2010

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Abstract: An effort to reintroduce a migratory population of whooping cranes (*Grus americana*) into eastern North America began in 2001. During 2001-2007, 125 juveniles were costume/isolation-reared and released: 106 were led by ultralight aircraft from Necedah National Wildlife Refuge (NWR), central Wisconsin, to Chassahowitzka NWR, central Gulf Coast of Florida, on their first autumn migration (ultralight-led or UL). The remaining 19 individuals were released directly on Necedah NWR during autumn of the hatch year (direct autumn release or DAR). Of 86 UL and 13 DAR cranes that completed their first spring migration, 72 (84%) and 5 (38%), respectively, returned unassisted as yearlings to central Wisconsin. Yearlings typically returned to Necedah NWR and then wandered to other spring locations, mainly in southern and eastern Wisconsin, but also to locations as far as 1,370 km distant. Most yearlings returned to central Wisconsin by early summer, especially males, and females associated with males. Lake Michigan posed an effective barrier to 16 yearlings that migrated too far eastward during spring migration. Some of these birds and others were retrieved and translocated. For UL cranes, 48% of returning bird-winters occurred in a primary wintering area within 88 km of the original release site and an additional 12% at a smaller area of concentration 82-103 km northward. Other UL and DAR cranes wintered at sites primarily in Florida, South Carolina, Tennessee, Alabama, or Indiana. Excluding 17 UL juveniles that died in a single weather-related event at the winter release site in 2007, 40 individuals (37% of those in the population) died during the first 7 years of the reintroduction. The primary cause was predation (minimally 50%). During 2005-2008, all 22 first nests with eggs failed. Of 2 renests during the same period, 2 chicks hatched from 1 nest and 1 chick fledged in 2006. Consistent nest failures were mainly synchronous and usually occurred on warm days. As of September 2008, the population contained a maximum 68 individuals (39 males and 29 females) including 12 adult pairs.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 11:124-132

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

Only 1 naturally occurring population of whooping cranes (*Grus americana*) currently exists. This migratory population breeds in Wood Buffalo National Park, Northwest Territories of Canada, and winters on Aransas National Wildlife Refuge (NWR) on the Texas Gulf Coast. Attempts to create new populations of cranes by reintroduction have been limited. An attempted reintroduction of a migratory population of whooping cranes in the Rocky Mountains and of a non-migratory population in Florida have been unsuccessful (Ellis et al. 1992, Folk et al. 2008). Establishment of an eastern migratory population of whooping cranes began with the first release of costume/isolation-reared juveniles in 2001 (Urbanek et al. 2005*a*). This paper provides a broad overview of the survival, reproduction, and movements of reintroduced birds during the first 7 years of the reintroduction.

STUDY AREAS

The core reintroduction area consists of a large shallow wetland complex in parts of Juneau, Wood, Jackson, Monroe, Clark, and Adams counties in central Wisconsin. All ultralight-training and release sites were on Necedah NWR. The reintroduced whooping cranes used, for the most part, a relatively direct route between Wisconsin and wintering areas in the southeastern U.S. Most birds wintered in Florida, but some also wintered elsewhere, mainly in Tennessee and South Carolina. Cranes were led on their first autumn migration by ultralight aircraft to a release site on Chassahowitzka NWR, on the central Gulf Coast of Florida. Most common areas used by wintering birds after their first winter were inland areas of west-central Florida,

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especially large cattle ranches with associated wetlands (Fondow 2008). Summer, migration, and wintering areas used by the population have been previously described (Urbanek et al. 2005*b*).

METHODS

During 2001-07, 125 juveniles were costume/isolation-reared (Horwich 1989, Urbanek and Bookhout 1992) and released. Of these, 106 were led by ultralight aircraft (Lishman et al. 1997, Duff et al. 2001) from Necedah NWR, central Wisconsin, to Chassahowitzka NWR, central Gulf Coast of Florida, on their first autumn migration (ultralight-led or UL). The remaining 19 individuals were released directly on Necedah NWR during autumn of the hatch year (direct autumn release or DAR). One of the latter birds had originally been trained to follow ultralight aircraft, but did not participate in the ultralight-led migration because of flight feather problems (Table 1). The DAR method depended on association of the released juveniles with older whooping cranes to guide the former on their first autumn migration.

Eggs for the UL cohorts were hatched and initially trained to follow ultralight aircraft on the ground at USGS Patuxent Wildlife Research Center, Laurel, Maryland. Chicks were transferred to training sites on Necedah NWR when they were 38-66 days old. Ultralight-led migration began in early to mid-October from Necedah NWR. Juveniles were led 2,000 km to a

Table 1. Numbers (males, females) and release chronology of reintroduced juveniles, eastern migratory whooping crane population, 2001-2008. HY = hatch year.

	HY2001	HY2002	HY2003	HY2004	HY2005	HY2006	HY2007
Ultralight-led							
Initiation of migration	17 Oct	13 Oct	16 Oct	10 Oct	14 Oct	5 Oct	13 Oct
Number released	7 (4,3)	16 (6,10)	16 (11,5)	13 (10,3)	19 (11,8)	18 (9,9)	17 (9,8)[a]
Arrival date at Halpata holding site					13 Dec	19 Dec (17), 20 Dec (1)	27 Jan
Arrival date at Chassahowitzka release site	4 Dec (1), 5 Dec (6)	30 Nov	8 Dec	12 Dec	9 Jan (1), 10 Jan (6), 11 Jan (11), 19 Jan (1)	11 Jan (6), 12 Jan (12)	28 Jan (16), 2 Feb (1)
Initial release date	4 Dec (1), 5 Dec (6)	3 Dec	14 Dec	27 Dec[b]	21 Jan[b]	20 Jan[b]	5 Feb
Direct autumn release							
Number released				1 (1,0)[c]	4 (1,3)	4 (3,1)	10 (3,7)
Release date				23 Oct	25 Oct (2), 27 Oct (1), 29 Oct (1)	20 Oct (2), 21 Oct (2)	29 Oct (4), 30 Oct (6)
Initiation of migration				7 Nov	24 Nov	28 Oct (2), 30 Nov (2)	31 Oct (3)[d], 6 Nov (6)
Natural recruitment							
Number fledged						1 (0,1)	
Initiation of migration						19 Nov	

[a] One juvenile sustained an undetermined handling injury, never recovered flight capability, and was eventually removed from the project.
[b] Juveniles may have been released and then temporarily returned to a top-netted pen 1 or more times in some winters (see Urbanek et al. 2010*a*).
[c] Originally reared for UL migration but removed because flight feather problems prohibited sufficient training.
[d] One juvenile died between release and migration.

release pen in tidal marsh on Chassahowitzka NWR. This open-topped release pen was expanded from 0.6 ha in winter 2001-2002 to 1.6 ha thereafter. During 2001-2003 the juvenile cranes arrived at the winter release pen during 30 November-8 December and were released from a temporary top-netted enclosure 0-6 days later. In 2004, to manage conflicts between the juveniles and returning adults, caretakers alternately held and released juveniles from a permanent top-netted enclosure attached to a corner of the main pen through mid-winter (Urbanek et al. 2010*a*). Juveniles were provided with supplemental feed during their first winter at the Chassahowitzka pen, and all remained at that site during their first winter. Beginning in 2005, the ultralight-led flock stopped at a holding site on Halpata Tastanaki Preserve, Marion County, Florida, 42 km north of Chassahowitzka, and remained there until older whooping cranes had departed to inland sites after returning to the Chassahowitzka pensite. The juveniles were then led to the winter release site by ultralight aircraft.

Eggs for DAR cohorts were hatched at the International Crane Foundation, Baraboo, Wisconsin. Chicks were transferred to a field facility at Necedah NWR when they were 17-47 days old and released near older whooping cranes on the refuge in October. The bird numbering system consisted of a number designating the individual within a hatch year, followed by a hyphen, followed by the 2 last digits of the hatch year, e.g., 27-05 was bird number 27 in hatch year 2005.

All juveniles were individually marked with colored plastic leg bands above the tarsal joints. A leg band-mounted VHF transmitter (164-166 MHz, mainly lithium battery powered; Advanced Telemetry Systems, Isanti, MN) was attached to each juvenile. Some juveniles, usually 3 in each UL or DAR group each year, also carried similarly mounted satellite transmitters (platform transmitter terminals or PTTs; Microwave Telemetry, Columbia, MD; North Star Science and Technology, King George, VA). Total weight of either transmitter plus bands on which it was mounted was 52-55 g. Beginning during the first spring migration for UL cranes and at time of release for DAR cranes, birds were tracked by VHF telemetry with scanner receivers (Advanced Telemetry Systems, Isanti, MN; Telonics, Mesa, AZ). Most of this tracking was done from vehicles on the ground, although Cessna aircraft were sometimes used, especially during migration and to search for missing birds. Each ground tracking vehicle was equipped with a through-the-roof, 7-element yagi antenna (Cushcraft Corporation, Manchester, NH). A dedicated team of 3-4 trackers continuously monitored released cranes throughout the annual cycle and geographic range of the cranes. Resources were apportioned to cover as many birds as possible with priorities assigned to youngest birds, those with most variable movement patterns, or nesting adults. Coordinates of locations were recorded, and where access permitted, visual observations were made to document habitat and associations among whooping cranes and with sandhill cranes (*G. canadensis*). The PTTs were used to identify distant search locations in areas not routinely covered by VHF tracking, and follow up VHF tracking was performed at these sites as possible. The PTTs were programmed to transmit more frequently during youngest age periods and migrations. On the wintering grounds monitoring effort was determined by logistics of travel to birds within 100 km of Chassahowitzka NWR, and being checked at least twice per week. Other cranes were monitored less frequently as resources permitted, and cooperators were often recruited and used to check birds outside of Florida.

RESULTS

Distribution

Spring migration of UL juveniles from the winter release site was self-initiated and began during a narrow interval between 25 March and 9 April of each year. Departure dates were more variable for DAR and older birds but most often occurred during March (Table 2).

Of 86 UL and 13 DAR cranes that completed their first spring migration, 72 (84%) UL and 5 (38%) DAR returned unassisted as yearlings to central Wisconsin. Yearlings typically returned to Necedah NWR and then wandered to spring locations, mainly in southern and eastern Wisconsin, but also to locations as far as 780 km westward (North Dakota) or 1,370 km eastward (Vermont) (Fig. 1). Yearlings typically returned to central Wisconsin by early summer, especially males, and females that were associated with males. Lake Michigan posed an effective barrier to 16 of the

Table 2. Dates of initiation of spring migration, eastern migratory whooping crane population, 2002-2008.

	Mean start date[a]	*n*	Earliest	Latest
UL juveniles	31 Mar	84	25 Mar	9 Apr
DAR juveniles	20 Mar	15	26 Feb	21-22 Apr
No. 6-01 and 7-01 with sandhill cranes	20 Feb	7	3-14 Feb	5-6 Mar
Older birds at Chassahowitzka pensite	31 Mar	8	27 Mar	8-13 Apr
No. 16-05 in 2008	25 Jun-2 Jul	1		
All other older cranes	15 Mar	162	13-21 Feb	22-28 Apr
ALL CRANES	20 Mar	277		

[a] When exact date of departure was unknown, the midpoint between earliest and latest possible date was used in calculation of mean.

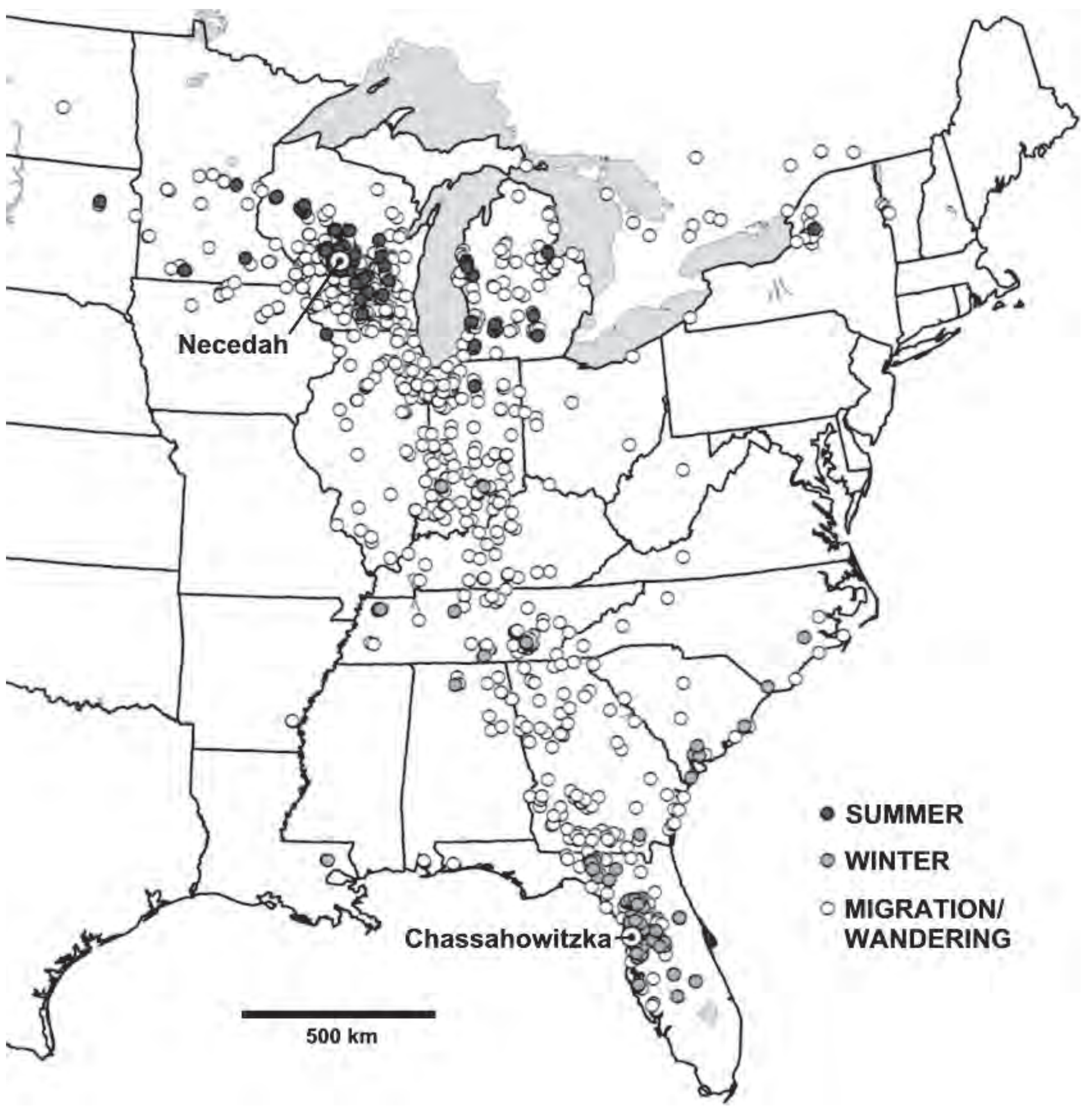

Figure 1. Distribution of the reintroduced eastern migratory whooping crane population, 2001-2008.

Table 3. Winter distribution of reintroduced eastern migratory whooping cranes as typified by location in mid-February, 2003-2008. Does not include juvenile UL birds overwintering on protected release area. Number of total from DAR cranes in parentheses. PWA and PP = Primary Wintering and Paynes Prairie Areas.

Location	2003	2004	2005	2006	2007	2008
Florida total	5	19	20	33[a] (2)	45 (5[b])	26[c] (2)
Florida (PWA & PP)	3	17	18	22[a] (1)	34 (2)	21 (2)
Florida (other)	2	2	2	11 (1)	11 (3[b])	5
Georgia					2[d]	
South Carolina			7	3	4	4
North Carolina			3	1[e]		
Tennessee			4	7 (2)	4 (3)	18 (10)
Alabama					2	2
Louisiana					1	
Indiana					4	1
Undetermined		1		1		5
Total	5	20	34	45 (4)	62 (8[b])	56 (12)

[a] Includes 1 pair that moved from location in Florida on 1 Feb, and final wintering area was not determined.
[b] Includes 1 juvenile that died in Jan.
[c] Includes 6 birds that were present earlier in winter but final winter location was not determined (nos. 3-03, 17-03, 9-05, and 12-05 included in PWA, nos. 13-03 and 18-03 included in other).
[d] This pair was observed only once (19 Feb) during the winter.
[e] This bird moved to South Carolina on ca. 19 Feb.

yearlings that migrated too far eastward during spring migration. Seven of these yearlings and others were retrieved and translocated (Zimorski and Urbanek 2010).

Autumn migration of free-flying birds in the population began from 22 October to 11 December and was concentrated in November. Some birds made significant autumn staging movements (e.g., to southern Wisconsin) preceding migration. Many whooping cranes returned to the Chassahowitzka release site in subsequent winters, including (minimally) 2, 15, 13, 19, and 22 individuals in winters 2002-2003 to 2006-2007, respectively. These birds usually remained only briefly before moving to inland sites for winter. Autumn migration was completed from November through early January.

For UL cranes (i.e., juveniles that were led to a predetermined wintering area), 48% of returning bird-winters (i.e., 1 bird-winter = 1 bird during 1 winter) occurred in a primary wintering area within 88 km of the original release site and an additional 12% at a smaller area of concentration 82-103 km northward, near Paynes Prairie State Preserve, Florida (Table 3, Urbanek et al. 2010*a*). Other UL and DAR cranes wintered at sites primarily in Florida, South Carolina, Tennessee, Alabama, or Indiana (Fig. 1).

Survival

Of total individuals released in the population, 63.0% representing 7 year classes were alive as of 30 September 2008 (Table 4). Among UL birds, males had higher survival (69.2%) than females (55.6%) while female DAR birds had higher survival (72.7%) than males (37.5%), although number of released DAR birds was small. Mortalities were dispersed among sex/age classes within the annual cycle (Table 5). Excluding 17 UL juveniles that died in a single weather-related catastrophic event at the winter release site in 2007, 40 individuals died during the first 7 years of the reintroduction (Table 6). The primary cause was predation (minimally 50%), especially among UL cranes. Collisions with power lines were also a major contributor to mortality (37.5%) of DAR cranes.

During the 16-month period from late May 2006 through late September 2007, the annual mortality rate in the population was 26.7% (Table 7). The annual mortality rate during the previous history of the reintroduction was only 7.1%. The increase coincided with simultaneous drought on both the wintering areas and in Wisconsin. The drought was especially severe in west-central Florida and other areas of the southeastern U.S. The mortality rate decreased to approximate the earlier rate when water conditions improved in winter 2007-2008 and in Wisconsin during the following spring and summer.

Reproduction

Except for 2 females from hatch year 2001, all females 4 years of age or older that summered in the core reintroduction area were paired and on territory with males. Mean age of first nesting of females (n = 13) was 3.92 years (3-5 years). Mean age of first nesting of males (n = 13) was 3.85 years (3-6 years). Pairing of males was limited by shortage of females. During 2005-2008, 24 nests with eggs were produced (Table 8). These nests were concentrated in 2 major areas on the southern and northern portions of Necedah NWR. In addition, 1 territory

Table 4. Survival (number surviving/number released[a]) of reintroduced eastern migratory whooping cranes by hatch year (HY), as of 30 September 2008[b].

	HY2001	HY2002	HY2003	HY2004	HY2005	HY2006	HY2007	Total
Ultralight-led								
Males	2/4	5[c]/6	6/11	6/10	8/11	0/1	9/9	36/52
Females	1/3	2[d]/10	4/5	3/3	4/8	-	6/7	20/36
Total	3/7	7/16	10/16	9/13	12/19	0/1	15/16	56/88
Direct autumn release								
Males				0/1	0/1	2/3	1/3	3/8
Females				-	3/3	0/1	5/7	8/11
Total				0/1	3/4	2/4	6/10	11/19
Natural recruitment								
Females						1/1		1/1
Grand total	3/7	7/16	10/16	9/14	15/23	3/6	21/26	68/108

[a] One juvenile sustained an undetermined handling injury, never recovered flight capability, and was eventually removed from the project.
[b] Juveniles may have been released and then temporarily returned to a top-netted pen 1 or more times in some winters (see Urbanek et al. 2010*a*).
[c] Originally reared for UL migration but removed because flight feather problems prohibited sufficient training.
[d] One juvenile died between release and migration.

Table 5. Mortalities by sex, age, and location in annual cycle, eastern migratory whooping crane population, 2001-2008.

Sex/age class	Winter[a]	Spring migration	Summer	Autumn migration[b]
Ultralight-led: Released: 56 males, 32 females[c]				
Male/juvenile	3		3	1
Male/yearling[d]	1		7	1[e]
Male/older				
Female/juvenile	1	1		
Female/yearling	1			
Female/older	2	1	7	1
Direct autumn release: Released: 8 males, 11 females				
Male/juvenile				2
Male/yearling			1[f]	
Male/older			1	
Female/juvenile	1	1	1	
Female/yearling				
Female/older				

[a] Does not include 17 ultralight-led juveniles that died in winter pen mortality event.
[b] Does not include first migration of ultralight-led juveniles.
[c] 1 bird with capture myopathy and euthanized is not included.
[d] Cranes are defined as yearlings as soon as they return from spring migration even if they are not quite 1 year old.
[e] Male found immobile under powerline (no. 8-02) later died in captivity.
[f] Includes 1 bird salvaged from UL.

occurred east of the refuge on Monroe County Flowage, Meadow Valley State Wildlife Area, and another farther north in Wood County Forest (Fig. 2).

During 2005-2008, all 22 first nests containing eggs of 14 different pairs failed. Of 2 renests during the same period, 2 chicks hatched from 1 nest and 1 chick fledged in 2006. Nest failures were mainly synchronous and usually coincident with warm, sunny days. Consistent nest failure is currently the major topic of investigation and must be resolved if the reintroduction is to succeed.

DISCUSSION

Costume-reared whooping cranes led on their first migration behind ultralight aircraft subsequently demonstrated successful migration, homing, habitat use, pair formation, and territory establishment. Survival was poor during an extended 1.4-year period of drought that occurred on both wintering and summer use areas. However, survival was otherwise comparable to average annual mortality of white-plumaged whooping cranes in the natural Wood Buffalo-Aransas population (9.7% during 1938-2008, B. Johns, Canadian Wildlife Service, unpublished data). The main cause of mortality, as discussed earlier by Cole et al. (2009), continued to be predation with no evidence of disease as a significant risk factor.

Table 6. Mortalities (*n* = 40) of reintroduced eastern migratory whooping cranes by confirmed or probable causative factor, sex (number of males, number of females), and location in annual cycle[a], 2001-2008.

Cause of mortality	Winter area	Spring migration	Summer area	Autumn migration[b]	Total
Ultralight-led: Total released = 88 (52 males, 36 females)[c]					
Predation (unidentified predator)[d]		0,1	4,4		4,5
Bobcat predation	2,3			1,0	3,3
Alligator predation	1,0				1,0
Powerline collision[e]				1,0	1,0
Gunshot			1,0	0,1	1,1
Trauma (source unknown)			1,0		1,0
Epicardial hemorrhage			0,1		0,1
Predation of injured bird			1,0		1,0
Euthanized (capture myopathy)			0,1		0,1
Undetermined[f]	1,1		3,1		4,2
Missing[g], no carcass recovered		0,1	0,2		0,3
Direct autumn release: Total released = 19 (8 males, 11 females)					
Coyote predation			0,1		0,1
Predation (suspected canid)			1,0		1,0
Bobcat predation					1,0
Alligator predation	0,1			1,0	0,1
Powerline collision			1,0	1,0	2,1
Aircraft collision					1,0

[a] Does not include 17 ultralight-led juveniles that died in winter pen mortality event.
[b] Does not include first migration of ultralight-led juveniles.
[c] Does not include no. 35-07, remanded to captivity.
[d] Includes unknown predator, suspected eagle (*n* = 1) and suspected canid (*n* = 3).
[e] Includes male found alive under power line that later died from unrelated cause in captivity.
[f] Carcass recovered, but cause of mortality could not be determined.
[g] Presumed dead.

The major problem currently hindering success of the reintroduction is lack of reproduction. The cause of the problem has not yet been confirmed, but synchrony in nest failure related to weather cues indicates that an environmental factor or incompatibility affecting whooping cranes on the breeding area may be responsible (Urbanek et al. 2010*b*). Current hypotheses relate to harassment by black flies (Simuliidae) or to limited food availability during incubation. Otherwise, normal pair formation and behavior of breeding pairs does not

Table 7. Mortality rates during 3 periods in the eastern migratory whooping crane reintroduction, 2001 through 30 September 2008[a].

	Before 25 May 2006	25 May 2006-25 Sep 2007	After 25 Sep 2007	Total
Bird-days[b]	41,405	28,757	22,863	93,025
No. of mortalities	8	21	6[c]	35
Mortalities/bird-year	0.0706	0.2667	0.0959	0.1374

[a] Data conventions: To better capture effects of environmental factors rather than technique on mortality, analysis does not include data prior to first spring migration for UL juveniles (3 mortalities) or prior to first autumn migration (1 mortality) for DAR juveniles. One bird that was euthanized after developing capture myopathy was treated as a removal rather than a mortality. If specific mortality date was unknown, mean of range of possible dates or, for closely monitored birds, date of disappearance was used as mortality date. One bird in captivity for 3 weeks was treated as removed from population and then re-released. One non-trackable bird not located since October 2007 was counted as alive through the third period.
[b] Bird-days = Sum of number of days that each bird was alive during period.
[c] Two of these 6 mortalities were of DAR juveniles that died on migration within 1 week of release, i.e., the directly released juveniles were not yet adapted to wild conditions.

Table 8. Number of whooping crane nests (*n* = 24) with eggs, core reintroduction area of central Wisconsin, 2005-2008.

Area	2005	2006	2007	2008
Necedah NWR south	2	3 + 1 renest	2	4
Necedah NWR north		1	1 + 1 renest	5
Monroe County/Dandy Creek Flowages, Meadow Valley SWA		1	1	1
Owl Creek, Wood County Forest				1
Total	2	5 + 1 renest	4 + 1 renest	11

indicate that the problem is due to reintroduction of costume-reared birds.

Beginning in 2005, the DAR technique was regularly used as a less expensive and logistically less complicated means to supplement numbers of reintroduced birds. Juveniles released on the summering area by the DAR technique have so far shown lower survival, migration, and homing success than UL cranes. Unlike UL cranes, DAR juveniles are not protected from release through their first winter; therefore, additional risk of mortality during this period is evident. Beyond this disadvantage, the number of released DAR birds has been small, and the oldest birds were only 3 years old in 2008. Therefore, additional time and a larger number of birds will be needed to evaluate this reintroduction method.

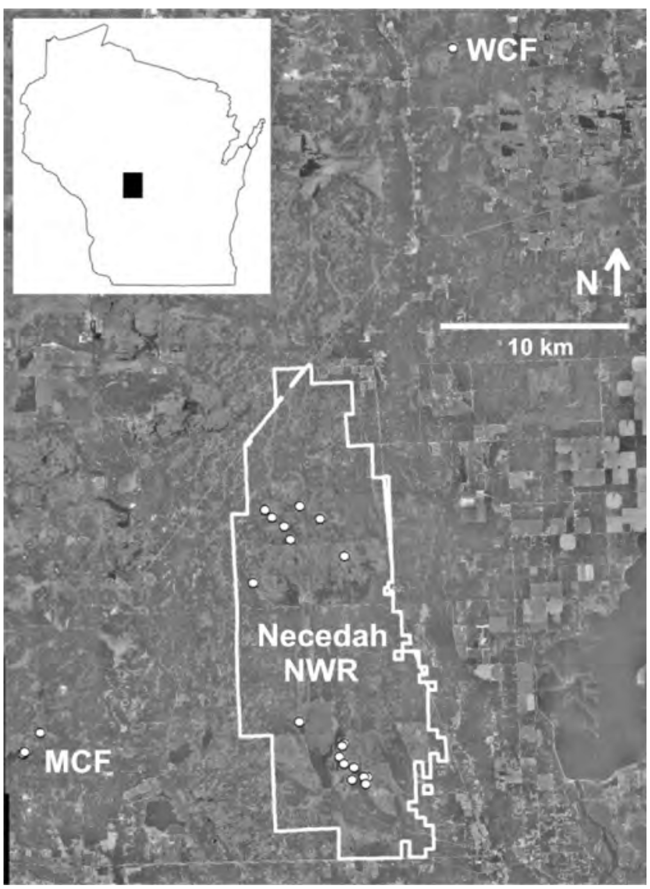

Figure 2. Nest locations of eastern migratory whooping cranes, central Wisconsin, 2005-2008. MCF = Monroe County Flowage, WCF = Wood County Forest.

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/ultralight-led technique has been successful and should be continued until the population becomes self-sustaining. The latter goal, however, will depend on solving the major problem of nest failure. Water management to specifically minimize impacts of drought also needs to be implemented where possible, especially on the breeding grounds. The DAR method needs to be evaluated as time and number of birds increase, and improvements in increasing integration into the existing flock, e.g., by relocating wayward individuals, should be made.

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 still requires more numbers of birds and time for evaluation but also indicates potential for success. These techniques can play a key role in further management and recovery of this endangered species.

ACKNOWLEDGMENTS

This work is a product of the Whooping Crane Eastern Partnership (WCEP), which was established in 1999 to reintroduce a migratory population of whooping cranes to eastern North America. Many additional organizations and individuals have played an important role in the reintroduction, and the efforts of all participants are acknowledged as vital to the success of the project.

We thank tracking staff, especially C. Satyshur, J. Kroese, J. Watson, T. Kallgren, S. Castelda, K. Maguire, C. Malachowski, T. Love, S. Grover, S. Kerley, N. Frey, C. Wisinski, A. Fasoli, and E. Szyszkoski, International Crane Foundation; M. Nipper, Operation Migration; and N. Winstead, Louisiana Cooperative Fish and Wildlife Research Unit, and numerous cooperators for monitoring free-ranging birds in the population. We thank J. Duff and staff of Operation Migration and staff of USGS Patuxent Wildlife Research Center for rearing, training, and leading migration of UL chicks; M. Wellington, International Crane Foundation, and DAR interns, U.S. Fish and Wildlife Service, for rearing DAR chicks; T. Kohler and staff of Windway Capital Corporation for contributions and aircraft support; the Wildlife Trust for additional aircraft assistance; M. Spalding and staff of USGS National Wildlife Health Center for necropsy services; and Necedah NWR, International Crane Foundation, Chassahowitzka NWR, Crystal River Preserve State Park, Natural Resources Foundation of Wisconsin, U.S. Fish and Wildlife Service-Migratory Birds and State Programs, and Southwest Florida Water Management District for logistical support. Without the contributions of these and many others, this effort would not have been possible. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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