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Whooping Crane Collisions with Power Lines: an Issue Paper

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WHOOPING CRANE COLLISIONS WITH POWER LINES: AN ISSUE PAPER

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Abstract: Collision with power lines is the greatest source of mortality for fledged whooping cranes (*Grus americana*) in the Aransas-Wood Buffalo population (AWBP) that migrate between the Northwest Territories, Canada to the Texas coast. This paper compiles 45 documented whooping crane mortalities from power line strikes in North America and provides known information on crane / power line interactions. A map of the AWBP whooping crane migration corridor was derived with 100 and 200-mile wide corridors delineated showing the location of known mortalities. Recommendations are provided to try to reduce this major threat facing whooping cranes.

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Key words: Aransas, collisions, *Grus americana*, power lines, whooping crane.

The whooping crane (*Grus americana*) is one of the most widely known endangered species in North America and symbolizes the struggle to maintain the vanishing creatures of this world. Collision with power lines is the greatest known source of mortality for fledged whooping cranes in the Aransas-Wood Buffalo population (AWBP) that migrate from nesting grounds in the Northwest Territories, Canada through the central U. S. to winter on the Texas coast (Fjetland 1987, Lingle 1987, Lewis et al. 1992). Such mortality affects the recovery of this endangered species and accentuates the need to minimize such losses (Howe 1989). Power line expansion in North America remains one of the chief threats to the species (USFWS 1994). This paper provides background on the issue and seeks to promote actions to reduce whooping crane mortality from collisions with utility lines.

Environmental concerns of the public about bird collisions have grown with the expansion of electric utilities that has multiplied miles of lines to meet increased demand for electric power (APLIC 1994). In an attempt to begin addressing both collision (specifically whooping cranes) and electrocution problems, an ad hoc committee represented by several investor-owned electric utilities (IOUs), the National Audubon Society, and the U.S. Fish and Wildlife Service (USFWS) was created in 1983. By 1989, a more formal relationship was established with the creation of the Avian Power Line Interaction Committee (APLIC) composed then of 9 IOUs and USFWS, with technical advice from staff of the National Audubon Society, Clemson University, and the University of Idaho (Lewis 1997). APLIC, housed in the IOU trade association Edison Electric Institute (EEI), Washington, D.C. (Huckabee 1993), has served as a clearinghouse for information and communication on avian and power line interaction issues. Currently, APLIC is composed of electric utilities, utility organizations, and federal agencies involved in bird and power line interaction issues.

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Species Status

There were once over 10,000 whooping cranes in North America that ranged from the Rocky Mountains to the Atlantic Coast and from northern Canada to Mexico (CWS and USFWS 2007). Population numbers declined to the brink of extinction from shooting, the destruction of nesting and migration habitat due to drainage of wetlands for farming, and collection of eggs and specimens as the species became increasingly rare. In 1941, only 15 individuals remained in the AWBP, the only migratory population that survived. Since yearly census estimates were initiated in 1938, the growth of this population has averaged 4.5% annually and numbered 215 in spring, 2005.

Until the whooping crane population grows to at least 1,000 individuals, the species is in a race against time as the limited genetic material that survived the bottleneck continues to be lost in each generation (CWS and USFWS 2007). Thus, it is important to accelerate the rate of species recovery to minimize genetic loss. Also, with the very restricted range of the AWBP in both summer and winter, chances of species survival in case of a catastrophic event would be increased if additional populations were established (USFWS 1994). Attempts from 1975-1989 to establish a whooping crane flock in the Rocky Mountains using cross-fostering with whooping crane eggs placed in sandhill crane (*G. canadensis*) nests were unsuccessful, due to high flock mortality and no attempts at breeding because of improper sexual imprinting of the whooping cranes.

The current range of the whooping crane is shown in Figure 1. A non-migratory flock in Florida started in 1993 numbered about 60 birds in August, 2005. Adults in this flock have paired, nested and fledged young, but mortality continues to be high and is preventing population growth (CWS and USFWS 2007).

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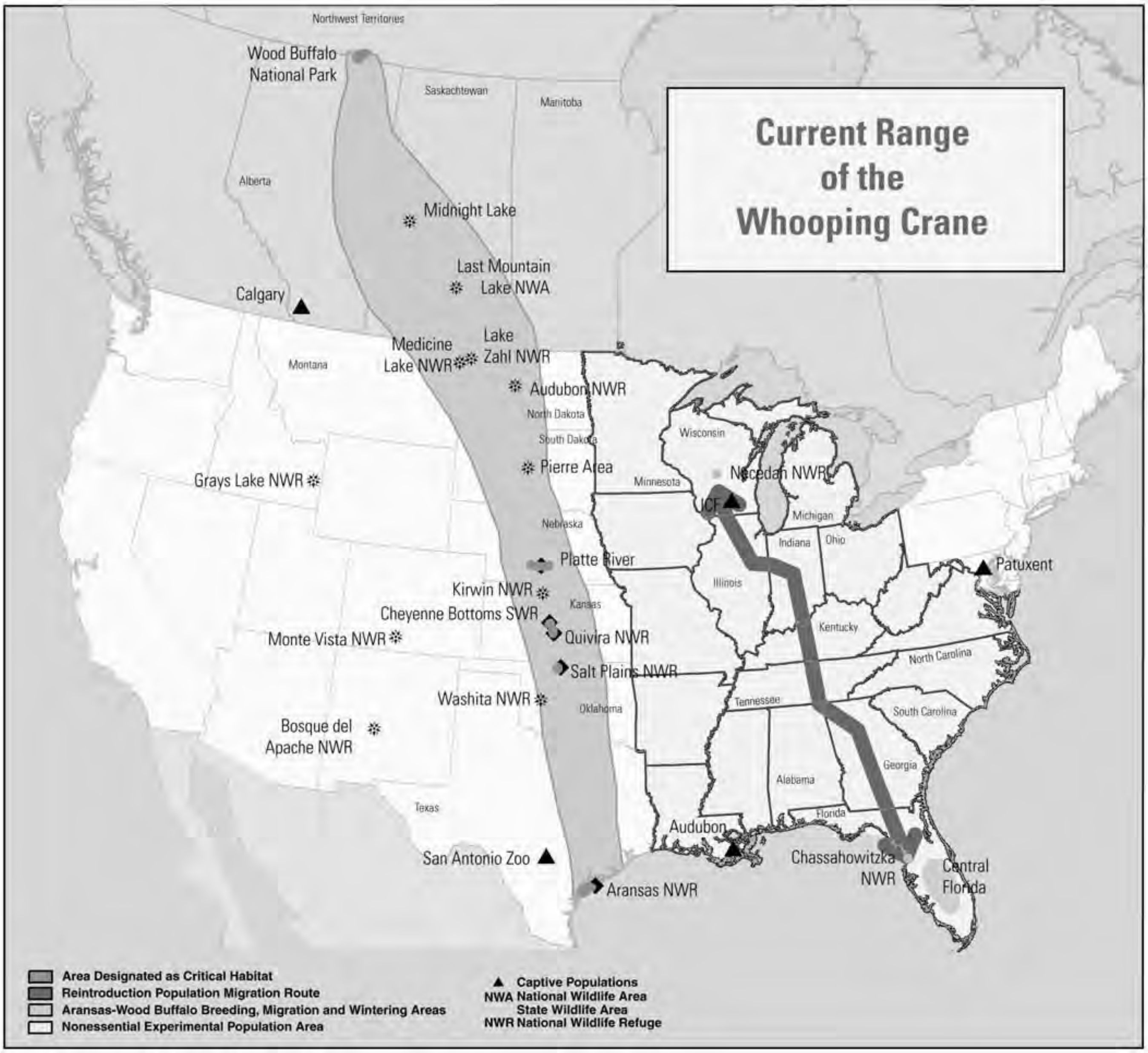

Figure 1. Current range of the Whooping Crane.

An eastern migratory flock started in 2001 that uses ultralight aircraft to teach juvenile whooping cranes a migration between Wisconsin and Florida numbered 66 birds in August, 2005. At that time, there were 481 whooping cranes in North America, including the 3 wild flocks mentioned above and 139 birds in captivity. Three major captive breeding flocks produce 25-40 young annually for reintroductions.

Problem

Rural electrification in North America resulted in the proliferation of power lines into areas traditionally used by migratory birds, resulting in substantial whooping crane mortality during migration (Brown et al. 1987, USFWS 1994). At the present time, with a growing human population in the U.S., industrial expansion and public demand for more electricity, additional power lines are being installed (Manville 2005). This will increase the potential for whooping crane collision mortalities. The most recent nationwide estimates indicate that there are more than 500,000 miles (804,500 km) of bulk transmission lines in the U.S. (APLIC 1996, Harness 1997, Edison Electric Institute 2000). Transmission lines in the

U.S. carry ≥115,000 volts/115 kV, with conductors attached to either tall wood, concrete, or steel towers. Distribution lines (those in the U.S. carrying ≤ 69,000 volts/69 kV) are constructed on 11-15 m wooden, steel, or concrete poles, typically configured with 1, 2, or 3 energized (phase) wires and one neutral (grounded) wire. Williams (2000) cited the figure of 116,531,289 distribution poles in the U.S. but listed no figure for wire length. Because of rapid expansion, new development, and jurisdictional issues, no good accounting of the total amount of distribution line is available for the U.S.; it is certainly in the millions of kilometers (Manville 2005).

Cranes and other birds apparently collide with lines because they do not see them in time to avoid them and suffer traumatic injury from the collision itself, or from the resulting impact of falling to the ground (Brown et al. 1984). Non-conducting ground wires, usually installed above conductor wires to intercept lightning strikes and prevent power outages, are the wires most often struck by birds in flight (Scott et al. 1972, Willard et al. 1977, Ward and Anderson 1992). Because ground wires are normally 0.9-1.3 cm in diameter and smaller than conductor wires, they sometimes appear to be invisible because of background or lighting conditions. Consequently, birds often see and avoid conductor wires only to strike the less visible ground wires (Brown et al. 1987, Faanes 1987, Ward and Anderson 1992), and are more prone to strike wires mid-span rather than near utility poles (Ward et al. 1986).

Collisions with transmission and distribution power lines can be a significant source of mortality for bird populations and may kill annually anywhere from hundreds of thousands to 175 million birds in the U.S. based on extrapolations by Koops (1987) and Erickson et al. (2001). The range of values is so large because of poor monitoring of utility lines for strikes (Manville 2005). Faanes (1987) observed 7,000 flights of all types of birds near prairie wetlands and lakes in North Dakota. He observed about a 1% collision rate and estimated 124 avian fatalities/km/yr. He also counted dead birds under power lines and found 122 dead in the fall and 511 in the spring.

Sandhill cranes, a species closely related to whooping cranes that can serve as a surrogate species to study the problem, suffer appreciable mortality from collision with power lines (Morkill and Anderson 1991). Line collisions resulted in 36% of the known mortality to fledged sandhill cranes in the

Table 1. Known mortalities from whooping crane collisions with power lines in North America, 1956–2006.

Aransas – Wood Buffalo flock									
#	Date	State/ Province	County	Site	Died	Age	Sex	Wire	Notes
1	May 56	Tex.	Lampasas	–	No[a]	YRL	F	Trans.	Clear skies
2	Nov 65	Kans.	Rawlins	Ludell	Yes	A	F	Distr. (3-wire)	Clear skies
3	Apr 67	Kans.	Russell	Dorrance	Yes	A	F	Distr. (3-wire)	Clear skies
4	Oct 81	Sask.	–	Glaslyn	Yes[b]	JUV		Distr. (1-wire, 30 ft)	In barley
5	Oct 82	Tex.	Coryell	Oglesby	Yes	A	F	Distr. (4-wire, <25 ft)	Clear, in corn
6	Oct 88	Nebr.	Howard	St Paul	No[c]	A		Distr. (2-wire, 35 ft)	Corn granary
7	Oct 89	Nebr.	Hitchcock	Stratton	Yes	YRL	M	Distr. (12kV)	Wheat by wetland
8	Oct 97	Sask.	–	Zelma	Yes	SA		Distr. (1-wire 14.4kV)	Agric. field
9	Apr 02	Tex.	Comanche	DeLeon	Yes	A	F	Distr.	
Rocky Mountain flock									
#	Date	State/ Province	County	Site	Died	Age	Sex	Wire	Notes
1	May 77	Wyo.	Uinta	Lonetree	Yes[d]	JUV	M	Distr.	roadside
2	Apr 81	Colo.	Rio Grande	Monte Vista	Yes	JUV		Distr. (69kV)	barley
3	Oct 82	Colo.	Alamosa	Alamosa	No[e]	A		Trans. (115 kV)	
4	Mar 83	Colo.	Alamosa	Alamosa	Yes	A	F	Trans. (115 kV)	Hit same line as # 3
5	Apr 84	Colo.	Alamosa	Alamosa	Yes	JUV		Distr. (69kV)	High wind, barley
6	Apr 84	Colo.		Monte Vista	No[f]	JUV		Unk	
7	May 84	Colo.		Monte Vista	Yes	JUV		Possible distr. (69kV)	
8	Sept 85	Id.	Caribou	Grays Lake	Yes	JUV	M	Trans.	Died 10-2-85 of injuries
9	Apr 86	Id.	Bancock	Oxford Slough	Yes	A	M	Unk	Wetland
10	Fall 87	Colo.		San Luis Valley	Yes	JUV		Unk	Bird had Tuberculosis
11	Mar 89	Colo.		San Luis Valley	Yes	A	F	Unk	
12	Mar 98	Colo.	Alamosa	Monte Vista	Yes	A	F	Trans.	
13	Mar 00	Colo.	Rio Grande	Monte Vista	Yes	A	F	Distr.	

Table 1. **Continued**

#	Date	State/ Province	County	Site	Died	Age	Sex	Wire	Notes
Florida nonmigratory flock									
1	Jan 97	Fla.	Osceola	Escape	Yes[g]	JUV	M	Distr.	Along dirt road
2[h]	Nov 97	Fla.	Brevard	Sartori	Yes	SA	M	Distr. (4-wire)	By road
3[h]	Nov 97	Fla.	Brevard	Sartori	Yes	SA	M	Distr. (4-wire)	By road
4[h]	Nov 97	Fla.	Brevard	Sartori	Yes	SA	M	Distr. (4-wire)	By road
5	Mar 98	Fla.	Lake	Geraci	Yes	SA	M	Distr.	
6	Feb 99	Fla.	Lake	Geraci	Yes	SA	M	Distr. (3-wire)	
7	Jan 01	Fla.	Lake	Groveland	Yes	A	M	Distr. (4-wire)	
8	Mar 02	Fla.	Polk	Lake Wales	Yes	JUV	F	Distr.	
9	Mar 03	Fla.	Sumter	Bexley	Yes	JUV	M	Trans.[i]	
10	Aug 03	Fla.	Polk	Lake Wales	Yes	A	M	Distr.	
11	Dec 03	Fla.	Lake	Pruitt	Yes	JUV	F	Trans.[i]	
12	Nov 04	Fla.	Sumter	Bexley	Yes	SA	M	Trans.[i]	
13[j]	Jan 05	Fla.	Lake	Pruitt	Yes	SA	F	Trans.[i]	
14	Feb 05	Fla.	Lake	Pruitt	Yes	SA	F	Trans.[i]	
15	Mar 05	Fla.	Sumter	Hi Acres	Yes	SA	F	Trans.[i]	
16	Mar 05	Fla.	Lake	Pruitt	Yes	SA	M	Trans.[i]	
17	Apr 05	Fla.	Osceola	Holopaw	Yes	A	M	Trans.	
18	Aug 05	Fla.	Sumter	Pruitt	Yes	SA	M	Trans.	
19	Dec 05	Fla.	Polk		Yes	A	M	Trans.	
20	May 06	Fla.	Lake/ Sumter	Near Pruitt	Yes	A	M	Trans.	
Wisconsin-Florida migratory flock									
#	Date	State/ Province	County	Site	Died	Age	Sex	Wire	Notes
1[k]	Oct 01	Wis.	Green		Yes	JUV	M	Distri.	Windstorm, collision at night
2	July 05	Wis.	Green Lake		Yes	SA	M	Trans.	
3	Dec 06	Ind.	Green		Yes	A	M	Distr.	

A = adult, JUV = juvenile, SA = subadult, YRL = yearling, F = female, M = male, Trans = transmission line (> 115 kV), Distr = distribution line (< 69 kV), Unk = unknown

[a] Injured and had to be kept in captivity (named Rosie) and bred.

[b] Injured bird died while being transported to captivity.

[c] Bird fell to ground and flew off after 5-10 minutes. Postulated it was 1 of birds that failed to show up on wintering grounds that fall.

[d] Collision could have been from power line, vehicle, or fence, but believed to be power line.

[e] Fractured tarsus. Continued migration, but never recovered. Died 20 Jan 1983.

[f] Upper elbow injury required amputation. Placed in captivity.

[g] Cause of death considered as probable power line. However, necropsy could not rule out being struck by a car on the roadway next to the power line.

[h] Three whooping cranes killed in the same incident.

[i] This major transmission line follows the border of Lake/Sumter County and has been hit in multiple incidents.

[j] Radio found hanging from power line and bird disappeared indicating mortality.

[k] Strike occurred at a migration stopover at night when the crane escaped from a pen during a storm.

Rocky Mountains (Drewien 1973). Archibald (1987) found that 2.1% of adults and 13.4% of chicks of red-crowned cranes (*G. japonensis*) were killed striking power lines. Sundar and Choudhury (2005) found nearly 1% of sarus cranes (*G. antigone*) were killed annually hitting power lines. Janss and Ferrer (2000) estimated mortality from power line collisions for a wintering population of common cranes (*G. grus*) in Spain. The collision rate (i.e. number of cranes hitting a power line / number of cranes crossing a power line) was 3.93×10^{-5} and minimum annual collision mortality was 2.36/km/yr. Morkill and Anderson (1991) observed 3.4 sandhill crane collisions / km, as reported in Janss and Ferrer (2000). Whooping cranes are presumably even more susceptible to striking power lines than sandhill cranes (Morkill and Anderson 1991) because of their larger body size and wing span, slower wing beat, and relative lack of maneuverability. Juveniles are more vulnerable to collisions than adults, presumably due to lack of experience and flight skills (Ward et al. 1986, Brown et al. 1987, Ward and Anderson 1992, APLIC 1994, Brown and Drewien 1995).

Most studies have concluded that collision with power lines is not a major threat to bird populations but may be more of a problem for large birds (APLIC 1994). Crivelli et al. (1993) estimated a 1.3-3.5% decrease of dalmation pelicans (*Pelecanus crispus*) in the breeding population from collisions. Collisions caused 44% of the mortality of fledged trumpeter swans (*Cygnus buccinator*) in Wyoming (Lockman 1988).

Collisions become biologically significant when they affect a bird population's ability to sustain or increase its numbers, a problem that may be especially acute with endangered species (APLIC 1994). Whooping crane mortality from striking utility lines may be biologically significant to a small, endangered population and lower the probability of survival for the entire population (Wassenich 2003*a*). Collisions with power lines are known to have accounted for the death or serious injury of at least 45 whooping cranes since 1956 (Table 1). Of 18 documented mortalities of fledged whooping cranes in the reintroduced Rocky Mountain population prior to 1987, 8 (39%) were a result of collisions with power lines (Brown et al. 1987) (Table 2). Twenty individuals out of a total of 166 known causes of mortality (12%) of the nonmigratory Florida whooping crane population, and 3 out of 18 cases (17%) of post-release mortality in the migratory Wisconsin population, have been from collisions with power lines (T. Stehn, unpublished data). The percentage of whooping crane mortality caused by collisions with power lines is hard to extrapolate for the AWBP because of the less intense monitoring of that population during migration compared to reintroduced flocks. In the 1980s, 2 of 9 radio-marked juvenile whooping cranes in the AWBP died within the first 18 months of life as a result of power line collisions, 33% of the total post fledging losses (n = 6) of the radioed birds during the study (Kuyt 1992). Five of 13 known causes of mortality (38%) for the AWBP between the months of April and November, 1950 to 1987 resulted from collisions with utility lines (total mortality equaled 133 cranes) (Lewis et al. 1992). Extrapolating from the known causes of mortality, an estimated 51 of the 133 whooping cranes (38%) may have been killed colliding with power lines. Whereas predation by bobcats has been the primary source of mortality for the nonmigratory Florida whooping cranes, predation of fledged whooping cranes is thought to be uncommon in the AWBP (CWS and USFWS 2007).

Table 2. Percent causation of known mortality from power line strikes of fledged birds in whooping crane populations in North America, 1956–2006.

Whooping crane population	Number of documented mortalities from power lines	% Mortality of fledged birds	Source
Rocky Mountain	13	39	Brown et al. 1987
Florida nonmigratory	20	12	Stehn unpublished
Wisconsin to Florida migratory	3	18	Stehn unpublished
AWBP radioed juveniles[a]	2[a]	33	Kuyt 1992
AWBP all fledged birds[b]	5[b]	38	Lewis et al. 1992

[a] Two of 6 juveniles radioed between 1981-1984 died in power line collisions during the course of Kuyt's study.
[b] Losses that occurred between April and November, 1950–1987.

Whooping cranes are no longer radio-tracked in migration between Texas and Canada and color bands or radios have not been placed on AWBP whooping cranes since 1988. This is partly because of a mortality rate approaching 1% during capture of wild whooping cranes in Canada. Thus, data on power line strikes of AWBP whooping cranes are being obtained through chance observations as reported by the general public and agency personnel, and tabulated by the Whooping Crane Migration Cooperative Monitoring Project (CWS and USFWS 2007).

Crane Biology and Power Lines

Although migration involves only 17-20% of a whooping crane's annual activities, bird deaths are significantly greater during migration due to exposure to new hazards in unfamiliar environments. Losses during migration may comprise 60-80% of annual mortality (Lewis et al. 1992). Whooping cranes normally migrate 305-1,829 m above the ground (Kuyt 1992) and well above the height of power lines, but stop every night to roost in shallow wetlands (Howe 1989). When radiotracking whooping cranes in migration, T. Stehn (unpublished data) noted cranes were commonly seen at foraging sites with power lines nearby. Encounters with power lines usually occur as whooping cranes are making short, low altitude flights between foraging and roosting areas. These local flights frequently occur near sunrise and sunset when light levels are diminished. With approximately 12-15 stopovers during each 4,000 km migration (Kuyt 1992), whooping cranes have multiple opportunities to encounter power lines.

For local flights, the proximity of power lines to locations where birds are landing and taking off is critical (Lee 1978, Thompson 1978, Faanes 1987). Power lines suspended across a river channel near crane roosts present hazardous obstacles to cranes flying after dark (Windingstad 1988, Morkill 1990).

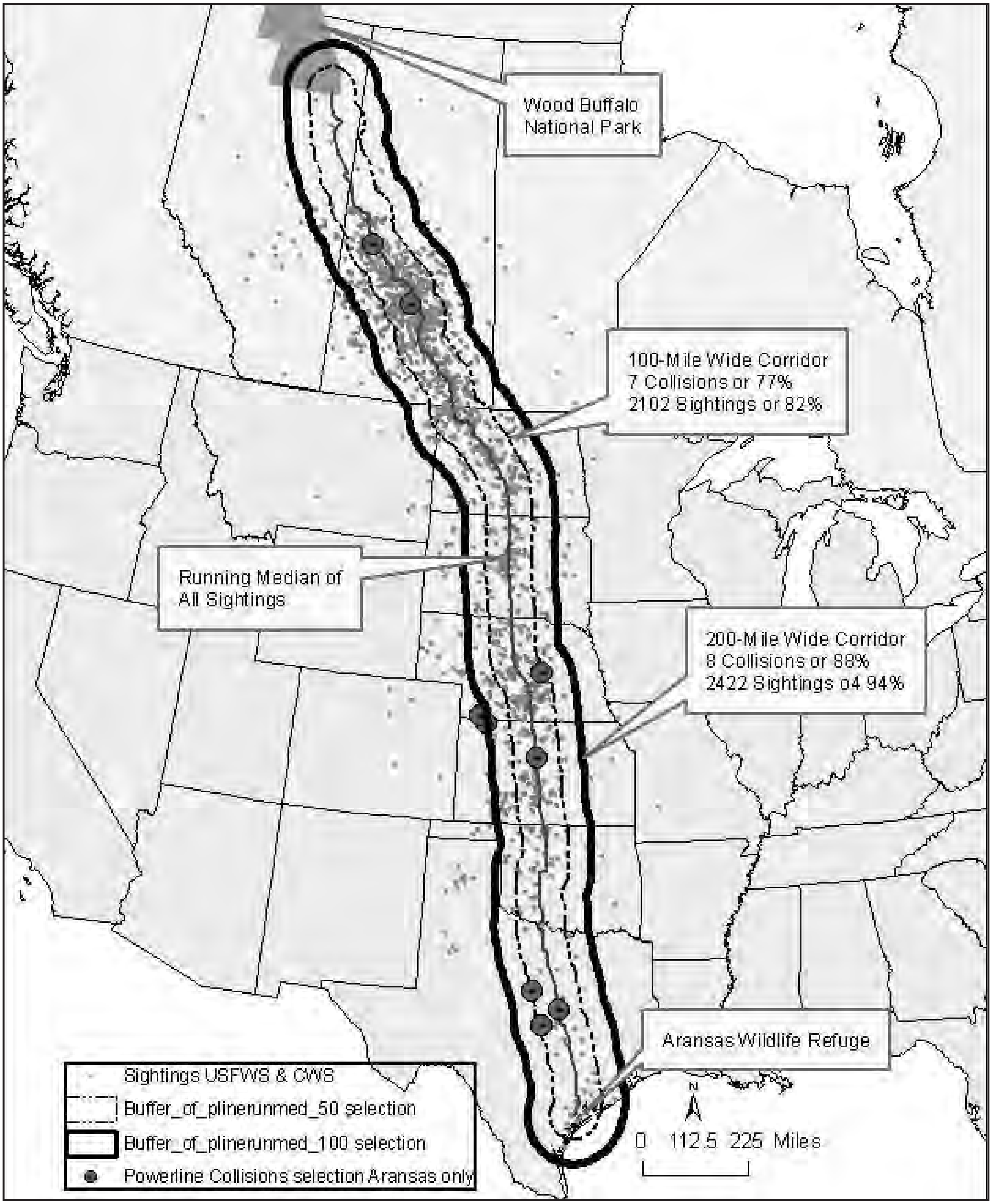

Figure 2. Whooping crane 100 and 200-mile migration corridor with location of known power line collision mortalities.

Power lines dividing wetlands used for roosting from grain fields used for feeding caused the most collisions for cranes because these circumstances encouraged crossing the lines at low altitude several times each day (Brown et al. 1987). Cranes frequently flew 10-15 m above the ground between fields; as a consequence, 12-m-high transmission lines obstructed their typical flight path. No sandhill crane or waterfowl collisions were observed where distances from power lines to bird use areas exceeded 1.6 km (Brown et al. 1984, 1987).

Birds flying over power lines from adjacent roosting or foraging sites have less time and distance to react and avoid wires (Thompson 1978, Beaulaurier (1981), Brown et al. 1987, Scott et al. 1972). Observations of sandhill crane flight behavior by Morkill and Anderson (1991) indicated that crane flocks reacted more when flying less than 250 m before or after crossing a power line and were lower in altitude and increased their altitude to avoid the wires, similar to reactions of cranes observed by Brown et al. (1987). Flight distance was also related to height flown above wires; cranes flying less than 250 m before or after line crossing tended to fly 1-5 m above the wires, but cranes flying more than 250 m tended to fly higher than 6 m above the wires (Morkill and Anderson 1991). Cranes were not observed to fly under transmission lines except occasionally when flushed near a line. Even at a 27-m-high study segment, cranes seemed reluctant to fly under the lines and instead flew vigorously upwards to cross over the wires (Morkill and Anderson 1991).

Cranes reacted more often to marked than unmarked spans, and more dead cranes were found under unmarked spans than marked spans (Morkill and Anderson 1991). When approaching marked spans, cranes commonly increased altitude farther than 5 m from the wires, suggesting they saw marker balls from a distance and avoided them. Cranes flared more often within 5 m of unmarked than marked spans, as if they were unaware of the unmarked wires (Morkill and Anderson 1991).

Table 3. Locations of known whooping crane strikes with utility lines in North America, 1956-2006.

Location	Number
Saskatchewan	2
Colorado	10
Florida	20
Texas	3
Idaho	2
Indiana	1
Kansas	2
Nebraska	2
Wisconsin	2
Wyoming	1
Total	45

Collisions can occur under optimal weather conditions. One whooping crane at Monte Vista National Wildlife Refuge (NWR) in Colorado died apparently in good weather hitting a power line that it had crossed numerous times (R. Garcia, Alamosa NWR, Colorado, personal communication). However, inclement weather is one of the most frequently described factors affecting collisions and can increase the probability of collisions (Walkinshaw 1956, Avery et al. 1977, Willard et al. 1977, Anderson 1978). The weather conditions most associated with collisions are related to reduced visibility (fog, dense cloud cover, and precipitation), and reduced flight control (high-velocity winds) (APLIC 1994). Brown and Drewien (1995) found that wind was a significant factor increasing the frequency of sandhill cranes hitting utility lines. When flying in high-velocity winds, birds may be buffeted into fully visible power lines with which they are quite familiar, but which they cannot avoid because they cannot maintain flight control (Brown et al. 1987, Morkill and Anderson 1991, Brown and Drewien 1995).

Whooping crane mortality does occur with birds striking both high transmission lines as well as low distribution lines in rural prairie areas. Manville (2005) found that much of the problem of bird collisions is associated with transmission lines. Ward and Anderson (1992) found sandhill cranes collided 4 times more frequently with transmission lines than distribution lines, although distribution lines were twice as abundant in their study area. Some studies have suggested that distribution lines are a greater threat for bird strikes because of their smaller size and lower visibility of conductors (Thompson 1978, Beaularier 1981, APLIC 1994).

For whooping cranes, more collisions have been documented on distribution lines (Wassenich 2003*a*), although this could simply reflect a greater frequency of encounters with distribution lines. Of the 45 known whooping crane mortalities, 17 hit transmission lines, 24 collided with distribution lines, and 4 were unknown. Exact geographic locations of many of the known whooping crane collisions with power lines were not recorded, with only general descriptions noted (i.e. location from nearest town). Thus, it is not possible to analyze the exact type of line or habitat in the vicinity of every known collision.

Power line strikes by whooping cranes do not always cause serious injury. One collision of a whooping crane in Florida was discovered when the bird's radio transmitter that had been attached to a plastic band on its leg was found wrapped around a distribution line. The crane subsequently limped for a day with a swollen hock but recovered (M. Folk, Florida Fish and Wildlife Conservation Commission, personal communication).

One of the eastern migratory whooping cranes after being flushed by the public hit a distribution line in North Carolina in April 2004, but remained airborne and later rejoined the other birds it was migrating with (R. Urbanek, U. S. Fish and Wildlife Service, personal communication). In 1983, a juvenile whooping crane hit a 115 kV line in the San Luis Valley, Colorado after being flushed by a landowner checking on his irrigation system (Brown et al. 1984). The bird was found under the line, struggling to stand, appearing dazed, but was able to fly off 30 minutes later and recovered. Increased hazard from human disturbance (e.g., flushing birds from farming activities, hunting, or intentional hazing of birds depredating crops) has been well-documented as a contributing factor to collisions (Krapu 1974, Blokpoel and Hatch 1976, Anderson 1978, Brown et al. 1984, Archibald 1987).

Recent Research

Wassenich (2003*a*) compiled and analyzed a database consisting of 30 known collisions between 1956 and 2002, updating a list initiated by Halvorson (1984). This was done in collaboration with T. Stehn as a first step to try to come up with a remedy for reducing the high rate of whooping crane/power line strikes. Subsequent to this list being compiled, there have been 15 additional whooping crane/utility line strike mortalities between 2002 and 2006 located in Florida (12), Indiana (1), and Wisconsin (2) (Table 1). Collisions have occurred in 9 states and 1 province, with the most strikes in Colorado and Florida (Table 3).

In Colorado, 80% of total losses (n = 10) occurred as cranes gathered together for a prolonged stopover during the spring migration, a behavior referred to as staging. Whooping cranes from the now extirpated Rocky Mountain population would spend from 4-6 weeks with sandhills during the spring migration in the San Luis Valley of Colorado, an area where most strikes occurred as power line density increased dramatically due to development of center pivot irrigation of agricultural fields. The high number of strikes in Florida (n = 20) are from the resident Florida whooping crane population that have exposure to power lines throughout the year, whereas the AWBP usually only has exposure to lines during migration. The AWBP stages in the fall in southcentral Saskatchewan.

The difficulty for protecting whooping crane in the AWBP comes from deciding which lines to mark for a species with a 4,023 by 322 km migration corridor that mostly does not use traditional stopover sites (Wassenich 2003*a*). It is hard to predict where whooping cranes will stop. Howe (1989) using telemetry data on migrating whooping cranes found that "individuals did not use the same stopovers in different migrations, and groups migrating independently rarely shared stopovers used by other groups". However, some locations considered to be traditional stopover sites are used by small groups of whooping cranes nearly annually (Austin and Richert 1999). Some of these are designated by law as Critical Habitat since they are areas considered as required for the survival of the species. Examples of critical habitat include Salt Plains NWR in Oklahoma, Quivira NWR in Kansas, and a 90 km stretch of the Platte River in Nebraska.

Collision locations and all known confirmed sightings of AWBP whooping cranes in the U.S. (n = 1,100, Austin and Richert 1999) and Canada (n = 1,600, Brian Johns 2003, Canadian Wildlife Service files, Saskatoon, Saskatchewan) were placed on a map using ArcGIS for visual analysis (Wassenich 2003*b*)(Fig. 2). SPSS 2003 statistical software was used to calculate a running median on all migration sighting data points to better define the whooping crane migration corridor. From the derived centerline of the migration pathway, corridors of various widths were defined to determine how many of the known collisions and total sightings occurred within that given corridor width. Results showed that a migration corridor 100 miles wide (161 km) contained 77% of known collisions and 82% of total sightings. Increasing the corridor width to 200 miles (322 km) accounted for 88% of known collisions and 94% of all sightings, an increase of only 12% of total sightings (Fig. 2). This type of information could be used to target which power lines to mark to more effectively reduce whooping crane mortality.

Management Actions

Power lines can sometimes be redesigned or altered when necessary to reduce collisions. However, marking is neither necessary nor appropriate over large areas with low bird-collision potential (APLIC 1994). Studies have concluded that marking lines is a highly effective way to reduce sandhill crane collisions in specific problem areas (Morkill 1990, Morkill and Anderson 1991, Brown and Drewien 1995) and would also be expected to reduce whooping crane mortality (Morkill and Anderson 1991). The marking of the overhead ground wire has been the focus of research because it appears to be the one most often struck by birds in flight (Scott et al. 1972, Willard et al. 1977, Brown et al. 1987, Faanes 1987). A review of the literature indicated that increasing the visibility of power lines by installing markers on the ground wires was the most cost-effective and logistically feasible potential method for reducing bird collisions (Beaulaurier 1981, Archibald 1987) and was the most common modification made by the electric power industry to reduce bird collisions (APLIC 1994). Except for part of the Brown and Drewien (1995) study, all other marking systems discussed below have been installed on the unenergized overhead ground wires (APLIC 1994).

Aerial marking spheres, spiral vibration dampers (SVD's), Bird Flight Diverters (BFD's) and Swan Flight Diverters have all been used to significantly reduce collisions (APLIC 1994).

The latter 3 devices are similar and made out of high-impact polyvinyl chloride in a preformed shape that wraps around the ground wire to make it more visible. Total bird mortality was reduced 57-89% depending on spacing by BFD's placed on overhead ground wires in the Netherlands where it has become standard to mark lines in bird-collision zones (Koops 1987). Collisions were reduced by 53% for non-passerine species at a South Carolina transmission line outfitted with yellow marker balls (Savereno et al. 1996) and by 54% for lesser sandhill cranes in Nebraska using 1-5 spheres per span (Morkill and Anderson 1991). In southwestern Colorado, yellow SVD's installed to cover 27.5% of a span reduced collisions of cranes and waterfowl by 61%, while yellow fiberglass square plates reduced mortality to the same species by 63% (Brown and Drewien 1995). However, the aerodynamic instability of the swinging plates proved to be very damaging to the conductors (Miller 1990, Brown and Drewien 1995). Yellow plastic tubes placed on power lines near Hokaiddo, Japan reduced mortality and was a primary factor for the increase in the population of red-crowned cranes after 1976 (Archibald 1987).

Brown and Drewien (1995) suggested that color is an important factor in marker effectiveness; they selected yellow-colored SVD's in their study because SVD's were highly visible in poor light. Yellow has been shown to be useful in color-marking system studies because it reflects light longer on both ends of the day, and does not blend in with background colors as readily as international orange (APLIC 1994). Other potentially helpful devices to reduce strikes include bird flappers and diverters, such as the Firefly and BirdMark, which swivel in the wind, glow in the dark, and use fluorescent colors designed specifically for bird vision. More research is needed on such devices to test their effectiveness.

A limited study compared the use of an oversized overhead ground wire with a conventional overhead ground wire (Brown et al. 1987, Miller 1990), however researchers concluded that there were no significant effects on crane and waterfowl response (APLIC 1994). Removal of overhead ground wires can be an effective means of reducing bird collisions (Beaulaurier 1981, Brown et al. 1987), but in areas of high lightning levels, reliability of electrical service is severely jeopardized (APLIC 1994). The development of polymer insulation and polymer lightning arrestors has introduced another option in the removal of overhead ground wires (APLIC 1994).

Manville (2005) provided an update on industry efforts to minimize avian collisions. *"In an attempt to comprehensively address the collision problem, APLIC (1994) provided voluntary guidance to the industry on avoiding power line strikes. The document will be updated once research being conducted by the Electric Power Research Institute and others at the Audubon NWR, North Dakota, is completed, and results of tests on a Bird Strike Indicator and Bird Activity Monitor can be published. Other research findings will also likely be included."*

Techniques currently recommended to reduce whooping crane strikes include marking lines to make them more visible in areas frequently used by cranes (Brown et al. 1987). USFWS recommends to avoid placing new line corridors near wetlands or other crane use areas, and usually recommends lines should be marked when crossing wetlands, or at a minimum distance within 0.4 km of a known crane roost or use area (W. Jobman, USFWS, Grand Island, Nebraska, personal communication). Brown et al. (1987) recommended locating new power lines at least 2.0 km from traditional roost and feeding sites based on their finding of no collisions observed when roosting and foraging sites were more than 1.6 km apart.

Additional Recommended Actions

The following actions recommended for species recovery are listed in the Canada-U.S. Whooping Crane Recovery Plan (CWS and USFWS 2007):

- Use telemetry to better document mortality and/or continue to document sightings with the whooping crane reporting network to better define areas receiving high crane use and locations where power lines are a significant problem.
- Monitor the placement and design of all new power lines in areas of known crane use. When possible, bury new power lines or route them around areas frequently used by whooping cranes. For example, lines have been buried at Monte Vista National Wildlife Refuge in Colorado and the Last Mountain Lake National Wetland Area in Saskatchewan where multiple bird strikes had been documented.
- Mark existing problem lines to reduce collisions. Visibility should be maximized on any existing structures or those, which of necessity, must be constructed in whooping crane use areas or flight routes by following CWS and/or USFWS guidelines to reduce bird strikes.
- Remove unnecessary power lines from traditional stopover sites, Critical Habitat, National Wildlife Areas, National Wildlife Refuges and National Wetland Areas used by whooping cranes.
- The Whooping Crane Recovery Team should make contact with the Avian Power Line Interaction Committee (APLIC) to stay appraised of new developments in collision reduction and work jointly to ascertain and implement actions to reduce whooping crane mortality due to collisions with power lines.

With power line strikes the greatest source of mortality of fledged whooping cranes, a species still very endangered, it is important to try to reduce the current level of mortality. The USFWS, working in collaboration with representatives of the electric utility industry, desires over the next several years to perform the following tasks. The point of contact for USFWS will be its Whooping Crane Coordinator.

- Develop contacts with key members of APLIC and work together to agree upon the most effective actions needed to reduce whooping crane mortality. Create a Whooping Crane Strike Avoidance Team to more formally address this issue with industry and other stakeholders.
- Work with APLIC to better define criteria for which lines need to be marked. Create maps showing the main whooping crane migration corridor where lines may need to be marked. Define areas where lines do not need to be marked, such as highly developed urban areas or areas at the edges of the migration corridor.
- Spread information about power line strikes being the primary short-term threat to survival of fledged whooping cranes in migration. Send out information to USFWS Ecological Services offices, other agencies and industry representatives.
- Standardize USFWS policy carried out by Ecological Services offices within the whooping crane migration corridor to ensure an increased effort to recommend marking existing and new lines where needed.
- Work with the Ecological Services and Refuge divisions of USFWS to concentrate initially on getting lines marked within or near Critical Habitat, National Wildlife Refuges, and Wildlife Management Areas. Ensure that areas around traditional stopover sites are adequately marked.
- Monitor the placement and design of all new lines in the whooping crane migration corridor.
- Work to gain support to increase the overall percentage of marked lines in the whooping crane migration corridor to reduce mortality. Insure that this percentage continues to increase even as new lines are constructed.
- Encourage the electric utility industry and others to fund further research into reducing whooping crane strikes that would provide beneficial information for all diurnal species.
- Use information from this issue paper to help write and implement voluntary Avian Protection Plans for utilities in the migration corridor of the AWBP corridor. These plans would be utility-specific programs to reduce damage caused by avian interactions with electric utility facilities and reduce bird strikes. Guidelines for Avian Protection Plans are currently available on-line.

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Cranes wintering near Ascension Chihuahua, Mexico (northwest corner of the state). Photo by Roderick C. Drewien.