Mississippi Sandhill Crane
(*Grus canadensis pulla*)

5-Year Review:
Summary and Evaluation

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5-YEAR REVIEW
Mississippi Sandhill Crane / *Grus canadensis pulla*

I. GENERAL INFORMATION

A. Methodology used to complete the review:

In conducting this 5-year review, we relied on the best available information pertaining to historic and current distributions, life histories, threats to, and habitats of this species. We announced initiation of this review and requested information in a published *Federal Register* notice on April 9, 2010 (75 FR 18233). We reviewed information in our files and solicited information from all knowledgeable individuals including those associated with academia and State conservation programs. Our sources include the final rule listing this species under the Endangered Species Act; the Recovery Plan; peer reviewed scientific publications; unpublished field observations by the U.S. Fish and Wildlife Service (Service), State, and other experienced biologists; unpublished survey reports; and notes and communications from other qualified biologists or experts. The completed draft was forwarded to five peer reviewers for their review. Their comments were reviewed and incorporated into this final document as appropriate (see Appendix A).

B. Reviewers

Lead Region: Southeast Region: Kelly Bibb, 404-679-7132

Lead Field Office: Mississippi Ecological Services Field Office: Linda LaClaire, 601-321-1126

C. Background

1. **Federal Register Notice citation announcing initiation of this review:** April 9, 2010 (75 FR 18233)

2. **Species status:** Stable. Estimates of the only known crane population that occurs on and near the Mississippi Sandhill Crane National Wildlife Refuge (Refuge) are generated annually from monitoring results. The current (March 2019) population estimate on the Refuge was 129 cranes (Hereford and Dedrickson 2019a). The number of chicks fledging on the Refuge has improved somewhat in recent years; however it is the consistent release of captive-bred and reared crane chicks that has provided population stability. An analysis of threats indicates several new post-listing threats have been identified and that the threats present at the time of listing are still present.

3. **Recovery achieved**: 2 (2 = 26-50% recovery objectives achieved)
Long-term protection has been achieved for the primary habitat occupied by the Mississippi sandhill crane. However, the crane population is not self-

sustaining and its stability relies on reintroduction of captive-reared juveniles onto the Refuge.

4. **Listing history**
   Original Listing
   FR notice: 38 FR 14678
   Date listed: June 4, 1973
   Entity listed: Subspecies
   Classification: Endangered

   Critical Habitat
   FR notice: 42 FR 39985
   Date: August 8, 1977

5. **Review History**:
   Recovery Plan: 1991

   Each year, the Service reviews and updates listed species information to benefit the required Recovery Report to Congress. Through 2013, we performed a recovery data call that included status recommendations, such as "Stable" for the crane. We continue to show this species' status recommendation in 5-year reviews. The most recent evaluation for this species was completed in 2018.

   Five Year Review: November 6, 1991. (56 FR 56882)
   In this review, multiple species were simultaneously evaluated with no species-specific, in-depth assessment of the five factors as they pertained to the different species' recovery. In particular, no changes were proposed for the status of the Mississippi sandhill crane in the review.

6. **Species' Recovery Priority Number at start of review (48 FR 43098)**: 6C
   Degree of Threat: High
   Recovery Potential: Low
   Taxonomy: Subspecies
   The "C" indicates a species that is, or may be, in conflict with construction or other development projects or other forms of economic activity.

7. **Recovery Plan**
   Name of plan: Mississippi Sandhill Crane Recovery Plan
   Date issued: September 6, 1991

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy

1. **Is the species under review listed as a DPS?** No

2. **Is there relevant new information that would lead you to re-consider the classification of this species with regard to designation of DPSs?** There is unpublished data that indicate the currently named subspecies of North American sandhill cranes may be overrepresented (or too many subspecies named when there should be fewer subspecies identified). However, there has been no peer-reviewed publication renaming or reassessing the subspecies to warrant a change in the status of the Mississippi sandhill crane at this time. The International Crane Foundation, the North American Crane Working Group, and the International Union for Conservation of Nature (IUCN) all still consider the Mississippi sandhill crane as a separate subspecies (S. Hereford, pers. comm., 2019).

B. Recovery Criteria

1. **Does the species have a final, approved recovery plan containing objective, measurable criteria?** Yes.

2. **Adequacy of recovery criteria.**

   a. **Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?** Yes.

   b. **Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria?** Yes. The 5 listing factors address issues related to achieving a self-sustaining population, without the need for captive-raised chicks, and protecting sufficient habitat to support it. New threats have come to light since listing and have been incorporated into the 5 factors (see C.2. Five-Factor Analysis).

3. **List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information.**

   The recovery objective in the recovery plan is to maintain a genetically viable, stable, self-sustaining, free-living Mississippi sandhill crane population. The criteria for attaining the objective are:

   Criterion (1): Cessation of the need for captive-raised cranes.

   Status: Criterion is not met. Currently, the number of fledged chicks are not sufficient to maintain the Mississippi sandhill crane population at our recovery population goal of 130 to 150 birds. This population number is based on an assessment (PHVA) derived from the Mississippi Sandhill Crane Population and Habitat Viability Assessment Workshop (IUCN/SSC Captive Breeding Specialist Group (CBSG) 1992) identified as a task in the Mississippi Sandhill

Crane Recovery Plan (U.S. Fish and Wildlife Service (1991) and conducted in 1992. A Memorandum of Understanding is in place with the Audubon Nature Institute, New Orleans, Louisiana, and White Oak Conservation Holdings LLC, Yulee, Florida, which facilitates annual captive breeding at these facilities and subsequent release of crane juveniles onto the Refuge. The addition of these juveniles to the Refuge population has allowed it to achieve stability. For example, during the 13 years from 2000 through 2012, an annual average of only two wild-reared juveniles resulted from natural nesting on the refuge. However, the success rate of natural nests is improving. During the last 6 years from 2013 through 2018, the number of wild chicks fledged at the Refuge has been on an increasing trend from the past, likely due to combination of habitat improvements, focused predator removal, and increasing experience of breeding pairs. This increase in recruitment moves recovery towards the goal of achieving population stability without the need for captive-raised crane juveniles.

Criterion (2): Attaining a free-living, stable, and self-sustaining standing population which demonstrates stability and self-sustenance for at least 10 continuous years.

Status: Criterion is not met. As discussed under Criterion 1, the Mississippi sandhill crane population at the Refuge is not yet self-sustaining and captive-raised juveniles are needed to sustain the population. However, over the past 6 years, the number of chicks fledged has improved to almost 6 juveniles annually and the average population size of 127 adult cranes is close to our recovery goal of 130 to 170 birds. Adult mortality rates over this period have averaged 8.1 percent, which is approaching a goal of the 7.7 percent adult mortality rate needed to support a stable population if an annual fledging rate of 10 to 15 juveniles is achieved. However, both the recovery plan and the PHVA indicated that to ensure survival and recovery, Mississippi sandhill cranes should be established at a second site in the lower Gulf Coastal Plain (U.S. Fish and Wildlife Service 1991, CBSG 1992). Appropriate habitat for the crane has virtually disappeared, but progress on habitat restoration at the nearby Grand Bay National Wildlife Refuge (Grand Bay) may soon result in an area suitable for establishing a small number of breeding pairs (**see Criterion 3**).

Criterion (3): Providing the habitat required to support the crane population.

Status: Criterion has been partially met. The Mississippi Sandhill Crane National Wildlife Refuge was established in 1975 to protect habitat for the non-migratory Mississippi sandhill cranes. On-going habitat management through prescribed burning and other techniques has significantly restored longleaf wet pine savanna habitat and increased the number of available nesting territories on the Refuge. Foraging habitat is still a limiting factor; however, efforts are being made to manage food plots on the Refuge, subject

to available funding, and to work towards habitat conservation off-Refuge through use of permanent conservation easements to protect grasslands. Managing nearby Grand Bay for reestablishment of cranes at the site is included as a task under the recovery plan (U.S. Fish and Wildlife Service 1991). Funding has been obtained for habitat management and the expectation is that within 5 years, habitat restoration on Grand Bay will provide several thousand acres (ac) (several thousand hectares (ha)) of additional longleaf pine savanna for five to seven Mississippi sandhill crane nesting pairs beyond what can be supported by the Refuge (U.S. Fish and Wildlife Service 2008). As restoration efforts for Grand Bay are completed, planning will begin to identify specific sites for future releases of captive-bred juveniles and establishment of Mississippi sandhill cranes. Sandhill cranes bred historically in southern Louisiana. In 1964, and prior to the listing of the crane under the Endangered Species Act (Act), plans were made to reintroduce the species at Sabine National Wildlife Refuge in Louisiana (U.S. Fish and Wildlife Service 1991). However, when the Mississippi sandhill crane was listed as an endangered species, these plans were postponed and all reintroduction efforts to date have been directed towards increasing the population on the Refuge. Currently, the 1964 plans have not been resurrected and a site to reestablish cranes in Louisiana has not been identified. Efforts to do so may begin in the near term as improvements in natural recruitment on the Refuge have reduced the number of captive-bred juveniles needed to maintain the Refuge population and cranes excess to this effort could be made available for release at other locations.

C. Updated Information and Current Species Status

1. Biology and Habitat

a. New information on the species' biology and life history:

Mississippi sandhill cranes are long-lived species that are monogamous in a breeding season, have low annual reproductive potential, and provide extended parent care. The Mississippi Sandhill Crane Recovery Plan (U.S. Fish and Wildlife Service 1991) provided an extensive summary of information on the crane's biology and life history. Since that time, a significant amount of data on the species has been gathered and a more complete understanding of the cranes' biology and life history has been attained. The Mississippi sandhill crane breeding season begins in late February and extends through mid-June (Hereford and Dedrickson 2019b). A few nests have been reported as late as July and one has been found in August (Hereford and Billodeaux 2010). Mean clutch size is 1.8 eggs, but many females double clutch. Egg incubation extends to approximately 30 days. Within 24 hours of hatching, chicks are capable of walking, wading, and swimming. The time to fledgling (attaining flight) averages approximately 75 days (Walkinshaw 1981, Hereford 1994). The fledged chicks stay with their parents and begin learning how

to search for food. The family group stays together until the next breeding season (Walkinshaw 1981); around 290 days post-hatching the family disperses from the nest area (Valentine 1992). In the captive flock, both males and females have bred at 2 years of age; the oldest age of reproduction is 32 years old for males and 30 years of age for females (Lewis 2018). In the wild, age at first reproduction is approximately 5 years for both males and females (S. Hereford pers. comm. 2019).

Sandhill cranes eat many types of food including bulbs, roots, grass seeds, berries, earthworms, insects such as grasshoppers and crickets, snails, crayfish, mice, even eggs and small birds (Walkinshaw 1981). Mississippi sandhill cranes frequently feed off-Refuge in privately-owned pasture areas and also on areas of the Refuge where agricultural crops are planted for them. A study of Mississippi sandhill crane food preferences has not been conducted, however they are assumed to be omnivorous, opportunistic feeders similar to other sandhill cranes. A graduate student at the University of New Orleans is currently conducting a study to look at food availability within nesting territories to determine if this could be a factor limiting Mississippi sandhill crane recruitment.

Males and females are similar in appearance and difficult to tell apart in the field, although males are slightly larger than females. When part of a pair, the sexes can be told apart behaviorally as they perform their unison call differently; for every note of the male, the female makes two notes. The male tends to hold his head in a more vertical position and pitch his voice a bit lower than the female (S. Hereford pers. comm. 2019).

There are no observable differences in behavior between successful and unsuccessful nests or between captive- or wild-bred birds (J. Howard, pers. comm., 2014). However, there is a trend of parents of unsuccessful nests spending a longer time away from their nest than those parents with successful nests. Butler (2009) used motion-activated cameras to document nest defense and documented heavy daily predation pressure on nests. Some limited defense behaviors by adults at the nest were observed, but these behaviors were frequently unsuccessful against raccoons (*Procyon lotor*) and coyotes (*Canis latrans*) (Butler 2009). Similar poor nest defense by introduced whooping cranes has been documented in Florida in a comparative study with Florida sandhill cranes (Folk 2011). Worldwide, low recruitment is a problem in reintroduced crane populations, possibly as a result of captive-rearing techniques (See discussion in parent vs hand-rearing, below). Nest defense is likely a learned behavior. Due to the historically low number of wild pairs and large influx of young captive-bred birds, adult parent models have been rare. The recent improvement in number of fledged chicks may indicate that birds are learning better parenting skills, possibly after several years of nesting experience. In addition, having a wild-bred parent increases the

potential for chick survival. Of the 31 Mississippi sandhill crane nests that fledged chicks from 2013 through 2018, 77 percent had a least one wild-hatched parent (S. Hereford, pers. comm., 2019).

The oldest marked crane currently alive in the wild is 30 years old (Hereford and Dedrickson 2019a). The record for longevity in the captive flock is 40 years; two captive cranes reached 33 years of age in 2018 (Lewis 2018). The median life expectancy of both wild and captive cranes is 14.4 years with 25 percent of the birds reaching 22.8 years of age (Lewis 2018). Mississippi sandhill cranes can be successful breeders into their third decade. In the captive flock, the oldest male to have a first chick was 22 years old and the oldest female to have a first chick was 23 (Lewis 2018).

b. Abundance, population trends, demographic features, or demographic trends:

Historically, non-migratory sandhill cranes formed a continuous population in Georgia and Florida with widely separated populations along the Gulf Coastal Plain of Texas, Louisiana, Mississippi, and Alabama (Gee and Hereford 1995). In the late 1800's, they were so abundant in the prairies of southern Louisiana that they were considered pests; however the construction of the Southern Pacific Railroad across the state in 1881 resulted in expansion of human development with subsequent reduction in wildlife populations and the disappearance of many species including the sandhill crane (McIlhenny 1938). European settlement of the southeastern United States resulted in a steady decline of the resident sandhill cranes throughout the area (Meine and Archibald 1996). Specific details concerning the original Gulf Coastal Plain sandhill crane populations are very limited and all of these populations have been extirpated except for the cranes in Mississippi (see discussion below). Therefore, the genetic relationships among the Gulf Coastal Plain populations cannot be studied, however it can be assumed that historically there was gene flow between them (Johnsgard 1983, Meine and Archibald 1996).

Leopold (1929) described a non-migratory sandhill crane colony in Jackson County, Mississippi, that he estimated to be at least 50 birds, and possibly as many as 100 or more. McIlhenny (1938) presented the first published information on the Mississippi sandhill cranes and described their nests in detail. Mississippi sandhill cranes may represent the western remnant of a formerly more extensive non-migratory population that ranged from Texas to Cuba (Meine and Archibald 1996). By the late 1960s, the wild Mississippi sandhill population numbered less than 40 birds (Valentine and Noble 1970). The last records in coastal Texas for nesting sandhill cranes were from 1900 (cited in Meine and Archibald 1996), 1911 in Alabama (cited in Imhof 1962), and 1919 in southern

Louisiana (Figgins 1923). In Mississippi, a low of 30 wild birds was documented in 1981 (Valentine 1981). The Mississippi population likely survived due to its relative isolation and occupation of an area with poor soils unsuited to agriculture (Valentine and Noble 1970). Bailey (1994) surveyed areas of southwest Alabama in Baldwin and Mobile Counties and documented that the habitat of the known historical occurrences was no longer suitable. After completing surveys to locate suitable habitat and conducting interviews with knowledgeable local naturalists and birders, Bailey (1994) concluded that the Mississippi sandhill crane no longer occurs in Alabama.

Captive-reared juvenile Mississippi sandhill cranes have been released at the Refuge since 1981 (Zwank and Wilson 1987). Beginning in 1965, one egg from a few of the two-egg Mississippi sandhill crane clutches was removed from the wild to form a captive breeding flock (Valentine and Logan 1991). The Patuxent Wildlife Research Center (PWRC) in Laurel, Maryland, was the primary facility conducting the breeding program until 1995. Research was conducted at PWRC on improving captive-breeding techniques to benefit survival in the wild and developing appropriate captive-breeding protocols. Crane chicks were raised at PWRC to further development of the captive flock there, and released as socialized groups (cohorts) on the Refuge. Juvenile cranes at PWRC were placed in communal pens and formed cohorts before release; cranes released without the communal pen experience did not flock and had lower survival post-release (Zwank and Dewhurst 1992). Release pens on the Refuge were placed within the territory of older established birds that could provide guidance on living in the wild to the young captive-bred birds. Generally, the newly-released cranes would join with established birds that would lead them to appropriate forging and roosting habitats on the Refuge.

In 1992, responsibility for the Mississippi sandhill crane captive flock was transferred to U.S. Fish and Wildlife Service, Southeast Region. The majority of the Mississippi sandhill captive flock was transferred from PWRC to two non-governmental facilities, White Oak Conservation Center (WOCC) (1994) and Audubon Nature Institute's Species Survival Center (ASSC) (1996). These two facilities have continued to build on the experience and research developed at PWRC to improve survival and fitness of the captive-bred cranes released at the Refuge. A studbook keeper maintains the demographic data for the two captive flocks and the available data for wild cranes (Lewis 2018). Willoughby e*t al.* (2015) found that when selecting individuals in captive populations for mating, using mean kinship values provides a tool to protect against loss of genetic diversity. Lewis (2018) has analyzed the Mississippi sandhill crane genetic data and drafts annual plans for breeding pairs based on less than a 0.016 inbreeding coefficient in efforts to maximize genetic diversity in the

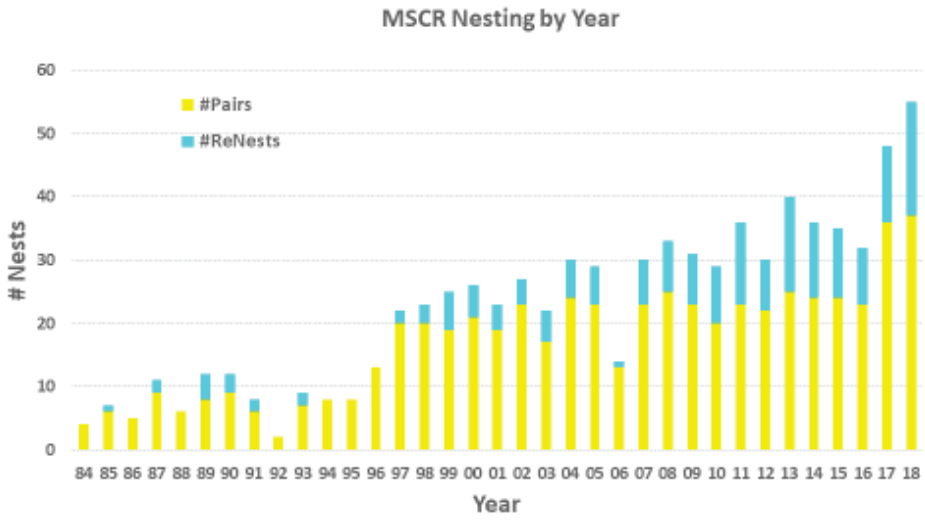
population. There is a direct correlation between fitness and genetic diversity (Reed and Frankham 2003). Based on the known mean kinship rates within the crane population, it is believed that inbreeding is not currently an issue for the Mississippi sandhill crane population (A. Lewis, ASSC, pers. comm., 2019). Eggs from wild cranes deemed to be genetically important, and not represented in the captive flocks, are collected when possible and transferred to one of the captive facilities to maintain genetic diversity. Monitoring of Mississippi sandhill crane population genetics continues to be a priority of the recovery program. Currently, 32 Mississippi sandhill cranes are housed at ASSC and 15 are housed at WOCC (A. Lewis, pers. comm., 2019). As of April 2019, 536 captive-bred juvenile Mississippi sandhill cranes have been released on the Refuge over a period of 39 years (Hereford and Dedrickson 2019b).

The Mississippi Sandhill Crane Population and Habitat Viability Assessment Workshop, a task identified in the Mississippi Sandhill Crane Recovery Plan (1991), was conducted in September of 1992. During the assessment, predation was identified as the number one factor limiting Mississippi sandhill crane population recovery due to low levels of recruitment to the population at the Refuge (CBSG 1992). In the years 1979 through 1992, mean fledged young was less than one, essentially no natural recruitment (CBSG 1992). It became clear that recruitment problems were most likely due to external, non-physiological factors intervening between egg laying and fledging of chicks during the last one-third of the incubation period, rather than genetic issues. An overview of historic rates of egg fertility (79 percent) and hatchability (83 percent) of eggs taken from the Refuge to Patuxent revealed that they fell within the normal limits for reproduction in other sandhill crane populations (CBSG 1992). An analysis of historic demographic data indicated that an egg had a greater chance of surviving to become a juvenile if it was sent to PWRC and raised there instead of remaining at the Refuge (CBSG 1992). In results presented in the PHVA, nest failure, egg loss during incubation, and chick loss before fledging were the key elements in crane recruitment failure due to predation (CBSG 1992). The PVHA model also stressed the need to reduce mortality in the first year post-fledging to increase the growth rate (CBSG 1992). Recent research on crane mortality indicates that over 85 percent of known causes of chick mortality are from predation and that predation remains the number one cause of chick mortality today (Hereford and Dedrickson 2017). The PHVA estimate of annual adult mortality in the wild Mississippi sandhill crane population was 8.7 percent (CBSG 1992). Results from the PHVA models indicated that with habitat enhancement and predator control used to improve hatchling production to 50 percent, reduce juvenile (from hatching to fledging) mortality to 20 percent, and reduce adult mortality to a rate of 7.7 percent, recovery was possible (CBSG 1992). The conclusion of the PHVA was that a goal of a self-sustaining recovery population of 130 to 170 individuals could be

achieved if there were 30-35 nesting pairs that fledged 10 to 15 young annually for at least 10 years (CBSG 1992).

Figure 1. Crane Nesting Results

1984 through 2018



Over the years of captive-breeding and releasing Mississippi sandhill crane chicks on the Refuge, the focus has gradually changed from quantity to quality. Quantity of release chicks was important initially to build the Mississippi sandhill crane population. Quality of chicks, based on the genetic diversity they provide to the population, is achieved through pairings of adults with the lowest mean kinship rates. The crane population became skewed towards younger age classes during the 1990s as costume-rearing (using puppets and humans costumed as adult cranes to raise chicks to fledging) was used to annually raise as many juvenile birds as possible to rapidly expand the population on the Refuge. Now that the wild population on the Refuge is close to the carrying capacity estimated in the PHVA, the number of captive-bred chicks released on the Refuge has been reduced and the age classes within the wild Mississippi sandhill crane population are becoming more normally distributed. Because fewer chicks are needed, this has allowed a shift towards more parent-rearing (adult cranes raise chicks to fledging) of chicks at captive-breeding facilities which may improve the ability of chicks to learn predator defense behavior and other beneficial behaviors from their parents (see discussion under **C. 2. c. Disease or Predation**).

Figure 2. Mississippi sandhill crane population age class and sex distribution.

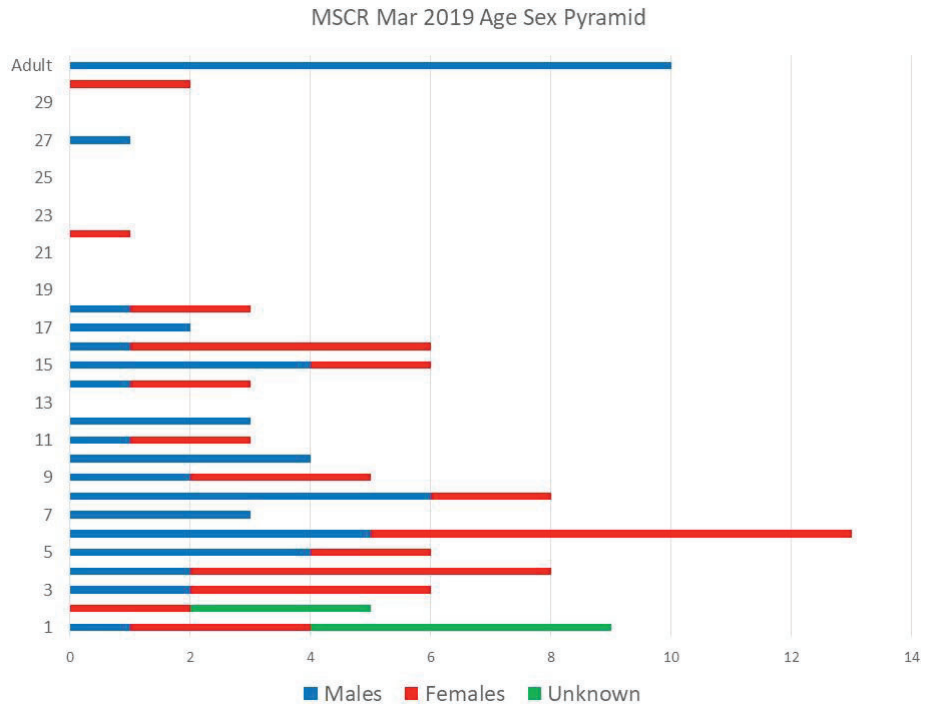
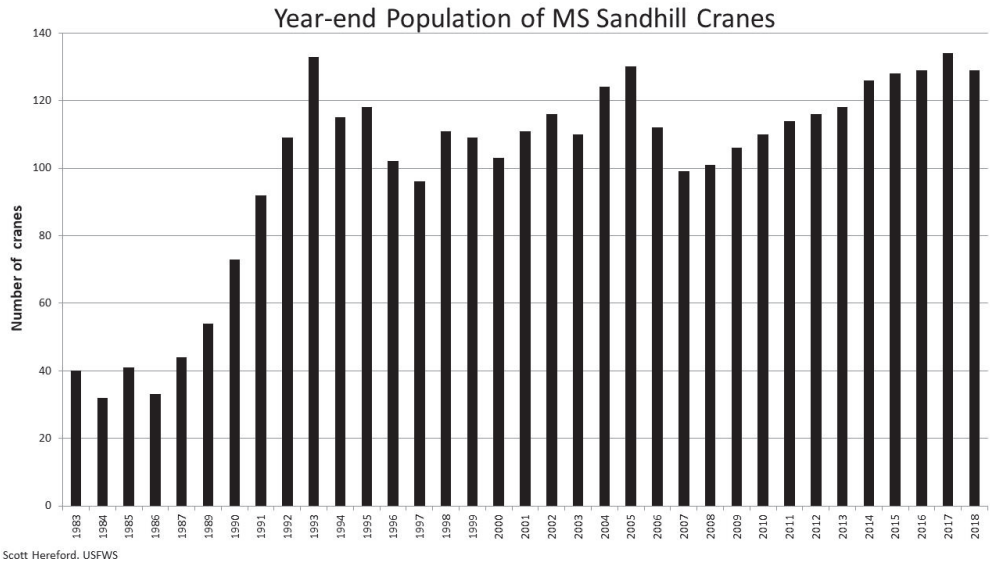


Figure 3. Summary of Mississippi sandhill crane population by year.



The wild Mississippi sandhill crane population has remained relatively stable since 1993, ranging from 110-140 individuals (Hereford and Dedrickson 2018c, 2019b), primarily due to augmentation from annual releases of captive-bred juveniles, although the age distribution of the population is skewed towards younger birds. Although the number of

breeding pairs has increased, recruitment remains low (below replacement) and releases will still need to be continued for the foreseeable future. Predation of young birds is likely the primary factor affecting mortality in the population (see discussion under **C. 2. c. Disease or Predation**).

The current estimate of the wild Mississippi sandhill crane population is 129 birds; there are 52 males, 58 females, and 19 cranes of unknown sex (Hereford and Dedrickson 2019a). As the population ages and habitat improves, more pairs are forming. A record high 37 pairs nested in 2017 and 2018 (Hereford and Dedrickson 2018b, 2019b). Egg hatchability continues to be good (S. Hereford pers. comm. 2019) and the number of fledged chicks from the wild population is increasing from a low period in the mid-2000's (Hereford and Dedrickson 2016). Six chicks fledged in each year from 2013 through 2017 and 5 chicks survived to fledging in 2018 (4 percent recruitment rate) (Hereford and Dedrickson 2019a). Thirty-five chicks have fledged over the past 6 years; this increase in fledgling success continues a trend of record survival greater than any similar period in the Refuge's history (S. Hereford, pers. comm., 2018). In addition, the number of twins fledging has increased in recent years. From 1965 through 2012, there were only two known instances of fledged twins on the Refuge; since 2013, four sets of twins have fledged (S. Hereford, pers. comm., 2019). Increasing natural recruitment likely has additional positive impacts of stabilizing the natural population and providing wild models of breeding and parenting behavior for chicks. Seventy-seven percent of the nesting pairs that successfully fledged a chick on the Refuge over the past 6 years had at least one wild-hatched parent (S. Hereford, pers. comm., 2019). The current wild population estimate includes 62 birds released from ASSC, 17 from WOCC, 3 from PWRC, and 47 wild-hatched birds (Hereford and Dedrickson 2019b). There are 50 unpaired cranes on the Refuge (Hereford and Dedrickson 2019b).

Table 1. Mississippi Sandhill Crane Population: 2013-2018

Year	Wild Chicks Fledged on Refuge	Captive-reared Juveniles Released+	Adult Mortality (percent of population)	End of Year Cranes
2013	6	22	11 (8.5 %)	118
2014	6	11	10 (7.5 %)	123
2015	6	12	10 (7.2%)	129
2016	6	7	14 (9.9%)	128
2017	6	3	9 (6.2 %)	134
2018	5	6	13 (9.2%)	129

+Some captive releases are from wild eggs transferred from the Refuge

c. Genetics, genetic variation, or trends in genetic variation:
The sandhill crane is the most common of the world's crane species and includes six subspecies throughout North America, three of which are non-migratory (Johnson *et al.* 2005, Gerber *et al.* 2014, Christidis *et al.* 2018). Aldrich (1972) described the non-migratory Mississippi sandhill crane (*Grus canadensis pulla*) as a subspecies based on its darker-colored plumage and differences in overall size and body proportions. Some researchers (Rhymer *et al*. 2001, Jones 2003, Henkel 2009) have questioned the validity of the currently designated subspecies, but the distinction of the Mississippi sandhill crane as a separate entity worthy of continued conservation efforts has been supported (Rhymer *et al*. 2001, Jones 2003). No peer-reviewed scientific papers have formally eliminated or re-described any of the subspecies of sandhill cranes.

Jones (2003) studied the genetic variation in sandhill cranes using microsatellite DNA (short arrays of simple DNA sequences used as nuclear DNA markers). Cranes as a group are lower in genetic diversity than other birds. The study results indicate that mid-continental sandhill cranes show a natural gradation from Arctic nesting lesser sandhill cranes (*G. c. canadensis*) to non-Arctic greater sandhill cranes (*G. c. tabida*) (Jones 2003). The analysis illustrated only minor allele frequency differences between migratory and non-migratory sandhill crane populations although there are many ecological differences, especially in feeding habits (Jones 2003). Mississippi sandhill cranes are part of the greater sandhill crane lineage that includes the migratory Rocky Mountain population of the Eastern Flyway Population and non-migratory Florida sandhill cranes (Jones 2003). Relatedness to greater sandhill cranes was also reported by Dessauer *et al.* (1992) who documented that Mississippi sandhill cranes shared an allele with greater sandhill cranes. Jones *et al.* (2005) provided additional genetic assessment of non-migratory sandhill crane populations. The population structure and historical and recent gene flow patterns among non-migratory sandhills were quantified using microsatellite DNA genotyping from six populations. Results indicated a complex web of gene flow between migratory and non-migratory populations (Jones *et al.* 2005). Unfortunately, habitat destruction within the last one hundred years has resulted in the loss of all but the Mississippi sandhill crane representative of the non-migratory Gulf Coastal breeding populations and severed the gene flow from the mid-continental population of migratory greater sandhill cranes (Jones 2003, Jones *et al.* 2005). As a result, the allele frequency differences between Mississippi sandhill cranes and other populations likely resulted from genetic drift and inbreeding in the small disjunct population (Jones 2003, Jones *et al.* 2005). Wintering greater sandhill cranes arrive on the Gulf coast in mid-November and leave in mid- to late February (S. Hereford pers. comm.

2019). Although approximately 20 greater sandhill cranes typically winter at the Refuge, none have remained during the breeding season in the history of the Refuge, nor have Mississippi sandhill cranes migrated north (S. Hereford, pers. comm., 2019). Jones (2003) suggested the Mississippi sandhill crane is unique in the ecology of its habitat and may be more appropriately considered an ecotype than a subspecies. For this reason, he suggested that preservation of the Mississippi sandhill crane habitat should be a priority recovery focus.

A pedigree analysis of the Mississippi sandhill crane was conducted by Henkel (2010). The existing Mississippi sandhill crane population is based on 31 founder birds. The pedigree analysis indicated that, on average, mean kinship in the current population is equivalent to individuals being related at the level of first cousins; however, there are relatively low mean inbreeding values in both captive and wild populations (Henkel 2010, Henkel *et al.* 2011). These low mean inbreeding values may be the result of no individuals with very high inbreeding coefficients surviving past the first year of release (Henkel 2010). Although highly inbred individuals have existed in the two populations, they have not survived long enough to reach sexual maturity. Currently, the captive flock is managed to maximize genetic diversity and no closely related birds are bred (See discussion under **b. Abundance, population trends, demographic features, or demographic trends**).

d. Taxonomic classification or changes in nomenclature:
A new binomial name has been advanced by the American Ornithologists' Union that changes *Grus canadensis* to *Antigone canadensis* (Chesser *et al.* 2016). This alteration in phylogenetic relationships is based solely on mitochondrial genomes (Krajewski *et al.* 2010) that can be misleading because of the small size of the genome and its solely maternal transmission. A comparison of the much larger nuclear genome would provide clarification of the taxonomic relationships within sandhill crane species and between sandhill cranes and the other non-North American cranes to which this change would also apply. The International Crane Foundation, the IUCN Crane Specialist Group, and the North American Crane Working Group are not currently endorsing the reclassification (Aborn 2016, Henderson 2016). The Service will wait until the scientific community reaches agreement before we make a recommendation regarding this change.

e. Spatial distribution, trends in spatial distribution or historic range:
The Mississippi sandhill crane is restricted to the Mississippi Sandhill Crane National Wildlife Refuge and its immediate environs in Jackson County, Mississippi, between the cities of Ocean Springs and Gautier (U.S. Fish and Wildlife Service 1991, Hereford and Dedrickson 2019b). The entire range of the crane was estimated to be 137.5 square miles (sq.

mi) (356 square kilometers (sq. km)) during the PHVA (CBSG 1992). More recently, an estimate of habitat area used by Mississippi sandhill cranes from 2014 through 2016, calculated using minimum convex polygon analysis, was 108 sq. mi (280 sq. km) (Hereford and Dedrickson 2018c). The Refuge is composed of three noncontiguous units designated as the Gautier Unit, Ocean Springs Unit, and Fontainebleau Unit (Hereford and Dedrickson 2019b). The Ocean Springs and Gautier units straddle Interstate 10 (I-10); the Fontainebleau Unit is located south of U.S. Highway 90 and is much smaller than the other two units. Nest searches that document breeding habitats have been conducted annually on the Refuge area since the mid-1960s (Valentine 1992, Valentine and Hereford 1997, Hereford and Dedrickson 2019b). There is an annual population census conducted in the autumn of each year and individual cranes are monitored as frequently as possible given constraints of personnel and budget. Mississippi sandhill cranes are distributed patchily across the Refuge, primarily occupying the unit where each individual was released as a captive-bred juvenile. The results of the 2018 population survey indicated that 55 percent of the population occupied the Gautier Unit, 36 percent the Ocean Springs Unit, and 9 percent the Fontainebleau Unit (Hereford and Dedrickson 2019b). The non-migratory Mississippi sandhill crane still occupies essentially the same geographic area as when it was originally described by Aldrich (1972), however habitat management on the refuge has improved the quality of its roosting, loafing, and breeding habitat.

f. Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

The Mississippi sandhill crane occurs on wet pine savanna grasslands predominated by wiregrass (*Aristida* spp.), with scattered longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and pond cypress (*Taxodium ascendens)* trees (U.S. Fish and Wildlife Service 1991). Mississippi sandhill crane nests are typically located in open, shallow herbaceous wetlands and are generally composed of plants common to wetlands and savanna (Valentine and Noble 1970). The cranes may also nest in savannas and swamp or marsh edges. Open upland habitats, such as savannas, wet prairies, improved pastures, and croplands, are used for foraging; marshes, shallow freshwater ponds, and ponded swamp strand edges provide roosting areas and loafing areas used during hot weather. During fall, winter, and early spring the cranes will feed in small corn and chufa (plant in sedge family used for bird food plots) fields and pastures, often off-Refuge.

Timber from Mississippi sandhill crane habitat was first removed during the 1870s (Walkinshaw 1981). By the time Leopold (1929) conducted the first survey of Mississippi sandhill cranes, extensive habitat alteration had occurred as a result of the removal of timber in Jackson County,

Mississippi (Walkinshaw 1981). After 1940, timber companies converted thousands of ac (ha) of the remaining savannas to slash pine plantations. As the trees in the pine plantations matured, the understory became dense and many areas previously occupied by cranes became unsuitable habitat (U.S. Fish and Wildlife Service 1991).

After the listing of the Mississippi sandhill crane in 1973, The Nature Conservancy (TNC) began the process of acquiring property that would become the Mississippi Sandhill Crane National Wildlife Refuge in 1975. In addition, because the original construction of I-10 in Jackson County, Mississippi, threatened the remaining Mississippi sandhill crane habitat, Federal court actions were filed for violations of Section 7 of the Act. After the completion of Section 7 consultation and court actions, additional property was acquired and transferred to the Service for creation of the Refuge near the I-10 interchange at Gautier-Vancleave Road. The Refuge currently totals approximately 19,300 ac (47,690 ha) (Hereford and Dedrickson 2018b).

During the PHVA workshop discussed above under **C. 1. b., Abundance, population trends, demographic features, or demographic trends**, questions of habitat quantity and quality on the Refuge were addressed relative to recovery of the crane. It was estimated that 75 percent of the Mississippi mesic coastal pine savanna had been lost with the remainder highly fragmented amid other land uses and habitat types (CBSG 1992). A number of recommendations to improve habitat conditions for the crane on the Refuge were suggested (CBSG 1992). Specifically, the need for a more rapid rate of conversion of pine scrub habitat to suitable savanna was identified. A review of the habitat analysis data identified areas of mesic and hydric savanna suitable for nesting. Habitat management techniques to improve these habitats, especially hand and machine clearing and the effective use of prescribed fire, were described in the PHVA and have subsequently been put into practice on the Refuge. The PHVA modeling set the carrying capacity of the Refuge at 150 cranes, with a range of 130 to 170 birds, as determined by the estimated habitat availability. At the time of the PHVA, 34 existing breeding territories were known with the potential for about 19 more after completion of habitat improvements, for a total of 53 nesting territories on the Refuge (CBSG 1992).

In 1992, an area southeast of the original Refuge that contains the only other large tract of remnant savanna that could provide nesting habitat for the Mississippi sandhill crane (Gee and Hereford 1995) was designated as the Grand Bay National Wildlife Refuge (Grand Bay) (U.S. Fish and Wildlife Service 2008). Although the acquisition boundary encompasses approximately 15,500 ac (38,300 ha) (U.S. Fish and Wildlife Service 2008), there are still a number of parcels within the boundary that the Service has not acquired. Funding, obtained through the RESTORE Act

(Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act 2012) using Clean Water Act financial penalties resulting from the Deepwater Horizon Spill in the Gulf of Mexico, is supporting conservation efforts at Grand Bay. Funding is currently being used to acquire more lands within the Grand Bay acquisition boundary; to conduct prescribed burns and other habitat improvements on Grand Bay; and to provide temporary personnel to conduct management efforts there. When the habitat is restored to a suitable condition, the Service will develop a plan to establish Mississippi sandhill cranes on Grand Bay, a task identified in both the recovery plan and the Grand Bay Comprehensive Conservation Plan (U.S. Fish and Wildlife Service 1991, 2008). The goal is to have 1,000 ac (405 ha) of open, potential Mississippi crane habitat at Grand Bay within 5 years (S. Hereford, pers. comm., 2019).

In 1997, TNC established the Old Fort Bayou Mitigation Bank (OFBMB) on 1,730 ac (700 ha) purchased north of I-10 between the Gautier Unit and the Ocean Springs Unit of the Refuge. As a part of the mitigation process, TNC is restoring the savanna and longleaf pine habitat on this acreage by removing the plantation pine; planting longleaf pine; and conducting prescribed burning. Restoration of this tract will provide additional habitat for the crane and will reduce fragmentation of Refuge lands. The site contains multiple potential crane nesting territories and a pair of cranes nested on the property in 2013 (Hereford 2014a). The OFBMB site may eventually become part of the Refuge as the location is within its acquisition boundary.

Gee and Hereford (1995) reported Mississippi sandhill crane nesting habitat data as known at that time; 49 percent of nests were located in savanna, 38 percent in swamp edges, and 7 percent in pine plantations. Data from 2000 through 2018 indicated that 39 percent of nests were in savannas, 36 percent in ponds, 16 percent in swamp strands, 7 percent in estuarine marsh, and 1 percent in pine flatwoods (S. Hereford, pers. comm., 2019). Restoring these habitats and managing them for the recovery of the Mississippi sandhill crane has been ongoing ever since the Refuge was established (Smith and Valentine 1987, Hereford and Dedrickson 2018c, 2019b). Prescribed burning is the main tool used to manage the Refuge. Other conservation actions include mechanical removal of understory trees and brush to open and enhance savanna habitat; control of invasive plant species; farming and mowing to provide on-Refuge food plots and pasture for crane foraging; and pond establishment and enhancement. Long-term vegetation monitoring has provided a method to document improvements in the native vegetation on the Refuge (Eco-Logic Restoration Services, LLC 2012). The most notable metric reflecting improvements in native savanna vegetation is the decline in coverage by woody species (Eco-Logic Restoration Services,

LLC 2012). Improvements have been made on the Refuge to restore natural hydrology altered by previous timber management and road construction by plugging ditches and constructing water control structures. Twenty-four shallow ponds have been created or enhanced on the Refuge for crane roosting and nesting. Funding for habitat management is limited and the availability of Service recovery funds continues a downward trend that has been occurring throughout the 2000's. As a result, the Refuge has prioritized focus areas for management based on crane use. The factors used to score these areas include the number of radio-fixes over 5 years; the number of nests; the number of fledglings; presence of roost ponds; and presence of a release pen.

Most of the known Mississippi sandhill crane nesting territories are near where the breeding adults were originally released as captive-bred juveniles. Both male and female cranes show fidelity to their nesting territories. Over the last 5 years, 10 new territories were established and used by Mississippi sandhill cranes for nesting (Hereford and Dedrickson 2019 a, b). This increase in habitat use is likely a direct response to habitat improvements on the Refuge (Hereford and Dedrickson 2019a). The number of nest territories on the Refuge are probably close to maintenance stage and it is possible that carrying capacity has been achieved in key areas; however, about 10 more unused territories are available in the eastern Ocean Springs Unit (S. Hereford, pers. comm., 2019). In 2017 and 2018, captive-bred juveniles were introduced to the Refuge at a new acclimation pen in the eastern Ocean Springs Unit to establish more cranes in the area.

In the mid-1980s, the Service entered into a 20-year Memorandum of Understanding with the Mississippi Gulf Coast Regional Wastewater Authority (now the Jackson County Utility Authority (JCUA)) for the development of a segment of their wastewater irrigation treatment facility on the Refuge near the existing Seaman Road treatment plant (U.S. Fish and Wildlife Service 1991). In 1986, 56.7 ac (140 ha) of the Ocean Springs Unit were converted to a wastewater sprayfield which was sprayed with treated effluent and planted to grasses; three "wetland cells" (artificial ponds) totaling 12.4 ac (5 ha) were constructed to percolate water from the sprayfields (CBSG 1992). At that time, it was thought that this facility would benefit the cranes by creating nesting and roosting habitat in the artificial ponds, and foraging habitat in the sprayfields. The sprayfields were planted with hay grasses but, due to the high level of soil moisture, the site became impossible to manage through burning or mechanical vegetation management and the high nutrient loading of the site resulted in an overgrowth of native and nonnative invasive species. As the high nutrient water from the sprayfields flowed into natural drainages and onto the Refuge, it spread deleterious impacts to additional crane habitat and resulted in a transition from open, wet pine savanna to

overgrown shrub scrub and freshwater marsh (Eco-Tech, Inc. 2000). The JCUA ceased operation of the wastewater treatment sprayfield on refuge lands in 2011. In 2011, JCUA removed surface sprayfield pipes, mulched existing vegetation, and sprayed herbicide on some areas in an attempt to kill invasive species (cogongrass). The refuge has begun managing the site through annual mowing, but crane use of the altered area is limited.

Mississippi sandhill cranes frequently use habitat off-refuge, especially in autumn and winter. Approximately 30 percent of the crane observations recorded in 2018 were off-refuge (Hereford and Dedrickson 2019b). Typically, more males (generally unpaired males) than females use off-refuge habitat. A large number of cranes that occupy the Ocean Springs Unit roost or feed off-refuge in the area of the JCUA wastewater treatment plant on Seaman Road (see discussion of *Salmonella* under **C. 2. c., Disease or predation**). The Fontainebleau Unit has limited roosting habitat and as a result cranes occupying this unit frequently roost south in the Graveline and Bellefontaine marshes. Off-refuge habitat is used less frequently for nesting as there is very limited nesting habitat off-refuge, primarily due to habitat loss and degradation. For example, only 7 of the 55 (13 percent) total nests in 2018 occurred off-refuge. The Nature Conservancy's OFBMB between the Ocean Springs and Gautier units has the potential to add possibly three or four Mississippi sandhill crane nesting territories there as habitat improves (S. Hereford, pers. comm., 2019). With future cooperation and coordination with TNC, captive-bred birds could be released on the Refuge adjacent to OFBMB to repopulate that area.

Wildlife Mississippi, a nonprofit organization working on conservation projects in the state of Mississippi, has been developing relationships with private landowners whose properties in Jackson County are used, or have the potential to be used, by Mississippi sandhill cranes. Wildlife Mississippi has received a grant through the National Fish and Wildlife Foundation's Gulf Coast Conservation Grants Program, with matching funding from the USDA Natural Resources Conservation Service, to facilitate placement of a permanent conservation easement on 80 ac (198 ha) of off-Refuge pasture frequented by cranes. Wildlife Mississippi is also working with several other landowners on similar agreements and assisting landowners in managing and improving their properties for the benefit of crane recovery with funding from the Service through the Southeast Region Coastal Program.

2. Five-Factor Analysis

a. The present or threatened destruction, modification, or curtailment of its habitat or range:

The Mississippi sandhill crane occurs only in Jackson County, Mississippi, on wet pine savanna grasslands predominated by wiregrass, with scattered longleaf pine, slash pine, and pond cypress trees (U.S. Fish and Wildlife Service 1991). Crane nests are typically laid in an open area of grasses and sedges with perennial shallow water, but they may also nest in swamp or marsh edges. During fall, winter, and early spring, the cranes will feed in pastures and fields, often off-Refuge.

The destruction of wet savanna habitat in the eastern Gulf Coastal Plain is almost complete. Suppression of wildfires has led to the decline and disappearance of this type habitat and led to an unnatural buildup of hazardous fuels in the form of flammable shrubs, vines, and planted pine on and around the Refuge. The Refuge and nearby Grand Bay represent the largest remaining tracts of the wet prairie community habitat type in the Southeast (Clewell *et al*. 1998).

Restoration and maintenance of the wet pine savanna is one of the primary purposes of the Refuge. In addition to wet pine savanna providing primary habitat for the Mississippi sandhill crane, the savanna system itself is considered highly threatened (NatureServe 2018). Refuge improvements of upland habitat continue, primarily through rehabilitation of hydrology altered during historical timber operations; reductions in stocking of remaining pines on Refuge; control of invasive species; mechanical treatments of agricultural units to provide grassy areas for foraging on the Refuge; and maintenance of prescribed burning at 2 to 3 year intervals for each burn compartment. Restoring and maintaining the coastal longleaf pine savannah ecosystem for the benefit of the crane is best accomplished through conducting prescribed burns (Billodeaux *et al.* 2010). The use of growing season burns for at least 50 percent of annual prescribed burns is a goal. Unfortunately, one hundred percent of funding for prescribed burning on the Refuge is to fight fire or reduce fuels for wildfire in the urban interface; none of this funding has wildlife management as its primary purpose. Another difficulty in achieving prescribed burning targets is due to smoke management concerns as nearly the entire refuge is within the wildland/urban interface. Prevailing winds limit the frequency of opportunities to meet the fire prescription; wind direction is very important because I-10 runs through the Refuge. A north wind, which is necessary to burn several compartments south of I-10, is a less frequent wind direction during the growing season when prescribed burning provides the best habitat management. This has resulted in some habitat degradation in those compartments south of I-10. Clearing and creation of ponds for crane use has also been ongoing on the Refuge; through 2018, 24 ponds have been created for roosting and nesting and many have been used as release sites for juvenile cranes (Hereford and Dedrickson 2019b).

Habitat loss/conversion/degradation outside of the Refuge is an ongoing threat, including in areas designated as critical habitat. Increasing commercial, industrial and residential development in the area surrounding the Refuge is limiting the availability of off-Refuge habitat for the crane. Examples of post-listing on-going habitat loss include destruction of previously occupied nesting territories due to construction of military housing and a golf course. Jackson County census data provide a snapshot of growing population in the county; from 2000 to 2018, population in Jackson County grew by 9.0 percent (U.S. Census Bureau 2019a, b; U. S. Department of Agriculture 2019). This increase occurred even though the destruction of Hurricane Katrina in 2005 resulted in some immediate population declines of coastal areas (U.S. Census Bureau 2019b). Between the 2010 and 2015 U.S. Census, Jackson County had the fifth highest growth rate in the state of Mississippi (U.S. Census Bureau 2019b). In contrast, during this same period there were more declines than increases in population when looking at all the counties in Mississippi (U.S. Census Bureau 2019b). Loss of off-Refuge habitat is important because approximately 30 percent of the Mississippi sandhill crane population spends time in these off-Refuge habitats, primarily foraging and roosting (Hereford and Dedrickson 2019b). Loss of foraging habitat is a particular concern because it is limited on the Refuge. The number of undeveloped areas available for use by cranes are decreasing as new residential developments are constructed (S. Hereford, pers. comm., 2017). In addition, increased development results in an increase in roads and vehicular traffic that increases the likelihood that cranes will be hit and killed as they fly between nesting, foraging, and roosting areas that may be off-Refuge or between Refuge units (See **e: Other natural or manmade factors affecting its continued existence**).

Increasing development surrounding the Refuge is also limiting the timing and frequency of when prescribed burning can be used as a management tool. The number of "burn days" (the number of days when it is possible to burn) have decreased over the past 20 years and are likely to continue to decrease due to climate change (see discussion under **e. Other natural or manmade factors affecting its continued existence**). Wind direction, temperature, and humidity must meet precise standards in order for Refuge burn staff to obtain a permit to burn. Wind direction is an especially important factor due to the presence of I-10 through the middle of the Refuge and the amount of development surrounding the Refuge.

b. Overutilization for commercial, recreational, scientific, or educational purposes:

This activity is not currently considered a threat to the Mississippi sandhill crane nor was it considered a threat at the time of listing.

c. Disease or predation:

There was no known threat from disease at the time of listing. Due to the extensive research conducted post-listing, primarily at or by researchers from PWRC, multiple diseases have been identified and studied that pose a threat to both wild and captive cranes. Diseases increase the susceptibility of cranes to other threats such as predation, accidents, and malnutrition in addition to being a cause of crane mortality (Carpenter and Derrickson 1987). Parasites, including coccidian protozoans, trematodes, nematodes, and biting lice, are commonly found in sandhill cranes (Forrester e*t al.* 1974), but strategies intended to prevent disease and its transmission are in place. In general, the wild Mississippi sandhill crane population is thought to be healthy, however crane monitoring at the level necessary to determine cause of death has not been possible for several years due to insufficient resources (when carcasses are found they are too decomposed to determine cause of death) (S. Hereford, pers. comm., 2019).

Bacteria

Avian tuberculosis (TB) is an infectious disease caused by *Mycobacterium* sp. and can result in lesions in the liver and spleen (Carpenter and Derrickson 1987). Avian TB is rarely observed in the wild, however in a routine pre-release screening of Mississippi sandhill chicks conducted in 2000 at the ASSC, one of the birds tested positive for TB (S. Hereford, pers. comm., 2000). The bacteria causing TB are shed through feces and can persist in the soil for 7 years. Uninfected cranes feeding in the area of contaminated soil can become infected during that period of time. As a result, chicks from the 2000 release cohort remained at ASSC and where tested five times during 2001 (ASSC 2001). These tests were all negative for TB and the chicks were subsequently released in two cohorts during 2001. Captive cranes are routinely tested for TB and no further incidences of avian TB have been documented in the captive population.

Salmonella can cause disease issues for cranes (Carpenter and Derrickson 1987). *Salmonella* spp. are potential bacterial pathogens of eggs and embryos that can cause reproductive failure in adult birds (documented in chickens and turkeys) and are shed from infected birds through feces. To prevent spread of these diseases, captive-bred Mississippi sandhill crane chicks are routinely screened prior to release, release pens on the Refuge are monitored for soil-borne pathogens, and pens used for captive and released birds are alternated to prevent accumulation of disease agents (bacteria and parasite spores). *Salmonella* has been found in water draining from the Ocean Springs sewage treatment plant (JCUA). Although JCUA ceased operation of the wastewater treatment sprayfield on Refuge lands near the plant, 20 to 30 cranes exclusively roost and forage in sprayfields and wet cells used for sewage treatment on JCUA property, primarily birds released as juveniles from the Ocean Springs release pens (S. Hereford, pers. comm., 2019). *Salmonella* has been

found in cranes using the area, but the effects of this infection on the health of these birds in unknown.

Viruses

Eastern equine encephalitis virus (EEE) was originally described in endangered cranes in the whooping crane flock at PWRC (Dein *et al.* 1986). This virus is spread by mosquitoes and is endemic to the eastern United States. In 2013, the first case in wild Mississippi sandhill cranes was identified from an adult female mortality at the Refuge (U.S. Geological Survey 2013). All captive-bred juveniles are now vaccinated for EEE prior to their release at Refuge.

West Nile virus (WNV) was introduced into the United States in New York, New York in 1999 (Olsen *et al.* (2009). In 2002 and 2003, WNV contributed to or directly caused the death of 11 Mississippi sandhill crane chicks housed outdoors at the ASSC; adult cranes housed nearby did not die (ASSC 2002, 2003). The fact that there was no mortality of adult cranes may indicate that young cranes are more susceptible to the disease than adult cranes (Olsen *et al.* 2009). All captive-bred chicks are now vaccinated for WNV prior to their release at Refuge.

Fungi

Olsen *et al.* (1995) described an incident of mycotoxin-induced disease in captive whooping cranes and sandhill cranes at PWRC. Study of the illness resulted in the isolation of *Fusarium* sp. mold from the grain-based diet provided to the cranes and low levels of two mycotoxins from the pelleted feed. Mycotoxins are produced as secondary metabolites of molds and will grow on corn in field situations. Protocols have been developed when using grain-based feeds for captive cranes and are followed at the two Mississippi sandhill crane captive-breeding sites. In 1991, Couvillion *et al*. (1991) provided results of a survey to determine if carcinogenic mycotoxins were present in crop foods (field corn, feed corn, chufa, and pecans) potentially consumed by Mississippi sandhill cranes on or near the Refuge in fall/winter 1987 through 1988, fall 1988, and fall 1989. Chufa and pecan samples were negative for mycotoxins. Corn from field samples, however, was contaminated with a mycotoxin (aflatoxin) that may pose a serious health risk to the cranes. Concentration of aflatoxin B_1 was most prevalent in those corn samples obtained from the ground post-harvest (Couvillion *et al*. 1991), the time when cranes would be most likely to eat the corn and be exposed. The extent of exposure of Mississippi sandhill cranes to this toxin is unknown.

Protozoa

Disseminated visceral coccidiosis (DVC) is a disease caused by extra-intestinal multiplication of *Eimeria* spp. coccidia (spore-forming single-celled obligate protozoan parasites) (Carpenter and Derrickson (1987).

Coccidia can be a problem in captive cranes and to reduce risk of transfer of this disease to the Refuge, captive-bred juveniles are treated before transfer to the Refuge. To reduce the potential for parasite problems at Refuge release sites, release pens are not used more than three successive years and 2 to 3 years are allowed to pass before pens are used again. Infection by DVC has been a factor in at least five wild Mississippi sandhill crane mortalities (S. Hereford, pers. comm., 2019).

Nematodes are known to be pathogenic to sandhill cranes (Carpenter and Derrickson 1987). One species, *Capillaria* sp. contributed to the death or debility of several captive-reared Mississippi sandhill cranes following their reintroduction to the wild. No further mortalities resulting from nematode infection have been reported.

Ascaridia sp., an intestinal parasite, has been documented in Mississippi sandhill cranes during examination of a dead bird (U.S. Geological Survey 2013). This individual was infected with the EEE virus and the parasite is probably unrelated to its mortality.

Disease of Unknown Origin

Liver tumors have been implicated in past and current crane mortalities. These tumors are carcinomas of respiratory origin, but have not been reported in Mississippi sandhill cranes until the birds are at least 4 years old. A number of studies were conducted from the late 1980s into the early 1990s to test for various environmental contaminants that might be affecting the health of the Mississippi sandhill cranes. The concern was their potential to cause development liver tumors or sublethal effects on reproduction and fitness, however results were inconclusive (White and Hardy 1994, White *et al.* 1994). In 2018, an approximately 19-year old crane was found dead and necropsy results indicated presence of a liver tumor (Hereford and Dedrickson 2019b). It is not known if there is a genetic link to the development of liver tumors.

Heart murmurs resulting from congenital heart defects were first recorded in 1974 and were prevalent in chicks hatched 1988 to 1991 at PWRC (Gee and Hereford 1995). These defects were not universally lethal, but there was concern that the defect would affect crane performance and survival in the wild; chicks with heart murmurs showed a four times greater mortality rate than other released birds although the defect was not the proximal cause of death (Gee and Hereford 1995). The genetic lines that produced heart murmur chicks were identified and are no longer included as breeders within the captive flock (A. Lewis, pers. comm., 2018).

Predation is a current threat and is the number one reason for egg and chick mortality (Hereford and Dedrickson 2019b). Butler (2009) studied the sources of nest failure for 54 Mississippi sandhill crane nests during

2008 and 2009. Butler (2009) used cameras placed in the vicinity of nests to identify predation as the primary source (44 percent) of nest failure. In addition, mammalian predators on the Refuge were identified. Coyotes and raccoons were the most common, with gray foxes, red foxes (*Vulper vulpes*), domestic dogs (*C. l. familiaris)* and bobcats (*Lynx rufus*) detected frequently; all attacks observed by coyotes resulted in chick mortality and in one instance, a domestic dog killed an entire family (Butler 2009). Nest predation attempts were also made by barred owls, crows, alligators and snakes (Butler 2009). Nests laid later in the season were more likely to be predated as predator density and activity increased. Thirty-one nests were assessed for predation pressure; 45 percent of nests experienced some level of exposure to predators, but only distance from a nest to a road had a significant effect on predation pressure and this may reflect a closer distance to human disturbance and development (Butler 2009). High levels of predation are an indicator of habitat loss or degradation where the predator-prey relationship is out of equilibrium (Goodrich and Buskirk 1995). Additionally, many predators such as coyotes, red fox, and raccoons thrive in disturbed habitats (Crooks 2002).

Due to predation, the Mississippi sandhill crane population is maintained by the addition of fledglings from the two captive populations. Over the past 30 years, predators have been removed from the refuge. Predator removal has focused on the two most vulnerable periods for achieving recruitment to the population, the nesting season and the annual release of captive-reared juveniles (Hereford 2014b). Target species include all animals documented as taking crane eggs, chicks, juveniles, or adults (Hereford and Dedrickson 2018a). From 1985 through 2016 (with the exception of 2007 when no trapping occurred), there was an average of 3,647 trap-nights and 77.5 target mammals removed per year (Hereford and Dedrickson 2018a). Stable water levels within nesting habitat, which may be affected by climate change, can improve nesting success by reducing access to nests by some predators (see **e. Other natural or manmade factors affecting its continued existence**). The increase in predators on the Refuge is likely tied to the increased development pressure along the boundaries of the Refuge that has provided more habitat for "human-subsidized" predators (see **a. The present or threatened destruction, modification, or curtailment of its habitat or range**). Interestingly, when Valentine and Noble (1970) studied the Mississippi sandhill crane 50 years ago, there was little development in the area of the Refuge, few native predatory birds and mammals, and no evidence of nests destroyed by predators.

There is concern that the captive-bred history of the population has resulted in a reduction of learned predator-defense behaviors. It is also possible some of the behaviors were lost during the bottleneck when there were only five to six nesting pairs. Since the initial objective of rearing

chicks in captivity was to increase the Mississippi sandhill crane population on the Refuge as quickly as possible, the number of chicks was in excess of what could be naturally reared by parents and foster parents. As a result, chicks were hand-reared which entailed hatching eggs in incubators and rearing chicks using keepers in crane costumes. Hereford and Leaf (2017, 2018) conducted a survival analysis of captive-reared and released Mississippi sandhill cranes. The results of this quantitative survival analysis of release data from 1979 to 2015 indicated the mean annual survival probability has increased over time (Hereford and Leaf 2018). Data also indicated that hand-reared chicks had a higher survival rate than parent-reared chicks (Hereford and Leaf 2017). However, models generated from a study of rearing treatments in captive whooping cranes (*Grus americana*) indicated that parent-reared birds spent more time being vigilant than costume-reared birds (Kreger *et al.* 2004, Olsen *et al.* 2016). Although chick survival has improved, high survival rates of chicks has not translated to high recruitment in the wild (Hereford and Leaf 2018). A study of Mississippi sandhill crane nesting activity budgets indicated that parental behavior influenced nest outcomes (Howard *et al.* 2016). Mississippi sandhill crane pairs at unsuccessful nests spent more time away from the nest, cooperated poorly, and started nesting a month later on average than successful nests (Howard *et al.* 2016). Due to low recruitment rates on the Refuge, the focus at the captive-breeding facilities has switched from hand-rearing to parent-rearing of chicks for release. This change may help reduce predation rates if chicks learn predator defensive skills from their parents, as well as other important nesting behaviors. Howard *et al.* (2016) found that wild-reared birds gave more agonistic displays toward potential threats than captive-reared birds. As a result, the captive-breeding facilities are trying various techniques to provide chicks with training in antipredator behaviors before release (Heatley 2002, Howard *et al.* 2018). Once the chicks are released, predator aversion learning opportunities are provided during the birds' initial confinement on the Refuge prior to becoming free-flying. The reduced success of captive-bred birds in fledging chicks may also reflect a lag time in successful nests if it takes a year or more of failure before even a wild-born inexperienced pair raises their first chick to fledgling, as in Florida sandhill cranes (Nesbitt *et al.* 2008).

d. Inadequacy of existing regulatory mechanisms:

The State of Mississippi lists the Mississippi sandhill crane as Endangered which provides protection under "The Nongame and Endangered Species Conservation Act of 1974" against take, capture, and trade or selling (Mississippi Natural Heritage Program 2015). There are no state regulations in Mississippi to protect against the loss or alteration of crane habitat. In addition, there are no regulations restricting the use of lead shot in Mississippi; lead poisoning from ingestion of lead shot has resulted in mortality of a juvenile female Mississippi sandhill crane (Franson and

Hereford 1994). After Congress created the State Wildlife Grants (SWG) program in 2001, a national planning initiative was begun to ensure the best use of the grant funding for long-term conservation of the nation's biodiversity. The State of Mississippi developed a 10-year State Wildlife Action Plan that updates their 2005 Comprehensive Wildlife conservation Strategy and acts as the implementation document for SWG funding (Mississippi Museum of Natural Science 2016). The revised plan acts as a conservation "blueprint" for all wildlife species in the state's jurisdiction. Although over 10 million dollars in SWG funds have been obligated within Mississippi over the past 10 years, none of this funding has directly supported recovery of the Mississippi sandhill crane (M. Roberts, Mississippi Department of Wildlife, Fisheries, and Parks, pers. comm., 2019).

The listing of the Mississippi sandhill crane as an endangered species under the Act (U.S. Fish and Wildlife Service 1973) was critical to the survival of the species. When it was listed in 1973, the crane population was less than 40 birds and development of its habitat was imminent due to the construction of I-10. Due to listing and provisions of the Act, the Mississippi sandhill crane became the first species to gain habitat protection under section 7. Results of what eventually became a court case was the establishment of the Refuge. In addition to the crane being listed as endangered under the Act, critical habitat was also designated for the species (U.S. Fish and Wildlife Service 1977). It is likely that without Federal protection, the presence of the Refuge, and the considerable efforts accomplished thus far on species and habitat management, the crane would be extinct in Mississippi. Recovery efforts are ongoing in large part due to the protection afforded by the Act and funding provided through the Service.

There are other Federal regulations that may support recovery of the Mississippi sandhill crane. These include the National Wildlife Refuge System Improvement Act of 1997 (NWRSIA), the Clean Water Act (CWA), and National Environmental Protection Act (NEPA).

The NWRSIA requires that every refuge develop a Comprehensive Conservation Plan (CCP) and revise it every 15 years, as needed. These CCPs are written to identify management actions necessary to fulfill the purpose for which a specific refuge was established and generally include strategies for improving habitat conditions for the benefit of wildlife. There are CCPs for both the Refuge and Grand Bay (U.S. Fish and Wildlife Service 2007, 2008). Within these documents, habitat and wildlife population goals for the refuges have been established that include recovery strategies for the Mississippi sandhill crane as identified in the Mississippi Sandhill Crane Recovery Plan (1991) and recommended in the Mississippi sandhill crane population and habitat viability assessment

workshop report (CBSG 1992). In 2011, a "pulse-check" was conducted to review the progress made in meeting goals established by the CCPs, identify new issues or priorities, and provide any new data that would inform the process (U.S. Fish and Wildlife Service 2011). In general, the review team concluded that refuge staff has done an excellent job of keeping pace with the population and habitat management needs of the cranes as outlined in the CCP. The review team also provided recommendations for areas of improvement to refuge managers for their consideration, however, additional funds and/or personnel may be required to meet these recommendations (U.S. Fish and Wildlife Service 2011).

Protections provided by the CWA may benefit the Mississippi sandhill crane. Potential benefits relate to implementation of Environmental Protection Agency (EPA) pollution control programs that make it unlawful to discharge any pollutant from a point source into navigable waters without a permit. Violations of the CWA would include discharge into wetlands used by cranes if they were considered jurisdictional wetlands (connected to navigable waterways).

Requirements of NEPA include requiring Federal agencies to incorporate environmental considerations in their planning and decision-making. Specifically, all Federal agencies are to prepare detailed statements assessing the environmental impact of and alternatives to major Federal actions significantly affecting the environment. If a major Federal action is planned in the future in habitat where the Mississippi sandhill crane occurs, the agency carrying out the Federal action would be responsible for complying with the requirements of NEPA.

e: Other natural or manmade factors affecting its continued existence: Sandhill cranes in general have low productivity due to laying just 2 eggs per nest. Although the last several years have seen increases in the number of wild-born Mississippi sandhill crane fledglings surviving on the Refuge, the current low level of natural recruitment, approximately five percent, continues to be an issue that has not been resolved in this small, isolated population. Arnold *et al.* (2016) suggested that average annual sandhill crane recruitment rates (expressed as fledged young per adult in the preseason population) would need to be 15 percent to achieve a stable population.

Recruitment to the Mississippi sandhill crane population has been primarily a result of bringing juveniles bred in captivity to the Refuge. A majority of the cranes in the extant population are the result of captive-breeding efforts conducted by hand-rearing chicks. There is concern that the impact of this rearing practice may have negatively affected parenting skills of Mississippi sandhill cranes and may be a factor in the low natural

recruitment in the population (see discussion under **c. Disease or predation**).

Environmental pollution has been considered a possible threat contributing to poor hatchability and chick survival (White *et al.* 1994). Potentially harmful concentrations of highly toxic polychlorinated dibenzo-*p*-dioxins (PCDDS) and dibenzofurans (PCDFs) have been found in nonviable Mississippi sandhill crane eggs (White and Hardy 1994, White *et al.* 1994). The Refuge is bisected by I-10 and is less than 10 mi (16 km) from an industrial complex at Pascagoula, Mississippi, and a remnant solution pond from a closed paper mill. Both automobile exhaust and paper mills are potential sources of some microcontaminants (Edgerton *et al.* 1989, Tiernan *et al.* 1989) which may have negative consequences for crane health, however specific threats are unknown.

Trauma deaths due to collision with human-created structures like fences, cell towers, and especially powerlines are increasingly important causes of Mississippi sandhill crane mortality as development increases and surrounds the Refuge. From 1989 through 2013, there have been 13 known Mississippi sandhill crane mortalities from powerlines; 3 from electrocution and 8 from entanglement trauma (S. Hereford, pers. comm., 2018). Marking powerlines to increase line visibility and reduce sandhill crane collisions is an effective technique to avoid mortalities (Morkell and Anderson 1990, Faanes and Johnson 1992, Murphy *et al.* 2016). Powerline companies, with lines running across the Refuge and other areas frequented by Mississippi sandhill cranes, have installed bird flight diverters on powerlines, shown to alter behavior of cranes near powerlines (Morkill and Anderson 1992). In one case, a powerline company removed a portion of a line and replaced it with an underground line (S. Hereford, pers. comm., 2018).

Roads within occupied habitat are a threat to all ages of cranes. The number of roads and the increase in volume of traffic affecting cranes is directly tied to the development surrounding the Refuge (see discussion under **a. The present or threatened destruction, modification, or curtailment of its habitat or range**). Because cranes fly between nesting, foraging, and rooting areas that may be off-Refuge or between Refuge units, the increase in motorized vehicular traffic increases the likelihood that a crane will be hit and killed. From 1994 through 2017, a total 44 vehicle collisions have been documented which resulted in the death of 39 (93 percent collision mortality rate) Mississippi sandhill cranes (Hereford, pers. comm., 2017). Fourteen (33 percent) of the vehicle collisions occurred on I-10.

Changing climatic conditions in the Southeast including increasing drought, variations in seasonal timing of precipitation, and heavy rain

events (U.S. Environmental Protection Agency 2014, U.S. Global Change Research Program 2017), are expected to influence breeding behavior and impact recruitment to the Mississippi sandhill crane population. Extended droughts can lead to lower annual-productivity and recruitment (Hereford and Billodeux 2010) by reducing the quality and quantity of flooded and ponded sites selected by the cranes for nesting, and increasing the accessibility of nests to predators. Alterations in the seasonal timing of precipitation may result in flooded conditions appropriate for nesting occurring outside of the typical crane breeding season. Heavy downpours may flood nests and require re-nesting. Although the crane has a prolonged nesting season and can re-nest, climate change will add an additional level of threat onto this non-migratory species that already has low natural recruitment.

D. Synthesis

After decades of habitat restoration work and release of captive-bred juveniles, the status of the Mississippi sandhill crane population has reached a level of stability. However, to achieve recovery, the population must become self-sustaining without the need for augmentation of captive-bred chicks. This goal has not been achieved.

Increased development outside the Refuge and the concomitant increase in vehicle traffic, roads, powerlines, towers, and fences will likely grow in importance as threats to individual cranes. Tracking diseases in the wild Mississippi sandhill crane population is made difficult by the limited funding available to monitor cranes and locate dead birds, thus the current effects of disease on the extant population are unknown. Heavy levels of predation at nest sites is still ongoing and the level of juvenile recruitment is still below population replacement. It is expected that the threat of climate change will increase pressure on breeding cranes and negatively impact the already low levels of natural recruitment.

In summary, the best available information indicates that threats currently affecting the Mississippi sandhill crane are expected to continue into the future. Release of captive-bred juveniles will need to be continued until the problem with low natural juvenile survival rates can be resolved and the Mississippi sandhill crane has demonstrated the ability to sustain its population over time. Although there has been some progress towards achieving recovery goals for the Mississippi sandhill crane, especially in habitat restoration, the recovery criteria have not been met and this species continues to meet the definition of endangered species under the Act.

III. RESULTS

A. Recommended Classification: No change is needed.

B. New Recovery Priority Number: No change.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

1. Monitor the Mississippi sandhill crane population. Monitor mortality, survival, nesting, juvenile recruitment, and habitat use including movements and use of roosting, nesting, foraging, and loafing areas. Conduct a new PHVA using up-to-date data.

2. Assess the genetic relationship of Mississippi sandhill cranes to other North American sandhill cranes and determine if restoring gene flow with other populations of cranes would be beneficial to Mississippi sandhill crane recovery.

3. Increase natural recruitment in the wild population. Conduct predator management and study habitat variables associated with successful nesting territories. Explore the need and feasibility of using sterilized sandhill cranes from other populations outside Mississippi for cross-fostering Mississippi sandhill chicks at the Refuge in order to increase exposure of chicks to appropriate parenting skills.

4. Maximize the quality and quantity of habitat on and near the Refuge by continuing to restore, improve, and maintain nesting, feeding, and roosting habitats. Control the spread of invasive plants onto the Refuge and limit or negate crane contact with potential toxins. Explore ways to mitigate crane mortality due to increased development outside the refuge and increased density of roads.

5. Continue the captive propagation program. Determine the number of releases necessary to maintain a stable population and to create new populations elsewhere.

6. Introduce Mississippi sandhill cranes onto Grand Bay National Wildlife Refuge and look for appropriate savanna habitat in Louisiana that could potentially support an additional Mississippi sandhill crane population.

7. Implement all other tasks identified in the recovery plan.

8. Revise the recovery plan as appropriate to address new threats and conservation needs.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Mississippi Sandhill Crane (*Grus canadensis pulla*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review

__X__ No change needed

Review Conducted By: Linda LaClaire, Mississippi Ecological Services Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve Cary Norquist Date 8/2/19

REGIONAL OFFICE APPROVAL:

Lead Regional Director, Fish and Wildlife Service

Approve CATHERINE PHILLIPS Digitally signed by CATHERINE PHILLIPS Date: 2019.08.30 07:39:08 -04'00' Date

APPENDIX A.
Summary of peer review for the 5-year review of the Mississippi sandhill crane (*Grus canadensis pulla*)

A. Peer Review Method

The document was peer-reviewed internally by Cary Norquist, Mississippi Ecological Services Field Office and Scott Hereford, Mississippi Sandhill Crane National Wildlife Refuge. It was also sent to five outside reviewers via email (see below). The outside peer reviewers were chosen based on their qualifications and knowledge of the species and its habitat. Individual responses were received from four of the five peer reviewers.

Peer Reviewers:

Dr. Jerry Howard
University of New Orleans
Department of Biological Sciences
New Orleans, LA 70148
504-280-5441
jjhoward@uno.edu

Anne Lacy
International Crane Foundation
9445, E11376 Shady Lane Rd.
Baraboo, WI 53913
608-956-9462
anne@savingcranes.org

Dr. Glenn Olsen
U.S. Geological Survey
Patuxent Wildlife Research Center
Laurel, MD 20708
301-497-5603
golsen@usgs.gov

Nick Winstead
Mississippi Department of Wildlife, Fisheries, and Parks
Mississippi Museum of Natural Science
2148 Riverside Drive
Jackson, MS 39202-1353
601-576-6064
nick.winstead@mmns.state.ms.us

Dr. Mark Woodrey
Grand Bay National Estuarine Research Reserve
6005 Bayou Heron Rd.

Moss Point, MS 39562-9706
228-475-7047
mark.woodrey@msstate.edu

B. Peer Review Charge: See attached guidance.

C. Summary of Peer Review Comments:

Dr. Jerry Howard, University of New Orleans:

Dr. Howard stated that the data and analyses provided in the five-year review provide a well-justified basis for determining the status of the species. He believes the existing PHVA continues to serve its purpose due to relatively minor changes in land acquisition and population trends. He supports the change in focus of the captive breeding program from quantity to quality of released juveniles. Dr. Howard suggested that it would be desirable to develop a more detailed understanding of the ecological values of habitat important to Mississippi sandhill cranes in order to support planning as we move forward on population recovery at the Refuge and work to establish new localities for the cranes.

Anne Lacy, International Crane Foundation:

Ms. Lacy reviewed the document but had no comments, edits, or additions.

Dr. Glenn Olsen, Patuxent Wildlife Research Center:

Dr. Olsen suggested that we repeat the PHVA and revise the recovery plan based on any resulting new information. He stated that we listed increased development outside the refuge boundaries as a threat to the cranes and asked if some solution or mitigation might reduce vehicle fatalities.

He addressed the need to increase "wildness" in captive-bred birds as a way to improve nest defense and suggested using sterilized Florida sandhill cranes to raise Mississippi sandhill crane chicks in order to provide better parent models. He recommended learning more about the threat of predation in order to provide more scientific support for the predator management program. He questioned whether there might be an underlying disease issue involved in wild-raised chick deaths labeled as predation. As part of this discussion, he wondered if vaccinating wild chicks against West Nile Virus might improve survival rates.

Nick Winstead, Mississippi Museum of Natural Science:

Mr. Winstead's comments focused on the genetic relationships among North American sandhill cranes and what those relationships might mean for Mississippi sandhill crane recovery. He assessed the available genetic data and suggested the data do not support the Mississippi sandhill crane's designation as a subspecies and that designation as a DPS might be more appropriate. In addition, he believes maintaining management of the Mississippi population as a subspecies restricts techniques that could improve recovery outcomes such as cross-breeding between Mississippi sandhill cranes and Florida sandhill cranes to increase genetic diversity. He suggested that a more detailed genetic analysis is needed to clarify relationships among currently described populations and named subspecies.

D. Response to Peer Review

Peer reviewer comments were evaluated and incorporated into the revised document, as appropriate.

Guidance for Peer Reviewers of Five-Year Status Reviews
U.S. Fish and Wildlife Service

As a peer reviewer, you are asked to adhere to the following guidance to ensure your review complies with U.S. Fish and Wildlife Service (Service) policy.

Peer reviewers should:

1. Review all materials provided by the Service.

2. Identify, review, and provide other relevant data apparently not used by the Service.

3. Not provide recommendations on the Endangered Species Act classification (e.g., endangered, threatened) of the species.

4. Provide written comments on:
   - Validity of any models, data, or analyses used or relied on in the review.
   - Adequacy of the data (e.g., are the data sufficient to support the biological conclusions reached). If data are inadequate, identify additional data or studies that are needed to adequately justify biological conclusions.
   - Oversights, omissions, and inconsistencies.
   - Reasonableness of judgments made from the scientific evidence.
   - Scientific uncertainties by ensuring that they are clearly identified and characterized, and that any potential implications of uncertainties for the technical conclusions drawn are clear.
   - Strengths and limitations of the overall product.

5. Keep in mind the requirement that the Service must use the best available scientific data in determining the species' status. This does not mean the Service must have statistically significant data on population trends or data from all known populations.

All peer reviews and comments will be public documents and portions may be incorporated verbatim into the Service's final decision document with appropriate credit given to the author of the review.

Questions regarding this guidance or the peer review process should be referred to Shannon Holbrook, Fish and Wildlife Biologist, Daphne Alabama Ecological Services Field Office, at (251) 441-5871, e-mail: shannon_holbrook@fws.gov.