SPECIES REVIEW:

SANDHILL CRANE (*Grus canadensis*)

Gary L. Krapu[1], Gary L. Ivey[2], and Jeb A. Barzen[3]

(with inputs from George W. Archibald, Inga Bysykatova, and Scott Hereford)

[1]US Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA,
Email: gkrapu@usgs.gov

[2]International Crane Foundation, Baraboo, Wisconsin, USA
Email: Ivey@savingcranes.org

[3]Private Lands Conservation LLC, Spring Green, Wisconsin, USA
E-mail: jeb@privatelandsconservation.org

Sandhill Cranes unison call at nest (Photographer: Ted Thousand, International Crane Foundation)

Red List Category: Least Concern
Population Size: 827,000
Population Trend: Increasing
Distribution: North America and eastern Siberia

Mirande CM, Harris JT, editors. 2019. Crane Conservation Strategy. Baraboo, Wisconsin, USA: International Crane Foundation.

DISTRIBUTION AND STATUS OF KEY SITES

The Sandhill Crane is one of the most abundant of the 15 crane species (Harris and Mirande 2013), with populations distributed widely across North America, including Mexico, extending to Russia's Far East, and as far south as Cuba. Small numbers of Sandhill Cranes even occur regularly in China during winter (Harris and Mirande 2013). Six subspecies have been recognized based on plumage and morphological characteristics, including three migratory subspecies, Lesser Sandhill Crane (*G. c. canadensis*), Canadian Sandhill Crane (*G. c. rowani*), Greater Sandhill Crane (*G. c. tabida*), and three non-migratory subspecies, Florida Sandhill Crane (*G. c. pratensis*), Mississippi Sandhill Crane (*G. c. pulla*), and Cuban Sandhill Crane (*G. c. nesiotes*; Walkinshaw 1973, Lewis 1977, Tacha et al. 1985, Meine and Archibald 1996). Mitochondrial DNA analysis of these subspecies indicates two evolutionary lineages: lineage I, which is comprised primarily of G. c. canadensis; and lineage II, which contains the remaining five subspecies (Rhymer et al. 2001). Studies concluded that only two of the three migratory subspecies were phylogenetically distinct and that *G. c. rowan*i and *G. c. tabida* should be consolidated (Rhymer et al. 2001, Glenn et al. 2002, Petersen et al. 2003). Further, variation in the migratory subspecies is generally clinal from north to south, and *G. c. rowani* is intermediate in morphology, geography, and genetics, suggesting consideration as a transitional form (Jones et al. 2005).

Flyway Councils have formally designated six populations of migratory Sandhill Cranes for management purposes, including Pacific Coast (PCP), Central Valley (CVP), Lower Colorado River Valley (LCRVP), Rocky Mountain (RMP), Mid-Continent (MCP), and Eastern (EP) (Dubovsky 2018). In addition, Krapu et al. (2011) delineated four breeding affiliations for the MCP—Western Alaska-Siberia, Northern Canada-Nunavut, West-central Canada-Alaska, and East-central Canada-Minnesota—to improve management of crane groups within the MCP. Meine and Archibald (1996) also recognized a Prairie Population of Greater Sandhill Cranes that overlapped with the latter breeding affiliation, breeding in in western Minnesota, southwestern Ontario, and southern Manitoba. Additionally, non-migratory Florida, Mississippi, and Cuban subspecies are considered separate populations (U.S. Fish and Wildlife Service [USFWS] 1991, Meine and Archibald 1996).

While some sites that are important to the MCP are protected, numerous other key sites have little permanent protection. For example, the major staging area that has developed in South Dakota for Greater Sandhill Cranes in recent decades remains largely unprotected, as does much of the spring staging habitat used by Lesser Sandhill Cranes in Saskatchewan. For migratory cranes using staging areas along the Platte River in central Nebraska, it is highly important to secure adequate instream flows to help maintain sufficient roosting habitat, along with securing additional protection for other key staging and wintering areas (Graf et al. 2005). For the EP, protected staging and wintering areas include Jasper-Pulaski Fish and Wildlife Area (Indiana), Hiwassee State Wildlife Refuge (Tennessee), and Wheeler National Wildlife Refuge (NWR) (Alabama), but many other areas important to the population remain unprotected. For the RMP, LCRVP, CVP, and PCP, a number of national wildlife refuges and state wildlife areas provide key staging and wintering sites; however, the vast majority of these populations of Greater Sandhill Cranes rely on unprotected private lands in western states for breeding. Needs for the non-migratory subspecies include acquisition and protection of additional habitats of the Florida Sandhill Crane to ensure that the range of the species remains contiguous throughout the Florida peninsula and securing existing and potential habitats for the Mississippi and Cuban Sandhill Cranes.

ECOLOGY

Sandhill Cranes are primarily birds of open freshwater wetlands, shallow marshes, wet meadows, and adjacent uplands; however, populations breeding along the Pacific Coast use tidal brackish wetlands for foraging, and Cuban Sandhill Cranes nest in uplands (Walkinshaw 1973). Peak Greater Sandhill Crane nesting densities occur where wetlands and agricultural habitats intermix (Barzen et al. 2016) because Sandhill Cranes often place their nests in wetlands but feed their young in both wetland and upland habitats located within each territory (Miller and Barzen 2016). Sandhill Cranes utilize a broad range of habitat types, from bogs, sedge (*Carex*) meadows, and fens to open grasslands, agricultural fields, savannas, and intertidal zones. They are omnivorous, feeding on a wide variety of plant materials (including waste grains), invertebrates, and small vertebrates, both on land and in shallow wetlands and estuaries. Critical components of habitats at staging and wintering areas include large, undisturbed, shallow wetlands or flooded agricultural fields for roost sites and foraging. Large concentrations of cranes also use associated agricultural landscapes dominated by grain crops (Ivey et al. 2014a). For reviews of the species' breeding, migration, and winter habitats, food habits, behavior, breeding biology, and demographics, see Walkinshaw (1949, 1973); Johnsgard (1983); Tacha et al. (1992, 1994); Krapu et al. (2014); and Gerber et al. (2014).

The endangered Mississippi and Cuban Sandhill Cranes are confined to drier or seasonally flooded habitats. Within their limited territory, Mississippi Sandhill Cranes use wet pine savannas and coastal prairies dominated by wiregrass (*Aristida*) and a rich herbaceous community with scattered longleaf pine (*Pinus palustris*), slash pine (*P. elliottii*), pond cypress (*Taxodium*), riverine swamp strands, estuarine marsh and occasionally open pine flatwoods (Valentine and Noble 1970, USFWS 1991, Gee and Hereford 1995). Much of this habitat has been altered since the 1940s by afforestation, fire suppression, and urban and agricultural development (Smith and Valentine 1987). The Cuban Sandhill Crane occupies relatively dry upland grasslands, hammocks, and pine and palmetto (*Sabal palmetto*) savannas, often associated with wetlands (Walkinshaw 1949; Faanes 1990; Xiomara Galvez, personal comm. 2017). Some pairs of the non-migratory cranes remain on their breeding territories throughout the year (particularly Okefenokee-nesting Florida Sandhill Cranes and Mississippi Sandhill Cranes). Others gather in flocks and forage on agricultural gleanings, in pastures, and (in the case of the Mississippi Sandhill Crane) supplemental food plots within wildlife refuges (Scott Hereford, personal comm. 2017).

NUMBERS AND TRENDS

An estimate of total number of individuals for all populations is 827,000 birds. Estimates and status by population and subspecies are:

Eastern (EP): 87,000 Greater Sandhill Cranes (three-year average; Dubovsky 2018). A coordinated fall index survey indicated a long-term growth rate of 4.4% (Dubovsky 2018). Greater Sandhill Cranes are increasing more rapidly in the eastern portion of their range than in other regions (Urbanek 1994, Lacy et al. 2015).

Mid-continent (MCP): Total of 660,000 cranes (three-year average; Dubovsky 2018), composed of about 65% Lesser Sandhill Cranes (Krapu et al. 2011), 30% putative Canadian Sandhill Cranes, and 5% Greater Sandhill Cranes, which are found largely in the East-central Canada-Minnesota breeding affiliation (Krapu and Brandt 2010). Greater Sandhill Cranes have failed to re-occupy most of their former extensive breeding range in the northern Great Plains (Krapu and Brandt 2010). The numbers of Sandhill Cranes in the West-central Canada-Alaska and East-central Canada-Minnesota breeding affiliation (composed of Greaters and putative Canadians) may be declining due to a disproportionate harvest (Krapu et al. 2011). Overall, the MCP is stable to increasing, but counts have high interannual variability (Dubovsky 2018).

Pacific Coast (PCP): Total of 41,500, including 36,500 Lesser Sandhill cranes, believed to be stable or increasing (Ivey et al. 2014c), and 5,000 putative Canadian Sandhill Cranes, considered stable (Ivey 2014c).

Central Valley (CV): Total of 8,500 Greater Sandhill Cranes, (Ivey et al. 2014c); this population is increasing at a more moderate pace in the western portion of the range than in the EP (Collins et al. 2015).

Lower Colorado River Valley (LCRV): 2,500 Greater Sandhill Cranes (three-year average; Dubovsky 2018).

Rocky Mountain (RMP): 22,000 Greater Sandhill Cranes, considered stable (three-year average; Dubovsky 2018).

Florida: Non-migratory population of 5,000 Florida Sandhill Cranes, including an Okefenokee subpopulation of ~400. Florida Sandhill Cranes have been thought to be declining due to significant habitat destruction (Bennett 1988, Nesbitt and Hatchitt 2008). However, recent data from North American Breeding Bird Surveys, conducted in May each year, suggest that the subspecies' population in Florida is stable or perhaps increasing as cranes adapt to more human-defined habitats (W. A. Cox, T. Dellinger, R. Kiltie, B. Bankovich and B. Tornwall, unpublished data).

Mississippi: A non-migratory population of 133 Mississippi Sandhill Cranes, as of January 2018 (Hereford 2018). Numbers in the wild are increasing through augmentation with captive-bred birds; reproduction in the wild is below replacement level but increasing (Scott Hereford, personal comm. 2017).

Cuba: Non-migratory population of 526 of Cuban Sandhill Cranes. The population is decreasing in some areas (Galvez-Aguilera and Chavez-Ramirez 2010).

THREATS

- Loss and degradation of wetlands, as well as upland foraging habitats, are the most important threats to populations. For the migratory subspecies, this threat is of greatest concern in staging and wintering areas, where changes in land use, hydrology, and vegetation have reduced available habitat and concentrated the flocks during the non-breeding season (Krapu et al. 1982, Tacha et al. 1994, Drewein et al. 1996). Changes in agricultural landscapes, which reduce availability of grain crops within important wintering and staging sites, could limit populations in the future (Krapu et al. 2004, 2005, Pearse et al. 2010, Barcelo 2012, Ivey et al. 2014c). The drier meadow, savanna, and other upland habitats to which the non-migratory subspecies are partially adapted have also been widely altered by agricultural conversion, development, and fire suppression;

- Construction of upstream dams, other flood-control structures, and water withdrawals have altered wet meadow and roost site suitability at spring staging areas along the Platte River in Nebraska (U.S. Fish and Wildlife Service 1981). This change is of special concern because of the Platte River's importance to the MCP and other migratory birds (see USFWS 1981, Johnsgard 1984, Currier et al. 1985, Krapu et al. 1985, VanDerwalker 1987, Faanes 1992, Graf et al. 2005). With about 80% of the MCP using the Platte River during spring, the long-term degradation and loss of high-quality habitat at this site constitutes a major threat to the species. Intensive channel management for cranes, after taking into account crane roost-site requirements (U.S. Fish and Wildlife Service 1981, Krapu et al. 1984, Pearse et al. 2017), has helped to stabilize distribution and use of nocturnal roosts in the Central Platte River Valley in recent decades (Krapu et al. 2014). These management activities

likely will need to continue for the foreseeable future because of growing demands on available water resources;

- Overhunting poses a potential risk to some populations. The migratory subspecies are hunted for recreation in some parts of Canada, United States, and Mexico. They are also hunted for subsistence in arctic Alaska, Canada, and Russia. MCP Greater Sandhill Cranes are the first to stage during fall in the northern plains and are harvested disproportionately to their numbers based on their patterns of exposure to hunting obtained through monitoring a random sample of satellite-monitored cranes (Krapu and Brandt 2010, Krapu et al. 2011). Since the mid-1980s, the estimated overall annual crane harvest (including crippling losses) in the MCP has ranged between 25,000 and 31,700, or about 4–5% of the fall population (Sharp and Vogel 1992, Tacha et al. 1994, Central Flyway Webless Migratory Game Bird Technical Committee 2006). Failure of Greater Sandhill Cranes to reoccupy most of their former breeding range in the northern Great Plains occurred concurrently with a disproportionate harvest resulting from their arrival on fall staging areas several weeks before subarctic- and arctic-nesting cranes arrive, as well as the later departure of Greater Sandhill Cranes (Krapu and Brandt 2010, Krapu et al. 2011). In North Dakota, Greater Sandhill Cranes accounted for 60, 28, 35, and 44% of birds shot in Benson, Pierce, Sheridan, and Stutsman counties respectively (Kendall et al. 1997), despite their relatively small numbers in the MCP (Krapu et al. 2011). The Sandhill Crane has the lowest recruitment rate of any bird hunted in North America (Drewien et al. 1995, Wheeler et al. 2019), which increases the need for detailed information on recruitment and survival rates to effectively manage hunted populations. The core breeding population of Greater Sandhill Cranes in Wisconsin consistently has as few as 0.20 chicks/territory that survive to fall migration each year which, if widespread, would be comparable to approximately 5% of the winter population composed of chicks produced that year (Jeb Barzen, unpublished data from 1993–2017); and

- Cranes are exposed to a variety of threats while on wintering grounds and during spring migration. In the northern State of Chihuahua, Mexico, the arid climate has resulted in extensive development of irrigation for agriculture, resulting in water being diverted from wetlands used by Sandhill Cranes (Drewien et al. 1996). Elsewhere, mycotoxins ingested through the consumption of waste peanuts (*Arachis hypogea*) have caused large-scale mortality events (up to 5,000 individuals), while lead poisoning and collisions with fences and power lines also cause significant injury and death (Brown et al. 1987, Windingstad 1988, Allen and Ramirez 1990, Ward and Anderson 1992, Franson and Hereford 1994, Wright et al. 2010). The dense concentrations of migratory flocks along the Platte River are potentially susceptible to outbreaks of avian cholera and other diseases particularly under low flow conditions (Krapu et al. 2014).

CHANGES SINCE 1996

- Several major gaps in information on the MCP have been filled, in part using satellite telemetry to monitor tagged cranes throughout the annual cycle (Krapu et al. 2011, 2014). Four breeding affiliations have been delineated for management purposes (Krapu et al. 2011);

- Corn (maize, *Zea mays*) has been the food of choice for Sandhill Cranes on wintering grounds where available, including the Chihuahuan Desert in northern Mexico (Barcelo 2012) and the Middle Rio Grande Valley in New Mexico (Boggie et al. 2018). Along the Platte River, a sharp decline in corn residues due to more efficient corn harvesting techniques, growing competition for corn (particularly from snow geese [*Anser caerulescens*]), and an expansion in production of soybeans (*Glycine max*), a crop poorly suited for meeting crane nutritional needs (Krapu et al. 2004, Pearse et al. 2010), has led to reduced fat storage by Greater Sandhill Cranes. This larger-bodied subspecies

has higher maintenance energy requirements than do the smaller Lesser Sandhill Cranes, leaving less corn being synthesized into fat (Krapu et al. 2014). A reduction in corn residues in the absence of a high-energy replacement has prompted concern that reduced fat storage in the future could adversely affect reproduction and reduce recruitment of young into the MCP. Spring staging areas in Saskatchewan serve as important sites for fat storage in Lesser Sandhill Crane (Krapu et al. 2014), as likely do spring staging sites in South Dakota for Greater Sandhill Cranes. Fat storage may be less critical for spring migrants of the EP as the migration itself can be completed in as little as one day (Thompson and Lacy 2016). Also, during inclement weather, breeding birds can retreat south instead of relying solely on stored fat for energy requirements when food is unavailable (Thompson and Lacy 2016). EP cranes, however, still stage for significant time periods in both fall and spring, presumably to acquire fat reserves (Thompson and Lacy 2016, Fronczak et al. 2017).

- Sandhill Crane harvest has increased in recent decades. The MCP appears to have remained stable at about 660,000 cranes during the past three decades, but changes identified in Krapu et al. (2011) have been occurring within segments of the population, and the number of Greater Sandhill Cranes in the East-central Canada–Minnesota and West-central Canada–Alaska breeding affiliations may be declining due to an apparent disproportionate harvest on fall staging areas (Krapu and Brandt 2010, Krapu et al. 2011). The current breeding distribution of the East-central Canada-Minnesota breeding affiliation of Greater Sandhill Cranes is centered along the northern periphery of the its historic range. Their inability to re-occupy much of the original breeding range in the northern Great Plains likely is linked, in part, to high mortality from early hunting seasons on key fall staging areas in the northern plains. Fall harvest of MCP Greater Sandhill Cranes increased starting in 2010 when Minnesota initiated a relatively liberal fall hunting season on a major breeding ground not previously open to crane hunting (Krapu and Brandt 2010). The most compelling evidence that hunting is keeping the number of MCP Greater Sandhill Cranes well below carrying capacity comes from failure of this subspecies to re-occupy most of its former vast breeding range in the northern Great Plains despite habitat remaining plentiful;

- A warming climate has led to significant numbers of Sandhill Cranes overwintering in the Central Platte River Valley in some years and migrants arriving earlier in late winter or early spring (Harner et al. 2015). Changes in climate likely also have contributed to cranes leaving the Central Platte River Valley earlier in spring and the development in recent decades of a major Sandhill Crane spring staging area in eastern South Dakota (Krapu et al. 2011, 2014).

- The breeding and wintering distributions of Sandhill Cranes in the Pacific Flyway became better understood during the past two decades. A study of migration of PCP cranes breeding in southwest Alaska described their migration route and important staging and wintering areas (Petrula and Rothe 2005). An important advance was the discovery that a separate subpopulation of the Canadian Sandhill Crane breeds on islands in southeastern Alaska and along the coast of British Columbia, stages along the lower Columbia River, and winters primarily in the Sacramento Valley of California (Ivey et al. 2005);

- The EP has been the fastest growing population of Sandhill Cranes for the past 40 years, and population growth has been accompanied by major range expansion on breeding and wintering grounds (Lacy et al. 2015). However, an estimated 66% of the population still breeds in Wisconsin (Lacy et al. 2015), and at least some portions of the EP are no longer growing (Wheeler et al. 2019). The breeding range has expanded to the eastern United States and Canada along with Minnesota and Iowa (Lacy et al. 2015, Wolfson et al. 2017). Wintering cranes in the EP have expanded their distribution dramatically north, concurrent with population growth, and simultaneously with

changing habitat conditions and warming trends (Lacy et al. 2015). Population studies have estimated 95% annual survival for the population as a whole (Fronczak et al. 2015), 94% for territorial individuals (Wheeler et al. 2019), and 92% survival from first migration to independence (Hayes and Barzen 2016a). Satellite-telemetry studies also provided new insight into migratory habits and wintering distribution of the EP (Fronczak et al. 2017, Wolfson et al. 2017). In addition, individuals from the same breeding area can be found widely across the EP winter range (Thompson and Lacy 2016, Hayes 2015). Finally, damage to planted corn caused by Sandhill Cranes has been markedly reduced in the Midwest through deployment of anthraquinone (Avipel®), a seed treatment purchased and applied by the agricultural community and without necessitating expenditure of funds designated for conservation (Lacy et al. 2013, Barzen and Ballinger 2018). Crop damage was cited as one reason for hunting proposals being considered (Barzen 1997, Skasa and Barzen 2010);

- Destruction and degradation of habitats comprise the most important current threat to the Greater Sandhill Crane, especially on wintering grounds in California (Ivey et al. 2014c), New Mexico (Boggie et al. 2018), Florida (Nesbitt and Hatchitt 2008), and southern Great Plains (Iverson et al. 1985); breeding grounds in the American upper Midwest (Barzen et al. 2016); and migration stopover areas on the Platte River (Krapu et al. 1982) or other sites in the plains states (Drewien et al. 1995). The habitats of the RMP, CVP, PCP, and LCRVP are increasingly affected by development, changing agricultural practices and conversion to incompatible crop types, wetland drainage, water diversions, oil and gas development, and other land-use changes. Habitat in Florida is being fragmented by development (Nesbitt and Hatchitt 2008). Habitat needs have been described for Greater Sandhill Cranes on breeding areas in the EP (Su 2003, Barzen et al. 2016, Hayes and Barzen 2016b, McKinney et al. 2016, Miller and Barzen 2016) and on staging as well as winter areas (Thompson and Lacy 2016);

- The Mississippi Sandhill Crane continues to face a broad range of interrelated threats leading to low reproduction and survival rates, and this population continues to rely on releases of captive-bred birds to bolster its numbers (Scott Hereford, personal comm. 2017). Smoke management concerns affect ability of land managers to use frequent, low-intensity prescribed fire to maintain open habitat; and

- The Cuban Sandhill Crane is subject to similar threats facing other non-migratory cranes: changes in the hydrology and fire regime of its savanna habitat and loss of habitat to deforestation, development, land reclamation, and agricultural expansion (Galvez-Aguilera and Chavez-Ramirez 2010). Results of a comprehensive research project that began in 1996 have been used to consider development of additional protected areas. For example, establishment in 2004 of Gran Humedal Norte de Ciego de Avila Reserve was justified in large part to support one of the largest Sandhill Crane populations in the country. Most in-depth studies (e.g., habitat use, reproduction, movement rates) were conducted on the Isle of Youth; however, research activities continue in other areas such as Ciego de Avila Province. Monitoring activities of breeding and productivity continue on the Isle of Youth and Ciego de Avila Province.

CONSERVATION AND RESEARCH EFFORTS UNDERWAY

International Cooperation, Legal and Cultural Protection

The Sandhill Crane experienced marked declines in the late 19th and early 20th centuries from uncontrolled hunting (Walkinshaw 1949), but populations rebounded by the mid-20th century in response to extensive conservation efforts and changes in American agriculture that allowed the birds to congregate in large numbers on remaining suitable habitats. See Walkinshaw (1973); Johnsgard (1983, 1991); Tacha et al. (1992; 1994); Krapu and Brandt (2010); and Krapu et al. (2011) for overviews

of these efforts. The five countries supporting Sandhill Crane populations (Canada, Cuba, Mexico, Russian Federation, and United States) are signatories of the Ramsar Convention. In Canada and the United States, the species falls under the protection of the Migratory Bird Treaty Act of 1918, which declared Sandhill Cranes a game species with a closed season. The Treaty allows for regulation of hunting and other forms of direct exploitation. Hunting was prohibited until increased size of the MCP resulted in major crop depredation, prompting initiation of harvest seasons in Canada starting in 1959 and in the United States in 1961 (Subcommittee on Rocky Mountain Greater Sandhill Cranes 2007). Currently, Sandhill Cranes are legally hunted in Alaska, Arizona, Colorado, Idaho, Kansas, Kentucky (added in 2011), Manitoba, Minnesota (added in 2010), Montana, New Mexico, North Dakota, Oklahoma, Saskatchewan, South Dakota, Tennessee (added in 2013), Texas, Utah, and Wyoming. In 1936, the United States and Mexico signed a similar Treaty for the Protection of Migratory Birds and Game Mammals; however, while considered a species at risk under Mexican law (NOM-059-ECOL-2010), cranes have been legally hunted there since at least 1940 in eight northern and central states. In Russia, the Sandhill Crane is a protected species but subsistence harvest is allowed. Crane biologists from the Russian Academy of Science, Institute for Biological Problems of the Permafrost Zone at Yakutsk in the Sakha Republic (Yakutia), and researchers from the U.S. Geological Survey Northern Prairie Wildlife Research Center have been conducting a joint study of Sandhill Cranes breeding in Russia since 2009.

Both the Cuban and Mississippi Sandhill Cranes are protected under the U.S. Endangered Species Act. The former is also listed as Endangered in Cuba, and the latter is listed as Endangered and is also protected under Mississippi's Nongame and Endangered Species Act of 1974 (USFWS 1991). Since 1994, crane conservationists in Cuba and the United States have worked more closely on Cuban Sandhill Crane conservation efforts (Galvez-Aguilera and Perera 1995). The Florida Sandhill Crane is listed as Threatened on the Florida Endangered and Threatened Species List (Florida Fish and Wildlife Conservation Commission 2013). Greater Sandhill Cranes are listed as Threatened by California and Endangered by Ohio (http://wildlife.ohiodnr.gov/species-and-habitats/species-guide-index/birds/sandhill-crane; accessed May 4, 2017). Sandhill Cranes are also listed as Endangered in Washington (Littlefield and Ivey 2002).

Protected Areas

Sandhill Cranes use many national, provincial, and state protected areas as well as private conservation lands. A few areas, such as the Platte River corridor, are especially significant for cranes and have been the focus of protection efforts primarily for that reason (VanDerwalker 1987, Graf et al. 2005). In most cases, however, cranes are only one of many species that benefit from the protected status of these areas. The MCP Canadian breeding grounds lie mostly on federal and provincial lands in remote regions where development usually is less prevalent than on privately-owned lands, and many birds nest in regions where terrain limits the likelihood of major development (e.g., James Bay Lowlands). In contrast, most nesting areas for the EP of Greater Sandhill Cranes are found on privately owned lands (Lacy et al. 2015, Barzen et al. 2016).

Protected areas have played a key role in the protection and recovery of other Greater Sandhill Crane populations in the United States, especially in the Rocky Mountain and Pacific states.

Protected areas have been especially important in efforts to protect the non-migratory subspecies. Large areas of Florida habitat are protected within a matrix of state parks, preserves, state wildlife areas and private conservation lands. These areas are important to both Florida Sandhill Cranes and wintering EP cranes. However, due to habitat loss, alteration, and lack of management, the Florida Sandhill Crane population was reported to have declined an estimated 36% from 1974 to 2003 due

to habitat loss (Nesbitt and Hatchitt 2008). More recent analysis, based on Breeding Bird Survey data, suggests that actual crane numbers may have stabilized or possibly increased as individuals have adapted to more urbanized landscapes (W.A. Cox, T. Dellinger, R. Kiltie, B. Bankovich and B. Tornwall, unpublished data). To what extent this adjustment by cranes can continue, however, is unclear. Much of remaining crane habitat in Florida is under management that does not appear to favor cranes. Okefenokee NWR (Georgia) protects critical Florida Sandhill Crane habitat. The Mississippi Sandhill Crane NWR was established to protect habitat for the Mississippi Sandhill Crane. Purposes of Grand Bay NWR (Mississippi, Alabama) include providing habitat and a reintroduction site for Mississippi Sandhill Cranes. Eight of the 10 areas supporting Cuban Sandhill Cranes are protected, either as formal reserves and wildlife conservation areas or forestry management areas (Galvez-Aguilera and Chavez-Ramirez 2010). Protected areas include Birama, Cayo Romano, Norte de Moron (Gran Humedal Norte de Ciego de Avila), Cienega de Guayaberas, Cienega de Zapata, Majaguillar, Jucaro, and Los Indios Sabana Grande.

Habitat Protection and Management

Sandhill Cranes have benefitted from many national, provincial, and state policies as well as programs to conserve wetlands. Cranes have also benefited from work by private conservation organizations, especially in parts of the United States where populations were reduced or extirpated and in the Platte River Valley. This pertains to habitat both within protected areas and on private lands. Restoration of hydrological regimes through re-flooding and management of water levels has played a critical role in re-establishing the ecological functions of previously drained wetlands, especially in the upper Midwest (e.g. Necedah National Wildlife Refuge [NWR; Wisconsin], Seney NWR [Michigan], and Sherburne NWR [Minnesota]). In some areas, habitat management programs have been undertaken specifically for cranes. The Platte River Whooping Crane Habitat Maintenance Trust (now the Crane Trust) was established by a federal court ruling. The Crane Trust has acquired, through fee title and conservation easement, over 4,050 ha (10,000 ac) for Sandhill and Whooping Cranes in the Central Platte River Valley (Strom 1987, Currier 1991). In recent decades, efforts to protect and maintain crane habitat have been undertaken by the National Audubon Society, The Nature Conservancy, the Crane Trust, and the Nebraska Public Power District, the latter in conjunction with habitat restoration efforts for cranes under the Platte River Recovery Implementation Program (Platte River Recovery Implementation Program 2017). The Nature Conservancy, Ducks Unlimited, Inc., and government agencies from county to federal level have cooperated in wetland restoration and habitat management for wintering cranes at the Cosumnes River Preserve in the Central Valley of California. Management of wetland habitats to produce food for cranes in winter has been intensive in some areas such as New Mexico (Taylor and Smith 2005). Frequent burning and mechanical removal of woody vegetation is critical to maintain open meadows and savannas in Mississippi, Texas, and other areas used by cranes (Scott Hereford, personal comm. 2017). Food crops have been planted in many of the important staging areas, both to benefit cranes directly and to lure them away from commercial croplands (USFWS 1991, Gee and Hereford 1995).

In the EP, the majority of breeding Sandhill Cranes use private lands. As such, solving problems that result from the resurgence of this population is important for people who provide Sandhill Crane habitat. Management actions include mitigating crop damage issues where they arise, such as with planted corn (Barzen and Ballinger 2017, 2018), and developing consensus in the public arena over how to best use cranes as a resource (Harris and Barzen 1996, Barzen 1997, Beilfuss 2012). Successful solutions to crop damage have been developed, particularly the development and registration of anthraquinone (Avipel®) for use as a taste deterrent for seeds (Lacy et al. 2013, Barzen et al. 2018, Lacy et al. 2018), which can be deployed at landscape scales (>40,500 ha; Barzen and Ballinger 2018).

Ultimately private landowners will protect numerous, scattered wetlands that nesting cranes need if required by federal and state laws, are guided by a land ethic (Leopold 1968), or for other reasons feel it is in their interest to do so. Management assistance is particularly needed in areas where lands are predominantly in private ownership.

Surveys/Censuses/Monitoring

The MCP has been monitored through annual March surveys in the Platte River Valley since 1957 (Lewis 1979). Development of aerial infrared videography to survey cranes while on nocturnal roosts in the Platte River has been shown to be a particularly effective tool for obtaining reliable estimates of population size (Kinzel et al. 2006). The RMP and EP are monitored via autumn pre-migration and staging-area surveys (Dubovsky 2018). Coordinated roost counts are used to monitor winter crane numbers in the Central Valley of California (Ivey et al. 2014c). Differential detection rates for territorial and non-territorial social groups of cranes during summer has been determined (McKinney et al. 2016).

Research

The Sandhill Crane is among the most thoroughly studied of crane species. Research has been conducted in various parts of the species' range and has focused on a wide array of topics involving life history, breeding biology, ecology, ethology, migration, and demography. Genetic relationships have been the subject of numerous investigations over the past 20 years focusing on mitochondrial DNA to define more precisely the phylogenetic relationships and degree of genetic variance within the species (Krajewski and Fetzner 1994), subspecies (Rhymer et al. 2001, Petersen et al. 2003, Jones et al. 2005), and populations (Hayes 2015). Results from many studies have been reported in the proceedings of the North American Crane Workshop and international crane workshops. The Unison Call, the biannual newsletter of the North American Crane Working Group, provides regular summaries of ongoing studies.

For the MCP, studies are underway evaluating current geographic distribution and ecology of Sandhill Cranes breeding in Russia (Gary Krapu, unpublished data), and results of studies estimating annual recruitment and survival rates in the MCP currently are being prepared for publication (Aaron Pearse, personal comm. 2017).

For the EP, a 25-year study of marked Greater Sandhill Cranes breeding in a region of high population density (Barzen et al. 2016) showed mate switches are frequent (Hayes and Barzen 2006, Hayes 2015), productivity is low (Wheeler et al. 2019), extensive interactions occur between breeding and non-breeding individuals in the summer flock (Hayes and Barzen 2006, Hayes 2015, Barzen and Gossens 2014), and extra-pair paternity is possible (Hayes et al. 2006). Habitat selection in relation to crop damage (Barzen et al. 2018) and other factors (Su 2003, Hayes and Barzen 2016b, Miller and Barzen 2016) occurs at multiple geographic scales. Areas of overlap between crane populations have also been studied on breeding areas (Krapu et al. 2011, Wolfson et al. 2017). On staging and winter areas, crane movements have been studied in ways similar to the MCP (Aborn 2011, King et al. 2011, Fronczak 2014, Fronczak et al. 2015, Fronczak et al. 2017). Studies also have been conducted on wintering grounds and staging areas in the southeastern United States (Aborn 2010, Hannah et al. 2014, Thompson and Lacy 2016) that included intensive monitoring of marked individuals in Florida (Nesbitt and Carpenter 1993) and Georgia (Bennett and Bennett 1989).

For the RMP, LCRVP, and CVP, recent research using satellite telemetry has helped to establish connectivity among these western populations (Collins et al. 2015). Results to date show the primary breeding grounds of the LCRVP are located in northeastern Nevada and southwestern Idaho with

breeding extending into west-central Idaho where their breeding distribution was found for the first time to overlap with the RMP. To date, no evidence has been found of CVP cranes overlapping on their breeding grounds with either the RMP or LCRVP.

For the CVP and PCP, recent research on Greater and Lesser Sandhill Crane wintering ecology in the Central Valley of California has defined roost site and foraging habitats (Ivey et al. 2014a), distribution of wintering flocks (Ivey et al 2014b, 2014c, 2016), described how the two subspecies use winter landscapes and their differences in home range sizes (Ivey et al. 2015), and crop selection patterns (Shaskey 2012, Ivey 2015). Recommendations for conservation and management strategies are provided by Shaskey (2012), Ivey et al. (2014c), Ivey (2015), and Ivey et al. (2015).

The precarious state of the Mississippi Sandhill Crane has prompted scientific attention on a wide range of topics relevant to crane conservation including habitat management, causes of mortality and nest failure, evaluation of release techniques, genetic management, effects of predators, the role of disease, and dispersal patterns (USFWS 1991). A Population and Habitat Viability Assessment was conducted for the Mississippi Sandhill Crane (Seal and Hereford 1992), resulting in a number of recommendations aimed at increasing nesting success reducing mortality of wild cranes, dividing the captive flock, and addressing health issues. A number of these recommendations have been implemented. Research is underway to evaluate food availability for chicks. A habitat suitability model was recently completed but is under revision before publication.

Information on Cuban Sandhill Cranes has been limited, historically, because of insufficient funds being available for training and hiring of personnel. Until recently only a few non-Cuban researchers have been able to conduct studies (Faanes 1990, Galvez-Aguilera and Perera 1995; E. Santana, personal comm. 1991; Xiomara Galvez, personal comm. 2017). In 1996, a research project was initiated to study life history traits of the subspecies, resulting in a Master thesis (Marrero Garcia et al. 2003), dissertation (Galvez 2002), and several scientific articles.

Population Management and Recovery Plans

Flyway Councils have developed management plans for formally designated populations of migratory Sandhill Cranes. These include the PCP, CVP, LCRVP, RMP, MCP, and EP (Subcommittee on the Pacific Flyway Population of Lesser Sandhill Cranes 1983; Pacific Flyway Council 1995, 1997; Central Flyway Webless Migratory Game Bird Technical Committee 2006, Subcommittee on Rocky Mountain Greater Sandhill Cranes 2007, Ad Hoc Eastern Population Sandhill Crane Committee 2010). Recovery plans have been prepared for several Sandhill Crane subspecies and populations: Mississippi Sandhill Crane Recovery Plan (USFWS 1991); Florida Species Action Plan for the state-threatened Florida Sandhill Crane (Florida Fish and Wildlife Conservation Commission 2013); and Washington State Recovery Plan for all three state-endangered migratory subspecies (Littlefield and Ivey 2002). Additionally, several national wildlife refuges have included Sandhill Cranes as a focal species for management in their 15-year Comprehensive Conservation Plans: Mississippi Sandhill Crane NWR (USFWS 2007), Grand Bay NWR (USFWS 2008), Conboy Lake NWR (USFWS 2014a), Columbia NWR (USFWS 2011), Malheur NWR (USFWS 2013), and San Luis Valley NWR Complex (USFWS 2014b).

Non-governmental Organizations

The North American Crane Working Group has played a key role in focusing interest on the Sandhill Crane through regular workshops, publications (many now available at https://digitalcommons.unl.edu/nacwg) and other activities. The group hosted its 14th workshop at Chattanooga, Tennessee, in January 2017. Private conservation organizations have contributed to the protection of valuable

Sandhill Crane habitat. For example, The Nature Conservancy (TNC) has played an instrumental role (beginning in 1974) in acquiring lands for the establishment and expansion of the Mississippi Sandhill Crane NWR (USFWS 1991) and manages 728 ha (1,800 ac) of savanna habitat between the refuge Gautier and Ocean Springs Units. Important spring staging areas along the Platte River are held by TNC, the National Audubon Society, the Crane Trust, and the State of Nebraska (Logan et al. 1976, Currier et al. 1985, VanDerwalker 1987, Strom 1993). TNC also manages reserves in California that support wintering Sandhill Cranes (Staten Island, Cosumnes River Preserve). The International Crane Foundation (ICF) has focused on the Sandhill Crane in many of its education, research, training, and habitat management programs. ICF has also sought sustainable solutions to problems arising from the recovery of Sandhill Crane populations (Lacy et al. 2013; Barzen and Ballinger 2017, 2018).

Education and Training

As a wide-ranging, abundant, and easily identified species, the Sandhill Crane has been incorporated into many conservation education programs and projects, especially those focusing on wetland values, functions, and conservation. These programs include the annual Midwestern crane count, which not only provides data on the size of breeding populations and status of habitat quality but allows participants to learn about crane and wetland conservation in the process (Dietzman and Swengel 1994). Annual crane festivals have been organized at key staging and wintering grounds, including the Platte River staging grounds, the Sacramento-San Joaquin Delta (Lodi, California), Hiwassee State Wildlife Area (Tennessee), Columbia NWR (Othello, Washington), Monte Vista NWR, Colorado, and Bosque del Apache NWR (New Mexico). A new headquarters and Visitor Center for the Mississippi Sandhill Crane NWR was built in 2008, and a full-time Refuge Ranger was hired, expanding crane education efforts there. In addition to the key role that Sandhill Cranes play in public education programs, the species also has been used extensively as a model for professional training in field research, captive propagation, and reintroduction methods. Practices that have been applied mainly to other species have often been "tested" first on Sandhill Cranes. These include the development of techniques for isolation rearing (Horwich 1989), banding (Melvin et al. 1983, Dickerson and Hayes 2014), and migration studies (Melvin and Temple 1983). Sandhill Cranes have also been used in experiments to teach migration routes to captive-reared cranes (see the Whooping Crane species review).

PRIORITIY RESEARCH AND CONSERVATION ACTIONS

Research

Research related to the rarer Sandhill Crane taxa should focus on:

- Continued studies of factors responsible for poor reproduction and low recruitment rates in the Mississippi Sandhill Crane population;
- Clarification of intraspecific genetic structure and phylogenetic relationships among the Cuban, Florida, and Mississippi Sandhill Cranes; and
- Quantitative analysis of genetic distinctiveness and long-term viability of Okefenokee nesting Florida Sandhill Cranes.

Research related to more abundant Sandhill Crane taxa should focus on:

- Improved assessments of population dynamics of the MCP. Identify factors affecting accuracy of surveys, develop alternative and/or supplemental means of monitoring, and continue to evaluate annual recruitment rates;

- Improved techniques for controlling and minimizing crop depredation on cereal grains and potatoes (*Solanum tuberosum*);
- Improved understanding of energetic needs in relation to conservation planning to maintain carrying capacities of crane wintering landscapes; and
- Increase assessments on effect of climate change on Sandhill Crane populations.

Legal and Cultural Protection

- Secure adequate Platte River inflows to meet crane needs and provide for protection, restoration, and maintenance of habitat (both upland and riverine) within areas traditionally used by migrating cranes; and
- Assess the need for listing of the Florida Sandhill Crane by the U.S. Fish and Wildlife Service.

International Agreements and Cooperation

- Support continued international efforts for research and conservation for the Cuban Sandhill Crane (see below); and
- Expand cooperation among biologists studying MCP Sandhill Cranes on wintering grounds in Mexico with those working in other parts of the winter range and on breeding grounds of this population.

Habitat Protection and Management

- Protect and restore essential wetland or upland habitats of the non-migratory subspecies including: acquisition and protection of additional habitats for the Florida Sandhill Crane to ensure that the range of the species remains contiguous throughout Florida and southern Georgia; secure potential habitats for the Mississippi and Cuban Sandhill Cranes; and provide management of these habitats to maintain appropriate vegetation and ecosystem function;
- Protect and restore additional vital staging and wintering areas of the migratory subspecies, including: the seasonal playa lakes of western Texas (Iverson et al. 1985); wet meadows and riparian roosting areas along the North Platte and Platte Rivers (Krapu et al. 1984, Tacha et al. 1994); basin wetlands and adjacent native grasslands in eastern South Dakota (Gary Krapu, 2017); prairie pothole landscapes in central and western Saskatchewan (Krapu et al. 2014); EP wintering grounds in Florida (Nesbitt and Hatchitt 2008); wetlands of the Intermountain West (Austin et al. 2007, Collins et al. 2015), California, and the American Southwest (Taylor and Smith 2005); and Laguna de Babicora and other wintering areas in northern Mexico (see Drewien et al. 1996); and
- Promote habitat conservation on private lands on key breeding, staging and wintering areas. Since much of the non-breeding habitat of migratory populations (and breeding habitat of migratory populations of Greater Sandhill Cranes) occur on private land, it is important that conservationists and private landowners collaborate in efforts to protect, improve, and restore wetlands, to exchange information, and to monitor and respond to crop depredation problems. Greater attention to trends in agricultural policy and agricultural practices, and their impact on habitat conditions, is needed. Cooperative agreements, easements, and other methods of habitat protection should be explored (see Subcommittee on Rocky Mountain Greater Sandhill Cranes 2007; Ivey et al. 2014c; Barzen and Ballinger 2017, 2018; Barzen 2018). Conservation on private lands is becoming increasingly important as Mississippi Sandhill Crane foraging habitat off refuge is being lost to development and fire suppression (Scott Hereford, personal comm. 2017).

Recovery of the Mississippi Sandhill Crane

- Update and fully implement the Mississippi Sandhill Crane Recovery Plan (USFWS 1991);
- Complete a refuge Habitat Management Plan for both Mississippi Sandhill Crane and Grand Bay NWRs;
- Complete a crane Inventory and Monitoring Plan; and
- Give special consideration, within the framework of the Recovery Plan, to the following:
  - o Continue active savanna and prairie restoration efforts at the Mississippi Sandhill Crane NWR, and secondarily at Grand Bay NWR; continue to expand mechanical removal of woody vegetation. With reduced funding for prescribed burning program, find additional ways to continue frequent burning of refuge;
  - o Increase number of cranes that defend nests and chicks from predators. Consider efforts to translocate defense behavior from wild Florida Sandhill Cranes, including transfer of pairs or sub-adults and or transfer of Mississippi fledglings hatched and reared under successful Florida pairs;
  - o Expand education outreach activities directed to refuge visitors and the local community;
  - o Initiate additional releases of cranes in suitable habitat at Grand Bay NWR, and potentially in Hancock County, Mississippi, and southwestern Louisiana, based on studies of the potential for reintroduction in other areas of the subspecies' historic range and identify specific release sites;
  - o Continue to improve captive-rearing to produce cranes that enable expansion of the subspecies genetic heterozygosity;
  - o Expand research on causes of low recruitment, micro-habitat use, chick food availability, ways of increasing nest defense behavior, possible causes of low survival rates in the population, including loss of genetic viability; and
  - o Publish habitat suitability model based on geographic information system data for the subspecies (see Research above).

Developing a Cuban Sandhill Crane Conservation Program

To protect and restore the highly endangered population of the Cuban Sandhill Crane and its habitats, a comprehensive conservation program needs to be developed and implemented. This program should include the following components:

- Disseminate and publish information on the ecology and threats to the population;
- Establish a monitoring program to provide accurate assessments of population trends. This could involve conducting regular surveys, at least every 3–5 years, for different breeding areas to determine changes. Monitoring may be particularly important in the small breeding areas that appear to be declining (Galvez-Aguilera and Chavez-Ramirez 2010);
- Research the potential implementation of habitat management and restoration options, such as the role of fire and water level manipulations;
- Explore opportunities for collaboration and training involving Cuban and non-Cuban field ecologists, ornithologists, and conservationists; and

- Develop an education program to communicate the importance, status, and conservation needs of the subspecies.

Anticipating and Responding to Crop Depredation

Crop depredation is difficult to predict because it is often caused by non-territorial cranes during summer (Barzen et al. 2018). Damage can be intermittent and limited to certain geographic areas, crop types, and times of the year. These characteristics offer opportunities to conduct research, to anticipate future occurrences of damage, and to prepare effective responses (Barzen and Ballinger 2018). To do so, programs should:

- Continue to develop crop damage solutions that can be implemented through the marketplace as an alternative to compensation programs;
- Determine timing and extent of crop depredation in regions where damage patterns are unclear;
- Use habitat management techniques (e.g., taste deterrents) to minimize potential damage (Barzen et al. 2018, Lacy et al. 2018);
- Develop extension and public education programs involving farmers (Barzen and Ballinger 2018); and
- Investigate new techniques for preventing damage that can be integrated into current agricultural systems in crops, such as with potatoes (Barzen and Ballinger 2018).

Understanding the Impact of Hunting

Hunting of Sandhill Cranes has been controversial in some regions, particularly when occurring on or near breeding grounds. Sandhill Cranes became extirpated from most of the historical breeding range of the putative Prairie Population in the northern plains (including Prairie Pothole Region) by 1900 and have failed to re-occupy most of this region despite suitable breeding habitat being widely available. Their absence likely is linked to overharvest resulting in an insufficient number of breeders surviving to re-occupy most of this region (Krapu and Brandt 2010, Krapu et al. 2011). Studies utilizing satellite telemetry have shown a remnant population of Greater Sandhill Cranes from the East-central Canada-Minnesota breeding affiliation are now located mostly along the northern edge of their historic breeding range. These birds congregate on fall staging areas in mid-August to early September that are often located near breeding areas. Primarily local birds gather several weeks before subarctic and arctic breeders arrive, coinciding with the early to mid-September opening of hunting seasons on Sandhill Cranes in the northern plains. An early arrival along with a later departure, as compared to more northern-nesting cranes results in the East-central Canada-Minnesota breeding affiliation being exposed to much higher levels of hunting activity than northern breeders (Krapu and Brandt 2010, Krapu et al. 2011). Greater Sandhill Cranes in the East-central Canada-Minnesota breeding affiliation, therefore, form a disproportionate part of the fall crane harvest in the northern plains (Kendal et al. 1997). The impact of the early hunting season is exacerbated in Saskatchewan where hunting regulations allow a five-bird daily limit in seasons from early September to December and crane hunting extending throughout the province. Based on current knowledge on levels of exposure of cranes in the East-central Canada-Minnesota breeding affiliation to hunting seasons in the northern plains, the associated disproportionate harvest, and the vast area of unoccupied former crane breeding habitat existing in the northern plains, the size of the East-central Canada-Minnesota breeding affiliation likely is far below historic levels, and the decline may be continuing.

Minnesota initiated a Sandhill Crane hunting season for the first time in 2010 and set an early September opening after concluding that a major part of the harvest would come from migrant cranes staging in the hunting zone (Lawrence et al. 2012). This decision did not take into account evidence from satellite telemetry studies suggesting that locally reared Greater Sandhill Cranes from the East-central Canada-Minnesota breeding affiliation would account for most of the crane harvest in Minnesota and that significant numbers of Minnesota-reared cranes are harvested in the states of Kansas, Oklahoma, and Texas (Krapu and Brandt 2010, Krapu et al. 2011). August roadside surveys conducted in the hunted area in northwestern Minnesota in 2011, the summer following the first hunt on this population, recorded 43% fewer cranes than in 2010 (Jeff Lawrence, personal comm. 2012).

The apparent disproportionate harvest of Greater Sandhill Cranes in Minnesota starting in 2010 did not take into account that Greater Sandhill Cranes breeding in northwestern Minnesota are a remnant of the original Prairie Population that has been displaced from much of its historical breeding range (see Krapu and Brandt 2010). Harvest may have been sufficient to significantly reduce numbers of local individuals of the Prairie Population in Minnesota although Sandhill Crane survey data gathered in Minnesota are inconclusive on this matter (Lawrence et al. 2012, 2016). For further discussion on movements, population ecology and harvest rates of the Prairie Population of Greater Sandhill Crane see Melvin and Temple (1983), Meine and Archibald (1996, p. 108), and Krapu and Brandt (2010). In 2012, the start of the Minnesota crane season was moved from early September to mid-September, and bag limit of cranes was reduced from two to one per day which has reduced annual harvest in the state (Jeff Lawrence, personal comm. 2012).

In Wisconsin, where crane hunting has been proposed and an estimated 66% of the Eastern Population of Greater Sandhill Cranes currently breed (Lacy et al. 2015), it will be important to understand the impacts of fall hunting and harvest on density and distribution of cranes that breed in the state. To provide a sound scientific basis for understanding impacts of hunting on crane populations (including the accidental taking of Whooping Cranes), for informing policy debates, and for making policy decisions, the following measures should be given high priority:

- Evaluate the impact of proposed harvest rates on the EP where hunting would occur in or adjacent to summer breeding areas;
- Evaluate origin of cranes being shot where hunting is occurring on or near crane breeding grounds; and
- Continue monitoring of the legal kill, crippling losses, and poaching in all hunt areas.

For the Mid-continent Population that is hunted across part of four nations (United States, Canada, Mexico, and Russia), the following steps are needed:

- Improve documentation of the annual mortality from sport and subsistence hunting in Mexico, and from subsistence hunting in Russia, Alaska, and Canada; and
- Improve communication among crane managers in Canada, the United States, Mexico, and Russia about the impacts of hunting on crane populations, as well as about hunting practices, regulations, and prohibitions;
- Develop and test hunting strategies that have the potential to lessen the harvest of Greater Sandhill Cranes breeding along the northern edge of the Northern Plains; and

- Expand research comparing effects of hunting on different populations, effect of timing of hunting seasons on harvest by age, subspecies, and subpopulation, and long-term effects of hunting disturbance on crane distribution.

Education and Training

Because Sandhill Cranes are well studied, conspicuous, widespread, and migrate over great distances, they present many opportunities for innovative education programs. Specific educational priorities include:

- Involve students and citizen scientists in crane counts and censuses (https://www.savingcranes.org/education/annual-midwest-crane-count/);
- Involve students and citizen scientists in long-term monitoring programs for non-migratory populations;
- Develop cooperative projects involving schools in Russia, Canada, U.S, and Mexico in the study of avian migration, using cranes as a model;
- Develop primary and secondary school curriculum materials that use Sandhill Cranes to communicate information about the biology, status, and conservation of the species, other crane species, and wetlands. These materials should include field studies that stress the role of cranes as wetland "umbrella" species (i.e., species whose conservation can provide protection for a wide range of species and ecosystem processes); and
- Use present knowledge of crane social behavior to communicate lessons about the role of animal behavior in conservation.

REFERENCES

Aborn D. 2010. Behavior and habitat use of Greater Sandhill Cranes wintering in east Tennessee. In: Hartup BK, editor. Proceedings of the 11th North American Crane Workshop, 23–27 September 2008, Wisconsin Dells, Wisconsin, USA. Laurel, Maryland, USA: North American Crane Working Group. p 23–27.

Ad Hoc Eastern Population Sandhill Crane Committee. 2010. Management plan for the Eastern Population of Sandhill Cranes. Minneapolis, Minnesota, USA: Atlantic and Mississippi Flyway Council Representatives, USFWS. 38 p.

Allen GT, Ramirez P. 1990. A review of bird deaths on barbed-wire fences. Wilson Bulletin 102(3):553–558.

Austin JE, Henry AR, Ball IJ. 2007. Sandhill Crane abundance and nesting ecology at Grays Lake, Idaho. Journal of Wildlife Management 71:1067–1079.

Barcelo I. 2012. Winter ecology of sandhill cranes (*Grus canadensis*) in northern Mexico. Dissertation. Lincoln, Nebraska, USA: University of Nebraska. 246 p.

Barzen J. 1997. A crane hunt for Wisconsin? The Bugle 23(4):3.

Barzen J. 2018. How do we improve conservation on privately owned lands? In: Austin JE, Morrison K, and Harris JT, editors. Cranes and Agriculture: A Global Guide for Sharing the Landscape. International Crane Foundation, Baraboo, Wisconsin, USA. p 142–156. Available at https://www.savingcranes.org/wp-content/uploads/2018/10/cranes_and_agriculture_web_2018.pdf (accessed 10 May 2019).

Barzen J, Ballinger K. 2017. Sandhill and Whooping Cranes. Wildlife Damage Management Technical Series. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center. Fort Collins, Colorado, USA: National Wildlife Research Center. 16 p.

Barzen J, Ballinger K. 2018. Effective and sustainable prevention of avian damage to planted seeds through seed treatment. In: Austin JE, Urbanek RP, editors. Proceedings of the 14th North American Crane Workshop, 12–13 January 2017, Chattanooga, Tennessee, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 89–100.

Barzen J, Gossens A. 2014. Beneath the surface of sandhill crane behavior. Passenger Pigeon 76(3):339–343.

Barzen JA, Gossens AP, Lacy AE. 2018. Sandhill Crane foraging behavior and damage estimates in cornfields during spring. Austin JE, Urbanek RP, editors. Proceedings of the 14th North American Crane Workshop, 12–13 January 2017, Chattanooga, Tennessee, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 67–80.

Barzen JA, Su L, Lacy A, Gossens A, Moore D. 2016. High nest density for Sandhill Cranes of central Wisconsin. In: Aborn DA, editor. Proceedings of the 13th North American Crane Workshop, 14–17 April 2014, Lafayette, Louisiana, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 13–24.

Beilfuss R. 2012. Lessons from the proposed crane hunt in Wisconsin. The Bugle 38(2):3.

Bennett AJ. 1988. Population size and distribution of Florida Sandhill Cranes in the Okefenokee Swamp, Georgia. Journal of Field Ornithology 60:60–67.

Bennett AJ, Bennett LA. 1989. Wintering population of Greater Sandhill Cranes in Okefenokee Swamp, Georgia. Wilson Bulletin 101(1):87–93.

Boggie MA, Carleton SA, Collins DP, Vradenburg J, Sroka CJ. 2018. Using stable isotopes to estimate reliance on agricultural food subsidies and migration timing for a migratory bird. Ecosphere 9(2):e02083.10.1002/ecs2.2083.

Brown WM, Drewien RC, Bizeau EG. 1987. Mortality of cranes and waterfowl from power line collisions in the San Luis Valley, Colorado. In: Lewis JC, editor. Proceedings of the 1985 crane workshop. Grand Island, Nebraska, USA: Platte River Whooping Crane Maintenance Trust. p 128–136.

Central Flyway Webless Migratory Game Bird Technical Committee. 2006. Management guidelines for the Mid-Continent Population of Sandhill Cranes. Denver, Colorado, USA: Central Flyway Representative U.S. Fish and Wildlife Service. 61 p.

Collins DP, Grisham BA, Conring CM, Knetter JM, Conway WC, Carleton SA, Boggie MA. 2015. New summer areas and mixing of two greater sandhill crane populations in the Intermountain West. Journal of Fish and Wildlife Management 7:141–152.

Currier PJ. 1991. Reclamation of crane roosting habitat on the Platte River and restoration of riverine wetlands. In: Harris JT, editor. Proceedings of the 1987 International Crane Workshop, Qiqihar, 1–10 May 1987, Heilongjiang Province, China. Baraboo, Wisconsin, USA: International Crane Foundation. p 403–407.

Currier PJ, Lingle GR, Van Derwalker J D. 1985. Migratory bird habitat on the Platte and North Platte rivers in Nebraska. Grand Island, Nebraska, USA: Platte River Whooping Crane Critical Habitat Maintenance Trust. 177 p.

Dickerson KL, Hayes MA. 2014. Evaluation of longevity and wear of colored plastic leg-bands on Sandhill Cranes in Wisconsin. North American Bird Bander 39:7–20.

Dietzman G, Swengel S. 1994. 20 years of counting cranes: what have we learned? The Bugle 20(1):2–3.

Drewien RC, Brown WM. 1996. Distribution and abundance of sandhill cranes in Mexico. Journal of Wildlife Management 60:270–285.

Drewien RC, Brown WM, Kendall WL. 1995. Recruitment in Rocky Mountain Greater Sandhill Cranes and comparison with other crane populations. Journal of Wildlife Management 59:339–356.

Dubovsky JA. 2018. Status and harvests of sandhill cranes: Midcontinent, Rocky Mountain, Lower Colorado Valley, and Eastern populations. Administrative Report. Lakewood, Colorado, USA: U.S. Fish and Wildlife Service. 44 p.

Faanes CA. 1990. Cuban Sandhills still declining. The Bugle 16(3):2.

Faanes CA. 1992. Factors influencing the future of Whooping Crane habitat on the Platte River in Nebraska. In: Wood DA, editor. Proceedings of the 1988 North American Crane Workshop, Kissimmee Prairie, Florida, 22–24 February 1988. Tallahassee, Florida, USA: State of Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report 12. p 101–109.

Ferrer Sanchez Y. 1979. Characterization and selection of the nesting site of the Cuban crane (*Grus canadensis nesiotes*) in the herds of the El Venero Fauna Refuge, Cuba. Master's thesis. La Habana, Cuba: University of La Habana.

Florida Fish and Wildlife Conservation Commission. 2013. A species action plan for the Florida Sandhill Crane *Grus canadensis pratensis*. Tallahassee, Florida, USA: Florida Fish and Wildlife Conservation Commission. 27 p.

Franson JC, Hereford SG. 1994. Lead poisoning in a Mississippi sandhill crane. Wilson Bulletin 106:766–768.

Fronczak DL, Andersen DE, Hanna EE, Cooper TR. 2015. Annual survival rate estimates of satellite transmitter-marked Eastern Population greater sandhill cranes. Journal of Fish and Wildlife Management 6:464–471.

Fronczak DL, Andersen DE, Hanna EE, Cooper TR. 2017. Distribution and migration chronology of Eastern Population of sandhill cranes. Journal of Wildlife Management 81:1021–1032.

Galvez X 2002. Distribution and abundance of *Grus canadensis* nest sites in Cuba. Habitat use and reproduction of a population of this species in the Los Indios Ecological Reserve, Isla de la Juventud. Doctoral Thesis in Biological Sciences. Havana, Cuba: University of Havana. 120 p.

Galvez-Aguilera X, Chavez-Ramirez F. 2010. Distribution, abundance, and status of Cuban Sandhill Cranes (*Grus canadensis nesiotes*). Wilson Journal of Ornithology 122:556–562.

Galvez-Aguilera X, Perera A. 1995. A crane conservation revival in Cuba. The Bugle 21(l):2–3.

Gee GF, Hereford SG. 1995. Mississippi Sandhill Crane. In: LaRoe ET, Farris GS, Puckett CE, Doran PD, Mac MJ, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, D.C., USA: U.S. Department of the Interior, National Biological Service.

Gerber BD, Dwyer JF, Nesbitt SA, Drewien RC, Littlefield CD, Tacha TC, Vohs PA. 2014. Sandhill Crane (*Antigone canadensis*), version 2.0. In: The Birds of North America (Poole, AF, editor). Ithaca, New York, USA: Cornell Lab of Ornithology. https://doi.org/10.2173/bna.31.

Glenn TC, Thompson JE, Ballard BM, Roberson JA, French JO. 2002. Mitochondrial DNA variation among wintering Midcontinent Gulf Coast Sandhill Cranes. Journal of Wildlife Management 66:339–348.

Graf WL, Barzen JA, Cuthbert F, Doremus H, Butler-Harrington LM, Herricks EE, Jacobs KL, Johnson WC, Lupi F, Murphy DD, Palmer RN, Peters EJ, Shen HW, Thompson JA. 2005. Endangered and threatened species of the Platte River. Washington, D.C., USA: Natural Resources Council of the National Academies, National Academy of Science. 299 p.

Hanna EE, Schummer ML, Petrie SA. 2014. Migratory chronology, autumn recruitment, and population size of Eastern Population Sandhill Cranes (*Grus canadensis*) from the North Shore Region of Lake Huron. Ontario, Canada: Long Point Waterfowl Observatory. Available at http://longpointwaterfowl.org/wp-content/uploads/2011/05/Hanna-et-al.-2014-Migratory-chronology-autumn-recruitment-and-population-size-of-Eastern-Population-Sandhill-Cranes2.pdf (accessed 19 June 2017).

Harner M, Wright GD, Geluso K. 2015. Overwintering sandhill cranes (*Grus canadensis*) in Nebraska, USA. Wilson Bulletin 127 (3):457–466.

Harris J, Barzen J. 1996. Cranes on the farm. The Bugle 22(3):1–3.

Harris J, Mirande C. 2013. A global overview of cranes: status, threats and conservation priorities. Chinese Birds 4:189–209.

Hayes MA. 2015. Dispersal and population genetic structure in two flyways of Sandhill Cranes (*Grus canadensis*). Dissertation. Madison, Wisconsin, USA: University of Wisconsin. 287 p.

Hayes MA, Barzen JA. 2006. Dynamics of breeding and non-breeding Sandhill Cranes in south central Wisconsin. Passenger Pigeon 68:345–352.

Hayes MA, Barzen JA. 2016a. Timing of family dissociation does not affect long-term survival estimates of Sandhill Crane chicks. In: Aborn DA, editor. Proceedings of the 13th North American Crane Workshop, 14–17 April 2014, Lafayette, Louisiana, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 33–41.

Hayes MA, Barzen JA. 2016b. Dispersal patterns and pairing behaviors of non-territorial Sandhill Crane. Passenger Pigeon 78:411–425.

Hayes MA, Britton HB, Barzen JA. 2006. Extra-pair fertilizations in Sandhill Cranes revealed using microsatellite DNA markers. Condor 108:970–976.

Hereford S. 2018. Mississippi Sandhill Crane update. Unison Call 28(2):16–17.

Horwich RH. 1989. Use of surrogate parental models and age periods in a successful release of hand-reared Sandhill Cranes. Zoo Biology 8:379–390.

Iverson GC, Vohs PA, Tacha TC. 1985. Habitat use by sandhill cranes wintering in western Texas. Journal of Wildlife Management 49:1074–1083.

Ivey GL. 2015. Comparative wintering ecology of two subspecies of Sandhill Crane: informing conservation planning in the Sacramento-San Joaquin River Delta region of California. Dissertation. Corvallis, Oregon, USA: Oregon State University.

Ivey GL, Dugger BE, Herziger CP, Casazza ML, Fleskes JP. 2014a. Characteristics of Sandhill Crane roosts in the Sacramento-San Joaquin Delta of California. In: Aborn DA, editor. Proceedings of the 12th North American Crane Workshop, 13–16 March 2011 Grand Island, Nebraska, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 12–19.

Ivey GL, Dugger BE, Herziger CP, Casazza ML, Fleskes JP. 2014b. Distribution, abundance, and migration timing of Greater and Lesser Sandhill Cranes wintering in the Sacramento-San Joaquin River Delta region of California. In: Aborn DA, editor. Proceedings of the 12th North American Crane Workshop, 13–16 March 2011 Grand Island, Nebraska, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 1–11.

Ivey GL, Dugger BE, Herziger CP, Casazza ML, Fleskes JP. 2015. Wintering ecology of sympatric subspecies of Sandhill Cranes: correlations between body size, site fidelity, and movement patterns. Condor 117:518–529.

Ivey GL, Herziger CP, Hardt DA. 2014c. Conservation priorities and best management practices for wintering Sandhill Cranes in the Central Valley of California. Prepared for The Nature Conservancy of California. Baraboo, Wisconsin, USA: International Crane Foundation. 56 p.

Ivey GL, Herziger CP, Hardt DA, Golet GH. 2016. Historic and recent winter Sandhill Crane distribution in California. In: Aborn DA, editor. Proceedings of the 13th North American Crane Workshop, 14–17 April 2014, Lafayette, Louisiana, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 54–66.

Ivey GL, Herziger CP, Hoffmann TJ. 2005. Annual movements of Pacific Coast Sandhill Cranes. In: Chavez-Ramirez F, editor. Proceedings of the 9th North American Crane Workshop, 21–25 January 2003, Sacramento, California, USA. Facultad de Zootecnia, Universidad Autonoma de Chihuahua, Chihuahua City, Mexico: North American Crane Working Group. p 25–35.

Johnsgard PA. 1983. Cranes of the world. Bloomington, Indiana, USA: Indiana University Press. 257 p.

Johnsgard PA. 1984. The Platte: channels in time. Lincoln, Nebraska, USA: University of Nebraska Press. 168 p.

Johnsgard PA. 1991. Crane music: a natural history of North American cranes. Washington, D.C., USA: Smithsonian Institution Press. 136 p.

Jones KL, Krapu GL, Brandt DL, Ashley MV. 2005. Population genetic structure in migratory Sandhill Cranes and the role of Pleistocene glaciations. Molecular Ecology 14:2645–2657.

Kendall WL, Johnson DH, Kohn SC. 1997. Subspecies composition of Sandhill Crane harvest in North Dakota, 1968–94. In: Urbanek RP, Stahlecker DW, editors. Proceedings of the 7th North American Crane Workshop, 10–13 January 1996, Biloxi, Mississippi, USA. Grand Island, Nebraska, USA North American Crane Working Group. p 201–208.

King SL, Pierce AR, Hersey KR, Winstead N. 2011. Migration patterns and movements of Sandhill Cranes wintering in central and southwestern Louisiana. In: Hartup BK, editor. Proceedings of the 11th North American Crane Workshop, 23–27 September 2008, Wisconsin Dells, Wisconsin, USA. Laurel, Maryland, USA: North American Crane Working Group. p 57–61.

Kinzel PJ, Nelson JM, Parker RS, Davis LR. 2006. Spring census of mid-continent sandhill cranes using aerial infrared videography. Journal of Wildlife Management 70:70–77.

Krajewski C, Fetzner JW. 1994. Phylogeny of cranes (Gruiformes: Gruidae) based on cytochrome-B DNA sequences. Auk 111(2):351–365.

Krapu GL, Brandt DA. 2010. Population status and geographic distribution of Greater Sandhill Cranes in the mid-continent population. In: Hartup BK, editor. Proceedings of the 11th North American Crane Workshop, 23–27 September 2008, Wisconsin Dells, Wisconsin, USA. Laurel, Maryland, USA: North American Crane Working Group. p 72–82.

Krapu GL, Brandt DA, Buhl DA. 2005. Evidence of a decline in fat storage by mid-continental Sandhill Cranes in Nebraska during spring: a preliminary assessment. In: Chavez-Ramirez F, editor. Proceedings of the 9th North American Crane Workshop, 21–25 January 2003, Sacramento, California, USA. Facultad de Zootecnia, Universidad Autonoma de Chihuahua, Chihuahua City, Mexico: North American Crane Working Group. p 179–184.

Krapu GL, Brandt DA, Cox RR Jr. 2004. Less waste corn, more land in soybeans, and the switch to genetically modified crops: trends with important implications to wildlife management. Wildlife Society Bulletin 32:127–136.

Krapu GL, Brandt DA, Jones KL, Johnson DH. 2011. Geographic distribution of the Mid-continent Population of Sandhill Cranes and related management applications. Wildlife Monographs 175. 38 p.

Krapu GL, Brandt DA, Kinzel PJ, Pearse AT. 2014. Spring migration ecology of the Mid-continent Sandhill Crane Population with an emphasis on use of the Central Platte River Valley, Nebraska. Wildlife Monographs 189. 41 p.

Krapu GL, Facey D, Fritzell EK, Johnson DH. 1984. Habitat use by migrant sandhill cranes in Nebraska. Journal of Wildlife Management 48:407–417.

Krapu GL, Iverson GC, Reinecke KJ, Boise CM. 1985. Fat deposition and usage by arctic-nesting Sandhill Cranes during spring. Auk 102:362–368.

Krapu GL, Reinecke KJ, Frith CR. 1982. Sandhill cranes and the Platte River. Transactions of the North American Wildlife and Natural Resources Conference 47:542–552.

Lacy AE, Barzen JA, Moore DM, Norris KE. 2015. Changes in the number and distribution of Greater Sandhill Cranes in the Eastern Population. Journal of Field Ornithology 86:317–325.

Lacy A, Barzen JA, Gossens AP. 2018. Testing three chemicals for deterring crop damage by cranes. In: Austin JE, Urbanek RP, editors. In: Proceedings of the 14th North American Crane Workshop, 12–13 January 2017, Chattanooga, Tennessee, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 81–88.

Lacy A, Cullen E, Barzen J, Schramm S. 2013. Protect your corn from cranes. University of Wisconsin Extension Bulletin A3897. Madison, Wisconsin, USA. 4 p.

Lawrence JS, Giudice JH, Knutsen JA, Wright RG. 2012. Estimating numbers of breeding Sandhill Cranes in northwest Minnesota – 2012. Unpublished report to Minnesota Department of Natural Resources, St. Paul, Minnesota, USA. p 138–155.

Lawrence JS, Giudice JH, Wright RG. 2016. 2016 Northwest Minnesota Sandhill Crane Breeding Ground Survey. Unpublished report to Minnesota Department of Natural Resources, St. Paul, Minnesota, USA. 19 p.

Leopold A. 1968. A Sand County almanac. New York, New York, USA: Oxford University Press. 226 p.

Lewis JC (Chairman). 1977. Sandhill Crane. In: Sanderson GC, editor. Management of migratory shore and upland game birds in North America. Washington, D.C., USA: International Association of Fish and Wildlife Agencies. p 4–43.

Lewis JC. 1979. Factors affecting the spring inventory of Sandhill Cranes. In: Lewis JC, editor. Proceedings of the 1978 Crane Workshop, Rockport, Texas, 6–8 December 1978. Fort Collins, Colorado, USA: Colorado State University Printing Service. p 33–39.

Littlefield CD, Ivey GL. 2002. Washington State recovery plan for the Sandhill Crane. Olympia, Washington, USA: Washington Department of Fish and Wildlife. 71p.

Logan TH, Klataske RD, Wicht RJ. 1976. Preliminary report on the National Audubon Society's management efforts in the Platte River valley of Nebraska. In: Lewis JC, editor. Proceedings of the International Crane Workshop, 3–6 September 1975. Stillwater, Oklahoma, USA: Oklahoma State University. p 144–150.

Marrero-Garcia D, Osorio JA, Galvez-Aguilera X. 2003. The Cuban Sandhill Crane as umbrella species: relationship with plant diversity in threatened white sand savannahs. M.S. in Sciences. Havana, Cuba: University of La Habana. 55 p.

McKinney L, Barzen J, Riddle J, Dubay S, Ginnett T. 2016. Differential detection of territorial and non-territorial Greater Sandhill Cranes in summer. In: Aborn DA, editor. Proceedings of the 13th North American Crane Workshop, 14–17 April 2014, Lafayette, Louisiana, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 25–32.

Meine CD, Archibald GW, compilers. 1996. The cranes: Status survey and conservation action plan. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources. 282 p.

Melvin SM, Drewien RC, Temple SA, Bizeau EG. 1983. Leg-band attachment of radio transmitters for large birds. Wildlife Society Bulletin 11:282–285.

Melvin SM, Temple SA. 1983. Fall migration and mortality of Interlake, Manitoba sandhill cranes in North Dakota. Journal of Wildlife Management 47:805–817.

Miller TP, Barzen JA. 2016. Habitat selection by breeding Sandhill Cranes in central Wisconsin. In: Aborn DA, editor. Proceedings of the 13th North American Crane Workshop, 14–17 April 2014, Lafayette, Louisiana, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 1–12.

Nesbitt SA, Carpenter JW. 1993. Survival and movements of greater sandhill cranes experimentally released in Florida. Journal of Wildlife Management 57:673–679.

Nesbitt SA, Hatchitt JL. 2008. Trends in habitat and population of Florida Sandhill Cranes In: Folk MJ, Nesbitt SA, editors. Proceedings of the 10th North American Crane Workshop, 7–10 February 2006, Zacatecas City, Zacatecas, Mexico. Leesburg Printing, Leesburg, Florida, USA: North American Crane Working Group. p 40–42.

Pacific Flyway Council. 1995. Pacific Flyway management plan for the Greater Sandhill Crane population wintering along the lower Colorado River Valley. Portland, Oregon, USA: Pacific Flyway Study Committee (c/o Pacific Flyway Representative, U.S. Fish and Wildlife Service). 34 p.

Pacific Flyway Council. 1997. Pacific Flyway management plan for the Central Valley Population of Greater Sandhill Cranes. Portland, Oregon, USA: Pacific Flyway Study Committee (c/o Pacific Flyway Representative, U.S. Fish and Wildlife Service). 46 p.

Pearse AT, Krapu GL, Brandt DA. 2017. Sandhill Crane roost-site selection, human disturbance, and forage resources. Journal of Wildlife Management 81:477–486.

Pearse AT, Krapu GL, Brandt DA, Kinzel PJ. 2010. Changes in agriculture and abundance of snow geese affect spring carrying capacity of sandhill cranes in Nebraska. Journal of Wildlife Management 74:479–488.

Petersen JL, Bischof R, Krapu GL, Szalanski AL. 2003. Genetic variation in the Mid-continental Population of Sandhill Cranes *Grus canadensis*. Biochemical Genetics 41:1–12.

Petrula MJ, Rothe TC. 2005. Migration chronology, routes, and distribution of Pacific Flyway Population Lesser Sandhill Cranes. In: Chavez-Ramirez F, editor. Proceedings of the 9th North American Crane Workshop, 21–25 January 2003, Sacramento, California, USA. Facultad de Zootecnia, Universidad Autonoma de Chihuahua, Chihuahua City, Mexico: North American Crane Working Group. p 53–67.

Platte River Recovery Implementation Program. 2017. Available at www.platteriverprogram.org (accessed 3 July 2017).

Rhymer JM, Fain MG, Austin JE, Johnson DH, Krajewski C. 2001. Mitochondrial phylogeography, subspecific taxonomy, and conservation genetics of Sandhill Cranes (*Grus canadensis*; Aves; Gruidae). Conservation Genetics 2:203–218.

Seal US, Hereford SG. 1992. Mississippi Sandhill Crane (*Grus canadensis pulla*): population and habitat viability assessment workshop report. Apple Valley, Minnesota, USA: IUCN/SSC Captive Breeding Specialist Group. 146 p.

Sharp DE, Vogel WO. 1992. Population status, hunting regulations, hunting activity, and harvests of mid-continent Sandhill Cranes. In: Stahlecker DW, Urbanek RP, editors. Proceedings of the 6th North American Crane Workshop, 3–5 October 1991, Regina, Saskatchewan, Canada. Grand Island, Nebraska, USA: North American Crane Working Group. p 24–32.

Shaskey, LE. 2012. Local and landscape influences on Sandhill Crane habitat suitability in the northern Sacramento Valley, CA. M.S Thesis. Rohnert Park, California, USA: Sonoma State University.

Skasa C, Barzen J. 2010. A Crane Hunt? The Bugle 36(3):7.

Smirenski S, Barzen J. 2019. Threat: *Impacts of fire on cranes*. In: Mirande CM, Harris JT, editors. Crane Conservation Strategy. Baraboo, Wisconsin, USA: International Crane Foundation. p …

Smith PJ, Valentine JM Jr. 1987. Habitat changes within the Mississippi Sandhill Crane range in Jackson County, Mississippi (1942–1984). In: Lewis JC, editor. Proceedings of the 1985 North American Crane Workshop. Grand Island, Nebraska, USA: Platte River Whooping Crane Maintenance Trust. p 341–354.

Strom KJ. 1987. Lillian Annette Rowe Sanctuary– managing migratory crane habitat on the Platte River, Nebraska. In: Lewis JC, editor. Proceedings of the 1985 crane workshop. Grand Island, Nebraska, USA: Platte River Whooping Crane Maintenance Trust. p 326–330.

Strom KJ. 1993. Sharing the Earth: Audubon's work on the Platte, Indus, and Amur Rivers. In: Harris J, editor. Proceedings of the Second Annual International Crane Symposium. Boulder, Colorado, USA: National Audubon Society. p 15–18.

Su L. 2003. Habitat selection by Sandhill Cranes, *Grus canadensis tabida*, at multiple geographic scales in Wisconsin. Dissertation. Madison, Wisconsin, USA: University of Wisconsin.

Subcommittee on Rocky Mountain Greater Sandhill Cranes. 2007. Management plan of the Pacific and Central Flyways for the Rocky Mountain population of Greater Sandhill Cranes. Portland, Oregon, USA: [Joint] Subcommittees, Rocky Mountain Population Greater Sandhill Cranes, Pacific Flyway Study Committee, Central Flyway Webless Migratory Game Bird Technical Committee. 97 p.

Subcommittee on the Pacific Flyway Population of Lesser Sandhill Cranes. 1983. Pacific Flyway Management Plan: Pacific Flyway Population of Lesser Sandhill Cranes. Portland, Oregon, USA: Pacific Flyway Study Committee. 22 p.

Tacha TC, Nesbitt SA, Vohs PA. 1992. Sandhill Crane. In: Poole A, Stettenheim P, Gill F, editors. The Birds of North America, No. 31. Washington, D.C., USA: Academy of Natural Science, Philadelphia and American Ornithologists Union. 24 p.

Tacha TC, Nesbitt SA, Vohs PA. 1994. Sandhill Crane. In: Tacha TC, Braun CE, editors. Migratory shore and upland game bird management in North America. Washington, D.C., USA: International Association of Fish and Wildlife Agencies. p 77–94.

Tacha TC, Vohs PA, Warde WD. 1985. Morphometric variation of sandhill cranes from Mid-Continental North America. Journal of Wildlife Management 49:246–250.

Taylor JP, Smith LM. 2005. Migratory bird use of belowground foods in moist-soil managed wetlands in the Middle Rio Grande Valley, New Mexico. Wildlife Society Bulletin 33:574–582

Thompson HL, Lacy AE. 2016. Winter and migratory habitat use of six Eastern Greater Sandhill Cranes. In: Aborn DA, editor. Proceedings of the 13th North American Crane Workshop, 14–17 April 2014, Lafayette, Louisiana, USA. Omnipress, Madison, Wisconsin, USA: North American Crane Working Group. p 47–53.

Urbanek RP. 1994. Great Lakes regional report. 1993 Fall Sandhill Crane Census. The Unison Call 6(2):3.

U.S. Fish and Wildlife Service [USFWS]. 1981. The Platte River Ecology Study. Jamestown, North Dakota, USA: U.S. Fish and Wildlife Service Research Report. Available at http://digitalcommons.unl.edu/usgsnpwrc/248/ (accessed 7 June 2017).

U.S. Fish and Wildlife Service. 1991. Mississippi Sandhill Crane Recovery Plan. Atlanta, Georgia, USA: U.S. Fish and Wildlife Service. 42 p.

U.S. Fish and Wildlife Service. 2007. Mississippi Sandhill Crane National Wildlife Refuge Comprehensive Conservation Plan. Atlanta, Georgia, USA: U.S. Fish and Wildlife Service. 151 p.

U.S. Fish and Wildlife Service. 2008. Grand Bay National Wildlife Refuge Comprehensive Conservation Plan. Atlanta, Georgia, USA: U.S. Fish and Wildlife Service. 156 p.

U.S. Fish and Wildlife Service. 2011. Columbia National Wildlife Refuge Comprehensive Conservation Plan. Portland, Oregon, USA: U.S. Fish and Wildlife Service. 389 p.

U.S. Fish and Wildlife Service. 2013. Malheur National Wildlife Refuge Comprehensive Conservation Plan. Portland, Oregon, USA: U.S. Fish and Wildlife Service. 779 p.

U.S. Fish and Wildlife Service. 2014a. Conboy Lake National Wildlife Refuge Comprehensive Conservation Plan. Portland, Oregon, USA: U.S. Fish and Wildlife Service. Available at https://www.fws.gov/uploadedFiles/Region_1/NWRS/Zone_2/Mid-Columbia_River_Complex/Conboy_Lake/Documents/conboy-lake-final-ccp.pdf (accessed 23 July 2018).

U.S. Fish and Wildlife Service. 2014b. San Luis Valley National Wildlife Refuge Complex Comprehensive Conservation Plan. Denver, Colorado, USA: U.S. Fish and Wildlife Service. 3 p. Available at https://www.gpo.gov/fdsys/pkg/FR-2014-08-26/pdf/2014-20236.pdf (accessed 19 June 2017).

Valentine JM, Noble AE. 1970. A colony of sandhill cranes in Mississippi. Journal of Wildlife Management 34:761–768.

Van Derwalker JG. 1987. Preservation of crane habitat on the Platte River, Nebraska. In: Archibald G, Pasquier RF, editors. Proceedings of the 1983 International Crane Workshop, Bharatpur, India, February 1983. Baraboo, Wisconsin, USA: International Crane Foundation. p 425–437.

Walkinshaw LH. 1949. The Sandhill Cranes. Cranbrook Institute of Science Bulletin 29:1–202.

Walkinshaw LH.1973. Cranes of the world. New York, New York, USA: Winchester Press. 370 p.

Ward JP, Anderson SH. 1992. Sandhill Crane collisions with power lines in southcentral Nebraska. In: Wood DA, editor. Proceedings of the 1988 North American Crane Workshop, Kissimmee Prairie, Florida, 22–24 February 1988. Tallahassee, Florida, USA: Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report 12. p 189–195.

Wheeler ME, Barzen JA, Crimmins S, Van Deelen TR. 2019. Effects of territorial status and life history on Sandhill Crane population dynamics in south central Wisconsin. Canadian Journal of Zoology 97:112–120.

Windingstad RM. 1988. Non-hunting mortality in sandhill cranes. Journal of Wildlife Management 52:260–263.

Wolfson D, Fieberg J, Lawrence J, Cooper T, Anderson DE. 2017. Range overlap between Mid-Continent and Eastern Sandhill Cranes revealed by GPS-tracking. Wildlife Society Bulletin 41:489–498.

Wright GD, Smith TJ, Murphy RK, Runge JT, Harms RR. 2010. Mortality of cranes (Gruidae) associated with power lines over a major roost on the Platte River, Nebraska. Prairie Naturalist 41:116–120.