SPECIES REVIEW:

WHOOPING CRANE (*Grus americana*)

Elizabeth H. Smith

(with input from George W. Archibald, Jane E. Austin, John French, Tim Grunewald, Wade Harrell, James T. Harris, Barry K. Hartup, Sammy King, Anne Lacy, Claire M. Mirande, Glenn Olsen, Richard Urbanek, and Sara Zimorski)

International Crane Foundation, Baraboo, Wisconsin, USA
Email: esmith@savingcranes.org

Whooping tending nest and eggs (Photographer: Ted Thousand, International Crane Foundation)

Red List Category: Endangered
Population Size: 689
Population Trend: Increasing
Distribution: North America

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DISTRIBUTION AND STATUS OF KEY SITES

Subspecies/Populations

Four populations of Whooping Cranes currently exist in the wild. The Aransas-Wood Buffalo (AWB) population is the only self-sustaining remnant of the original migratory population. This population breeds mainly in Wood Buffalo National Park (WBNP) along the Sass and Klewi Rivers, Canada, and winters in and adjacent to the Aransas National Wildlife Refuge (NWR), central Texas coast, USA. Pursuant to the goals of the International Whooping Crane Recovery Plan (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2005), three additional distinct populations have been introduced within the United States (French et al. 2018). (1) Florida (FL) population: An attempt was initiated in 1993 to establish a non-migratory population at and surrounding Kissimmee Prairie in central Florida, USA. This reintroduction effort was terminated in 2008, and about 14 individuals were still within the area as of August 2016. (2) Eastern Migratory (EM) population: An effort was initiated in 2001 to create an eastern migratory population that is intended to breed in central Wisconsin and winter between the central Gulf Coast of Florida and southeastern United States. This reintroduction effort is ongoing and 103 adults were present as of April 2018. (3) Louisiana (LA) population: An attempt to establish a non-migratory population in southwestern Louisiana was initiated in 2011. Sixty-seven individuals were present as of April 2018 and reintroductions are ongoing. The FL, EM, and LA populations are considered "experimental" and "nonessential" to the Whooping Crane population as designated by the Endangered Species Act of 1973. "Experimental" is a designation given reintroduced populations established outside a species' current range, but within its historic range. "Nonessential" is a determination that a given reintroduced population is not essential to the continued existence of a species. The purpose of the designation is to reduce regulatory restrictions on reintroductions considered nonessential. A fifth population, the Rocky Mountain (RM) population, the first experiment to reintroduce Whooping Cranes to their historic range initiated in 1975, has died off. A total of 160 Whooping Cranes are maintained in 12 facilities in the U.S. and Canada through March 2017 (French et al. 2018).

Aransas-Wood Buffalo Population

The AWB population is the remnant of the migratory population (Allen 1952). It is recovering from a low of 15–16 birds in 1941, increased to 283 in the 2010–11 winter census, and in the winter of 2017–18 had an estimated 505 birds (95% CI = 439.2–576.6; CV = 0.069), which was a record high for this population (Butler and Harrell 2018). The population breeds and winters in very restricted areas and migrates 4,000 km through a narrow, 270-km wide corridor. Critical habitat areas in the migratory corridor in the United States was identified in 1978 in the breeding primary migratory corridor includes the Platte River Area and Quivira NWR in Kansas; Salt Plains NWR, Oklahoma; and the wintering area within surrounding Aransas NWR, Texas (Federal Register 43 FR 20938-942; U.S. Fish and Wildlife Service 1994). In Canada, critical habitat for the species is within Wood Buffalo National Park (Parks Canada 2008).

Breeding habitat in Canada is not believed to be a limiting factor for continued growth of the AWB population, as suitable habitat quantity within WBNP appears sufficient to support 250 nesting pairs (Olson and Olson Planning and Design Consultant, Inc. 2003, Tischendorf 2003 in Environment Canada 2007). However, protection may not be afforded outside the park, where new territories have become established.

The migration corridor encompasses a long, narrow portion of the central region of North America (Pearse et al. 2015). Earlier assessments identified most mortality as occurring during the seven weeks spent migrating to and from breeding and wintering grounds (Lewis et al. 1992, Canadian Wildlife Service and U. S. Fish and Wildlife Service 2005, Stehn and Haralson-Strobel 2014). However, results from birds marked with satellite telemetry transmitters, providing evidence less biased by season, indicate more mortality occurs in winter (~45%) and summer (~40%) than during migration (~15%) (Pearse et al. 2018). Habitat availability along the migration corridor does not appear to be limiting recovery. However, the potential for power line collisions if the lines are sited where Whooping Cranes are on the ground during migration is a serious concern (Stehn and Haralson-Strobel 2014). The potential avoidance of areas caused by energy development infrastructure needs to be closely monitored.

Human impacts resulting from increasing urbanization on the wintering grounds may limit the recovery potential for Whooping Cranes. These impacts include impaired freshwater inflows affecting bay salinities, an increase of pollution and environmental contaminants, and habitat loss (Smith et al. 2018). As the AWB population has continued to increase in numbers, cranes have moved out from the protection of the Aransas NWR into private lands and public waters. Conversion of this habitat from coastal marshes, freshwater marshes, and shallow seagrass beds to urban and industrial development will limit the ability of the landscape to support birds at recovery levels (Stehn and Prieto 2010, Smith et al. 2018).

The U.S. Fish and Wildlife Service discontinued the census method used the previous 29 years and initiated a standardized survey process in autumn 2011 based on distance sampling, which allowed for measurement of the precision of abundance estimates and improved repeatability (Butler et al. 2014b, Strobel and Butler 2014).

Florida Non-migratory Population

There were records of Whooping Cranes in Florida until the 1930s. An effort to reintroduce a sedentary population was initiated there in 1993. The Florida peninsula provided extensive areas of suitable crane habitat that supported a stable population of 4,000–6,000 Florida Sandhill Cranes (Nesbitt 1996). Florida offered a unique opportunity to establish a non-migratory population of Whooping Cranes similar to the non-migratory population that occurred in Louisiana until the late 1940s (Gomez 1992). Feasibility studies of establishing a population of Whooping Cranes in Florida began in 1980 (Nesbitt and Carpenter 1993) and the first experimental release occurred in 1993. Between 1993 and 2006, 289 Whooping Crane were released (Folk et al. 2010) within Lake, Osceola, and Polk counties in central Florida. Juveniles were raised in captivity using costume- and parent-reared techniques and were soft-released (held in pens for several weeks before being released in the wild) into lowland habitats used for cattle grazing (Folk et al. 2005). Although cattle encroachment into crane areas was an issue during drought periods, grazing was an efficient management tool to reduce shrub encroachment (Folk et al. 2010). In early years, cranes were more susceptible to predation, primarily bobcat (*Lynx rufus*) and to a much lesser degree alligator (*Alligator mississippiensis*), as they were selecting roosting areas on dry ground (Nesbitt et al. 1997, Folk et al. 2014). The inclusion of shallow water in pens for nocturnal roosting improved post-release survival rates (Gee et al. 2001). After the discovery of metal fragments in the digestive tracts of over 50% of cranes that died (Spalding et al. 1997), materials used in original pen construction were also modified and levels of metal ingestion were reduced (Nesbitt et al. 2001).

From 1995–2005, 47 nesting attempts by the FL population resulted in four fledged chicks. Environmental conditions or disease have been suggested as factors in low fertility and hatching rates (Spalding et al. 2009). Drought conditions may be responsible for the dispersal of individual Whooping Cranes from the release site (including some outside of Florida), which increased potential for predation and power line strikes, and decreased potential for pair formation in maturing birds (Folk et al. 2010). A severe drought in Florida, which coincided with the maturation of the introduced cranes, reduced water levels in wetlands and likely had a strong influence on nesting attempts and success (Folk et al. 2005, Spalding et al. 2009). Some of the Whooping Cranes associated with Sandhill Cranes. Although an evaluation did not disclose the factors that contributed to this association, they may have included gender, rearing method, release site or year, small population size, or low availability of Whooping Cranes as mates (Folk et al. 2010). Poor productivity within this experimental population was related to adult mortality (especially older males), a high proportion of delayed and non-productive birds, and poor hatching in some years (Spalding et al. 2009). The FL population also experienced health issues. Some of the released birds were confirmed to have Infectious Bursal Disease, which is not generally found in wild populations (Candelora et al. 2008).

In 2008, the International Whooping Crane Recovery Team reviewed ongoing population modeling results for the FL population that identified a lack of productivity through fledging (Moore et al. 2012) and a possible lack of genetic diversity (Converse et al. 2013) as contributing to low population viability. They recommended that additional releases of captive-reared birds be terminated. The population, as of March 2016, totaled approximately 14 birds. That year at least five wild-hatched chicks from this population were still alive and a pair of chicks fledged from a nest (Harrell and Bidwell 2016). Much essential information has been gained throughout this attempt to establish this experimental population. Research and monitoring continue that will contribute further insights for the other Whooping Crane introduction programs (Folk et al. 2010). An Environmental Assessment was completed in April 2018 by the U.S. Fish and Wildlife Service, enabling the translocation of the remaining Whooping Cranes to Louisiana over the next several years (David Oster, personal comm. 2018).

Eastern Migratory Population

Whooping Cranes historically nested in the interior portions of the upper Midwest USA (Allen 1952, Austin et al. 2018). Their numbers declined as a result of wetland drainage, the conversion of prairie into farmland, and shooting. There are also several anecdotal accounts of the presence of the birds documented in the autumn and winter along the southeastern Atlantic Coast (Allen 1952). The EM population program began in 2001 and continues to present, with a total of 268 juveniles released on the breeding grounds through 2016 (Whooping Crane Eastern Partnership 2016). In the beginning of the program, the primary method of reintroduction focused on releasing costume/isolation-reared juveniles at Necedah NWR, in central Wisconsin, USA. The juveniles received on-site flight training to follow ultralight (UL) aircraft in preparation for learning the migration route (Lishman et al. 1997). The autumn migration route (2,010 km) was a relatively direct path from Wisconsin to the intended wintering site on Chassahowitzka NWR on the central Gulf coast of Florida (Urbanek et al. 2010a). An evaluation of how social learning and innate abilities affect migration was conducted using migration data from 2001–2009. Results indicated the importance of having older, experienced birds for younger sub-adults to follow back along the EM population migration corridor (Mueller et al. 2013). More recent evaluations to address why more birds are not completing the original migration further indicated that older individuals elected to winter further north along the autumn migration path, using sites closer to the breeding range (Teitelbaum et al. 2016, Mueller et al. 2018).

In 2005, the UL flock began stopping at Halpata Tastanaki Preserve, Marion County, Florida, that is located 42 km north of Chassahowitzka NWR. This delay allowed older birds that had already arrived at Chassahowitzka NWR time to disperse to inland sites primarily throughout west central Florida and reduced potential conflicts with arriving juveniles. In 2005, an alternative rearing and release method (Direct Autumn Release – DAR) was introduced, where costume-reared juveniles were released in the autumn at Necedah NWR near adult Whooping Cranes. Association with older EM population birds in Wisconsin prior to migration was intended to provide the opportunity for the older UL birds to guide the DAR birds' first autumn migration (Urbanek et al. 2010a). In an attempt to improve hatching success, the reintroduction location was changed in 2011 to locations further east, at Horicon Marsh NWR and the White River Marsh State Wildlife Area, where densities of black flies (Simuliidae) were lower than at Necedah NWR (see notes on black flies below). Both rearing and release techniques were used until the UL technique was discontinued in 2015 (Harrell and Bidwell 2016). For the period 2001–2010, survival to one year from the start date of the UL-guided migration was 0.76 among 156 cranes (Hartup 2018a). For 2005–2010, survival to one year from autumn release for 44 DAR cranes was 0.68. The primary causes of death were predation, trauma from power line strikes (Cole et al. 2009), and shootings, which alone accounted for 19% of all mortality where the cause of death could be determined (Condon et al. 2018).

Lessons learned from previous experimental population programs, as well as advances in understanding through the EM population program, have led to successful results with respect to migration (for both UL and DAR birds) as well as homing ability for subsequent migration cycles, exploitation of available habitats, pair formation, territory establishment, laying of fertile eggs, and initiation of incubation. However, poor reproductive success due to abandonment of nests during incubation and poor chick survival has been the limiting factor thus far in the EM population (Urbanek et al. 2010a, Converse et al. 2012, Converse et al. 2018). From 2005 through 2008, all first nesting attempts failed. In 2006, two chicks hatched from one nest and one of these chicks fledged. Targeted research provided support for the hypothesis that the timing of emergence of blood-feeding black flies in each year contributed to nest abandonment and failure (Urbanek et al. 2010b, Converse et al. 2013, Barzen et al. 2018). Other hypotheses of factors contributing to poor productivity include environmental conditions (low food availability in wetlands) and bird-specific factors (effects of rearing method on subsequent reproduction or genetic structure) (Barzen et al. 2018, Converse et al. 2018). Challenges to reproductive success persist; through 2016, 86 chicks were produced in 178 nesting pair-years, a 46% nest success rate, but few chicks have survived to fledging (Whooping Crane Eastern Partnership 2017).

Beginning in 2011, DAR birds were also released at the Horicon NWR in an effort to encourage future breeding locations away from the range of black flies and because of low realized productivity at the Necedah NWR. A total of 101 adults were documented to be present in the EM population through March 2017 with 27 nesting pairs (Whooping Crane Eastern Partnership 2017).

Louisiana Non-migratory Population

The Chenier Plain and prairie terrace uplands of southwestern Louisiana were historically used by both migrating and non-migrating cranes (Gomez 1992). However, the two populations were extirpated from the region by 1918 and 1950, respectively (Allen 1952). Efforts to reintroduce an experimental, non-migratory LA population began in February 2011 with the release of ten captive-reared Whooping Cranes, hatched in 2010, at White Lake Wetlands Conservation Area near Gueydan. By May 2011, two individuals were missing (one later confirmed dead, presumably killed by a predator) and the remaining eight cranes had dispersed throughout Vermilion, Evangeline, and Acadia parishes as a consequence of drought conditions throughout the northwestern Gulf of Mexico states (King and Perkins 2011). By March 2014, all birds from the 2010 cohort were dead. One-year survival post-release of the 40 cranes released from 2010–2013 was 0.64 (Hartup 2018a). Maximum size of the Louisiana non-migratory population at the end of April 2018 was 67 individuals (32 males, 33 females, and 2 newly hatched chicks) (Szyszkoski 2018). A total of 125 chicks were reintroduced to the LA population between 2011 and 2018 (Sara Zimorski, personal comm. 2018). The first Whooping Crane chicks to successfully hatch in Louisiana in 75 years were observed in 2016. This nest was located in an actively farmed crawfish pond (Louisiana Department of Wildlife and Fisheries 2016). This population has experienced the highest rates of shooting mortalities, with nearly one in four Whooping Cranes killed by hunters (Harrell and Bidwell 2013, Condon et al. 2018).

Rocky Mountain Migratory Population
The fifth population, the experimental Rocky Mountain (RM) population, has died off. This initial reintroduction effort involved an attempt to cross-foster Whooping Crane chicks with wild pairs of adult Sandhill Cranes. Between 1975 and 1988, 289 Whooping Crane eggs were removed from the AWB population and captive pairs at the Patuxent Wildlife Research Center and placed in active Sandhill Crane nests at Grays Lake NWR, Idaho, USA. This cross-fostering attempt resulted in the surrogate Sandhill Crane parents hatching eggs, raising chicks, and successfully teaching the juveniles the migration route to the wintering range in the Rio Grande Valley and surrounding areas at Bosque del Apache NWR, New Mexico, USA. The young Whooping Cranes, however, imprinted on their Sandhill Crane parents instead of other Whooping Cranes. High mortality rates from predation on the breeding grounds (Drewien et al. 1985) and from power line collisions during migration (Brown et al. 1987), combined with no reproductive success depleted the introduced population numbers to 33 birds in 1988. In addition, the potential for sexual imprinting with Sandhill Cranes resulted in a decision to terminate the cross-fostering program in 1989 (Lewis 1990). The reintroduction effort continued with experimental "guide bird" (Drewien et al. 1997) and ultralight-led migrations (Clegg and Lewis 2001) of captive-raised Whooping and Sandhill Crane chicks. The last Whooping Crane in the RM Population died in 2002.

ECOLOGY
The AWB population of Whooping Cranes is a wetland-dependent species nesting in a freshwater mosaic of ponds and marshes within forested ridges in the northernmost portion of the Boreal Plains ecoregion in Canada (Timoney 1999). The birds migrate through the Prairie Pothole and Great Plains ecoregions in central USA and winter in the Gulf Coast Prairies ecoregion in Texas. In Canada, adults feed primarily on invertebrates and small vertebrates (Allen 1952, Novakowski 1966), and parents feed their chicks mostly dragonfly (Odonate) nymphs (88%) (Bergeson et al. 2001a). They utilize grain fields in their major staging area in central and south Saskatchewan and along the migratory corridor (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2005) and feed primarily on blue crabs (*Callinectes sapidus*), Texas wolfberries (*Lycium texanum*), and assorted estuarine invertebrates in the Texas wintering grounds (Hunt and Slack 1989, Chavez-Ramirez 1996, Westwood and Chavez-Ramirez 2005). Black mangrove (*Avicennia germinans*) stands are replacing salt marsh as a result of warming temperatures, which will limit habitat availability in the wintering grounds (Chavez-Ramirez and Wehjte 2012). Continued sea-level rise may reduce the available coastal habitat area by at least 25% in the next century (Smith et al. 2014, 2018). Unlike most other migratory crane species, Whooping Crane pairs in the AWB population defend territories on their wintering grounds in Texas.

The EM population resides in landscapes with more agriculture and development on summer and wintering grounds than the AWB population. Territorial cranes used a variety of landscapes, from the mosaic of wetlands and restored prairie within Necedah NWR to area cranberry (*Vaccinium erythrocarpum*) farms; non-territorial cranes often used cultivated cropland and wander widely (Barzen et al. 2018, Mueller et al. 2018). During summer, the population remains closely affiliated with wetlands: territorial cranes spent 75% of their time in wetlands, and during the remigial molt individuals spent nearly all their time in wetlands (Barzen et al. 2018). During migration and winter, however, cranes make less use of wetlands except for roosting, use a variety of habitats (particularly croplands), and do not establish winter territories. Migration is variable and has become shorter over time, as winter distribution has shifted northward away from their original release sites in Florida

(Urbanek et al. 2014, Mueller et al. 2018). Conservation planning for this population will therefore need to take into account the greater flexibility, large spatial scale of crane movements, and extensive reliance on private (mostly agricultural) lands during the non-breeding period.

The Louisiana population has been reintroduced into the freshwater marshes in the southwestern portion of the state where the resident flock occurred. Historically, this non-migratory flock used freshwater marshes for nesting and foraged in marshes, agricultural lands, and coastal prairie (Allen 1952). During the first year of the reintroduction, in June through November 2011, the birds were documented using the agricultural landscape, rice (*Oryza sativa*, 42%), and crawfish (18%) habitats, as well as freshwater wetlands (25%) (Louisiana Whooping Crane Reintroduction Research Team 2012). Since many of the 2010 (first cohort) individuals immediately moved from protection of the White Lake Wildlife Conservation Area to occupy private lands, understanding private landowner interest and support of the project was essential to its long-term success. Landowner sentiment varied from actively engaged (67%) to willing to learn about the project with no interaction (21%), to indifferent to the project and to presence of cranes on their property (13%). However, all landowners did allow access to their property (Louisiana Whooping Crane Reintroduction Research Team 2012). By 2016, about 150 individual landowners have been contacted and engaged in the reintroduction project and monitoring; landowner endorsement has remained strong (Louisiana Department of Wildlife and Fisheries 2016). Success of this reintroduction will depend on the answers to three questions: 1) can captive-reared Whooping Cranes reproduce at a great enough rate to sustain a viable population; 2) will crawfish farming operations be compatible with Whooping Crane reproduction in crawfish ponds; and 3) can shootings of Whooping Cranes be reduced or eliminated (King et al. 2018)?

NUMBERS AND TRENDS

The Whooping Crane is the rarest of the world's 15 species of cranes and is classified as Endangered in the 2011 IUCN Red List Categories. The total global population (i.e., wild, reintroduced, and captive populations) was estimated at around 764 as of March 2017 (French et al. 2018). The total population in the wild, including reintroduced populations, inhabits Canada and USA and was estimated to be 689 as of March 2018, as summarized below. The majority of the population exists in the AWB Population. Using a standardized survey protocol, the U.S. Fish and Wildlife Service estimated the abundance of Whooping Cranes in the AWB population for the winter of 2017–18. Those survey results indicated 505 Whooping Cranes (95% CI = 439–577; CV = 0.069) inhabited the primary survey area (Butler and Harrell 2018). This population has continued to increase since its low of 15–16 birds in 1941.

Fourteen Whooping Cranes remained in the experimental, non-migratory FL population in August 2016 (Tim Dellinger, personal comm. 2016), 103 in the experimental EM population in April 2018 (Thompson 2018), and 67 adults in experimental, non-migratory LA population in April 2018 (Szyszkoski 2018). The last bird in the experimental, migratory Rocky Mountain population died in 2002.

A total of 160 Whooping Cranes were maintained in 12 facilities in the U.S. and Canada as of March 2017 (Black and Swan 2018).

The current Whooping Crane recovery plan provides for down-listing the species from endangered to threatened if one of the following three alternatives is met; each requires that population levels be sustained for 10 years. Criterion 1: there are two experimental, introduced populations each with 100 individuals and 25 productive pairs, and the AWB population has 160 individuals and 40 productive pairs; or, Criterion 1A: one experimental, introduced population with 120 individuals and 30 productive pairs, and the AWB population has 400 individuals and 100 pairs; or, Criterion 1B: AWB population has 1,000 individuals and 250 productive pairs (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2005). One population recovery model indicated that the AWB population could attain 400 birds by 2040 (Butler et al. 2013). Another model projected that the AWB population may reach 700 by 2035 and the 1,000 target may not be reached until mid-2060s (Gil-Weir et al. 2012). While the AWB population has been steadily increasing at an average of 4% per year (Harrell and Bidwell 2016), conditions within the breeding, migratory, and wintering range ultimately have an influence on long-term recovery potential.

THREATS

Range-wide

- The killing of Whooping Cranes, both through vandalism and incidental hunting, is an increasing concern. Twenty-seven shooting mortalities of Whooping Cranes have been confirmed in the AWB, EM, FL, and LA populations between 1967 and 2016 (Condon 2018). This may be a minimal number because few of the AWB birds have been radio-marked (most of the EM and LA birds have radio transmitters or satellite transmitters). Seventy-seven percent of the confirmed shooting cases have taken place in the reintroduced populations (Condon et al. 2018). Any loss of individuals, especially breeding age adults, affects the potential growth of small, reintroduced populations by reducing the number of productive pairs or limiting potential for pairing;

- Collision with power lines has been reported as a cause of mortality, as were guy wires associated with telecommunication towers (Howe 1989, U.S. Fish and Wildlife Service 1994, Brown and Drewien 1995, Brown et al. 1987, Lewis et al. 1992). Mortality of 45 Whooping Cranes from collisions with power lines was documented from 1956–2006 with nine deaths in the AWB population, 20 in the FL population, three in the EM population, and 13 in the former RM population (Stehn and Wassenich 2008). Mortality from collisions with power lines remains difficult to quantify and death rates are likely higher. Energy infrastructure is significantly expanding and has potential to affect all Whooping Crane populations;

- Consequences of a genetic bottleneck in Whooping Cranes are largely unknown. It is believed that the population has recovered from a low of 15–16 birds in 1941 with an estimated six to eight founders and one maternal haplotype. Although the loss of genetic material is calculated as about 66% and concerns of inbreeding depression and declining productivity have been raised, this has not been observed in the AWB population (Wade Harrell, personal comm. 2017). A 2018 population viability analysis for the AWB population indicated a demographic sustainable and genetically robust population, with high genetic retention, and no risk of extinction over 100 years (Traylor-Holzer 2018).

- Predation is not a major threat to adult cranes unless they are flightless (undergoing a simultaneous wing molt) or weakened by disease. However, egg and chick mortality by predation is a concern (Bergeson et al. 2001b; John French, personal comm. 2017). Predation is an important mortality factor on the breeding grounds for all populations. A recent study showed 45% of deaths of birds marked with satellite transmitters from the AWB population occurred on wintering grounds; though predation was suspected in many of these events, causes of death could not be determined for most of them (Pearse et al. 2018). Predation risks for LA eggs and chicks is yet not known as pairs have only recently began nesting and hatching chicks in this young population.

Aransas-Wood Buffalo Population

Breeding

- Natural factors that can affect breeding success include warm and dry conditions, which often reduce water levels and thus suitable nesting ponds and chick-rearing habitat. Increased wildfires, although a natural component of the boreal ecosystem, may be a concern. As recently as summer 2015, fires covered almost 16,000 ha (3.8%) of designated critical habitat which was much higher than the 25-year average of 0.9% (Harrell and Bidwell 2016);

- Long-term increases in temperature from climate change will have differential effects on the breeding grounds of the Aransas-Wood Buffalo Population. Warmer wetland conditions may improve aquatic food resources; however, increases in precipitation in conjunction with more frequent rainfall may flood nests or decrease chick survival via chilling (Chavez-Ramirez and Wehtje 2012). In addition, by decreasing fire frequencies, open areas used for nesting may be converted to brush habitat and decrease nesting habitat quality. Juvenile recruitment appears to be the limiting factor to AWB population recovery in recent investigations that incorporated climate change factors, including changes in the breeding ground hydrology and survival in the autumn migration corridor (Butler et al. 2017); and

- Other threats that may impact the breeding habitat outside the WBNP include forestry, oil, and gas activities that could dramatically affect the region's hydrologic regimes, habitat loss and fragmentation, and disturbance to nesting Whooping Cranes (Environment Canada 2007, Johnson and Miyanishi 2008, Timoney 2012).

Migration

- Energy exploration activities in the migration corridor south of WBNP pose threats of water and air contamination. Recent expansion of these activities in this region for the exploitation of tar sands have raised concerns of short- and long-term impacts to this sensitive environment. Surface and groundwater contamination may already be occurring, and water usage for energy production could affect water levels; and

- The impacts of wind turbines have yet not been documented for Whooping Cranes, although permits have been approved and wind farms have been constructed in the migration corridor. In Nebraska, a model developed to assess locations that would have good potential for wind energy and high probability of overlap with Whooping Cranes encompassed 30% of the state (Belaire et al. 2014). A spatial model of habitat use developed for North and South Dakota (Niemuth et al. 2018) will be useful to guide the siting of new wind, oil, and electrical transmission infrastructure to minimize potential conflicts with Whooping Cranes and also to identify threats and associated opportunities for mitigation such as transmission line marking and wetland restoration. An unpublished study by the American Bird Conservancy (2014) indicated that 5,500 turbines already existed within the Whooping Crane migratory corridor and 18,500 new turbines were planned. More direct effects of wind turbines on cranes (e.g., mortality from strikes, habitat avoidence) remains uncertain and likely vary with crane numbers, weather, and landscape features (see also *Collisions and habitat loss associated with utility lines, wind turbines, and other human infrastructure*).

Wintering

- As human demand for water continues to increase in the Guadalupe-San Antonio Basin, Texas, essential fresh water inflows to the estuaries surrounding Aransas NWR continue to diminish. Decreases in fresh water inflows are especially critical because they cause salinity to increase throughout the coastal system, which reduces the availability of primary food items (particularly blue crabs and wolfberry fruits) for wintering Whooping Cranes;

- Recovery efforts to increase the AWB population will require sufficient quantity and quality of coastal habitat be available in the wintering range. Texas experienced the highest human population increase in the U.S. from 2000–2010, and coastal development continues to increase along the Texas coast as construction is permitted in low-lying areas. An estimated 51,000–71,000 ha (Stehn and Prieto 2010) of coastal marsh habitat is needed to support 250 nesting pairs in the AWB population, one of the criteria alternatives for down-listing this species from endangered to threatened status. A more recent effort to estimate available habitat extent, habitat selection by wintering Whooping Cranes, and what is needed to support these criteria was made in the U.S. Fish and Wildlife Service's Landscape Conservation Design model (Smith et al. 2014). Further spatial analyses indicated that the AWBP will need to expand beyond contiguous coastal systems and seek additional estuarine marsh mesohabitats as well as freshwater habitats to satisfy the target spatial requirements (Smith et al. 2018);

- Pollution and environmental contamination continue to be a major concern because the Gulf Intracoastal Waterway bisects the entire wintering range of the AWB population at Aransas NWR and surrounding areas. The Texas economy is dependent on this mode of transportation, yet the proximity of coastal marshes and bays to barges carrying toxic chemicals and contaminants creates a serious risk to the high concentration of wintering Whooping Cranes. The potential for chemical and pollutant spills within the wintering range is ever present; the Gulf Intracoastal Waterway traverses through the sensitive marsh complex within and adjacent to the Aransas NWR (Ramirez et al. 1993);

- Loss of existing coastal habitat is a serious concern. The effects of climate change are evident in the wintering grounds, as warmer temperatures have allowed the establishment of black mangrove (*Avicennia germinans*), which reduces habitat availability and quality for Whooping Cranes. Sea-level rise affects coastal habitats directly by converting upper transitional and high marsh habitats to low marsh, and drowning low marsh to become subtidal habitats. When development practices, such as construction of bulkheads or roads, are located along the transition between uplands and marshes, wetlands are unable to migrate inland and are lost. Preliminary estimates of habitat availability that would support recovery indicate that all remaining coastal habitat in Texas is essential to support down-listing the Whooping Crane (Smith et al. 2014, Smith et al. 2018);

- Effects from drought exacerbated by water withdrawals from the Guadalupe River include reduced prey populations, scarcity of dietary drinking water, and lower health conditions prior to spring migration that may affect subsequent breeding ability (Chavez-Ramirez 1996, Westwood and Chavez-Ramirez 2005). Long-term changes to inflows have also occurred in the Guadalupe River from permitted withdrawals, which provides two-thirds of the water to the receiving estuary (Johns et al. 2004). Extended drought conditions in the region can result in increased bird loss (Butler et al. 2014a). The recent drought of 2008–2009 resulted in the deaths of at least 23 cranes and lowered the population to 243 birds. The return of more normal water levels in the following years increased the total AWB population past previous levels, and almost 300 birds were expected to arrive at Aransas NWR in autumn 2011. However, these birds encountered severe to exceptional drought conditions throughout Kansas, Oklahoma, and Texas during migration as well as continued exceptional drought conditions throughout the autumns and winters of 2011–2014, and breeding grounds experienced recent wildfires within the critical habitat area. More normal water levels returned in 2015 and 2016; and

- Since the species received protection under the Endangered Species Preservation Act in 1967, documented mortalities from shooting have been primarily in winter (4) and spring migration (3); two occurred during autumn migration (Condon et al. 2018). Six of the nine shooting events have been related to hunting, but hunter intentions in those cases are unclear. In most instances, the hunter was in violation of additional laws.

Reintroduced Populations

- Low reproductive success of reintroduced populations has limited recovery efforts. While the RM population advanced our knowledge of surrogate parenting and migration skills, the cross-fostering approach was unsuccessful. Improved techniques of parent-rearing chicks, transporting them to the site, and soft releases were used in the FL population. However, low fertility rates, disease, high mortality from power lines and predators, and poor parenting hampered the reproductive success of this reintroduced population (Dellinger 2018). The EM population was trained to migrate from Wisconsin to Florida following ultralight aircraft and returned successfully to their release site in the spring (Duff 2018). However, the young adult pairs experienced several setbacks from nest abandonment, primarily attributed to blackfly disturbance, and low chick survival, presumably from predation or limited habitat quality.

CHANGES SINCE 1996

The total number of Whooping Cranes in the wild was 205 in 1996; that number has steadily increased to about 604 in March 2017, with substantial growth in the AWB population. However, the RM population dropped from three in 1996 to zero in 2002, and the FL population decreased from 52 in 1996 to 14 by December 2015. Two new, experimental flocks have been established since 1996; 103 individuals comprised the EM population in April 2018, and the LA population, established in 2011, had 67 birds as of April 2018. In addition, 160 cranes were housed in 12 captive breeding facilities in April 2017, a substantial increase from 91 birds in 1996.

One of the actions defined in 1996 involved integrating the USA and Canadian recovery plans. This action was completed in 2007 (Canadian Wildlife Service and United States Fish and Wildlife Service 2005), achieved under the authorities of the Canada Wildlife Act of 1974 and Canadian Species at Risk Act of 2003, and U.S. Endangered Species Act of 1973. The 2007 document exemplifies the international collaboration that is necessary to affect the recovery of an endangered species requiring conservation efforts in two countries.

Land protection is essential for the Whooping Crane as their ecological and social needs require large amounts of nesting, staging, migrating and wintering habitats. WBNP afforded regional protection, and the nesting area is further protected between 15 April and 31 October by government designation (Canada Gazette 2008). In Canada, the Whooping Crane was designated as Endangered in November 2000 by the Committee on the Status of Endangered Wildlife in Canada and was also listed as Endangered on Schedule 1 of the Species at Risk Act.

As a follow up to the Population Viability Assessment (PVA) workshop conducted in 1991, more information was generated in another PVA that indicated the likelihood that the AWB population would continue to increase in numbers (low probability of <1% of extinction) over the next century (Mirande et al. 1997). A more recent effort was undertaken in 2015 to update a PVA with more recent information. The International Recovery Team has in preparation a revision of the Whooping Crane International Recovery Plan (Miller et al. 2016). The meta-population model included five populations (AWB, EM, LA, FL, and captive), each with their own demographic rates, initial population structure, and management options. The second workshop to finalize the Population and Habitat Viability

Analysis was held in December 2016; this process is expected to be completed with the development of a Population and Habitat Viability Analysis.

Continued economic growth and development along the Texas coast and within the Guadalupe-San Antonio basin in Texas has precipitated concerns over freshwater inflows into the critical habitats of the Whooping Crane. These inflows are essential to maintain a balance of salinity gradients, food productivity, nutrients, and sediment that maintains a sound ecological environment (Texas Parks and Wildlife 1998). Several studies were initiated since 1996 to better understand the relationship between freshwater inflows, salinities, blue crab and wolfberry fruit production, and Whooping Crane mortality (Westwood and Chavez-Ramirez 2005, Houston Advanced Research Center 2006, Pugesek et al. 2008, Wozniak et al. 2012). The Texas state legislature passed several bills to initiate a process to set environmental flow regimes for each basin in Texas, and these rulings were finalized in 2012. However, the scientist and stakeholder inputs were not followed rigorously, and new permits will be allowed to divert more freshwater from the rivers than recommended potentially impacting blue crab populations.

One primary area of concern for the long-term conservation of the AWBP is the protection of winter habitat within its current range, as well as the identification and protection of future habitat areas that would support the potential growth of the population and expansion of their wintering range (Canadian Wildlife Service and United States Fish and Wildlife Service 2005). In recent evaluations of potential impacts under different climate change scenarios, sea-level rise (SLR) was identified as one of the primary concerns for future habitat availability on the winter range along the Texas coast (Chavez-Ramirez and Wehtje 2012, Harris and Mirande 2013). Projected habitat changes related to future sea-level rise have been evaluated using the Sea Level Affecting Marshes Model (SLAMM) (Clough and Larson 2010), to predict effects of sea-level rise on current and potential Whooping Crane habitat at a broader scale (Smith et al. 2014, 2018). Overall, habitat changes modeled within and surrounding Aransas NWR showed a 50% decrease in estuarine habitats at 1- and 1.5-m SLR by 2100, and a modest 23% increase in 2-m SLR. Recent advances on an improved SLAMM and broader extent of potential wintering habitat along the central Texas coast is nearing completion by U.S. Fish and Wildlife Service. Protecting remaining habitat is critical and identifying additional areas that will become habitat as sea levels continue to rise is imperative to the continued recovery of the AWB population.

CONSERVATION AND RESEARCH EFFORTS UNDERWAY

A large mapping project was undertaken to identify potentially suitable habitat for nesting and non-breeding summer range in Canada. The findings indicated that sufficient habitat is available to support 107–472 breeding pairs (Olson and Olson Planning and Design Consultant, Inc. 2003). Currently, only 10% of that area is actively used. Therefore, the limiting factor for Whooping Crane growth and recovery will not be breeding habitat availability.

Conservation strategies in the wintering grounds have been funded through government and non-governmental programs, especially in coastal Texas. Several thousand hectares have been protected through conservation easements and acquisition, which will ensure the coastal habitats are conserved for Whooping Crane use. A collaborative project that will identify coastal habitat areas suitable for Whooping Crane use now and under various sea-level regimes is underway. A work plan will be developed to implement conservation options on key areas in the wintering range.

Two reintroduction population programs are actively underway in the USA, supported by considerable monitoring, management, and research efforts that provide information for management decisions. Reintroduced populations are important to maintain multiple populations within the species and provide assurance for species survival in the event of a catastrophic event within the AWB population.

Captive breeding programs at five breeding centers and nine display facilities provide eggs and chicks for reintroduction programs. The ongoing research to maintain genetic diversity, detect and minimize disease outbreaks, and test new release techniques provides the scientific basis for the reintroduction programs.

The Whooping Crane Tracking Partnership (WCTP) is comprised of members from the U.S. Geological Survey, U.S. Fish and Wildlife Service, Canadian Wildlife Service, Platte River Recovery Implementation Program, and Crane Trust, with support from Parks Canada, Gulf Coast Bird Observatory, and International Crane Foundation. The team began banding and attaching Platform Transmitting Terminals with Global Positioning System capabilities (GPS-PTTs) to a total of 68 Whooping Cranes beginning in 2009 and completed the banding and GPS-PTT portion of the study in winter 2013 (Whooping Crane Tracking Partnership 2014). Thirty-three chicks were fitted with bands and GPS transmitters during late summer, and 35 adults and sub-adults were captured via noose traps and fitted with the equipment at Aransas NWR during winter. The primary objective of the multi-year project involves increasing our knowledge of the breeding, migratory, and wintering ecology, as well as completing a population health assessment (Hartup 2018b) and identifying threats to survival and demographics. This project is expected to continue until 2019. The data collected will enable researchers to examine individual, group, and family movements across the entire range of the AWBP.

PRIORITY RESEARCH AND CONSERVATION ACTIONS

- Continue land protection of high-quality habitats critical in the breeding, staging, migration, and wintering ranges of Whooping Crane populations to ensure populations will be supported as they continue to increase in numbers;
- Ensure appropriate amounts and timing of freshwater inflows to Aransas, San Antonio, and Matagorda Bays, Texas, are maintained to provide a sound ecological environment for Whooping Cranes and their associated food items;
- Improve enforcement of shooting laws as well as public and hunter education in current and adjacent ranges of Whooping Cranes to reduce human-caused mortalities in the populations;
- Reduce mortalities from power lines and contaminants through best conservation practices and collaboration with industry;
- Fully understand the relationships among priority food sources and hydrologic and environmental conditions in the wintering, staging, and breeding areas and incorporate these findings into management and conservation plans;
- Collaborate among partners to effectively monitor, research, and manage reintroduced populations and achieve reproductive success;
- Maintain captive breeding and reintroduction projects that ensure genetic diversity and the improvement of release methods and reintroduction techniques that ensure high success; and
- Monitor each population using direct observations and telemetry that provide information on total population size, mortality, adult/juvenile ratios, territories, and expansion movements useful for management decisions.

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