this reintroduction. Eggs originated from Audubon Species Survival Center, Calgary Zoo, PWRC, and abandoned nests of the Eastern Migratory Population (EMP) and were incubated under either whooping cranes or sandhill cranes for the first half of incubation before transfer to artificial incubators. Twelve chicks hatched in May and June 2010; one with scoliosis was euthanized and another was retained in captivity due to genetic considerations. PWRC caretakers costumed-reared chicks with modified procedures used to rear Mississippi sandhill cranes (*G. canadensis pulla*) and whooping cranes for the Florida Non-migratory Population and EMP. All chicks were housed near adult whooping crane imprint models. At 6.4 ± 1.4 days of age, chicks were taken on foraging trips. Socialization with other chicks was initiated at a mean age of 15.5 ± 5.0 days. Exposure to water during the foraging walks was also initiated during the third week. Foraging and walking trips continued until 46.1 ± 5.6 days-of-age. Formal socialization activities ended at 49.7 ± 10.1 mean days-of-age. Health examinations continued twice weekly and included vaccinations for eastern equine encephalitis and West Nile virus. Chicks were moved to outdoor pens, first to dry pens, and by 53.2 ± 3.4 days of age to pens with 10-m-diameter ponds. The 10 whooping cranes were flown to Louisiana in mid-February and released in early March.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:100

Key words: captive rearing, *Grus americana*, Louisiana, non-migratory, protocol, reintroduction, whooping crane

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COMPARISON OF BEHAVIORS OF CRANE CHICKS THAT WERE PARENT-REARED AND REARED BY COSTUMED HUMANS

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Abstract: USGS Patuxent Wildlife Research Center in Laurel, Maryland, uses 2 primary methods to rear crane chicks. Some chicks are reared by parent or foster parent whooping cranes (*Grus americana*) or sandhill cranes (*G. canadensis*), while other chicks are reared by humans wearing mock crane costumes and holding puppet heads. We have used both techniques to successfully rear and release Mississippi sandhill cranes (*G. c. pulla*) and whooping cranes for release in non-migratory situations. However, for the migratory releases of the Whooping Crane Eastern Partnership (WCEP) population, we have always costumed-reared birds and trained them to follow ultralight aircraft or other whooping cranes on their first southward migration. We are planning to use parent-rearing methods to supplement the eastern migratory population of whooping cranes in the future. In 2010, in preparation for parent-rearing whooping crane chicks, we gave 6 pairs of captive whooping cranes a sandhill crane chick to rear. We then compared results for survival, behavior, and health testing with costume-reared chicks from the same year. All 6 parent-reared chicks survived to fledge, versus only 25 of 30 costume-reared chicks. In addition, parent-reared chicks spent significantly more time hock-sitting and less time standing than did the costume-reared chicks. Parent-reared chicks also spent significantly more time foraging and being vigilant and less time preening. In the future, we hope to test the parent-rearing technique with whooping crane chicks that can then be released with wild adults in the fall and learn the migration route.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:101

Key words: costume-rearing, crane chicks, parent-rearing, Patuxent.

MIGRATION ECOLOGY OF THE ARANSAS-WOOD BUFFALO POPULATION OF WHOOPING CRANES

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Abstract: The Aransas-Wood Buffalo Whooping Crane Tracking Project is a collaborative effort among the Platte River Whooping Crane Trust, U.S. Geological Survey, Platte River Recovery Implementation Program, U.S. Fish and Wildlife Service, and Canadian Wildlife Service. Project objectives include identifying and describing migratory pathways, migration chronology, habitat use, and stopover sites used by whooping cranes during fall and spring and assessing potential risks to the birds during migration. GPS-platform transmitter terminals deployed are able to acquire 4-5 locations per day for 2+ years; thus, data gathered using this new technology will be useful for informing future recovery efforts. During spring 2010, 2 birds departed Aransas on 19 March, moved separately through the migration corridor, and arrived at Wood Buffalo on 17 and 18 April. After successful marking of juveniles in late summer 2010, we monitored 11 birds during fall migration. Birds departed from breeding grounds between 15 September and 2 November and migrated for an average of 35 days. These preliminary results will be updated as the project progresses and more data are collected.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:101

Key words: Aransas-Wood Buffalo Population, migration, Whooping Crane Tracking Project.

ASSESSING BREEDING WHOOPING CRANE HABITAT USE TO CHOOSE ALTERNATIVE RELEASE SITES IN WISCONSIN

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Abstract: In fall 2010, the Whooping Crane Eastern Partnership (WCEP) began its second decade of introducing a migratory population of whooping cranes (*Grus americana*) to eastern North America. This population has had high subadult and adult survivorship but very low productivity (3 fledged chicks over the course of the project), generally thought to be a result of the cranes abandoning their nests part-way through incubation. Using monitoring data from the core reintroduction area of Wisconsin, we analyzed the habitat selection of breeding whooping cranes of the reintroduced eastern migratory flock. First, a spatially based regression was used to model the habitat use of the whooping cranes. Key findings include that breeding whooping cranes are strongly choosing cropland as their preferred habitat outside of Necedah NWR, and open water is consistently associated with increased likelihood of breeding whooping crane presence. The results of this model were then used, along with average size of current breeding territories in Necedah NWR (166 ha), to identify potential reintroduction sites in other areas of Wisconsin by searching for wetlands meeting criteria developed from actual crane habitat use. Six areas were identified in the east-central portion of the state that met basic biological criteria we could measure. We ran a habitat suitability model (HSM) comparing the habitat composition of east-central Wisconsin with the average characteristics found in reintroduced whooping crane nesting territories from Necedah NWR. The HSM identified 3 large wetland complexes in the study area, roughly corresponding to areas associated with the Fox, Wolf, and Rock rivers.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:102

Key words: eastern migratory flock, *Grus americana*, habitat suitability model, reintroduction sites, Wisconsin, whooping crane,

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WHOOPING CRANES IN FLORIDA: WEATHER OR NOT CLIMATE MATTERS?

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Abstract: Historical evidence suggests that numbers of reproductive whooping cranes (*Grus americana*) were never very large in the southern United States. Because the genetic source of cranes reintroduced into Florida originated mostly from much higher latitudes than in Florida, we might expect that birds would be predisposed to greater reproductive success in cooler climates during laying and incubation. Warmer extremes of temperature and higher humidity might explain the poor reproductive success of reintroduced birds breeding in Florida. A retrospective look at the reproductive parameters of the reintroduced flock indicated that a number of factors were contributing to the overall low success. They include low survival, especially of males (high predation, traumatic death), reproductive dysfunction (congenital defects, inappropriate pairing behavior. infertility), and poor nest survival (low hatching rate, nest disturbance, intraspecific aggression). To address the low hatching rate we examined historical weather parameters for any association between hatch failure and extreme temperature, rainfall, and humidity events and failed to find them. However, a strong positive correlation association with winter rainfall and water levels prior to nest initiation was discovered. This indicates that physiologic and behavioral condition (neuroendocrine health) of the pair may be more important than the direct impact of weather conditions on the incubation process. In addition to its impact on hatching success, rainfall and water level variations may account for some of the reproductive dysfunction observed. Thus the forecasted increase in frequency of periodic droughts is likely to be a significant limiting factor in the survival of reproducing whooping cranes in Florida.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:102

Key words: Florida, *Grus americana*, reintroduced, reproduction, weather, whooping cranes.

CHANGING RAINFALL PATTERNS VERSUS WETLAND ATTRITION: WHAT AFFECTS LARGE WATERBIRD BREEDING SUCCESS MORE IN THE GANGETIC FLOODPLAINS, INDIA?

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Abstract: Waterbird breeding success, especially in cultivated landscapes, is affected by rainfall and agricultural intensification. Extreme rainfall events and agricultural expansion are predicted to occur in north India following global temperature rise. How will these changes affect breeding success of 2 resident large waterbirds of conservation concern: black-necked storks (BNS, *Ephippiorhynchus asiaticus*) and Sarus cranes (SC, *Grus antigone*)? I explored this question with observations on territorial pairs (BNS = 29; SC = 253) over 8 years between 1999 and 2010 in the southwestern Gangetic floodplains. I used logistic regression and generalized linear mixed models to understand factors (wetland extent and attrition in territories, 2 variables describing rainfall) affecting breeding success (whether or not pairs succeeded in raising chicks), and employed multi-model selection with Akaike's Information Criteria to make inferences. Annually 7-10% of territories of both species suffered wetland attrition, and urbanization permanently displaced 0.7% of SC pairs. Model selection supported the combination of habitat quality and rainfall as affecting breeding success of both species. Ability of pairs to successfully have chicks improved with increasing territory quality and rainfall, but declined with wetland attrition in territories. Increased cultivation, wetland attrition, and extreme rainfall occurred during the study, providing insights into future conditions. Predicted future increase in dry years can reduce waterbird breeding success, and wet years can likely buffer this effect. However, while climate change adaptations are deserving of focus, habitat loss due to agricultural intensification deserves far more urgent attention here if large waterbirds are to continue persisting.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:103

Key words: agricultural intensification, black-necked storks, breeding success, Gangetic floodplains, *Grus antigone*, India, rainfall, Sarus cranes.

CRANES AND CLIMATE CHANGE: A FACT SHEET

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Abstract: Due to increasing human activities and climate change, wetland habitats are worldwide disappearing, and many water bird species experience serious population declines. The family of cranes mostly depends on wetland habitats and is accordingly sensitive to climatic fluctuations. The objective of our project is to gather information on the 15 crane species, and to summarize actual facts and predictions about climate change effects on cranes. Further, conservation implications shall contribute to wetland conservation, using cranes as flagship species. The preliminary results consist of information on 4 species. For the Eurasian crane (*Grus grus*), increasing temperatures lead to a northward shifting of wintering grounds and earlier spring arrival dates, but also to a higher risk of drought on the breeding grounds. The whooping crane (*G. americana*) is affected by reduced precipitation and warmer temperatures leading to habitat loss on breeding, stop-over, and wintering sites. In India and Western China, the Sarus (*G. antigone*) and the black-necked crane (*G. nigricollis*), respectively, seem not as much affected by climate change as by intensification of agriculture. In contrast to the high variability of existing climatic scenarios, the effects of global change on cranes might lead to 3 major trends: Breeding habitat loss is expected for several species due to decreasing spring precipitations. Wetland loss along the flyways might reduce the survival rates of migratory species. Wintering ranges of several species might shift northward due to warmer temperatures. One major conservation implication to prevent wetland loss is an enhanced water management in all crane habitats.

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Key words: black-necked crane, climate change, Eurasian crane, *Grus*, Sarus crane, water management, wetland loss, whooping crane.

MOVEMENTS AND HABITAT USE OF THE BROLGA IN SOUTH WEST VICTORIA, AUSTRALIA

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Abstract: The south-western Victorian region of Australia supports a threatened population of the brolga (*Grus rubicunda*). The species is under threat from loss of habitat and poor breeding success and recruitment due to predation and collision with fences and power lines. A new potential threat has recently emerged due to the proliferation of wind farm developments within the brolga's key habitats. The species is considered to be at risk of collision with wind farm infrastructure. Disturbance and displacement from key habitats may also negatively affect the species. Lack of information on the brolgas' movements makes it difficult to assess the potential impact of wind farms on this population and to develop appropriate management strategies and mitigation measures. This study investigates movements of brolgas to define their spatial requirements, habitat use, and movement corridors. Brolgas were captured and fitted with GPS satellite transmitters and colour bands. GPS transmitters were programmed to log the location of the bird 4 times a day. Preliminary results indicate that brolgas utilize an area of up to 5-6 km at non-breeding sites and 2 km at breeding sites, and that they utilize similar flight paths between non-breeding and breeding areas. The outcomes of this study will be used to design turbine-free buffer zones around key breeding and non-breeding areas, thus aiding in wind farm planning to avoid long term population impacts.

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Key words: Australia, brolga, *Grus rubicunda*, habitat use, movements, Victoria, wind farms.

AERIAL CENSUS OF BROLGA NEST SITES IN SOUTH WEST VICTORIA, AUSTRALIA

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Abstract: The south-western Victorian region of Australia supports a threatened population of the brolga (*Grus rubicunda*). The species has suffered from loss of breeding habitat, predation of eggs and chicks, and poor breeding success. Little is known about current breeding density and key breeding areas within Victoria. Nest sites of brolgas in south-western Victoria are widely distributed, with majority occurring on private land. The sites are often difficult to access, survey, and monitor using ground-based survey methods. Aerial surveys were used to locate brolga nest sites for the first time in 2010 as part of a wind farm assessment. The current study employed and refined the methodology used in the wind farm assessment to locate and establish the density of brolga nests in 4 areas of south-west Victoria. Historical data was used to select survey areas with highest density of previous nesting records. Three blocks of 400 km^2 were surveyed in 2010 and 2011, flying transects at 500 meters apart, at 500 feet high, and with a flight speed of 60-70 knots. The results indicate that breeding density differs between survey areas and survey years. Some areas in south-west Victoria also appear to have higher density of nest sites overall than other areas, a result that was consistent over the 2 survey years, and that will aid in managing and protecting key breeding areas.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:104

Key words: Australia, brolga, *Grus rubicunda*, nest sites, Victoria.

MICROBIAL WATER QUALITY EFFECTS OF MIGRATORY BIRDS IN THE PLATTE RIVER, NEBRASKA 2009-2010

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Abstract: The U.S. Geological Survey has collected information to investigate microbial water-quality effects of migratory birds in the Platte River during spring bird migration in central Nebraska within a study reach between Grand Island and Overton. The focus of the study was to make comparisons between fecal indicator bacteria (related to crane and waterfowl use of the river) and pathogen concentrations. The study area that is within the Critical Habitat reach of the Platte River is a bottleneck portion of the Central Flyway utilized by cranes and several types of waterfowl. During the height of the migration season, hundreds of thousands of cranes and other waterfowl roost in the river in central Nebraska. Understanding the effects of varying flow conditions on water quality during these migrations is important to aiding managers and researchers of the Central Platte flyway. Samples were collected weekly in the study reach from 3 sites (upstream, middle, and downstream) during the springs of 2009 and 2010. The samples were analyzed for avian influenza, *Escherichia coli*, *Cryptosporidium* spp., *Giardia* spp., *Campylobacter* spp., and *Legionella* spp. Analysis indicates that peak *E .coli* and *Campylobacter* concentrations were concurrent with the peak population of migrating sandhill cranes (*Grus canadensis*) taken from bird counts from the Central Flyway. Concentrations of *E. coli* were significantly greater at the downstream site compared to the upstream site. Avian influenza was not detected in any sample during the study. To date, data collection has been completed and the analysis and interpretation is currently underway.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:105

Key words: Central Flyway, fecal bacteria, *Grus canadensis*, migratory birds, Nebraska, Platte River, sandhill cranes, waterfowl, water quality.

AN UPDATE ON THE DIRECT AUTUMN RELEASE OF WHOOPING CRANES INTO THE EASTERN MIGRATORY POPULATION

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Abstract: The whooping crane (*Grus americana*) is an endangered species endemic to North America with a native remnant population of less than 270 birds. The International Whooping Crane Recovery Plan has recommended the establishment of 2 separate self-sustaining populations, 1 migratory and 1 non-migratory. In 1999 the Whooping Crane Eastern Partnership (WCEP) was created to implement activities necessary for the establishment of a second migratory population separate from the Wood Buffalo/Aransas flock. In 2005 WCEP approved the development of the Direct Autumn Release (DAR) experiment. Young whooping crane chicks were hatched and costume-reared by humans at the International Crane Foundation until they were 3 to 7 weeks old. The young cranes were transferred to Necedah National Wildlife Refuge in central Wisconsin to be raised in the wild and soft-released in the fall. The DAR experiment released 33 birds in 2005-2009. This paper presents the results of the DAR releases thus far. Twenty-five birds (75.7%) survived their first migrations, overwintered, and successfully completed their first migration north. Eighteen returned to the core reintroduction area. Although the DAR population is relatively young, 2 females were in breeding situations in 2010; both successfully laid eggs and incubated full-term. One chick hatched and survived for 3-4 weeks. The DAR methodology continues to improve and appears to be a feasible means of reintroducing birds into the wild.

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Key words: costume-reared, DAR, Direct Autumn Release, *Grus americana*, Necedah National Wildlife Refuge, whooping crane, Wisconsin.

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