2016

TEN-YEAR STATUS OF THE EASTERN MIGRATORY WHOOPING CRANE REINTRODUCTION

Richard P. Urbanek
U.S. Fish and Wildlife Service, richard_urbanek@fws.gov

Sara E. Zimorski
International Crane Foundation

Eva K. Szyskoski
International Crane Foundation

Marianne M. Wellington
International Crane Foundation

TEN-YEAR STATUS OF THE EASTERN MIGRATORY WHOOPING CRANE REINTRODUCTION

RICHARD P. URBANEK,[1] U.S. Fish and Wildlife Service, Necedah National Wildlife Refuge, N11385 Headquarters Road, Necedah, WI 54646, USA

SARA E. ZIMORSKI,[2] International Crane Foundation, E-11376 Shady Lane Road, Baraboo, WI 53919, USA

EVA K. SZYSZKOSKI, International Crane Foundation, E-11376 Shady Lane Road, Baraboo, WI 53919, USA

MARIANNE M. WELLINGTON, International Crane Foundation, E-11376 Shady Lane Road, Baraboo, WI 53913 USA

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.

PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP 12:33-42

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

[1] E-mail: richard_urbanek@fws.gov

[2] Present address: Louisiana Department of Wildlife and Fisheries, White Lake Wetlands Conservation Area, 15926 LA Hwy 91, Gueydan, LA 70542, USA

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.

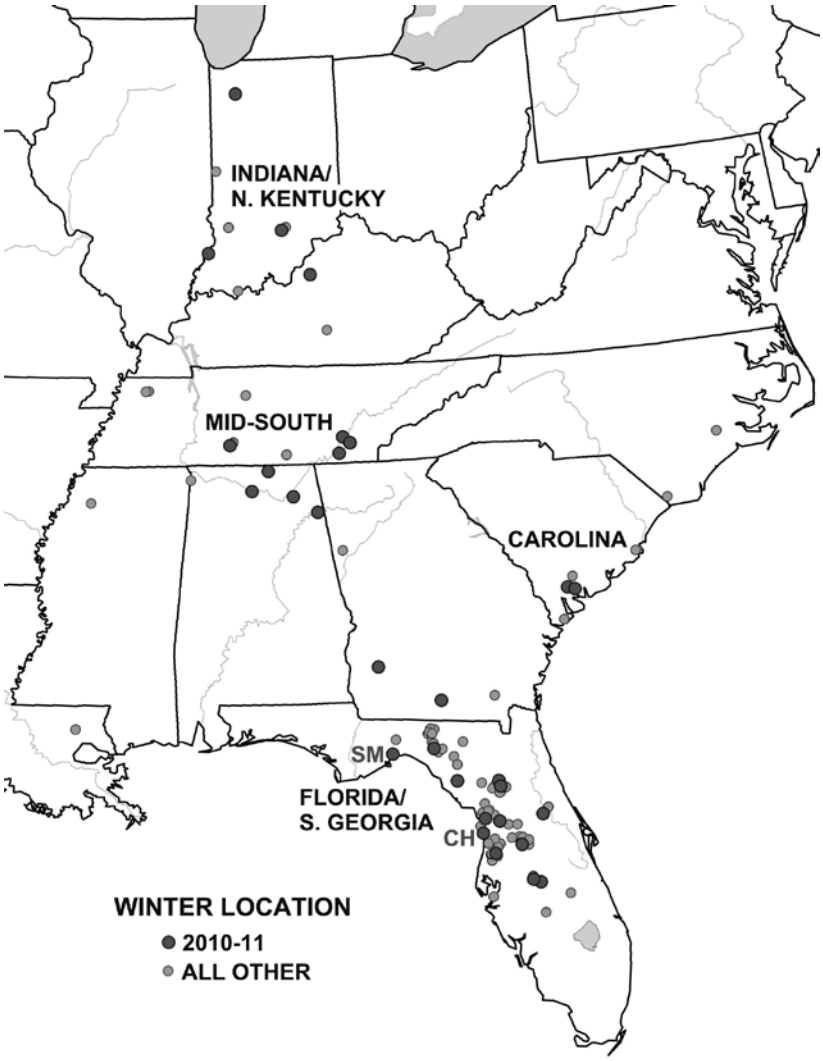

Figure 1. Winter distribution of the reintroduced eastern migratory whooping crane population in 4 geographic areas, 2001-2011. CH = Chassahowitzka NWR. SM = St. Marks NWR.

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.

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. The 9 founding members are the Canada-U.S. Whooping Crane Recovery Team, U.S. Fish and Wildlife Service, USGS Patuxent Wildlife Research Center, USGS National Wildlife Health Center, Wisconsin Department of Natural Resources, Operation Migration, Inc., International Crane Foundation, National Fish and Wildlife Foundation, and the Natural Resources Foundation of Wisconsin. 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 all past tracking staff of the International Crane Foundation and numerous cooperators for monitoring free-ranging birds in the population. We especially thank the following recent ICF or U.S. Fish and Wildlife Service interns who tracked released birds or assisted in rearing of DAR chicks: A. M. Fasoli, C. L. Wisinski, J. F. Cullum, B. Z. Elger, M. J. Fitzpatrick,

T. P. Czubek, R. K. Hartman, J. W. Thompson, K. J. Farrell, J. B. Longenecker, K. E. Wyman, J. A. Davis, A. E. Maccoux, C. A. Alexander, and M. W. Strausser. We thank J. Duff and staff of Operation Migration and staff of Patuxent Wildlife Research Center for rearing, training, and leading migration of UL chicks; T. Kohler and staff of Windway Capital Corporation for contributions and aircraft support; 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.

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.