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TWENTY-YEAR STATUS OF THE EASTERN MIGRATORY WHOOPING CRANE REINTRODUCTION

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TWENTY-YEAR STATUS OF THE EASTERN MIGRATORY WHOOPING CRANE REINTRODUCTION

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Abstract: Since the 10-year status update in 2011, the first parent-reared whooping cranes (*Grus americana*) were released in the Eastern Migratory Population, the ultralight program (UL) ended, and cranes were released at new sites in eastern Wisconsin. During 2011-2020, 117 captive-reared whooping cranes were released; 75 costume-reared (35 in UL and 40 in the Direct Autumn Release program) and 42 parent-reared. There were no significant differences in 1- or 3-year survival rates based on rearing technique or release site. The population size remained at about 100 cranes during 2010-2018 but then decreased during 2018-2020 due to a reduced number of releases of captive-reared cranes and low recruitment. Predation remained the leading cause of death (54.1% of confirmed cases) for cases in which the cause of death could be determined, followed by impact trauma (18.8%), gunshot (10.5%), and disease (9.0%). The winter distribution shifted northward into more agricultural landscapes, with the majority of the population wintering in southern Indiana or northern Alabama. The summer distribution remained concentrated in Wisconsin, and breeding areas expanded into eastern Wisconsin. As a management response to nest abandonments caused by avian-feeding black flies (*Simulium* spp.), the first clutch of eggs was removed from nests at Necedah National Wildlife Refuge (i.e., forced renesting), which increased renesting rates from 42% to 79%. In total, 152 cranes were confirmed to have hatched in the wild, 27 of which survived to fledging. Two male whooping cranes nested with female sandhill cranes (*Grus canadensis*) and produced hybrid chicks. Three cranes were removed from the population due to using an active air strip on an Air National Guard base. As of April 2021, the estimated population size was 76 individuals (38 females, 36 males, and 2 of unknown sex), 16 of which were wild-hatched.

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Key words: *Grus americana*, human avoidance, migratory population, reintroduction, reproduction, survival, translocation, whooping crane, Wisconsin.

Long-term monitoring is an important aspect of reintroduction efforts in order to evaluate release techniques, factors affecting viability of populations, and potential successes of future reintroductions (IUCN 1998, Seddon et al. 2007). Sutherland et al. (2010) recommended monitoring reintroduced populations at standardized time intervals for up to 10-20 years for long-lived species to better understand the factors affecting the success of the reintroduction and to inform the conservation community about lessons learned in the process.

To increase the number of wild whooping cranes (*Grus americana*) and ultimately downlist this endangered species, a reintroduction of migratory cranes into the eastern United States has been ongoing since 2001. This effort has been led by a partnership of federal and state agencies, non-profit organizations, and universities, known as the Whooping Crane Eastern Partnership (WCEP). Captive-reared cranes have been raised and released using a variety of techniques and the population has been intensively monitored and studied throughout this reintroduction. In 2011 the status of this population was evaluated by Urbanek et al. (2014*b*) with respect to survival, movements, and reproduction. Numerous other studies have also investigated the demographics and behavior of this population throughout the course of this reintroduction effort (Table 1). The goal of this paper is to provide a 20-year summary of the monitoring efforts and the status of the Eastern Migratory Population (EMP) of whooping cranes with references to the 10-year update (Urbanek et al. 2014*b*) and a focus on 2011-2020.

STUDY AREA

Throughout this reintroduction, whooping cranes in the EMP mainly used large shallow wetlands in central Wisconsin during summer, many of which were on the

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Table 1. Published papers on the Eastern Migratory Population of whooping cranes.

Topic	Published papers
Survival and mortality	Cole et al. (2009), Urbanek et al. (2010*a*), Urbanek et al. (2014*b*), Condon et al. (2018), Yaw et al. (2020), Stewart (2020)
Habitat use and movements	Maguire (2008), Urbanek et al. (2010*a*), Fondow (2013), Mueller et al. (2013), Urbanek et al. (2014*a*), Urbanek et al. (2014*b*), Van Schmidt et al. (2014), Teitelbaum et al. (2016), Barzen (2018), Barzen et al. (2018*b*), Cantrell and Wang (2018), Teitelbaum et al. (2018), Thompson (2018), Gondek (2020), Thompson et al. (2021), Abrahms et al. (2021), Szyszkoski and Thompson (2022)
Reproduction	Urbanek et al. (2010*a*), Urbanek et al. (2010*c*), King and Adler (2012), Converse et al. (2013), King et al. (2013*a*), King et al. (2013*b*), Bahleda (2014), McKinney (2014), Urbanek et al. (2014*b*), King et al. (2015), Jaworski (2016), Barzen et al. (2018*a*), Converse et al. (2018*b*), McLean (2019), Adler et al. (2019), Thompson and Gordon (2020), Urbanek and Adler (2022), Gordon et al. (2022), Kearns et al. (2022)
Captive-rearing	Urbanek et al. (2010*b*), Urbanek et al. (2016), Duff (2018), Hartup (2018), Sadowski et al. (2018), Thompson et al. (2022)
Diet and energetics	Fitzpatrick et al. (2015), Fitzpatrick (2016), Fitzpatrick et al. (2018), Barzen et al. (2018*c*), Thompson et al. (2018)
Population demographics	Converse et al. (2012), Servanty et al. (2014), Converse et al. (2018*a*)
Health	Hanley et al. (2005), Hartup et al. (2005), Hartup et al. (2006), Keller and Hartup (2013), Hausmann et al. (2015), Olsen et al. (2018)
Other	Urbanek et al. (2005), Urbanek (2010), Runge et al. (2011), Lacy and McElwee (2014), Barzen and Ballinger (2017), Teitelbaum et al. (2017), Urbanek (2018), Urbanek et al. (2018), Teitelbaum et al. (2019)

Necedah National Wildlife Refuge (NWR) in Juneau County (44°04′N, 90°10′W). Prior to 2011, all cranes were released at Necedah NWR. Due to concerns about the effect of large populations of avian-feeding black flies (*Simulium* spp.) on nesting success at Necedah NWR, captive-bred cranes were first released outside of Necedah NWR in 2011. The new release sites were in wetland complexes in eastern Wisconsin in an area designated as the Eastern Rectangle or the Wisconsin Rectangle (WCEP 2012, Van Schmidt et al. 2014) and included the White River Marsh State Wildlife Area (SWA) in Green Lake County (43°54′N, 89°06′W) and the Horicon NWR in Dodge and Fond du Lac Counties (43°36′N, 88°38′W). Despite the presence of avian-feeding black flies, the Necedah NWR continued to be the core breeding area of adult cranes. During 2013-2015, parent-reared (PR) cranes were released near breeding pairs at Necedah NWR. After 2015, releases of PR cranes occurred in areas throughout eastern and central Wisconsin (Thompson et al. 2022). In 2019, 1 juvenile crane was released on the wintering grounds at Goose Pond Fish and Wildlife Area in Greene County, Indiana (38°59′N, 87°07′W; Thompson et al. 2022). After 2010, ultralight-led (UL) cohorts were trained to follow ultralight aircraft and learned a migratory route from White River Marsh SWA in Wisconsin to winter release sites at St. Marks NWR in the Florida panhandle (30°06′N, 84°17′W) or in northern Alabama at Wheeler NWR (34°33′N, 86°57′W; WCEP 2012).

Since the 10-year status update (Urbanek et al. 2014*b*), the migratory routes of whooping cranes in the EMP remained relatively unchanged. The main changes in the distribution of the population were the expansion of breeding areas outside of Necedah NWR in the Eastern Rectangle of Wisconsin and the northward shift of the wintering grounds (Urbanek et al. 2014*a*, Teitelbaum et al. 2016, Thompson 2018). As of winter 2020-21, few EMP cranes migrated to Florida, and the majority spent the winter in southern Indiana or northern Alabama.

METHODS

Similar to the early stages of the reintroduction, captive-produced whooping crane eggs or eggs salvaged from abandoned nests were hatched and raised in captivity for release programs in the EMP and the Louisiana Non-migratory Population (LNMP, Urbanek et al. 2014*b*). Additionally, eggs were collected from first nests at Necedah NWR at the time of black fly emergence in a technique known as forced renesting (WCEP 2015, Fasbender et al. 2015). Collected eggs were also hatched and raised in captivity for both reintroduced populations. Throughout this reintroduction, the 2 main captive breeding centers that raised cranes for release into the EMP were the International Crane Foundation (ICF) in Baraboo, Wisconsin, and the Patuxent Wildlife

Research Center (PWRC) in Laurel, Maryland. The Calgary Zoo in Alberta, Canada, raised 2 whooping crane chicks during 2018, which were released in 2019 (Thompson et al. 2022). In 2017 PWRC announced it would end its whooping crane captive breeding program. The U.S. Fish and Wildlife Service (USFWS) and the Association of Zoos and Aquariums whooping crane Species Survival Plan program identified and approved 3 new partners to the whooping crane breeding program: White Oak Conservation in Yulee, Florida; Smithsonian Conservation Biology Institute in Front Royal, Virginia; and the Dallas Zoo in Dallas, Texas (WCEP 2019). The last cohort of cranes raised at PWRC were released during fall 2017. During 2018-2019, whooping cranes from PWRC were transferred to existing and new breeding centers as well as non-breeding centers for exhibit purposes. This transfer of breeding adult whooping cranes between facilities and the subsequent acclimation period in their new environments resulted in decreased captive chick production and reduced cohort sizes for release into the EMP (WCEP 2019, 2020).

During the first decade of this reintroduction, costume-reared (CR) cranes were either a part of the UL migration (2001-2010) or were released in Wisconsin during fall near adult cranes in a program known as Direct Autumn Release (DAR, 2005-2010; Urbanek et al. 2014*b*). Since 2011, whooping cranes were either CR or PR in captivity for release into the EMP (Wellington et al. 1996, Hartup 2018). DAR cohorts were raised at Necedah NWR and then moved to Horicon NWR prior to fledging (2011-2012), were raised at ICF and then moved to Horicon NWR (2013, 2015), or were hatched at PWRC and then raised at White River Marsh SWA (2017). UL cohorts were raised at White River Marsh SWA, then released on the wintering grounds in Alabama (2011) or Florida (2012-2015). The UL route used from 2011 to 2015 was the same westerly route used in 2008-2010, with the southern terminus at St. Marks NWR in Florida (Urbanek et al. 2014*b*). The 2011 UL migration ended at Wheeler NWR in northern Alabama instead of at St. Marks NWR as originally planned. Unfavorable weather for flying the ultralights resulted in very slow southward progress, and an ongoing investigation by the Federal Aviation Administration grounded the aircraft later that winter. After the 2015 cohort of UL cranes was released, the decision was made by the USFWS to end the UL program and focus support on more natural rearing and release techniques (DAR and PR) in the EMP (Fasbender et al. 2015). PR cranes were raised at ICF, White Oak Conservation, and the Calgary Zoo according to methods described by Wellington et al. (1996) and Hartup (2018). PR cranes were released near adult cranes at Necedah NWR (2013-2015) or in areas throughout central Wisconsin (2016-2019); 1 exception was a juvenile released in Indiana in fall 2019 after an injury-induced delay (Olsen and Converse 2016, 2018; Thompson et al. 2022). One unique example of PR cranes released in the EMP was a family-group in 2018, in which the adult male (no. 16-11) had been previously released in the fall of 2011. In 2015, he paired and nested with a female sandhill crane (*Grus canadensis*), producing 1 hybrid chick. The male was captured and brought into captivity, where he was paired with a captive-reared female whooping crane. The pair successfully hatched and raised 2 chicks in 2018 and all 4 birds were released back onto the male's original territory (Thompson et al. 2022). Constraints on breeding centers related to the human coronavirus (COVID-19) pandemic resulted in no captive-reared cranes being released during 2020.

All captive-reared whooping cranes were banded prior to release, and wild-hatched cranes, with a few exceptions, were captured and banded with a unique combination of colored leg bands (Urbanek 2018). Each crane also received a leg-mounted VHF transmitter (Advanced Telemetry Systems, Isanti, MN, USA) on 1 leg, and a subset of cranes also received a remote transmitter attached to bands on the other leg. Remote transmitters collected GPS coordinates and transmitted them via a platform transmitting terminal (PTT, i.e., satellite) or a global system for mobile communication (GSM, i.e., cellular) network (Microwave Telemetry, Columbia, MD, USA; Ornitela, Vilnius, Lithuania). During 2011-2020, 139 juvenile cranes were tagged with leg bands and a VHF transmitter; 73 also received a remote transmitter. Additionally, in 2019 we began deploying remote transmitters on adult cranes. As of April 2021, 1 juvenile and 8 adult cranes were marked only with leg bands and a remote transmitter.

Whooping cranes in the EMP were extensively monitored throughout their lives via telemetry, aerial and ground surveys, opportunistic visual observations, and nest cameras. Upon release, captive-reared cranes were monitored daily or weekly until their first fall migration. During winter, cranes were monitored throughout the flyway by partners or volunteers using radiotelemetry or visual observations at known wintering sites. For the purposes of this paper, wintering and summering sites were defined as the location in which the crane

Table 2. Summary of reproduction in the Eastern Migratory Population of whooping cranes, 2011-2020. For reference, value totals during 2005-2010 are provided (Urbanek et al. 2014*b*).

Year	Nest initiation dates	Nest order	No. confirmed nests	No. nests with eggs pulled[a]	No. successful nests	No. chicks confirmed hatched	No. chicks fledged	No. chicks alive after 6 months
2005-10	1 Apr-12 May	first nest	46	0	2	2	0	0
	29 Apr-23 May	renest	12	0	6	9	3	3
2011	3-4 Apr	first nest	20	2	4	4	0	0
	18 May	renest	2	0	0	0	0	0
2012	<2 Mar	first nest	22	0	6	7	1	1
	17 Apr	renest	7	0	2	2	1	1
2013	15 Apr	first nest	21	0	1	2	0	0
	25 May	renest	2	0	1	1	1	0
2014	7 Apr	first nest	25[b]	4	8	13	1	1
	10 May	renest	3	0	0	0	0	0
2015	1-3 Apr	first nest	27[b]	8	8[b]	13[c]	2	1
	29 Apr	renest	10	0	8	11	1	1
2016	29-31 Mar	first nest	26	7	5	8	1[d]	0
	24 Apr	renest	16	0	11	15	1	0
2017	28 Mar	first nest	27[e]	13	5	6	1	1
	25 Apr	renest	10	0	9	12	1	1
2018[f]	8 Apr	first nest	17	1	4	6	4	4
	3 May	renest	6	0	3	4	2[d]	1
2019	3 Apr	first nest	26[b,e]	12[b]	7	11	1	1
	27 Apr	renest	10	0	6	7	1	1
	30 May	2nd renest	1	0	1	1	1	1
2020	25 Mar	first nest	22[b,e]	1	12[b,e,g]	15[c,g]	3	3
	19 May	renest	3	0	3	3	1	NA
Total			361[b]	48[b]	112[b,g]	152[c,g]	27[d]	21

[a] Does not include eggs salvaged after natural nest failure. Only includes nests that failed due to egg collection.

[b] Does not include 1 sandhill-whooping crane hybrid nest (4 total confirmed hybrid nests, 1 with eggs removed, and 2 successful hybrid nests not included in totals).

[c] Does not include sandhill-whooping crane hybrid chicks (1 in 2015, 2 in 2020).

[d] Includes 1 chick that died around fledging but sustained flights were not confirmed (2 total, 1 in 2016, 1 in 2018).

[e] Includes female-female nests (2 in 2017, 1 in 2019, 1 in 2020).

[f] Adverse weather limited aerial and ground surveys during the early nesting season and a few early nests may not have been detected.

[g] Includes 1 chick hatched from an egg swapped into a female-female nest.

was during the majority of January and July of each year, respectively, which accurately represented the distribution of the vast majority of the population. On the breeding grounds in Wisconsin, aerial surveys were conducted to locate breeding pairs and nests. Once located, a subset of nests (8-14 nests per year during 2014-2020) was monitored via trail cameras (Trophy Cam model 119466, Bushnell, Overland Park, KS, USA; HyperFire HC600, Reconyx, Holmen, WI, USA) using methods described by Jaworski (2016). Wild-hatched chicks were monitored via aerial and ground surveys. In addition, implanted and glue-on VHF radio transmitters were used during 2016 and 2017-2018, respectively, to monitor survival and movements of newly-hatched chicks at Necedah NWR (McLean 2019; Stewart 2020; B. Strobel, USFWS, personal communication). If a wild-hatched chick lived past 80 days of age, we considered it to have fledged, even if flights were not confirmed prior to mortality. Two chicks (nos. W3-16 and W9-16) died around anticipated fledging time, 1 of which (no. W9-16) was considered to have fledged for this paper since it lived past 80 days of age and was seen making short flights. The other chick (no. W3-16) was last seen at 75 days of age and therefore was not included in this paper, but was considered fledged in WCEP annual reports (Table 2, WCEP 2017).

When a mortality event was suspected or confirmed, efforts were made to collect the carcass. Remains were transferred to the U.S. Geological Survey National Wildlife Health Center for necropsy and determination

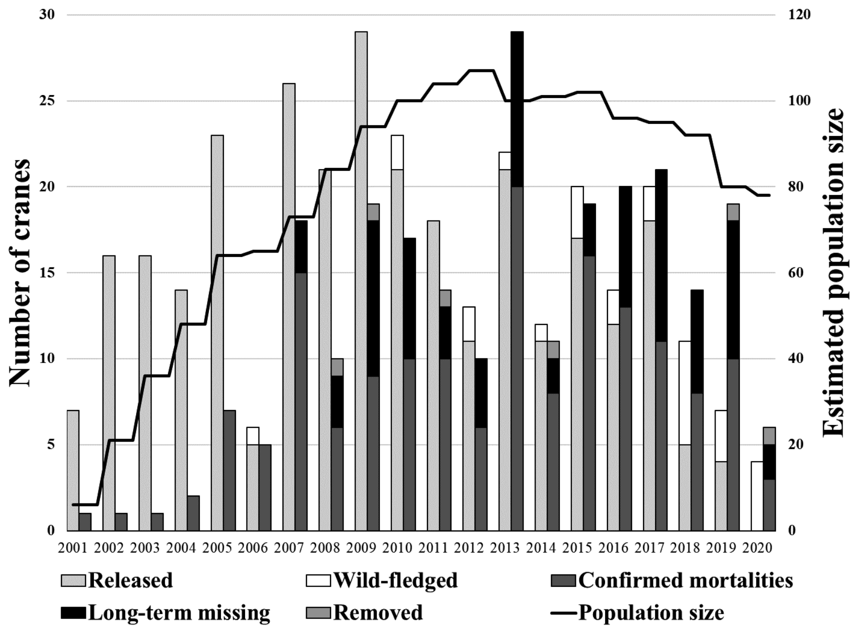

Figure 1. Estimated population size of the Eastern Migratory Population of whooping cranes, 2001-2020, based on the number of captive-reared cranes released, wild-fledged cranes, confirmed mortalities, cranes removed from the population, and long-term missing birds who had not been seen for more than 1 year. Estimates are based on end of year totals during 2001-2020. Long-term missing birds are included in the year in which they were last observed.

of a potential cause of death (Cole et al. 2009, Yaw et al. 2020). Mortalities were considered to be during spring or autumn migration if the bird was observed en route to the location it summered or wintered in previous years. We considered mortalities to occur during summer if we recovered the carcass on the bird's summering area, and during winter if it was at a previously known wintering area or at a more southern location.

Population sizes were estimated based on numbers of released captive-reared birds, fledging of wild-hatched chicks, confirmed mortalities, birds removed from the population, and the number of birds missing for 1 year or more (classified as long-term missing). For the purposes of this paper, we refer to birds <1 year old as juveniles or chicks, and birds 1 year old or older as adult-plumaged birds, hereafter simply adults. The season (summer, winter, fall or spring migration) in which a long-term missing crane disappeared was determined based on the last observation of the missing individual and the subsequent observations of their mates or associates. It is important to note that during the second decade of this reintroduction, there was less intensive monitoring on the wintering grounds and during migration than during the first decade. Intensive monitoring occurred on the breeding grounds during both periods. Long-term missing cranes were removed from end-of-year population size estimates in the year they were last observed.

One and 3-year survival rates were considered 1 or 3 years post-fledge for wild-hatched birds and post-release for captive-reared birds. For reference, in the 10-year status update (Urbanek et al. 2014*b*), the definition for 1-year survival for captive-reared birds was the same as was used in this study; only 1 wild-hatched bird (still surviving in 2021) occurred in that period and was not included in survival calculations. The 3-year survival in this study was considered survival between release date and 3 years post-release, whereas Urbanek (2014*b*) reported 3-year survival between 1 year post-release until age 3. We used Pearson's chi-square tests in R to compare the proportion of each cohort still alive at 1 and 3 years post-release for each rearing method, and Welch 2-sample *t*-tests to compare survival between release regions (R Core Team 2019). All reported measurements are mean and standard error.

RESULTS

Population Size and Survival

During the early stages of this reintroduction (2001-2010), 178 captive-reared cranes were released, all of which were costume-reared (132 in the UL program and 46 in the DAR program). Of these cranes, 80.8% survived 1 year post-release (HY2001-2009), and 83.9% survived between 1 year post-release and 3 years post-hatch (HY2001-2007, Urbanek et al. 2014*b*). For comparison to 3-year survival rates reported in this study, 62.0% survived 3 years post-release (HY2001-2007). During 2001-2010, UL cranes survived longer than DAR cranes, likely due, at least in part, to increased protection during the winter months for the UL cranes (Urbanek et al. 2014*b*).

During 2011-2020, 117 captive-reared whooping cranes were released into the EMP (Fig. 1); 75 costume-reared (35 in the UL program and 40 in the DAR program) and 42 parent-reared. Overall, 67.4% of captive-reared cranes (UL, DAR, and PR) released 2010-2019 survived 1 year post-release, and 49.7% of cranes released 2008-2017 survived 3 years post-release (Fig. 2). There were no differences in survival rates of cohorts reared by different methods (UL, DAR, PR, wild-hatched) at 1 (HY2010-2019) or 3 years (HY2008-2017) post-release or post-fledge ($P = 0.83$, $\chi^2 = 0.88$, df = 3; $P = 0.28$, $\chi^2 = 3.86$, df = 3, respectively, Fig. 2). During 2001-2020, at least 152 whooping cranes hatched in the wild in the EMP, and 27 (17.8%) survived to fledging (Fig. 1, Table 2).

Whooping Cranes were released or hatched in both the core breeding area in and around Necedah NWR as well as in the Eastern Rectangle during 2011-2020; however, more releases took place in the Eastern Rectangle during this time. There was no difference in 1-year survival rates between cranes released at Necedah NWR (76.8%) and cranes released in the ER (ER: 66.7%, HY2001-2019, $t = -1.03$, df = 1.14, $P = 0.47$), nor was there a difference in 3-year survival rates between release regions (NNWR: 55.3%, ER: 50.6%, HY2001-2017, $t = -5.56$, df = 1.00, $P = 0.11$).

In addition to low natural recruitment, releases of captive-reared cranes, long-term missing birds, and mortalities also affected the population size of the EMP (Fig. 1). During 2001-2012, the population grew as the number of cranes added to the population yearly remained greater than the number of losses. During 2013-2017, the population remained at approximately 100 individuals. However, during 2018-2020, the number of losses surpassed the number of cranes added each year and the population size declined (Fig. 1). During 2001-2020, the mean (± SE) number of losses in the population was 12.0 ± 1.8 birds (14.4 ± 1.7% of the population) per year. In order to compensate for those losses and have population growth, more birds would need to be added through captive-rearing or wild-fledged birds.

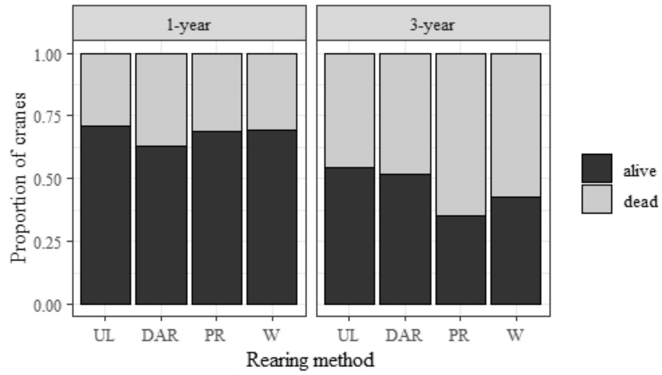

Figure 2. Proportion of whooping cranes from each rearing method that survived 1 or 3 years post-release for captive-reared cranes, or 1 or 3 years post-fledge for wild-hatched cranes in the Eastern Migratory Population. This includes cranes HY2010-2019 for 1-year survival and HY2008-2017 for 3-year survival. Captive-reared cranes were costume-reared and part of the ultralight-led migration (UL, *n* = 45 for 1-year, *n* = 79 for 3-year) or the direct autumn release program (DAR, *n* = 51 for 1-year, *n* = 66 for 3-year) or were parent-reared by captive adult whooping cranes (PR, *n* = 42 for 1-year, *n* = 34 for 3-year). Wild-hatched (W, *n* = 23 for 1-year, *n* = 14 for 3-year) whooping cranes were hatched and raised by their parents in the wild. No wild-hatched birds that died pre-fledging were included in these analyses.

As of April 2021, the EMP consisted of a maximum of 76 whooping cranes: 36 males, 38 females, and 2 of unknown sex. All rearing methods were represented in the population: 27 UL cranes, 20 DAR, 13 PR, and 16 wild-hatched cranes. Additionally, 4 cranes were fledged juveniles, 24 cranes were 1-3 years old, and 48 cranes were older than 3 years of age.

Mortality

During 2001-2020, 182 whooping crane carcasses were collected, consisting of 112 adults and 70 juveniles. Causes of death were determined for approximately half of the recovered carcasses (50.9% and 64.3% for adults and juveniles, respectively). In some cases, cause of death could not be confirmed by necropsy; however, including notes taken during carcass recovery, likely causes of death were determined for 73.1% of confirmed mortalities (65.2% and 85.7% for adults and juveniles, respectively). The following summaries include likely causes of death as determined from observations or conditions at the site of carcass collection.

Predation was the primary cause of death of adult (43.8%, $n = 32$) and juvenile (66.7%, $n = 40$) whooping

Table 3. Causes of confirmed mortalities of whooping cranes in the Eastern Migratory Population, 2001-2020. This does not include 17 juveniles that died in a single weather-related event at the winter pen of the 2006 ultralight aircraft-led cohort (Spalding et al. 2010), nor does it include mortalities that occurred pre-release. Long-term missing birds whose carcasses were not recovered are listed below as juveniles if they were last seen as a hatch-year bird.

Cause of Mortality	Juveniles	Adults	Total
Predation	40	32	72
Confirmed	27	18	45
Suspected	13	14	27
Impact trauma	12	13[a]	25[a]
Powerline collision (confirmed)	4	5[a]	9[a]
Powerline collision (suspected)	2	2	4
Vehicle collision (confirmed)	3	1	4
Vehicle collision (suspected)	1	0	1
Aircraft collision[b] (confirmed)	1	0	1
Unknown source of trauma	1	5	6
Disease	4	8	12
Gunshot	3	11	14
Other	1	9	10
Euthanized due to injury[c]	0	5	5
Hemorrhage while getting treatment for an injury	0	1	1
Emaciation	0	1	1
Capture myopathy	0	1	1
Egg binding	0	1	1
Exposure	1	0	1
Unknown cause (carcass recovered)	10	39	49
Total known causes	60	73	133
Total confirmed mortalities	70	112	182
Long-term missing (carcass not recovered)	9	67	76

[a] Includes 1 adult euthanized due to injuries from powerline collision.
[b] Collision with aircraft landing on runway.
[c] Does not include injuries related to impact trauma, which are included above.

cranes in the EMP (Table 3, Urbanek et al. 2014*b*, Yaw et al. 2020). Predators included bobcat (*Lynx rufus*), coyote (*Canis latrans*), alligator (*Alligator mississippiensis*), and raptors; however, in most cases the specific predator could not be identified. The second leading cause of death was impact trauma, which included collisions with powerlines, vehicles, and an aircraft landing on a runway (17.8% and 20% for adults and juveniles, respectively, Table 3). Gunshot was the cause of 15.1% of adult and 5.0% of juvenile mortalities; 14 birds were shot during 2001-2020. The "other" category, in which mortalities were attributed to causes other than predation, impact trauma, gunshot, or disease, accounted for 12.3% of adult and 1.7% of juvenile mortalities (Table 3). These "other" causes of death included euthanasia due to injuries of unknown origin or those not related to impact trauma, egg binding, capture myopathy, emaciation, exposure, and 1 death that occurred in captivity while the individual was being treated for an injury (Table 3). Mortalities due to disease remained relatively rare (Table 3, Urbanek et al. 2014*b*, Yaw et al. 2020). During 2001-2016, male and female whooping cranes died of similar causes and at similar ages (Yaw et al. 2020). Overall, the proportions of known causes of mortalities (predation, gunshot, impact trauma, and disease) have not changed substantially over time (Cole et al. 2009, Urbanek et al. 2014*b*, Yaw et al. 2020).

Adult mortalities occurred throughout the annual cycle, generally in similar proportions to the amount of time birds spent on the breeding grounds, wintering grounds, or on migration. The majority of confirmed adult mortalities (71.2%) occurred on the breeding grounds or in summering locations, followed by 20.7% on the wintering grounds, which were spread out across the eastern United States. Only 8.1% of confirmed adult mortalities occurred during either spring or autumn migration (0.9% and 7.2%, respectively).

While there was extensive monitoring of the EMP, not all carcasses were recovered, and long-term missing cranes were removed from population size estimates and were assumed to be dead. Prior to 2007, cranes were monitored intensively throughout the year and almost all carcasses were recovered. During 2007-2020, 76 whooping cranes became long-term missing (22 birds during 2007-2010, 54 birds during 2011-2020). Based on where long-term missing birds were last seen and the subsequent observations of their mates or associates, most cranes were last seen on the breeding grounds (57.9%, *n* = 44). Fifteen long-term missing cranes were last seen on the wintering grounds (19.7%), 11 disappeared during fall migration, and 6 disappeared during spring migration (14.5% and 7.9%, respectively).

Winter Distribution

Wintering whooping cranes in the EMP were distributed throughout the migratory route between Wisconsin and Florida during the second decade of this reintroduction. Although whooping cranes initially wintered in high numbers in Florida (Fondow 2013), the wintering grounds of the EMP began shifting northward by winter 2007-08, and cranes continued to winter farther north during 2010-2020 (Urbanek et al. 2014*a*, Teitelbaum et al. 2018). This change in winter distribution of the population may have been related to warmer winter weather, social learning of northern winter areas by younger cranes following older cranes, fewer UL cranes being shown the migration route to Florida, or availability of grains on agricultural land in the northern wintering areas (Urbanek et al. 2014*a*, Teitelbaum et al. 2016).

Whooping cranes wintered in 12 states during the past 10 years, with the majority wintering in Indiana and Alabama during winter 2020-21. Five additional states had wintering whooping cranes each winter since 2011-12: Tennessee, Kentucky, Florida, Georgia, and Illinois (Fig. 3, Table 4). Additionally, instead of spending all winter in 1 location, a small number of whooping cranes wintered at 2 distinct locations along the migratory path during a single season (Teitelbaum et al. 2018).

Some whooping cranes did not follow the typical migration south and required assistance or capture and translocation to the wintering grounds. Ten juvenile whooping cranes were translocated due to a lack of fall migratory behavior at a time when other cranes in the area had already migrated south. Some of these translocated birds were moved to core wintering areas and released near other whooping cranes, while others were translocated to fall staging areas of sandhill cranes where they subsequently migrated south on their own (Table 5). During winter 2017-18, 1 hatch-year bird (no. 38-17) failed to migrate from her release location at the Horicon NWR in Dodge County, Wisconsin (Table 4, Fig. 3). No. 38-17 survived the winter in Wisconsin, and in the fall of 2018, she migrated south to Illinois with an adult male whooping crane.

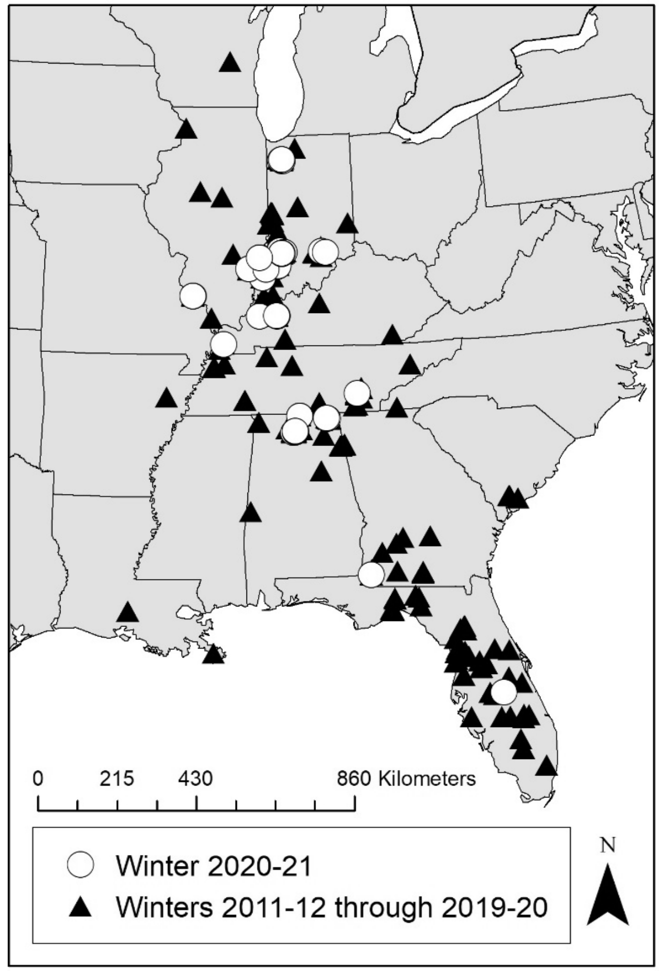

Figure 3. Winter distribution of whooping cranes in the Eastern Migratory Population, 2011-2021. Locations are median coordinates of all locations for each bird during the month of January.

During the winter, there have been several instances of population overlap and interaction between members of the EMP and the Florida Non-migratory Population (FLNMP) or the LNMP. During winter 2010-11, EMP cranes associated with FLNMP cranes in Alachua and Polk Counties, Florida. In 1 case, a FLNMP male temporarily

Table 4. Winter distribution of whooping cranes in the Eastern Migratory Population from winter 2011-12 through winter 2020-21 (winter defined here as majority of January). Totals do not include ultralight-led juveniles that were either in a pen or were recently released in Florida.

Location	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Wisconsin	0	0	0	0	0	0	1	0	0	0
Illinois	3	6	2	0	6	3	3	12	9	8
Indiana	38	43	19	27	31	27	23	33	28	38
Kentucky	6	8	7	11	9	7	8	9	8	11
Tennessee	6	12	16	10	6	7	6	5	2	1
Arkansas	0	0	0	0	0	2	0	0	0	0
North Carolina	2	0	0	0	0	0	0	0	0	0
South Carolina	2	0	2	0	0	0	0	0	0	0
Alabama	7	16	27	30	24	29	32	17	20	14
Georgia	6	3	2	3	2	6	5	3	2	2
Louisiana	0	0	0	0	1	1	2	1	0	0
Florida	12	12	8	10	11	5	7	5	2	1
Unknown	14	3	11	3	6	7	8	7	9	3

paired and migrated north with an EMP female; however, upon arriving in Wisconsin, the EMP female returned to her previous mate and the FLNMP male returned to Florida (Urbanek et al. 2018, Szyszkoski and Thompson 2022). Two additional EMP cranes have associated with FLNMP cranes in Florida; 1 in Polk County during winter 2011-12, and another in Citrus County in winter 2016-17. Lastly, 1 LNMP whooping crane moved to Wheeler NWR in Morgan County, Alabama, and associated with EMP cranes during winters 2018-19 and 2019-20. With the exception of the FLNMP crane who migrated to Wisconsin, none of these cases of population overlap changed the behavior or distribution of whooping cranes in reintroduced populations (Szyszkoski and Thompson 2022).

Summer Distribution

Throughout the 20 years of this reintroduction, the majority of EMP whooping cranes spent the summer in central Wisconsin (Urbanek et al. 2014*b*), and in the past 10 years cranes were typically at or near Necedah NWR, White River Marsh SWA, or Horicon NWR. Necedah NWR was the original release site and has always had the greatest number of breeding pairs in the EMP. Since releases outside of Necedah NWR began in 2011, the summer distribution of whooping cranes in Wisconsin has expanded. During the nesting season of 2020, at least 9 breeding pairs were located in Necedah NWR, 2 additional pairs were outside of Necedah NWR but in Juneau County, Wisconsin, and 10 breeding pairs occupied territories outside of Juneau County (Fig. 4). Of the 10 breeding pairs outside of Juneau County, 6 were in the Eastern Rectangle near new release areas. Similarly, most non-breeding whooping cranes spent the summer in Wisconsin during 2020 (ICF 2020).

There were some exceptions to the typical summer use areas, including long distance movements by young cranes (1-2 years old), as well as breeding pairs who have established territories outside of the core areas (Fig. 4, Teitelbaum et al. 2018). Young cranes have been in Wisconsin's neighboring states of Michigan, Minnesota, Illinois, and Iowa, and a few have strayed farther to North Dakota and South Dakota (Fig. 4). Prior to 2017, WCEP personnel would translocate whooping cranes back to the core areas in Wisconsin to encourage site fidelity in areas with higher numbers of whooping cranes (Table 5, Zimorski and Urbanek 2010). However, this management technique has not been used since 2016. During 2020, there were 4 whooping cranes summering in Michigan, but others that have spent time in Michigan in the past have later returned to summer in Wisconsin. There have only been 2 breeding pairs established outside of the eastern or central Wisconsin: 1 pair in far northwestern Wisconsin (St. Croix County), and a hybrid sandhill-whooping crane pair in southern Michigan (Lenawee County, Fig. 4).

Reproduction

At Necedah NWR, the core breeding area of the EMP, nest desertion was identified during the first decade of the reintroduction as the main factor affecting nest success. The emergence of avian-feeding black flies coincided with whooping cranes nesting and caused

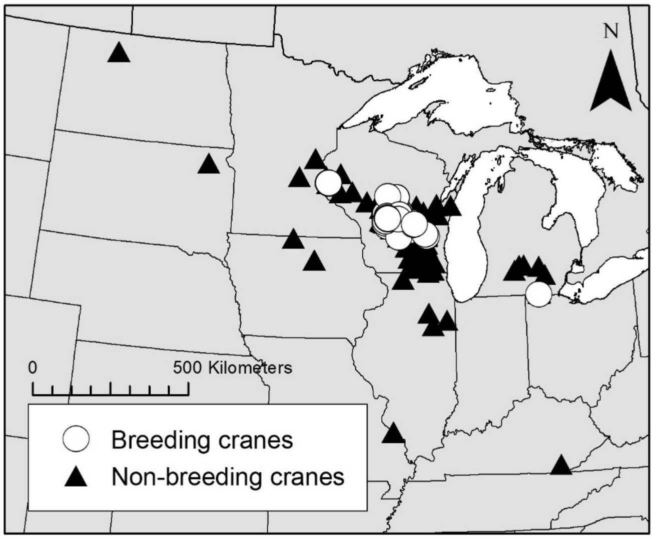

Figure 4. Summer distribution of whooping cranes in the Eastern Migratory Population during 2011-2020. Locations are median coordinates of all locations for each bird during the month of July.

widespread nest abandonments (Urbanek et al. 2010*c*, Barzen et al. 2018*a*). Due to low nest success at Necedah NWR, other areas of Wisconsin were investigated to find more suitable habitat for nesting whooping cranes and included sampling of black fly populations (Adler et al. 2019). In 2011, captive-reared whooping cranes were released in the Eastern Rectangle because it had wetland habitats and presumed smaller populations of black flies (Van Schmidt et al. 2014, Adler et al. 2019). Of note, 4 sites in the Eastern Rectangle and 3 additional sites were sampled for black fly populations in 2010; however White River Marsh SWA, 1 of the release sites, was not sampled in this initial survey but was later found to support black fly populations (Adler et al. 2019, Urbanek and Adler 2022). There have been 10 nests from 4 pairs in the White River Marsh area during 2017-2020. Of those nests, only 1 hatched, 2 were predated, 1 was abandoned, 3 had unknown outcomes but were incubated near full term (30 days), and 3 had unknown outcomes but ended prior to full term. There has not been sufficient evidence of black fly disturbance as a cause of widespread nest abandonment at White River Marsh SWA; however, beginning in 2020, we have deployed nest cameras to collect more information on nest outcomes in this area. Looking to combat nest abandonment at Necedah NWR, a 2014-2016 experimental trial of forced renesting was found to increase renesting rates from 42% of pairs whose nests failed naturally to 79% of pairs whose eggs were collected (Jaworski 2016, Adler et al. 2019). With the exception of the 2020 breeding season, this technique has been implemented every year since 2016. Forced renesting will continue to be used in the EMP, contingent on captive breeding facilities' ability to receive eggs and raise chicks for release.

As of 2021, there were at least 21 territorial breeding pairs. During 2001-2020, there were a total of 361 nests (279 first nests, 82 renests), at least 152 chicks hatched from those nests, 27 chicks survived past 80 days to fledging, and 21 chicks survived past 6 months (Table 2). There have been 2 documented third nesting attempts in a season (in 2010 and 2019), both of which hatched, and 1 nest produced a wild-fledged chick. The nest platforms built farthest from the core reintroduction area were in Gibson County, Indiana, during 2015; however, eggs were never confirmed (Kearns et al. 2022). The first nest in the Eastern Rectangle was in 2014 by male no. 10-11 and female no. 7-11, but the nest failed prior to reaching full term. In 2019, the male and a new mate became the first pair to hatch chicks in the Eastern Rectangle, and in 2020 a different pair hatched and fledged the first chick at Horicon NWR. Although, there have been only a few wild-hatched cranes that have reached sexual maturity and nested, in 2018 the first wild-hatched chick (male no. W5-18) from a wild-hatched parent (female no. W3-10) fledged at Necedah NWR.

Since 2001, there have been 3 male whooping cranes who have been documented nesting with sandhill cranes. One pair bond between a male whooping crane and female sandhill crane in Wisconsin in 2005 has been previously described (Urbanek et al. 2018). At Horicon NWR, a male whooping crane (no. 16-11) first nested with a sandhill crane in 2014 and the pair produced a hybrid chick the following spring. The chick was captured and placed in captivity at the ICF. Due to a lack of females in the area and in an attempt to break the pair bond and facilitate pairing with a female whooping crane, the male was translocated to Necedah NWR where there were single adult females so that he might find and pair with a conspecific. However, he immediately returned to his territory at Horicon NWR (Table 5). He was recaptured, brought into captivity in 2016 and paired with a captive female whooping crane. The family group (male no. 16-11, female no. 18-12, and their 2 chicks) was released in August 2018; unfortunately, female no. 18-12 died 1 month later. Male no. 16-11 stayed with his 2 chicks until

Table 5. Translocations of whooping cranes in the Eastern Migratory Population, 2001-2020. Locations are reported to the county level unless on state or federally managed land. Cranes that migrated outside of the route between Wisconsin and Florida were considered to be outside of the flyway (OF). Other reasons for translocation included cranes closely associating with human activity and development (HAD), associating with captive cranes in a zoo setting (ZOO), and cranes that did not migrate (DNM) and were moved to the wintering grounds. After translocation, many cranes migrated normally in subsequent years (MNSY) or avoided human activity and development (AHAD). Additional information can be found from Zimorski and Urbanek (2010).

Capture date	Release date	Capture location	Release location	Bird IDs	Reason	Outcome
4 May 2003	4 May 2003	Morgan Co., Oh.	Juneau Co., Wis.	9-02	OF	MNSY
17 Aug 2003	18 Aug 2003	Day Co., S.D.	Necedah NWR, Juneau Co., Wis.	15-02	OF	Flew with 3-02 to Allamakee Co., Ia., for the rest of the summer and did not return to S.D. in subsequent years.
18 Aug 2003	18 Aug 2003	Day Co., S.D.	Necedah NWR, Juneau Co., Wis.	3-02, 7-02	OF	7-02 died of capture myopathy. 3-02 flew with 15-02 to Allamakee Co., Ia., for the rest of the summer and did not return to S.D. in subsequent years.
30 Jun 2005	1 Jul 2005	Mason Co., Mich.	Necedah NWR, Juneau Co., Wis.	1-03, 18-03	OF	Both were detected in Mich. again in spring 2006. 1-03 returned to Wis. on her own and 18-03 stayed in Mich. for the summer. Both migrated normally after 2006.
28 Nov 2005	28 Nov 2005	Bullitt Co., Ky.	Taylorsville Lake WMA, Anderson Co., Ky.	27-05	HAD	AHAD
16 Dec 2005	16 Dec 2005	Beaufort Co., N.C.	Madison Co., Fla.	9-03	OF	Migrated outside of flyway again in 2006 (see below).
5 May 2006	5 May 2006	Lewis Co., N.Y.	Necedah NWR, Juneau Co., Wis.	9-03, 20-05	OF	9-03 migrated outside of flyway again in 2007 (see below). 20-05 MNSY.
16 May 2006	16 May 2006	Eaton Co., Mich.	Necedah NWR, Juneau Co., Wis.	16-05	OF	Migrated outside of flyway again in 2007 and 2008. He was last seen in Dec 2008.
12 Sep 2006	12 Sep 2006	Juneau Co., Wis.	Necedah NWR, Juneau Co., Wis.	W1-06	Other[a]	W1-06 re-joined parents 11-02 and 17-02 south of Necedah NWR on 13 Sep 2006.
1 Feb 2007	26 Feb 2007	Homosassa Springs Wildlife State Park (WSP), Citrus Co., Fla.	Paynes Prairie Preserve State Park, Alachua Co., Fla.	5-01	ZOO	Returned to Homosassa Springs WSP in fall 2007 (see below).
10 Feb 2007	3 Mar 2007	Halpata Tastanaki Preserve, Marion Co., Fla.	St. Martins Marsh Aquatic Preserve, Citrus Co., Fla.	15-06	Other[b]	Returned to Halpata Tastanaki on 7 Mar. Usually alone, he was later suspected killed by a predator shortly after 21 April.
14 May 2007	14 May 2007	Oceana Co., Mich.	Necedah NWR, Juneau Co., Wis.	27-06	OF	MNSY
3 Oct 2007	3 Oct 2007	Oswego Co., N.Y.	Necedah NWR, Juneau Co., Wis.	9-03	OF	After pairing with 3-04 in fall 2007, 9-03 migrated normally to Wis. all subsequent years.
1 Dec 2007	1 Dec 2007	Desha Co., Ark.	Hiwassee WR, Meigs Co., Tenn.	46-07	OF	MNSY
11 Dec 2007	11 Dec 2007	Monroe Co., Ill.	Hiwassee WR, Meigs Co., Tenn.	37-07, 39-07, 40-07, 42-07, 43-07, 44-07	HAD	AHAD
13 Dec 2007	16 Dec 2007	Homosassa Springs WSP, Citrus Co., Fla.	Hiwassee WR, Meigs Co., Tenn.	5-01	ZOO	Returned to Homosassa Springs WSP in winter 2008-09 (see below).
13 May 2008	13 May 2008	Dane Co., Wis.	Necedah NWR, Juneau Co., Wis.	16-07, 17-07, 21-07, 26-07	HAD	AHAD
2 Jun 2008	2 Jun 2008	Fish Point SWA, Tuscola Co., Mich.	Necedah NWR, Juneau Co., Wis.	37-07	OF	Continued to migrate to Mich. every summer until 2014, when he finally migrated to Wis. on his own. He did not return to Mich. on subsequent migrations.

Table 5. Continued.

Capture date	Release date	Capture location	Release location	Bird IDs	Reason	Outcome
10 Jun 2008	10 Jun 2008	Fish Point SWA, Tuscola Co., Mich.	Necedah NWR, Juneau Co., Wis.	39-07, 42-07, 46-07	OF	MNSY
17 Oct 2008	17 Oct 2008	Juneau Co., Wis.	Necedah NWR, Juneau Co., Wis.	22-07	HAD	Returned to ethanol plant in spring 2009 where mate 10-07 was captured and removed from the EMP. No. 22-07 returned to the ethanol plant briefly in fall 2009 and spring 2010 but then established a breeding territory at Necedah NWR and did not return again to ethanol plant.
20 Jan 2009	22 Jan 2009	Homosassa Springs WSP, Citrus Co., Fla.	Hiwassee WR, Meigs Co., Tenn.	5-01, 1-05	ZOO	Pair returned to Homosassa Springs WSP (see below).
1 Feb 2009	4 Feb 2009	Homosassa Springs WSP, Citrus Co., Fla.	Hiwassee WR, Meigs Co., Tenn.	5-01, 1-05	ZOO	After the death of 1-05, 5-01 returned to Homosassa Springs WSP during fall 2010 and associated with the captive female crane. He was removed from the population and kept in captivity.
26 Jan 2013	9 Feb 2013	Broward Co., Fla.	Hiwassee WR, Meigs Co., Tenn.	13-12	Injury	Returned to Wis. in spring but died summer 2013.
10 Feb 2013	10 Feb 2013	Broward Co., Fla.	Hendry Co., Fla.	15-12	HAD	Translocated to a more rural ranch area. Was last seen 20 Feb 2013 in Hendry Co., Fla.
11 Dec 2013	12 Dec 2013	Horicon NWR, Dodge Co., Wis.	Wheeler NWR, Morgan Co., Ala.	59-13	DNM	MNSY
1 May 2015	4 May 2015	Crab Orchard NWR, Williamson Co., Ill.	White River Marsh SWA, Green Lake Co., Wis.	8-14, 9-14, 10-14	Other[c]	8-14 MNSY. 9-14 and 10-14 migrated south to Fla. in fall 2015 but died on the wintering grounds.
13 Oct 2015	13 Oct 2015	Dubuque Co., Ia.	Iowa Co., Wis.	20-15	OF and HAD	Returned to Wis. in the spring, migrated to La. for winter in subsequent years.
8 Apr 2016	12 Apr 2016	Horicon NWR, Dodge Co., Wis.	Necedah NWR, Juneau Co., Wis.	16-11	Other[d]	Returned to Horicon NWR by 21 Apr 2016.
5 May 2016	5 May 2016	Macomb Co., Mich.	Marquette Co., Wis.	61-15, 62-15, 63-15, 67-15	OF	MNSY
12 Dec 2016	14 Dec 2016	Portage Co., Wis.	Wheeler NWR, Morgan Co., Ala.	70-16	DNM	Did not migrate again, stayed in Ky. for the summer.
22 Nov 2017	22 Nov 2017	White River Marsh SWA, Green Lake Co., Wis.	Sauk Co., Wis.	3-17, 7-17	DNM	MNSY
28 Nov 2017	28 Nov 2017	White River Marsh SWA, Green Lake Co., Wis.	Sauk Co., Wis.	4-17, 6-17	DNM	MNSY
12 Dec 2017	12 Dec 2017	White River Marsh SWA, Green Lake Co., Wis.	Goose Pond FWA, Greene Co., Ind.	1-17, 2-17, 8-17	DNM	Migrated to Ia. in spring 2018. MNSY.

[a] Family group left NNWR and flew approximately 3.3 km south of the refuge.
[b] Precaution against predation taken because of roosting outside pen holding captive crane.
[c] On the UL migration they had been boxed and driven from Wis. to Tenn. On their first northward migration they stopped moving north in Ky. and did not appear to be continuing on to Wis.
[d] Attempt to facilitate pairing with female whooping crane and break bond with female sandhill crane.

spring 2019, when he once again nested with a sandhill crane. The hybrid eggs were collected and the nest was destroyed. In 2020, he did not nest but was often seen associating with a sandhill crane as well as with 2 young males and a young female whooping crane (no. 79-19). Another male whooping crane (no. 14-12) nested with a sandhill crane in Lenawee County, Michigan, in 2020. To prevent hybrid chicks from hatching, an attempt was made by Michigan Department of Natural Resources staff to replace the eggs with dummy eggs; however, the pair had already hatched 2 hybrid chicks. The chicks did not survive long after hatching but the pair renested, and the eggs from the second clutch were replaced with dummy eggs.

There have been several instances of same-sex whooping crane pairs in the EMP. A male-male pair (nos. 19-09 and 25-10) occupied and defended a territory at Necedah NWR and migrated together since 2012. They have been observed unison calling but were not documented exhibiting any other breeding or nesting behaviors. In 2017, 2 female-female pairs were observed sitting on nests; however, eggs were never confirmed in either nest. In 2018, 1 female-female pair had separated and the females in the other pair were together but not observed nesting. In 2019, the female-female pair in Marathon County (nos. 28-05 and 2-15) nested again and laid 2 eggs which they incubated full-term (Thompson and Gordon 2020). In 2020, due to restrictions related to the COVID-19 pandemic, captive centers were not able to accept eggs, and forced renesting could not be conducted at Necedah NWR. In an effort to try to increase the number of chicks hatched in the wild, 2 fertile eggs were instead removed from a nest on Necedah NWR and swapped into the Marathon County female-female pair's nest. The female-female pair had laid 3 eggs, 2 of which were removed and exchanged for the 2 fertile eggs. The trail camera photos showed that at least 1 chick hatched; however, the pair was observed at the nest without the chick or the remaining eggs just 2 days later. The trail camera documented the disappearance of the 2 remaining eggs at the nest overnight. The pair was walking around the nest, never resumed incubation, and was not again seen with the chick. This evidence indicated predation but the trail camera did not capture a photograph of a predator. During July 2020, female no. 28-05 was found dead during flightless molt, and female no. 2-15 had a wing injury and was unable to fly. Female no. 2-15 was captured and brought to ICF for medical evaluation, where it was determined that her flight impairment was permanent and she would remain in captivity. As of April 2021, there were no known female-female whooping crane pairs in the EMP.

Human Avoidance

During 2001-2010, with a few exceptions most whooping cranes avoided human activities and structures (Urbanek et al. 2014*b*). As of 2021, most whooping cranes in the EMP continued to avoid close proximity to humans. However, there were still a few instances in which whooping cranes became habituated to human development. One PR juvenile originally released near other whooping cranes at Necedah NWR left Wisconsin and spent time in a restaurant parking lot located close to busy roads in Dubuque, Iowa. The bird was then translocated to a sandhill crane staging area in Iowa County, Wisconsin (Table 5, WCEP 2016). Additionally, other cranes used areas close to busy roads which posed a threat to their safety (WCEP 2011). Since 2001, at least 4 whooping cranes have died due to impact trauma related to a vehicle collision (Table 3). We have continued to see whooping cranes use areas near busy roads, which has prompted management actions including hazing and the translocation of 1 individual to a less developed area (Table 5). Hazing measures (e.g., honking horns, flashing lights, or a moving person under a tarp or ghillie suit known as the "swamp monster") to keep cranes out of roads have had limited success. In 1 case in Sauk County, Wisconsin, due to a busy highway with a blind curve running through the cranes' territory, "crane crossing" signs have been deployed to try to mitigate potential issues.

In total, 5 adult whooping cranes have been removed from the population due to issues related to human avoidance. The removal of male no. 10-07 due to his presence at an ethanol plant in Necedah, Wisconsin, and the removal of no. 5-01 due to his yearly arrival at the Homosassa Springs Wildlife State Park in Citrus County, Florida, have been previously described (Table 5, Urbanek et al. 2009, WCEP 2011, Urbanek et al. 2014*b*). Three additional adult male cranes (nos. 1-01, 12-09, and 16-12) were removed from the population due to their continued use of an active air strip on an Air National Guard base in Juneau County, Wisconsin (WCEP 2014, WCEP 2019, ICF 2021). One of these adult male whooping cranes (no. 1-01) began using the base in 2010, then he and his mate (no. 14-09) were on or near the base each summer from 2011 until his removal in spring 2014 (WCEP 2014). The pair had also habituated to humans on the wintering grounds in Florida, as well as in Wisconsin, where a landowner adjacent to the base had been feeding them. In 2016, 2 males (nos. 12-09 and 16-12) began using the base, and they were joined by a female (no. 69-16) 2 years later. The following spring, that female and male no. 12-09 nested on the base in a wetland adjacent to the runway. After many hazing attempts were unsuccessful, the male was captured and removed from the population in fall 2019 (WCEP 2019). The female repaired and nested with a male on Necedah NWR in spring 2020 and did not return to the air base. The remaining unpaired male (no. 16-12) continued to use the base and was removed from the population in April 2021 (ICF 2021). The U.S. Department of Agriculture Animal and Plant Health Inspection Service Wildlife Services has taken the lead in continuing to haze problem cranes from the base, and the Air National Guard has undertaken habitat management actions, e.g., repairing drain tiles and deepening wetlands, to reduce appeal of the area to cranes.

DISCUSSION

The reintroduction of cranes into the EMP continues to contribute to our knowledge of crane reintroductions as well as to whooping crane recovery in North America (CWS and USFWS 2005). During the first 20 years of this reintroduction, whooping cranes have learned a migration route in the eastern U.S., established summer and winter home ranges, found mates, nested, and hatched and raised chicks in the wild. Additionally, reintroduced whooping cranes in the EMP and LNMP are in agricultural and human-dominated landscapes, which provides an opportunity to learn how the remnant Aransas-Wood Buffalo population of whooping cranes might adapt to habitat changes in the Central Flyway, particularly on the wintering grounds where cranes are starting to use more developed and agricultural areas instead of strictly coastal marshes (Tiegs 2017).

There have been significant changes in management of the EMP since the 10-year status update through 2010 (Urbanek et al. 2014*b*). PWRC ended its breeding program and transferred whooping cranes to new breeding facilities (WCEP 2018), WCEP reduced the hands-on approach of translocating birds from outside of the core flyway, the UL program ended, and focus has been shifted to releasing PR cranes instead of CR cranes (Fasbender et al. 2015). On the breeding grounds, additional, conclusive information has been gathered on the effect of black flies on nesting cranes (Converse et al. 2013, 2018*b*; Barzen et al. 2018*a*), and forced renesting has been implemented as a strategy to increase renesting rates and allow nesting pairs to avoid black fly outbreaks at Necedah NWR (Jaworski 2016, Adler et al. 2019). In addition to forced renesting, the release areas for captive-reared birds were shifted from Necedah NWR to the Eastern Rectangle where there are now nesting pairs (Van Schmidt et al. 2014, Adler et al. 2019).

Due to these changes in management, there have been some changes in demographics of the EMP during 2010-2020. As of 2021, there is a lower proportion of CR cranes in the EMP, and there are more PR and wild-hatched cranes than there were in 2010. The summering range has expanded due to fewer translocations as well as new release areas. The core breeding area is still Necedah NWR and vicinity, but there are now breeding pairs in the Eastern Rectangle (Fig. 4). The wintering range has also expanded, and whooping cranes now winter in colder, more cropland-dominated areas rather than in wetlands or grasslands of Florida (Fondow 2013, Urbanek et al. 2014*a*, Thompson 2018). The population size has started to decrease due to reduced numbers of released captive-reared cranes and insufficient recruitment to balance mortalities (Fig. 1).

There have been multiple direct and indirect efforts to address the issues of low recruitment rates and poor chick survival in terms of behavior as well as breeding habitat. Stewart (2020) attempted to determine cause-specific mortality of whooping crane and sandhill crane chicks at Necedah NWR during 2016-2018. It was difficult to recover chick carcasses quickly enough to determine cause of mortality; however, for those that were able to be determined, predation was the leading cause of death, followed by disease and exposure (Stewart 2020).

It is possible there is some aspect of breeding habitat or predator communities that are affecting reproductive success and chick survival for whooping cranes in Wisconsin. Current ongoing research is evaluating mammalian predator communities at both of the core reintroduction sites, Necedah NWR and the Eastern Rectangle, to determine if there are particular sites or habitat types that pose a higher risk of predation for crane chicks (N. Gordon, University of Wisconsin, unpublished data). One tool that has been developed to mitigate low chick survival at Necedah NWR is the use of growing season drawdowns. McLean (2019) found increased rates of survival for both whooping crane and sandhill crane chicks in impoundments that were drawn down during the summer. Future and ongoing research will continue to evaluate breeding habitat and develop management strategies to promote colt survival and reproductive success.

To determine if adult cranes lack appropriate predator defense or parenting behavior, research projects have focused on rearing technique as well as the role of learning or experience. At this stage of the reintroduction, we have not seen an effect of rearing technique on reproductive success (Thompson et al. 2022); however, captive-rearing has focused on using parent-rearing over costume-rearing in case that ultimately does affect parenting behavior. Additionally, more wild-hatched cranes have been recruited into the population in recent years and will soon reach breeding age. In the near future we will be able to reassess if PR or wild-hatched cranes have different rates of reproductive success compared to CR cranes. We are beginning to see an effect of nesting experience and age of adult cranes on the survival of their chicks, where older cranes with more nesting experience have chicks who live longer than those of young, inexperienced parents (B. R. F. Sicich, International Crane Foundation, unpublished data). We will continue to assess the roles of rearing technique and nesting or parenting experience as the population ages and there are more breeding cranes that were PR or wild-hatched.

In the coming years, we will continue to monitor and research the EMP and the effects of our management strategies. As more PR and wild-hatched cranes reach breeding age, we will investigate if they have different parenting abilities than CR birds. Additionally, as the population grows, we will learn if parenting experience improves chick survival, and if nests in the Eastern Rectangle will have higher hatching rates or chick survival rates than nests at Necedah NWR. Current research projects are focused on habitat use during nesting and chick-rearing and potential habitat management techniques that may improve fledging success in the EMP (Urbanek 2015, McLean 2019, Stewart 2020). A better understanding of nesting and chick rearing in the EMP will facilitate development of scientifically informed management tools and decision-making that may help improve recruitment and ultimately lead to self-sustainability of the population.

MANAGEMENT IMPLICATIONS

This 20-year status report will help guide the next phase of this reintroduction by outlining what we have learned as well as identifying priority areas of research. In the future, we will continue to investigate ways to improve survival of wild-hatched whooping cranes that will ultimately contribute to this population's growth and success. Currently, research projects are evaluating breeding and chick-rearing habitat, potential habitat management tools on the breeding grounds, the effect of rearing techniques on parenting and predator aversion behaviors, and the role of nesting and chick-rearing experience on survival of wild-hatched birds. Continued releases of captive-reared cranes, post-release monitoring, and management of the EMP and their habitat will provide an opportunity to learn more about factors affecting the growth of this reintroduced population.

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