MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Prepared by U. S. Seal, Scott Hereford, and Workshop Participants

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IUCN/SSC CAPTIVE BREEDING SPECIALIST GROUP

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MISSISSIPPI SANDHILL CRANE PHVA REPORT

Grus canadensis pulla

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MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Section 1

EXECUTIVE SUMMARY AND RECOMMENDATIONS

Executive Summary

The Mississippi sandhill crane (MSC), an endangered subspecies, has become geographically isolated from other sandhill populations and is in danger of extinction. The recovery objective, as written in the U. S. Fish and Wildlife Recovery Plan (USFWS, 1991), is to maintain a genetically viable, self-sustaining, free-living MSC population. In order to achieve the goal of recovery, it is necessary to understand the risk factors that affect survival of the crane. Risk evaluation is a major concern in endangered species management and a goal is to reduce the risk of extinction to an acceptable level. A set of software tools to assist simulation and quantitative evaluation of risk of extinction is available and was used as part of Population and Habitat Viability Assessment Workshop. This technique can improve identification and ranking of risks and can assist assessment of management options.

Eighteen biologists, managers, and decision makers attended a PHVA in Pascagoula, Mississippi on September 22-24, 1992 to apply these recently developed procedures to the MSC. The workshop was first proposed for the subspecies by the USFWS Jackson Endangered Species Field Office and was a collaborative effort of the USFWS and the Captive Breeding Specialist Group (CBSG) SSC/IUCN. The purpose was to review data from the wild and captive flocks as a basis for developing stochastic simulation models. These models estimate risk of extinction and rates of genetic loss from the interactions of demographic, genetic, and environmental factors as a tool for ongoing management of the subspecies. Other goals included determination of habitat and capacity requirements, role of captive propagation, and prioritized research needs.

The first morning consisted of a series of presentations summarizing data from the wild and captive flock. After a presentation on the PHVA process by facilitator Ulysses Seal, CBSG, the participants formed three working groups (habitat, health and disease issues, and the captive flock) to review in detail current information, to brainstorm, and to develop management scenarios and recommendations. Concurrently, Seal developed stochastic population simulation models initialized with ranges of values for the key variables to estimate the viability of the wild population using the VORTEX software modelling package.

This workshop report includes a set of recommendations for research and management of the wild and captive populations as well as sections on the history of the population, release programs, and the population biology and simulation modelling of the population.

The minimum wild population estimate at the time of the PHVA Workshop was 108 cranes, 88 of which are captive-reared and released. However, before augmentation, wild population numbers were below 50 with no more than 10 breeding pairs for >3 generations. Because of the small effective population size, potential genetic problems were reviewed and evaluated. High reproductive success in the captive flock indicated no reduction in this trait. The subspecies has at least 2 unique alleles and moderate levels of allelic diversity. Detailed analysis of the actual nesting data at the PHVA Workshop indicated that the recruitment problems are probably due to external factors intervening between egg laying and fledging of the chicks. Estimated viability and hatching rates were well within the limits of other sandhill crane

populations. Data on the population biology of the MSC for use in population viability modelling were provided by published reports, Jane Nicolich, Jake Valentine, and Scott Hereford.

In the models, all adult males were assumed to be available for breeding. The risk of drought and hurricanes as stochastic events were included in the model. The initial population was set at 150 with an equal sex ratio and stable age distribution. Effects of inbreeding depression were included in some scenarios. Carrying capacity was set at 150, as a population of 130-170 birds was considered maximum after intensive habitat restoration on the Mississippi Sandhill Crane National Wildlife Refuge. Variables initialized with a range of values included juvenile mortality (20 and 30% for the interval between hatching and 1 year), annual adult mortality (7.7, 8.7, and 9.7% for post 1 year until death), and reproduction (here, rates of hatchling production per adult female were varied from 10 to 60%) were varied systematically to see which combinations would produce a viable population; i.e. a positive stochastic growth rate and reduction in risk of extinction to less than 5% in 100 years. Projections were done for 100 years with summary reports at 10 year intervals. Each scenario was run 500 times.

Under the present 30% hatchling (this value is calculated in terms of the number of adult females in the population and the number of chicks hatched) and 10% fledgling (only 1/3 of the hatched MSC chicks survived to fledge) production rates, the risk of extinction in 100 years is 100% regardless of post 1-year mortality rates and without inclusion of inbreeding depression. For a 40% hatchling production rate, the 50 year extinction risk is 5%, but the 100 year extinction risk varies from 5-85%. Even at 50% hatchling production rates, all populations with 30% juvenile (hatching to 1 year) mortality are in decline even though none were extinct at 50 years. It is only with 50% hatchling production and 20% juvenile mortality (hatching to 1 year) that positive stochastic growth rates are projected. Extinction always occurs in populations with negative growth rates. Fifty year population sizes are regularly near habitat carrying capacity only at 60% hatchling production with less than 30% juvenile mortality.

The models indicate the reproductive and mortality rates that will have to be achieved for recovery. The best chance of recovery has 60% hatchling production, 20% juvenile mortality, and 7.7% adult mortality. The resulting deterministic population growth rate is $r = 0.033$ (the stochastic $r=0.013 \pm 0.07$) with a zero probability of extinction over 100 years. The management implications are striking. Reducing the current 30% juvenile mortality rate to 20% is an important step toward recovery. As predation, primarily mammalian, is the leading cause of juvenile mortality, increased predator control must be a high priority.

Reproductive rates (production of surviving fledged chicks) was another concern at the start of the workshop, but this may not be due to factors (inbreeding, disease, nutrition) intrinsic to the cranes. Although fledgling production is only 10% in the wild MSC and is reported at 40% in the Florida sandhill cranes, fledgling production in the captive MSC flock is 60% and approaches 50-60% in wild whooping cranes. Egg and chick loss are the key events in low nest success. Normal productivity in the captive flock, occasional high success years in the wild, and other factors point to extrinsic reasons for nest failure. Since predation appears to be the primary cause, enhanced predator control (during nest season) should help.

There is a gradually increasing effect of inbreeding depression with the smaller populations modelled, with the effect highest at higher mortality rates. The loss of heterozygosity was estimated at 7-8% even under the best of conditions. This loss is higher than a recommended maximum rate of 5% loss in 10 generations.

Until fledgling production attains rates of 50-60%, population augmentation with captive produced birds will be necessary. However, the number of birds needed to be added to the population each year is far less than previously thought. This replacement number is estimated to be 14 per year. As current production is capable of 40 birds annually, more attention can be given to quality versus quantity. This included consideration of not releasing heart murmur birds, and special attention be given to genetic management to reduce the loss of heterozygosity.

Increased crane use of off-refuge areas in the last year prompted a number of questions. Are we providing sufficient feeding and roosting habitat? Has the refuge reached carrying capacity? There did seem to be evidence of density dependent mortality near the Ben Williams release site. Although there currently seems to be suitable nesting areas not being used, the expectations of a larger number of breeding age birds in the wild population in the near future due to the successful restocking program highlights the need for a more rapid rate of conversion of pine scrub habitat to suitable savanna. A detailed review of habitat analysis data at the PHVA identified a number of current and potential areas of mesic and hydric savanna suitable for nesting. Habitat management, especially hand and machine clearing and the effective use of prescribed fire, needs to be intensified to meet the needs of the cranes. The response of the cranes to habitat alterations and change in habitat use need to be considered when developing management guidelines.

There is evidence of a parasite problem, particularly at the Ocean Springs release site area. This site has more year-round crane activity than the other two. Larger numbers of birds from the recent release site may be intensifying the problem. More crane activity at current release sites also may be interfering with initiation of nesting at nearby savannas. Additional release sites (Fontainebeau, East Oceans Springs Unit) should be constructed to alleviate the problem and an alternation of sites be instituted. New release site locations should be selected and constructed to help increase crane use of the areas now on the periphery. Although some productive pairs are probably not affected, the lack of nesting activity in some areas may be affected.

At the onset of the PHVA there were concerns and problems regarding the viability and chance for recovery of this subspecies. After this exercise, it appears that most of the important problems i.e. predation and habitat enhancement can be effectively addressed.

Habitat Management Recommendations

1. Verify if the 34 existing nesting areas are actually in immediate need of habitat maintenance treatments.

2. Prioritize management activities by proximity to active or recently inactive nesting areas and ease of restoration.

3. Establish habitat restoration programs for abandoned and potential nesting areas.

4. Locate potential nesting territories on the DeSoto National Forest, the Weber Tract, and Jordan Tract. Encourage partnership with the Forest Service and private landowners in implementing habitat management on these tracts.

5. Evaluate feasibility of establishing an experimental population at Grand Bay NWR and/or other sites within the historical range of the MSC.

6. Determine the levels of manpower and costs required to implement the above listed recommendations.

7. Assess impacts to species recovery if resources are insufficient to improve and maintain required amounts of habitat.

8. Implement research projects to assess:

   a. Effects of altered wetland hydrology on nesting areas.

   b. Effects of increasing population size on nesting success and utilization of foraging, loafing, and roosting habitats.

   c. Other components of reproductive success, including mating, egg viability, and nest success following the provision of suitable habitat.

Predator Management Recommendations

1. Obtain necessary approval for use of leg-hold traps.

2. Concentrate control within:

   a. Half-mile radius of release enclosure several months pre-occupancy and post-release.

   b. Half-mile of active and recently active nesting areas. Consider control for a period beginning one month prior to nesting and continuing for 4 months.

3. Target coyote, bobcat, and possibly great horned owl. Control methods should be carefully scrutinized to avoid incidental take of cranes.

4. Investigate research to radio-tag coyotes.

5. Investigate other state-of-the-art predator management, i.e. removal, exclusion, deterrents, etc.

Health Issue Recommendations

Management Recommendations

1. a. Reassess policy of releasing birds identified as having a heart murmur (transient or persistent).

   b. Make decisions on the disposition of heart murmur affected birds dependent on the management needs of the captive flock, e.g. genetic diversity, surrogate rearers, research birds.

2. a. Continue development and implementation of protocols for captive flock, pre-release, pre-transfer and release pen health screening (especially for DVC and Salmonella).

   b. Move release pens regularly to control build-up of pathogens.

   c. Coccidial infections should be cleared (treated and minimized) from birds before transfer to new captive propagation sites.

3. a. Continue intensive necropsy surveillance of all birds dying in captivity and the wild.

   b. Identify one institution to perform all necropsies or develop a detailed uniform necropsy protocol for all institutions.

   c. Establish a skin/skeleton/tissue/egg bank at the Mississippi Museum of Natural Science, supported by a cooperative agreement between the US Fish and Wildlife Service and the Museum.

Prioritized Research Recommendations

1. Heart Defects/Murmurs:

   a. Quantitative computer analysis of the pedigrees of affected birds to explore the genetic basis.

   b. Explore diagnostic techniques to better define the heart abnormalities present, elucidate the etiology, and develop optimal techniques for early identification of affected chicks.

2. Tumors/Contaminant Exposure:

a. Continue ongoing MSC, wildlife, and environmental biomonitoring and surveillance projects.

b. Feeding/exposure trials with identified potential toxins (polycyclic aromatic hydrocarbons, aflatoxins) to measure tumor induction, liver pathology, mortality, and reproductive depression.

3. Salmonella:

a. Screening of eggs, eggshells, nests and captured birds to determine prevalence of Salmonella species.

b. Virulence testing of the isolated Salmonella serotypes to determine morbidity and mortality for eggs and chicks, and secondarily, effects on fertility.

4. Disseminated Visceral Coccidiosis:

a. Retrospective study of PWRC necropsy records to explore the relationship between release of captive birds and appearance of DVC in the wild flock.

b. Further research on identifying effective coccidiostats (especially if birds remain at PWRC).

5. Fractures:

a. Investigate etiologic factors and treatment strategies.

6. Exteriorized Yolk Sacs:

a. Investigate the pedigrees of affected chicks.

b. Develop a photographic/keyed embryo aging chart.

Recommendation for Captive Flock

Management Recommendations

1. Establish a second captive flock as soon as possible at the Audubon Institute. Develop another captive facility at Noxubee National Wildlife Refuge.

or

Leave half the captive flock at PWRC and move other half to Audubon.

2. Stage the move to minimize loss of production.

3. PWRC would be designated a parent-rearing facility and Audubon a costume- rearing facility.

4. To maintain the wild population at its present level, about 14-20 birds would be need for release annually.

5. Develop protocols for routine health screening and disease detection based upon whooping crane recommendations.

6. Preserve 50 semen samples from each founder line.

7. Establish a second wild flock.

Research Recommendations

1. Need further research in germ plasm banking and preservation of ova, embryos, and tissues.

2. Faster turn-round in genetic identification.

3. Need research on microclimate of wild and captive nests.

4. Develop screening techniques for disease prior to release.

5. Explore feasibility of pairs raising 2 chicks in captivity.

6. Continue research on development of rearing techniques that result in successful breeding in the wild by captive propogated birds.

7. Improve artificial incubation of eggs.

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REPORT

Section 2

HISTORY OF THE POPULATION

Historical Perspective

Jacob M. Valentine,Jr.

My first involvement with the Mississippi sandhill crane was when the Mississippi Game and Fish requested a report from the Fish and Wildlife Service (under the Highway Coordination Act) relating to the effect of the (proposed) construction of Interstate Highway. 10 on the Mississippi sandhill crane. I concluded that there were three dangers to the crane: (1) pine plantations had converted thousands of acres of crane habitat, (2) encroachment of urban and industrial development, (3) I-10 and interchanges would remove land from the range of the crane. Of the three dangers, the first was the worst. I recommended I-10 be routed north of the range of the crane and that a refuge be established.

Due to a proposed crane reintroduction to Louisiana, in 1965 I began collecting eggs for propagation and eventual release. The reintroduction plan for Louisiana was dropped but a plan to transplant young cranes to Mississippi to increase that population and increase (maintain) heterogeneity in the wild flock was initiated. One egg was taken from each two egg clutch and shipped or carried to PWRC or Lynch's aviary (1966-1967).

John Aldrich, FWS taxonomist, described Mississippi sandhill cranes as a distinct subspecies in 1971. *Grus canadensis pulla* was placed on the Federal list of Endangered Species. The Mississippi Sandhill Crane National Wildlife Refuge was established in 1974. In 1975, I was an expert witness in a suit of the National Wildlife Federation versus the highway departments (Federal Highway Administration, Mississippi Highway Department) in District Court. The verdict was in favor of the highway departments. The ruling was appealed by the National Wildlife Federation in August 1975. After a three year inter-departmental dispute over the Gautier-Vancleave interchange, resolution was achieved by an appropriation of approximately one million dollars to acquire land around the interchange and the Gautier-Vancleave Highway.

Biology of Mississippi Sandhill Cranes

Historically, there have been six nesting habitats (118 nests).

Table 1. Nesting habitats on the Mississippi Sandhill Crane NWR

Number	Type	Percentage
11	Savanna	52 %
2	Swamp edge (wet)	18 %
6	Pine plantation (young & open)	13 %
3	Cleared pine savanna	11 %
4	Forest edge	3 %
5	Cleared restored savanna	3 %

Understory of nests was composed of graminoids and forbs with a canopy of pine and pond cypress. Moisture conditions varied among 93 nests in an initial study (1983). Forty-three nests were under dry conditions (46 %), 33 nests were under wet conditions (35 %), 17 nests under moist conditions (18 %).

History

The Mississippi Sandhill Crane was first described, but not published, by Aldo Leopold (1928) and a population of 50 birds or more. McIlheny (1938) and others (Turcotte, 1938, 1939; Walkinshaw 1940-1950's; Valentine et al. to the present) contributed additional natural history information.

Table 2. Territories in use (1966-1993) on the Mississippi Sandhill Crane NWR Active=nests with eggs; Territories=nests with eggs in defended area.

Territory	Past	Active at Present
Gautier	10	4
Ocean Springs	13	5
Off Refuge	4	0

History of Nesting Sites, Breeding Pairs, and Habitats of the Mississippi sandhill crane in Jackson County, Mississippi.

Jacob M. Valentine, Jr.,

Abstract: The history (1965-1993) of 26 combined nesting areas (CNAs) and their habitats are described. Estimated pair numbers peaked in 1969-1971 (19); reduced to 9 in 1979-1981; increased to 11 in 1987. One combined nesting area (CNA) was occupied intermittently during 1965-1986 and another 1966-1987; 1 contained a nest each year for 10 years (1968-1977). Two new pairs established territories in vacant CNAs; 3 pairs found new territories; 1 pair took part of an occupied CNA. In 1987 5 released cranes in 4 pairs nested: 3 with wild cranes and 2 paired together. Habitat management for breeding areas includes of clearing trees by hand, bulldozing, commercial harvest, and prescribed burning. Water conditions were improved by road dams and water control structures.

Nests were located through annual nest searches (1965-1993), mostly on foot, but also by airplane, helicopter, and by radio telemetry. During 1965-1993 a total of 152 active (with eggs or young) nests plus 19 renests have been found within the nesting range in Jackson County, Mississippi. Studies (Valentine and Noble 1970, Valentine 1980, 1981, 1987, and Smith and Valentine 1987), have described breeding habitats, environmental changes, nesting ecology, and habitat management. Released captive-raised cranes and wild cranes were color-marked, radio-tagged, and followed by sight and telemetry (Zwank and Derrickson 1981, Mitchell and Zwank 1984, Dewhurst 1985, Wilson 1987, and Valentine and Logan 1991.).

The hundreds of anonymous people who have searched for nests with me and on their own are thanked; their reward is having participated in an exciting sporting event. Personnel from Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR), Patuxent Wildlife Research Center (PWRC), Louisiana State Univ., Univ. Southwestern Louisiana, Southeastern Louisiana Univ., Mississippi Depart. of Wildlife Conservation, and the International Crane Foundation have provided information and assistance. O. L Valentine edited many drafts; T. J. Logan and J. C. Lewis reviewed the manuscript.

Methods

In 1963 I evaluated the possible effect of the proposed Interstate Highway 10 on the Mississippi sandhill crane and its environment. A plan (1964) to reintroduce sandhill cranes into Louisiana prompted my search in Mississippi for nests in order to collect eggs for captive propagation. The Louisiana plan was postponed, but after the MSCNWR was established, intensive nest searches were continued in order to monitor the breeding population, evaluate the effect of management, and collect eggs from pairs not represented in the PWRC breeding flock.

During 1981-1992 captive-raised Mississippi sandhill cranes (169) were color-marked, banded, radio tagged, and released. Several wild cranes were trapped or captured by night-lighting and netting, and 2 flightless young were caught and marked (Logan and Chandler 1987). Some wild and released cranes were recaptured to replace radio transmitters.

Study Area

All crane nests were found within a triangular block of land, beginning at a point on the western Jackson County line 20 km north of the Gulf of Mexico, then running southeasterly along a diagonal line ending near the mouth of the Pascagoula River, with a southern border 5 km north and parallel to the Gulf. Logan (pers comm) estimated the entire range of the population to be 356 km2. The 7,200 ha MSCNWR is within this area. The refuge is surrounded by forest, urban areas, highways, and small farms.

Results

Nesting Habitats

I have defined 6 nesting habitats: savanna, cleared savanna, pine plantation, cleared pine plantation, swamp edge, and pine forest edge. These types all have a grass, sedge, and forb understory with a sparse to dense canopy of pine, bald cypress, and brush. Land-use, habitat management, degree of overstory cover, soil and surface water, and vegetation are distinguishing features. On initial visits to 93 nests (1965-1983), 43 (46%) were in dry, 17 (18%) in moist, and 33 (35%) in wet sites.

Savanna has been defined as vegetation that is bilayered with tree cover less than 30%. Graminoids are usually predominant, with the herb layer the best developed stratum (Frost et al 1986). Among 118 nests 61 (52%) were found in natural savanna. Most savanna nests were found in normally dry to moist soil situations. Early in the nesting season the ground cover averaged less than 40 cm in height. Four (3%) nests were found in improved savannas which, succeeding to dense tree and brush cover, had been hand-cleared and burned.

Within the nesting range slash pine had been planted on thousands of hectares of savanna. However, growth was slow in the wetter sites and wild fires often thinned the stands. Some pairs nested where the pines were small or scattered. Fifteen (13%) nests were found in pine plantations. Small pine plantations were hand-cleared, but larger pines were bulldozed with little ground disturbance. Savannas were recreated with subsequent prescribed fires. Thirteen (11%) nests were found in this habitat.

Swamp edges have attributes of savanna, but the openings were less than a hectare in size. Water was present except during droughts, and the tree and brush cover may be dense. Twenty-one (18%) nests were found on the edges of swamps. A small portion of the nesting range was in natural pine forest and 4 (3%) nests were found in this habitat.

Histories of Composite Nesting Areas

Ernie Kuyt (1981) coined "composite nesting area" (CNA) to delineate an area where a pair of whooping cranes built nests over a succession of years. In previous papers, I have used "territory" to identify the area where pairs have habitually nested. However, individual territories expand, contract, or otherwise change depending on where the nest is located.

In Mississippi, where the population was small and nesting habitats widely separated, territories were rarely close. Only one pair was resident even in the largest savannas. Where territories were close together (c. 0.8 km) they were separated by dense tree and brush cover. For this paper I have named nesting locales used by individual pairs as CNAs. During 1965-1993, 31 separated sites within 26 CNAs were delineated.

Browns Trail (Gautier Unit)

Before 1960 the Brown's Trail North Savanna was about 1.5 km wide and 3.5 km long and occupied 700 ha. Housing and commercial developments, and US Highway I-10 reduced the available breeding habitat to about 250 ha. Two active nests were found (1966-1967) in an adjacent savanna (NoSav lA) but the pair abandoned the territory after a wild fire coursed through the site. The cranes may have moved to the NoSav lB because the next year the first nest was found there. During 1968-1986 a nest was found each year. In 1990 a nest was found in NoSav 1A after an absence of 22 years.

The wild female (banded #627) of the pair occupying the NoSav lB was seen in summer 1984 when she alone was caring for a half-grown colt. Released crane #636 joined the family as a surrogate parent for some weeks. He was replaced by released male #608, who remained with wild female #627 and the subadult that winter. In 1985 the pair nested, but in December 1985 #608 died. In late winter female #627 joined with wild crane (banded #628) and the 2 nested in 1986. Although they were still mated they did not nest in 1987. If the nests of 1966-1967 (No Sav lA) are included, a pair has nested in this CNA for at least 20 years (17 nests and 1 renest). None nest at present (1993).

The adjacent Brown's Trail South Savanna (BR-2) CNA was occupied concurrently with the NoSav 1-AB from 1966 to 1974 (7 nests and 1 renest; 1 nest was used 3 years in succession). The shortest distance between the two CNA's was 1.2 km and the longest 2.4 km.

No nests were found in SoSav after 1974, except in 1981 when the Ben Williams 4 pair moved in temporarily. Five openings were hand-cleared and burned 1980-1993). Buffer strips of trees and shrubs separate the potential nesting habitats. Part of the Gautier acclimation-release pen is in the savanna.

Ben Williams Swamp (Gautier Unit)

Assisted by others I have found 4 separate nesting sites along the edge of Ben Williams Swamp. Only 1 nest was found in BWS 3 on the west side of the swamp (1965). In 1971-1974 there were 3 CNAs about 0.8 km apart on the eastern edge of BWS. One CNA (BWS 5) was abandoned after 1974, and another (BWS 6) after 1976. During 1966-1993, 18 nests and 3 renests (includes 1 in BWS 6A) were found in CNA BWS 4.

After their nesting site was burned in the winter of 1980, the BWS 4 pair moved 3.0 km to the vacant Brown's Trail SoSav where in 1981 they nested unsuccessfully. They returned in 1982 and 1983 to BWS 4, their original nesting grounds. After losing a chick (PWRC egg switch) in 1982, they renested nearby without success. In 1983, they abandoned their non-viable eggs, then renested in vacant BWS 6 where they hatched a chick from a PWRC switched egg.

In 1984 they nested 2.4 km away from BWS 4 in a cleared pine savanna (BWS 6B), but no nests were found in 1985 or 1986. A wild crane killed by a canine in May 1985 in the nearby I-10 Crop Unit may have been 1 of the BWS 4 pair.

In 1987, a newly formed pair (released HY1982 female #623 x wild male) nested in BWS 4. Their nonviable egg was replaced with a PWRC egg and the pair raised a subadult.

No nests were found in 1988 in BWS 4 but in 1989 #634 (6 yrs) x wild male nested 1.5 km NE of BWS 4 but the eggs were not viable. A renest was not found but the pair and a fledged colt were seen during the October 1989 survey. In 1990 #634 female acquired a new mate (#855). The pair nested in BWS4; laid 2 eggs but deserted the clutch after disturbance in setting up a TV camera. In 1991 the same pair nested in BWS 4 but again deserted the nest. No nests were found in 1992. A nest was found in 1993 but failed.

Vickers (Gautier Unit)

The Vickers CNA is located 4.4 km east of BWS 4 in a 48 ha mesic savanna. A narrow wet sump runs south from a wooded drainage. Six nests were found in the wet site, and 1 in a dry situation during 10 years (1975-1984).

In 1984, the Vickers pair raised a fledged youngster (radioequipped, banded #624) and spent most of the summer and fall 8 km north of their territory. In the fall, the male appeared to neglect his familial duties when he would wander away from the female and juvenile. During the winter of 1984-1985, one parent and #624 roosted with other cranes in the Bluff Creek Marsh.

Telemetry and sightings indicated that subadult #624 and a wild crane, (possibly his mother), spent most of March, April, and May in Vickers. In 1985 2 large nests were found but no eggs were laid. A pair (#922 x unbanded) in 1993 nested and renested and produced a fledgling.

Valentine Savanna (Gautier Unit)

Two CNAs were defined in the Valentine Savanna, an 80 ha pine plantation converted to a mesic savanna. Two ponds were created by raising the elevation of culverts in Valentine Road. CNA Val N was discovered in May 1983 when a pair and 2 chicks were seen along Valentine Road. After the 1984 nesting season a large nest, apparently used that spring, was found. The same nest in 1985 contained eggs and in 1986 another nest with eggs was found 1.0 km south of the 1985 nest.

A newly formed pair (released 5-yr male #623 x wild female) nested near the first pair's 1984-1985 nests in Val N. No nests were found in 1988, but in 1989, the pair nested in an impoundment along Valentine Road where they produced a colt. Two eggs were sent to PWRC in 1991 where 2 juveniles were produced (1 returned to MSCNWR). The pair renested but the 2 eggs were eaten by coyotes. In 1992, 1 egg was sent to PWRC; the other was eaten by a coyote. Nesting in the savanna SE of the pond in 1993, the pair produced a colt which was caught and radio-tagged.

In 1987 the original Val N pair (released #636 x wild), were forced from their territory or voluntarily moved 1.8 km south to the small impoundment (Val S) along Valentine Road (chick on 26 April 1987). The chick died and the pair renested in the pond but the eggs did not hatch. In 1988, the Val S pair nested and produced a chick that died (open umbilicus). The pair nested in 1989 but the 1 egg was destroyed by a predator. One egg laid in 1990 was sent to Patuxent but died. Fledged colts were produced in 1991 and 1992. Eggs were laid in 193, but failed.

Mary Bourne (Fontainebleau Unit)

The Mary Bourne CNA is a 130 ha area of savanna and planted pine. Some of the pine was hand-cleared in the early 1980s. The pair that occupied the Mary Bourne site nested for 10 years and laid eggs each year (1968-1977). Their nearest nesting neighbors (BWS 6) were 4.4 km away. On 5 May 1978 a crane that may have been part of the pair was killed by a vehicle or airplane near the territory. One or 2 cranes have been seen each spring (19781987) in the CNA; inactive nests have been found, but no nests with eggs.

Perigal Swamp (Ocean Springs Unit)

The Perigal Swamp area is a large region consisting of swamp, wooded drainage, pine plantation, and savanna. During 1966-1971 the area held 2 CNAs. Within Per 7A and Per 7B a pair used 2 sites, 1 at the eastern end of the swamp (Per 7A) and another 0.8 km south in an opening in a pine plantation (Per 7B). Nests were found in Per 7A in 1966, 1967, and 1970, and during 1969 and 1971 (same nest). No nests were found in Per 7A-B after 1971, until 1993 when a pair renested here after losing their first clutch in Doubletree.

A pair nested in CNA Per 8A in 1966-1968, but left in 1969 when I-10 Highway right of way was being cleared. A borrow pit excavated for fill for the highway now occupies the former nesting site. The Per 8A pair was the nearest neighbor of Per 7 A-B (1.8 km apart) when they nested concurrently (1966-1969). No nests were found 1969-1971, but during 1972-1973 nests were found 0.8 km north of Per 8A in a small wet opening (Per 8B, now named Blue Hole). No crane activity was observed in Per A-B after 1973 until 1993 when a new pair nested here.

In 1982, a nest used in 1981 was discovered in a St. Regis Company timber clear-cut (Per 14 A, Cottonmouth) when several of us were inspecting the site as a location for the acclimation-release site. In 1982 an active nest was found here, but in 1983 the pair moved 1.2 km west to a small savanna (Per 14 B, Utah) where their first nest failed; the pair renested in a reclaimed savanna 0.8 km SW of Utah, where they nested again in 1984.

In 1984 the Oceans Spring pen was constructed at the St. Regis clear-cut. In 1987, a pair of released cranes (#643 x 644, both 3 years) nested near the pen and laid 2 eggs (not viable); an egg was substituted but the chick died (flooded). Another nest was found near the same site in 1988; a chick was produced but died. No nests were found in the pen area after 1988.

Doubletree Territory, a new nesting site was discovered when a pair consisting of #644 (640?) x wild crane nested in 1989. The nest was in a reclaimed savanna located north of the Doubletree Road. The nest was destroyed by a predator. A new pair formed (#644 and #640) but no eggs were laid. The same pair nested in 1990; 2 eggs were sent to PWRC: 1 egg hatched. No nests were found to present.

In 1985 the pair originating at the St. Regis clear-cut (Per 14 A) nested first in Per 14 B; then renested in Per 14 C (a reclaimed savanna). In 1986 the Per 14 male was caught and radio-tagged (#629) at a roost. During the next two years (1986-1987), the pair nested in Per 14 B and in 1987 in the restored savanna (Per 14 C). On 1 July 1987, while his mate was incubating in 14 C, male #629 was caught again and a new transmitter was attached. The next morning radio-telemetry indicated that #629 was sitting on the nest.

The Mystery Territory was not discovered until an active nest was found in Wet Cell #2 in 1991. An old nest probably used in 1990 was found nearby. Three "wet cells" (impoundments) were constructed to collect run-off from a waste water treatment facility's spray fields. During 4 out of 7 years a chick or fledgling with its parents had been seen but no nests had been found. In 1992, the pond was dry and the surrounding lands had been burned under prescription. No nests were found in 1992 or 1993,

Simms Road (Ocean Springs Unit)

The Simms Road area is a 600 ha tract of forest interspersed by several savanna openings. The area is bounded on 3 sides by roads, including US I-10 on the south. Two nests were found

1.0 km apart in 1967, but only 1 in subsequent years (1968-1969). For several years after 1969, a single crane, apparently without a mate, was seen during the nesting season in the CNA.

Eglin Road (Ocean Springs Unit)

The Eglin Road nesting area (300 ha), located south of US I-10 and Simms Road area, consists of several savannas separated by planted and natural pine forest. During 1969 both Simms Road and Eglin Road (Eg Rd) CNAs held a nest 2.8 km apart. Nests were found during 1969-1972 in Eg Rd; then 4 years passed without nests. A nest was found in 1977 and 1978; a nest and renest in 1981. Just prior to the nesting season of 1983, Eg Rd was burned by a wild fire, but a pair nested in a small unburned section. Altogether 8 nests and 1 renest were found in Eg Rd (1969-1983).

Two cranes (#604 and #619) released from the Gautier pen and a wild crane spent the spring and summer in Eg Rd in 1986. A nest start was found, but no firm pairs were formed.

St. Regis (Ocean Springs)

A crane pair nested in two small wet savannas 400 m apart in the St. Regis CNA. The first nest was found in 1975 in St Reg A. In 1976 I found two small "dummy" nests; in 1978 the area was completely burned. The next active nest was found in 1981 again in St Reg A. In 1982, I found a start nest and other crane sign in the nearby savanna (St Reg B). In 1985 and 1987 active nests were found. The Costapia CNA 2.4 km away was the nearest occupied territory (in 1987).

After the 1987 nesting season, a prescribed fire burned the St. Regis territory and as a consequence no nests were found in 1988. In 1989, the Mystery Chick and his mate nested in the territory but in 1990 he and his mate moved to his natal home (#2 Wetland Cell).

Weber (off MSCNWR)

Weber 19 A-B CNA, located 10 km north of its nearest nesting neighbor (Costapia CNA), is on land owned by International Paper Company (IP) and on the DeSoto National Forest (l9B). During 1977-1978, an active nest was found each year in l9A. No nests were found during the next 6 years. During 1985 IP disked and furrowed most of the 19A savannas. Despite the habitat destruction and disturbance, a pair nested in 1985 in a ponded area too wet to disk. Considering the 6-year nesting hiatus, we may assume the pair was new. The pair lost the first clutch. A second clutch was destroyed by a mammalian predator. In 1986, the pair moved 0.6 km to an open pine plantation (19B) on the DeSoto National Forest, but returned to Web 19A in 1987 where they laid eggs at the site of the 1985 nest. Nest with eggs were found in 1988, 1989, and 1990 (plus 4 renests) in the south savanna pond, but no chicks fledged. The pair disappeared in the winter of 1990-1991.

Fort Bayou Church (off MSCNWR)

Fort Bayou CNA, located in the upper drainage of Costapia Bayou, was a 0.4 ha wet savanna. An old nest was found in 1967 and active nests in 1968 and 1969. In 1970 after several houses were moved in nearby, the pair no longer nested there. Several years later, the savanna was plowed and destroyed as nesting habitat.

Mallette (off MSCNWR)

The Mallette CNA, in School Section 16, owned by the State of Mississippi, is 2.8 km southwest of Fort Bayou CNA. The nesting habitat is a narrow wet savanna situated between low pine covered hills. The savanna had been planted to pine, but wild fires kept the site open.

Cranes frequented the Mallette CNA in the late 1960's but I did not find an active nest until 1978. Another was found in 1979 100 m from the 1978 nest. Two small start nests were found in May 1981, but no active nests. On 12 April 1982, I found a crane carcass, hardly scavenged, but the cause of the death was not determined.

In spring 1982 released crane #602 and a wild male frequented savannas near the Mallette CNA. Two small nests without eggs were found in spring 1983. In August 1983 #602 was found shot and dying near a road adjacent to Mallette CNA.

During the period 1984-1990 the area was searched yearly but no nests were found. The area was leased to a hunting-with-dogs club, fenced and closed to the public - the end of a nesting territory.

Costapia Bayou

Within a few months after female crane #640 was released in 1984 from the Ocean Springs pen she began associating with a wild unmarked crane in lands north of the Ocean Springs Unit. The two remained together from early 1985 until March 1987, when #640 was found in the company of wild radio-tagged #632.

In 1987, the newly formed pair (#640 and #632) nested in a pine plantation 300 m north of a wastewater treatment lagoon. The Costapia CNA is situated in an open pine and savanna complex in the upper reaches of Costapia Bayou.

In 1988 there was a switch in pair partners: wild crane #632 was replaced by a wild unbanded crane. A nest with 2 eggs was located 400 m west of sewage lagoons. The pair did not produce any eggs in 1989 but in 1990 in the same site the pair laid 1 egg that was assumed to have hatched. Again in 1991 the same pair nested (2 eggs, 1 viable) but no chick was found. No nests were found in 1992 or in 1993.

Populations

Crane counts (January and October) are conducted yearly on the whole range. The estimated minimum population in January (1983-1987) has ranged from 32 to 51 birds. The high of 51 may be skewed because it included 15 suspected migrants. During 1981-1986, 31 deaths were known or suspected. Most of the documented deaths were radio-tagged or marked released cranes. Among 45 released during 1981-1986, 26 died or disappeared (Valentine and Logan 1991).

A minimum population of 120 was estimated in January and 109 in October 1992. Among the 109, 21 (19%) were wild-hatched and 88 (81%) were captive-hatched. Fifty-one (47%) were less than 3 years old; 72 (67%) were less than 4. Among 169 juveniles released (1981-1992), 86 died or disappeared. Predation, accidents, and disease account for most of the deaths. An intensive predator control program is in progress (1981- present).

In 1971 when there were 8 known and 7 suspected CNAs, I estimated 16 nesting pairs. Between 1971 and 1979 6 CNA's became vacant. I believe 4 CNA's were lost because of the death of 1 or both mates. The nesting habitat in 2 had either been destroyed or overgrown, but only 1 pair moved to another site.

During 1979-1981, there were 6 active and 3 probable CNAs and possibly 9 breeding pairs. Between 1981 and 1987 3 CNA's (Vickers, Mallettes, and Eglin Road) were vacant. BWS 4 was vacant for 2 years (1985-1986), then was occupied by a new pair in 1987.

Six new pairs formed and nested between 1981 and 1987 (BWS 4, Val N, Val S, Mystery, Per 14A, and Costapia). Two pairs occupied formerly used CNAs and 4 pairs created new territories. In 1987, each of 4 pairs was composed of a released crane with a wild crane (BWS 4, Val S, Val N, and Costapia). Two released cranes formed another pair (Per 14A, OS pen).

In 1987, there were 9 active CNA's. The nest site of the Mystery pair, discovered in 1984 by the presence of chicks (also 1986, 1987, and 1990), was not found until 1991. Two pairs nested in formerly used territories; a pair usurped part of a wild pair's active CNA; and 1 pair occupied a site not previously used.

The largest number of pairs nesting in one year was 9 (1987, 1990); 8 in 1989 and 1993. In 1993, 15 former territory sites have been vacant for 5 or more years. Three territories, vacant for 8 or more years, were occupied by new pairs; and one new territory site was used.

Discussion and Conclusions

Kuyt (1981) reported that whooping crane territories become vacant only if both adults disappeared simultaneously because the survivor would soon remate. Nesbitt and Wenner (1987) found that Florida crane males having lost their mates quickly acquired females, but females took much longer to find a mate. In Mississippi one female with a chick soon regained a new mate and nested the next season in her territory. We do not know the history of many wild (unbanded) cranes, but most released cranes who mated with wild birds were females. Novice pairs exchanged partners, but not nearly as often as Nesbitt and Wenner (1987) found in Florida.

In the recent past in Mississippi when a breeder died there often was not another of breeding age to replace the lost mate. Nonbreeder flocks are the norm in sandhill crane populations throughout North America, but such groups did not exist in Mississippi until the release program had been underway for several years.

We did not always find nests each year in CNAs considered active. Nest searches are intensive, particularly in areas where pairs are territorial, and few nests are overlooked. At times, the pair may have been broken up or the site has been deserted. For example, nests were found in BWS 4 in 1966, 1969, and 1971; then during the next 20 years (1974 to 1993) a pair nested 16 times. For 2 years (1985-1986) the territory was not occupied; then in 1987 a newly formed pair nested. A BWS 4 pair (with changes in spouses) had temporarily nested in nearby vacant territory sites. After BWS burned, the pair nested one season in Br Tr 2 (3.2 km away). In 1982, they renested in BWS 6 (1.8 km away). After a nest failure in BWS 4 (1983), the pair renested in a cleared savanna 2.4 km away, but returned the next year to BWS 4.

Nests were found in 1977-1979 in Weber CNA; then 6 years passed before the next nest was found (1985). During 1985-1990, the pair nested each year. The site was not occupied during 1991-1993.

Territories with irregular use may imply the loss of one or both spouses and later occupancy by a new pair. Territories may be inherited by the surviving mate and a new spouse and handed down from one generation to the next. Walkinshaw (1960) found 2 nests in BWS 4 in 1940 and one in 1960. During 53 years, pairs have nested there off and on, certainly not the same individuals, and probably not of the same lineage. Newly formed pairs occupy vacant nesting habitats when a population is expanding, but in Mississippi this did not happen until 1987 when released cranes started breeding.

During the early 1980's, the breeding population was stable averaging only 5 pairs. When a population is expanding, newly formed pairs usually occupy vacant territories. In Mississippi, this did not happen until released cranes began breeding. Among 6 new territories established between 1984 and 1993, 5 were taken by pairs that had at least one released crane spouse. In 1993, 3 territories were reoccupied after long vacancies; 8 years after Vickers was abandoned, a released crane and its mate nested. A pair nested in Perigal 8A 24 years after it was deserted (1973). Unused since 1973, Perigal 8B (Blue Hole) was reoccupied 29 years later. A pair nested in a new site (Glendale 26) also in 1993.

Fourteen former territory sites have been vacant from 7 to 27 years; 2 others from 3 to 4 years. The nesting habitats of 2 sites (off refuge) were destroyed; the other 14 with environmental maintenance are in good condition. Six among the 16 are on the fringe of the nesting range where the pairs may have been killed or where disturbance was present. Released birds tend to nest within a few miles from the acclimation pens. Pens will have to be built in areas not now occupied if released cranes are to be induced to nest. With the large number of released cranes coming into breeding age in the next few years, preparing new nesting sites and improving vacant sites should have high priority in the refuge's work schedule.

Although encouraging, the initiation of breeding among the released cranes points out the need for increased production of young at PWRC. Since 1980, eggs have been collected for captive propagation only from territories not represented in the PWRC gene pool. I recommend that a single egg should be taken from all or most 2-egg clutches (provided both are viable), incubated at PWRC, and the juveniles returned to the refuge for release.

Nesbitt and Wenner (1987) found that among 4 novice Florida pairs who incubated eggs but failed to fledged young, 3 of those separated after the breeding season. If nonviable eggs are replaced with PWRC eggs a young pair may be given the experience of hatching and rearing a chick. This did happen in a 1987 egg switch when a released crane, nesting for the first time with a wild crane, raised a chick to subadulthood. In the wild when one nest has two viable eggs and another nest has only dead eggs, a viable egg can be switched.

Nesting Habitat Management

Savannas succeeding into forest and brushland were hand cleared by MSCNWR crews. Some clearings were nesting sites and others had potential as nesting habitat. Young pine plantations used by cranes as nesting sites were also hand-cleared. Strips of brush and trees were left to separate potential territories.

In the late 1970's there were 1,200 ha of marketable pine on the refuge. Most of this timber is being sold, cut for pulpwood, and the lands converted to savanna. Noncommercial pine plantations on the MCNWR were bulldozed in 1980-1981. These reclaimed savannas are now used as nesting and feeding sites.

Jackson County Land Treatment Facility cleared 140 ha of the Ocean Springs Unit. In 1986 the tract was converted to wastewater sprayfields and planted to hay grasses. Three "wetland cells" (total 5 ha) were constructed to collect percolate water from the sprayfields. The ponds are used for feeding and roosting and in 1991 an active nest was found.

During severe spring droughts the nesting sites may be devoid of water. Adults can fly to water, but the chicks may suffer so small dugouts have been scooped by bulldozers on the edges of territories and small impoundments have been made by using roads as dams at small drains. The latter have been used as roosts and nesting sites.

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MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Section 3

HABITAT REQUIREMENTS AND MANAGEMENT

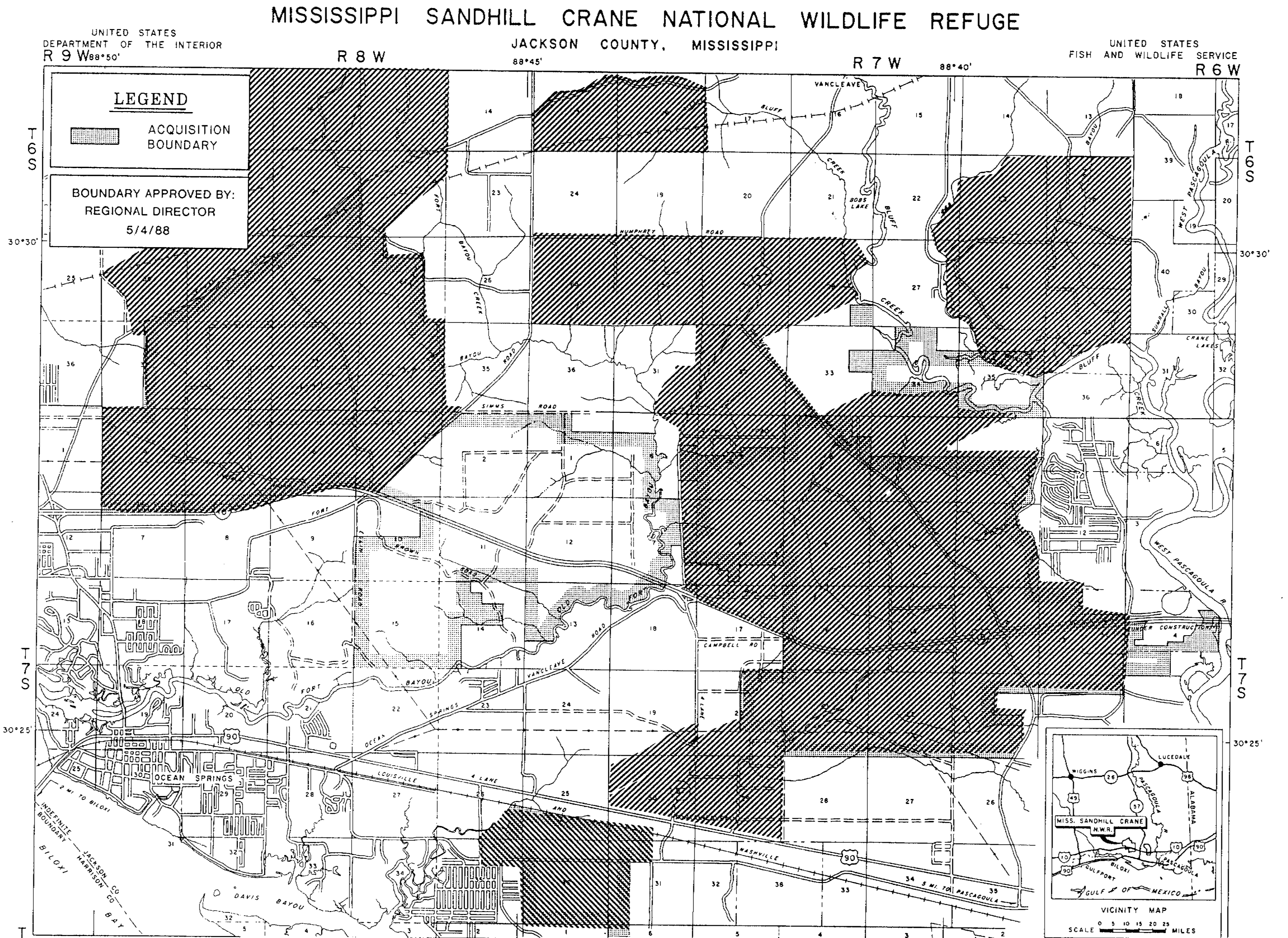


Figure 1. Current documented range of the Mississippi sandhill crane in Jackson County, Mississippi.

Habitat Requirements and Management

(Prepared by: Dwight Cooley, Joe Hardy, Jim Lewis, Will McDearman, Bob Strader, Jake Valentine, Tony Wilder.)

Summary

Mesic to hydric savannas provide important nesting area and territories for Mississippi sandhill cranes. Mesic savannas have been destroyed and fragmented throughout the coastal plain. Nesting areas and territories for the MSHC population are essentially restricted to the MSHC Refuge, and may limit population growth and viability depending upon Refuge population carrying capacity and demographics. Thirty-four existing, available nesting territories were identified on the Refuge. Another 19 areas were identified for future addition by ecological restoration of habitat. Though a total of 53 areas can exist at nesting area capacity, annual availability of sites will vary depending upon habitat management factors. Approximately 26 sites will be available on an average annual basis for nesting. Actual number of nest areas and territories annual available may be greater depending upon crane usage, in which case prescribed fire and other management methods will be suspended at the site.

Background

The decline of the Mississippi Sandhill Crane (MSC) is related to the loss of critical habitat - mesic and hydric pine savanna. Formerly common on low, coastal Pleistocene terraces, mesic savanna was a regionally important palustrine component of the landscape which consisted of several wetland types, juxtaposed according to soils, hydrology and fire history.

Mesic pine savannas are fire maintained wetland communities with a sparse and open overstory of slash and/or longleaf pine above a species rich ground layer dominated by sedges, grasses and members of the aster family. Savannas are successionally regulated by the ecological interactions between fire frequency/intensity and soils/hydrology. Without fire, savannas succeed to various other woody, forested communities, the composition of which is related to soils and hydroperiod. In general, savannas occupy sites on an ecological gradient with intermediate hydroperiods and fire frequencies, and sites on a topographic gradient between low, intermittent or perennial drainage ways and, where they occur on coastal terraces, elevated ridges and uplands. As soil hydroperiod increases, natural fire frequency declines, and vegetation types shift from savanna to other palustrine community types dominated by woody species such as titi, sweetbay magnolia, pond cypress, and water tupelo. These communities are typically located in intermittent drainages which bisect or border mesic savanna. As soil hydroperiod declines and fire frequency increases, mesic savannas are replaced by upland communities dominated by longleaf pine and yaupon holly. These communities are typically located on ridges and uplands, where they exist, adjacent to mesic savanna.

Intensive silvicultural practices, wetland drainage, urban and industrial development have altered hydrology and excluded fire. As a result, mesic pine savanna has either been directly destroyed or ecologically modified to one of several different forest types. Approximately 75% of the mesic coastal pine savanna in Mississippi has been lost, the remainder of which exists as highly fragmented remnants amid other land uses and habitat types.

Mesic and hydric pine savannas are vital habitat components for the MSHC. The MSHC nesting population is currently essentially restricted the MSHC National Wildlife Refuge (NWR). Elsewhere, the only other large tract of remnant savanna is located in southeastern Jackson County, on the proposed Grand Bay National Wildlife Refuge, a potential site for the introduction of a second population.

Habitat management on the MSHC NWR is required in order to provide essential nesting, foraging and roosting components which may limit population growth and viability. Management methods range from those required to maintain existing savanna to those needed to restore and reestablish savanna from slash pine plantations and other woodlands which have replaced former savanna.

The Habitat Team addressed habitat availability as a critical limiting population factor. The Habitat Team evaluated the current availability of nesting and foraging habitat (savanna), estimated the future rate at which additional nesting territories can be added as a result of management, and estimated the carrying capacity of the MSHC NWR. The Team defined carrying capacity, for management and modeling purposes, as the maximum number of nesting areas which could be made available on the Refuge.

Definition of Terms

Nesting area = a nesting site, often mesic or hydric savanna, usually 1 acre or more in size, with few trees, few large shrubs, with low graminoid understory on wet to moist soils, and surface water less than 15 inches in depth present throughout the nesting season..

Nesting territory = an area defended and utilized pre- and post-nesting for foraging and to fledge young, which encompasses the nesting area. Nesting territories are typically mesic savanna.

Procedure

1. Estimate number of currently available nest sites on Refuge.

Using historical nesting records, nesting area descriptions, and personal knowledge of suitable habitat types, high altitude aerial infrared photography (NHAP) was interpreted for signatures of mesic and wet savanna. Each locality was marked on the map (Figure 1.) A total of 34 existing, suitable nesting areas were identified; 19 on the Gautier Unit, 12 on the Ocean Springs Unit, and 3 on the Fontainebleau Unit.

2. Estimate number of nesting areas potentially available on an annual basis.

Nesting areas and territories require management in order to control and prevent natural, woody plant succession which would revert mesic and hydric savanna to other vegetation types. Nesting area management will require the use of prescribed fire and hand-chopping woody vegetation. Fire, by removing and reducing plant litter used for constructing nests, will essentially create an unsuitable nesting site for two years; the first year of the fire when little to no litter will be available, and most likely the second year during regrowth. The Team estimated that, on average, suitable nesting sites will require a fire frequency interval of no greater than once every five years to maintain suitable habitat. On a five-year fire rotation (prescribed fire on one-fifth of the 34 nesting areas annually), a minimum of 20 of the 34 potential nesting areas will be suitable and available on an annual basis following the first year of the fire management program (Table 3). More than 20 areas could be annually available since the actual frequency of prescribed fire would be dictated by crane usage. For example, as long as a nesting area is in use, fire will not be prescribed. If an active area is abandoned or not used, fire will be prescribed. Inactive areas will be burned on a five-year rotation until otherwise used as a nesting area.

3. Estimate the number of additional nesting areas that can be included on the Refuge as a result of habitat restoration.

Using high altitude infrared photography, a land cover class map of the Refuge, and knowledge of Refuge habitat types - additional potential nesting areas were identified on the basis of vegetation, vegetation/habitat response to management, and proximity to existing nesting areas and territories (existing savannas). As a result, 19 additional sites were identified. Most of these are currently slash-pine scrub areas; moist to wet sites with dense coverage and stocking of stunted or small slash pine, planted on former savanna sites during the 1950's, with a history of fire exclusion or reduced fire frequency prior to refuge establishment, which has resulted in woody succession with moderate to heavy understories of bitter gallberry, gallberry and titi. Composition and structure of the plant community can vary depending fire history and hydrology. Restoration management methods employed will depend upon site-specific characteristics. Factors to be considered will include the distribution and loading of fuels for fire, predicted future fuel characteristics required to continue a prescribed fire management program to reduce woody plant encroachment and to stimulate herbaceous plant growth. Restoration methods include commercial timber harvest, hand-felling and or bulldozing trees, drum roller chopping to reduce large woody fuels, and prescribed, intense fire during the growing season to control recruitment and growth of woody plants.

Fire frequencies required to control encroachment by woody plants will likely be greater than frequencies required to maintain existing savanna. It is difficult to accurately predict actual frequencies since the restoration program will depend upon many site specific factors. Generally, a prescribed fire once every three years can be foreseen as reasonably expected for upwards to three or four fire cycles.

4. Estimate rate at which additional nesting areas can be made available.

Based on current management duties and manpower, all 19 additional sites can be added at the end of four years, at a maximum rate of 5 sites added per year. The combined effects of this implementation schedule and the anticipated 3-year fire frequency create annual variation on the number of additional nesting sites available for use (Table 4). During the first two years of a management decade, no additional sites are available even though 10 sites have received the first management treatment. By the third year, five sites are available. Scheduling effects create a range from 5 to 9 sites available on an annual basis.

5. Estimate carrying capacity of Refuge, based on minimum estimates.

A total of 53 nesting areas were identified on the Refuge at nesting area carrying capacity. The effects of management implementation schedule and the effects of prescribed fire frequency create annual variation in the number of estimated nesting areas available, which range from a low of 20 to a high of 30 sites available per year (Table 5). These estimates are conservative, since any active nesting area will not be burned until the site is abandoned or not used during one annual period. Consequently, the actual number of available sites can exceed that estimated. Furthermore, annual projections will vary depending upon modification of management treatments in response to nest area occupancy and/or abandonment.

Related Factors

1. The estimated Refuge nesting area carrying capacity assumes that all identified nesting areas and territories will actually be utilized. Other factors may interact to limit actual nesting, particularly inter- and intrasexual territorial behavior in response to increasing population size. Habitat available for foraging and roosting for juveniles and non-breeding adults may limit nesting if these portions of the crane population must utilize nesting areas and territories. Thus, density dependent and habitat effects must be carefully monitored as the population increases in order to maximize refuge utilization.

2. Site fidelity and the lack of frequent, long distance exploratory movements by cranes indicates that nesting areas to be added by restoration should be prioritized according to their proximity to active or recently abandoned nesting territories.

3. Nesting densities in an area (Composite Nesting Area) can potentially be increased by maintaining or creating natural buffers, particularly along drainages.

4. Though standing water is an important factor in the use of nesting areas, the effects of wetland drainage and altered hydrology are poorly understood. Local ponding during seasonal wet periods which generally coincide with nesting should be monitored and evaluated in comparison to nesting success. Refuge maps depicting the location, and size of ditches and drains should be created as a basis for further research, management, and decision making. Other maps should be prepared which show changes in drainage patterns off of the refuge both above and down drain from the refuge. Observations should be made which indicate how quickly ponded water drains from once successful nesting areas and an attempt should be made to determine if off refuge drainage projects have altered drainage patterns on the refuge. Plans should be developed to block drainages in an inactive or unused but potential nesting area to evaluate hydrologic effects on seasonal depth to water table and local ponding. Hydrologists with the Soil Conservation Service should be contacted for assistance with evaluating hydrologic effects of altered and restored drainages.

5. For nesting areas to be established by restoration, the anticipated fire frequencies required to initially establish a site and the implementation schedule effectively limits the availability of a site to once in every five years (Table 4) during the first management decade. The availability of any unused nest area can be increased to consecutive years as the interval between prescribed fire increases. Changing the number of areas treated on an annual basis will also change the total number of nest areas available during any given period. For example, instead of implementing five sites per year (Table 4), an alternative schedule implementing 10 sites the first year, followed by the remaining 9 sites during the second year will increase the total number to nine sites available during one year (Table 6). However, no sites would be potentially available during some alternate years, assuming nests were not established, in which case the use prescribed fire would be immediately suspended. Depending upon population size and the anticipated need for nesting sites, the implementation schedule can be varied according to limiting factors and management priorities with different effects.

6. Possible problems in achieving the implementation schedule for making available additional sites include unpredictable rain events and difficulties in restoring sites due to the presence of higher quantities of woody vegetation and reduced amounts of herbaceous plants which would maintain a frequent fire regime. In order to restore these more difficult sites, more than one treatment year may be required to bring the area or territory back to a natural condition which would support nesting activity and a more normal fire regime. This will necessarily reduce the number of additional sites that will become available in the later years of the restoration decades. In order to insure that the required number of nesting areas can be added annually, restoration of more than the projected number of areas needed in the first half of the decade must be attempted. This will require beginning restoration of the more difficult sites, those that will require more than one prescribed fire to reduce woody vegetation and encourage the establishment of more desirable herbaceous vegetation, at least three years prior to the year they are scheduled to be available. This strategy will tax the current available refuge resources

for this type of work and will require specific funding for increases in manpower and equipment to perform accelerated rates of habitat improvement. Habitat improvement work must necessarily be done during dry periods when there is severe competition for resources to accomplish other refuge objectives such as moving of release pens, maintaining roads for telemetry operations, discing or mowing of crop units and performing certain non-refuge tasks such as partner projects and FHA and other farm bill activities. The types of activities needed to be accelerated are timber sale preparation and administration, preparation and administration of hand clearing contracts, increase in the number of roller-drum choppers and shearing machines in operation during the dry season and increase in the number of growing season prescribed fires that are attempted. Implementation costs and other requirements should be evaluated in relation to the accomplishment of nesting area management objectives. Where insufficient resources exist, effects of limited management activities should be evaluated in regard to the number of nesting areas available, population size, population stability, and estimated time to extinction.

7. The MSC population can possibly be increased by expanding to other land areas within a ten air mile range of the MSCNWR. These areas include Grand Bay NWR, the Jordan Tract, the Webber Tract and the Biloxi Ranger District of the DeSoto National Forest (Table 5) and (Figure 2). Approximately 19 additional nesting areas can be added on these lands. Potential nesting sites on non-public lands are very rare and declining in both quantity and quality as each year passes.

The Grand Bay National Wildlife Refuge is currently in the initial phases of acquisition. Approximately 90% of the Refuge lands are anticipated to be acquired within the next three years. One of the largest tracts of savanna remaining in the Gulf Coastal Plain occurs on Grand Bay, and occupies approximately 1/3 of the 12,350 acres targeted for acquisition. None of these lands were converted to slash pine plantations in the 1950's. Consequently, habitat management and restoration will be less difficult than that on the MSHC NWR.

Additional nesting areas can be established on the DeSoto National Forest. Initial planning can be based on the U.S. Forest Service Action Plan for Mississippi Sandhill Crane Management, Biloxi Ranger District (January 22, 1981).

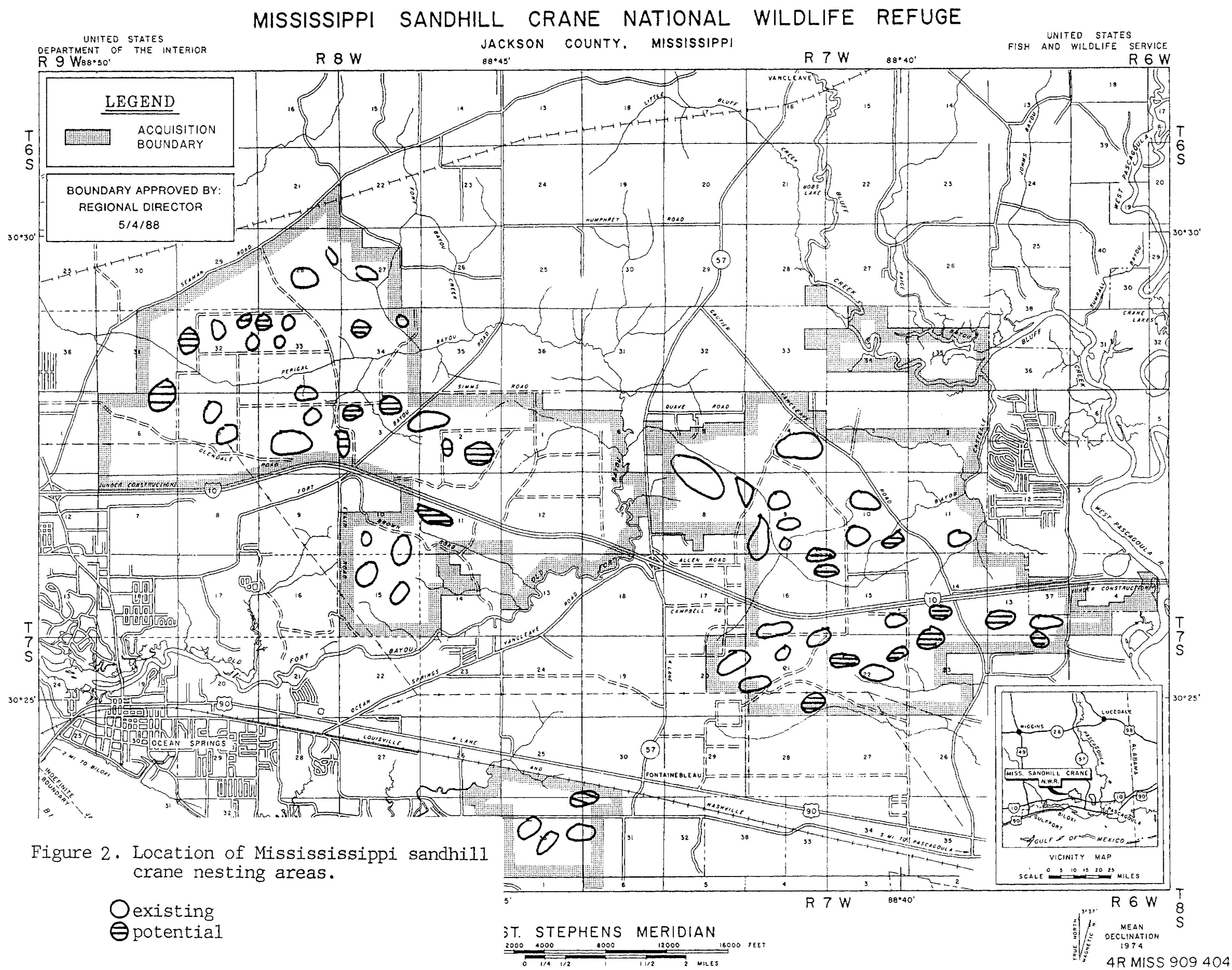


Figure 2. Location of Mississississippi sandhill crane nesting areas.

○existing
⊖potential

Table 3. Availability of existing suitable nesting areas based on five year prescribed fire rotation. F=Prescribed fire, NA=site not available during year following fire due to litter reduction and low availability of nest building materials.

Sites	Site Availability by Year of Fire									
	1	2	3	4	5	6	7	8	9	10
1 - 7	F	NA	A	A	A	F	NA	A	A	A
8 - 14	A	F	NA	A	A	A	F	NA	A	A
15 - 21	A	A	F	NA	A	A	A	F	NA	A
22 - 28	A	A	A	F	NA	A	A	A	F	NA
29 - 34	A	A	A	A	F	NA	A	A	A	F
Total Number of Available Nest Sites	27	20	20	20	21	21	20	20	20	21

Table 4. Availability of additional nesting areas to be established based on estimated average three year prescribed fire frequency, as required to restore sites to suitable habitat. Five sites will be established on an annual basis, i.e. a total of five sites will receive a first restoration treatment each year, until all 19 sites have been "established" at the end of four years. Actual fire frequency may vary due to habitat response. *=Site not scheduled for first restoration treatment, F=Prescribed fire, NA=site not available during year following fire due to litter reduction and low availability of nest building materials.

	Site Availability by Management Year									
Sites	1	2	3	4	5	6	7	8	9	10
1 - 5	F	NA	A	F	NA	A	F	NA	A	F
6 - 10	*	F	NA	A	F	NA	A	F	NA	A
11 - 15		*	*	F	NA	A	F	NA	A	FNA
16 - 19		*	*	*	F	NA	A	F	NA	AF
Total number of available nest sites	0	0	5	5	5	9	5	5	9	5

Table 5. Total estimated number of available nest areas, including existing areas and additional areas established, by management year, to reach Refuge carrying capacity, over the first decade.

	Year									
Nesting Area Type	1	2	3	4	5	6	7	8	9	10
Existing	27	20	20	20	21	21	20	20	20	21
Additional Established	0	0	5	5	5	9	5	5	9	5
TOTAL NEST AREAS	27	20	25	25	26	30	25	25	29	26

Table 6. Effect of alternative implementation schedule on the availability of nesting areas to be established based on estimated average three year prescribed fire frequency, as required to restore sites to suitable habitat. 10 sites will receive the first management treatment during the first year, followed by 9 sites during the second year. Actual fire frequency may vary due to habitat response. *=Site not scheduled for first restoration treatment, F=Prescribed fire, NA=site not available during year following fire due to litter reduction and low availability of nest building materials.

Sites	Site Availability by Management Year									
	1	2	3	4	5	6	7	8	9	10
1 - 10	F	NA	A	F	NA	A	F	NA	A	F
11 - 19		*	F	NA	A	F	NA	A	F	NAA
Total number of available nest sites	0	0	10	9	0	10	9	0	10	9

Table 7. Number of potential nesting sites on non refuge lands which could be available at some point in the future.

Location	Ownership	Number of Potential Nests
Grand Bay NWR	USFWS	10
Jordan Tract	Naif Jordan	3
DeSoto NF	USFWS	5
Webber Tract	Inter. Paper Co.	1
Totals		19

Table 8. Distribution of refuge lands by habitat type and land use on the Ocean Springs, Gautier and Fountainbleau Units(*).

Habitat Type/ Land Use	Gautier	Ocean Springs	Fntnbleau.	Totals
		Acres		
Savanna	2496	1430	183	4109
Pine Scrub	1502	1976	335	3813
Pine Forest	2293	3860	519	6672
Swamp	1664	1251	134	3049
Sprayfield	----	300	----	300
Crop Units	90	40	----	130
Wet Cells	----	65	----	65
Pasture	50	----	----	50
Roads	71	100	15	186
Administr.	162	----	----	162
Fire Breaks	116	97	29	242
Totals	8444	9119	1215	18778

* These acres do not include the Dees Tract or small outlying parcels not contiguous with the three main refuge units.

Recommendations

1. Field evaluate and verify that the 34 nesting areas classified as "existing" and available without restoration management do not actually require immediate habitat maintenance treatments - particularly for inactive nesting areas and territories. Prioritize survey and management strategies to ensure that nest areas are available in proximity to active or recently inactive nest areas. Other inactive areas mistakenly considered as "existing", which actually need management should receive immediate treatments, because these are most likely to respond quickly to restoration efforts, in comparison to other, ecologically more difficult restoration sites.

2. Establish habitat restoration program for the additional 19 nesting territories.

3. Maintain predator control program, using snares, steel, traps, etc. as appropriate to reduce nest predation. Concentrate control in 1) one-half mile radius of release enclosure several months pre occupancy and post-release of captive produced cranes, and 2) within one-half mile of active and recently active nesting areas. Target predators should include coyote, bobcat, and possibly great-horned owl. Consider predator control for a period beginning one month prior to nesting and continuing for 4 months. Control methods should be carefully scrutinized in order to avoid an incidental taking of cranes.

4. Concurrent with nesting area/territory management and restoration, implement research to assess:

A. Effects of altered wetland hydrology on seasonal water levels generally required for good nesting areas,

B. density dependent effects of increasing population size on nesting success and utilization of foraging, loafing and roosting habitats - with the use of telemetry and other methods,

C. other components of reproductive success following the provision of suitable nesting areas, including mating, incubation, egg fertility, hatching success and fledgling success.

5. Identify suitable nesting areas and territories on Grand Bay NWR, DeSoto National Forest, the Webber Tract and the Jordan Tract. Implement habitat maintenance and restoration. Evaluate feasibility of establishing second population at Grand Bay, assess demographic effects of the new population to recovery and viability.

6. Plan and evaluate manpower and costs required to accomplish the above recommendations. Assess impacts to recovery if resources are insufficient for habitat management and restoration programs.

MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Section 4

RELEASE PROGRAMS

Release Programs
Scott Hereford

To augment the endangered Mississippi sandhill crane population, juvenile cranes captive-reared at the Patuxent Wildlife Research Center were released on the refuge starting in early 1981. Releases have continued annually since then. The release program has been described in more detail elsewhere (Zwank and Derrickson 1982, Mitchell and Zwank 1986, Valentine and Logan 1988). The captive flock at Patuxent resulted from viable eggs removed from Mississippi nests in the 1960's and '70s.

The important techniques found to be responsible for success have been the development of a social bond among individuals in the release group and the role of the older birds in "teaching" the new arrivals. Some of these improvements were discovered by trial and error as differences in survival among the different release years indicates, especially early in the program (Table 9). Juveniles are placed together in socialization pens at Patuxent a month before shipment to the refuge where they form attachments necessary for survival in the wild. Just before transfer, a plastic temporary wing-restraint is placed on each bird. The restraint is left on for the first month after transfer so the birds are forced to remain in the release pen during that time allowing them to slowly acclimate to their new environment and enabling social interaction with older free-flying birds attracted to the provided feed as well as the new cranes. The brails are removed after a month and the birds can come and go from the release pen as they wish. Pelleted crane feed and corn is provided for them as long as they seem to be depending on it, usually 2-4 months.

Most of the juveniles released before late 1989, except for 1982, were parent-reared as hand-reared birds had not been suitable for release. Hand-rearing has some advantages, however, and methods were devised to produce such birds for release beginning in late 1989. More egg-producing females, enhanced techniques for parent-reared chick survival and the addition of hand-reared birds resulted in a 3-fold increase in release size (Table 9). The hand-reared birds are surviving as well or better than the parent-reared birds.

The release program has become one of the most successful parts of the recovery effort. The captive-bred birds have incorporated themselves into the free-flying population and now comprise 80% of the population. Overall first year survival is 70% (Table 10). Adult survival (>4y) is 91.3%. A Patuxent bird was first involved in a nest attempt in 1985 and in a successful nest attempt in 1987. Patuxent birds now are one or both member of 60% of known breeding pairs. Hand-reared birds have been observed in new pair bonds.

Table 9. First year post-release survival by release group.

Release Year	No. Released	Number Survived First Year	% Survival
1981	9	7	78
1982	5	0	0
1983	7	5	71
1984	4	4	100
1985	10	5	50
1986	7	3	43
1987	3	1	67
1988	9	7	78
1989	13	10	77
1990	29	25	86
1991	36	28	78
1992	35	21**	60**

**by September

Table 10. Mortality by year post release (to Sept 1992)

Year post release	No. Cranes starting year	No. Deaths during year	% Mortality
0-1	169	51	30.1
1-2	96	11	11.4
2-3	61	8	13.1
3-4	29	5	17.2
>4 (Adult)	69	6	8.7

Table 11. Fate of release birds to September 1992. (see Fig 3)

Release Date	Number	Comments
Jan 1981	9	**0 survived of release group to 09/92** 601 last seen 04-84 602 shot north of refuge 10-83 603 died of trauma 10-83 604 died of tumor 1-87 605 died 11-81 of unknown causes 606 died 10-87 of " " 607 last seen 5-83 608 died 12-85 of internal hem. 609 last seen 05-92

604 was paired with wild mate in 1986. 606 was paired with 623 in 1986. 608 paired with wild mate in first nest attempt (unsuccessful, 1985) by captive-produced bird.

Release Date	Number	Comments
Feb 1982	5	**0 survived of release group to 09/92** 610 died of predation 4-82 611 killed by vehicle 4-82 612 "tame", back to PWRC 7-82 613 died parasites 4-82 614 died of predation(?) 5-92
Oct 1982	7	**3 survived of release group to 09/92** 615 died 2-83 of trauma, parasites 618 last seen 12-82 620 last seen 12-87 621 died of tumor 4-86

616 male paired briefly with wild female 627, later with 912. 623 paired with 606 in 1986, and wild female since 1987 nesting then and fledging two chicks since becoming one of the most consistent and successful pairs.

Release Date	Number	Comments
Dec 1983	4	**3 survived of release group to 09/92** 635 died 7-87 of unknown causes

634 nested with unbanded male in 1987-9 fledging chicks in 1987 (PWRC egg) and 1989, re-paired with 855 in 1990 and 1991 unsuccessful nest attempts. 636 paired and has nested with wild female since 1988(?) and have fledged 3 chicks in 5 years, making them the most successful pair in the population.

Release Date	Number	Comments
Dec 1984	10	**4 survived of release group to 09/92** 638 died of predation 7-85 639 died of predation 1-85 641 last seen 4-91

		646 killed 11-85 by coyote getter
		647 died of predation 7-85
		648 died of predation 7-85

All four survivors have been involved in nest attempts. 640 paired with wild male in 1986, then began nesting in 1987 with wild male 632 producing viable egg that was predated. She then paired and nested unsuccessfully with wild male in 1989, then re-paired and has remained so with 644, nesting unsuccessfully in 1990. 641 and unknown female hatched chick in 1989. 642 nested unsuccessfully with wild female in 1990 and 1991. 643 female nested successfully (hatched chick) with 644 in 1987 (PWRC egg) and 1988, then she re-paired with wild male and nested in successfully in 1990 and 1991.

Dec 1985	7	**1 survived of release group to 09/92**
		851 died of predation 6-86
		852 died 1-89 of unknown causes
		853 died of predation 12-85
		854 died of predation 8-86
		856 last seen 6-86
		857 died 11-87 of capture myopathy

855 paired and nested unsuccessfully with 634 in 1990 and 1991.

Dec 1986	3	**0 survived of release group to 09/92**
		861 Died 1-88 of trauma
		862 last seen 2-87
		863 unable to fly, 1-87 back to PWRC
Dec 1987	9	**3 survived of release group to 09/92**
		873 last seen 7-90
		875 last seen 4-90
		876 presumed dead 8-90 of unk. cause
		877 last seen 7-88
		878 last seen 2-88
		879 last seen 6-91

872 has been paired with large wild male since 1991 but have not nested.

Dec 1988	13	**4 survived of release group to 09/92**
		881 died 12-89 of trauma
		882 died 7-90 of unknown causes
		886 died 2-89 of emaciation
		887 last seen 7-88
		888 died 6-90 of unknown causes
		889 last seen 10-89
		8811 last seen 4-90
		8812 last seen 2-89
		8813 last seen 4-90

880 formed pair bond with 927 in late 1992.

Dec 1989 29 **21 survived of release group to 09/92**

91 last seen 4-91
92 died 1-90 of unknown causes
93 died 12-89 of predation
94 died 3-90 of trauma
97 last seen 6-90
98 last seen 12-90
99 died of predation 2-91
915 died 7-90 of trauma

912 paired with 616 in 1992. 922 paired with wild female in 1992. 927 female formed pair bond with 880 in late 1992.

Dec 1990 36 **28 survived of release group to 09/92**

08 died 3-92 of asphyxiation
013 died 11-90 of trauma, pre-release
015 died 1-91 of trauma, pre-release
020 last seen 1-91
021 last seen 2-91
028 died 2-91 of trauma
033 died 6-91 of predation(?)
034 died 3-92 of trauma
036 died 12-91 of predation(?)
041 died 6-91 of enteritis

038 male had formed weak pair bond with 931 by late 1992.

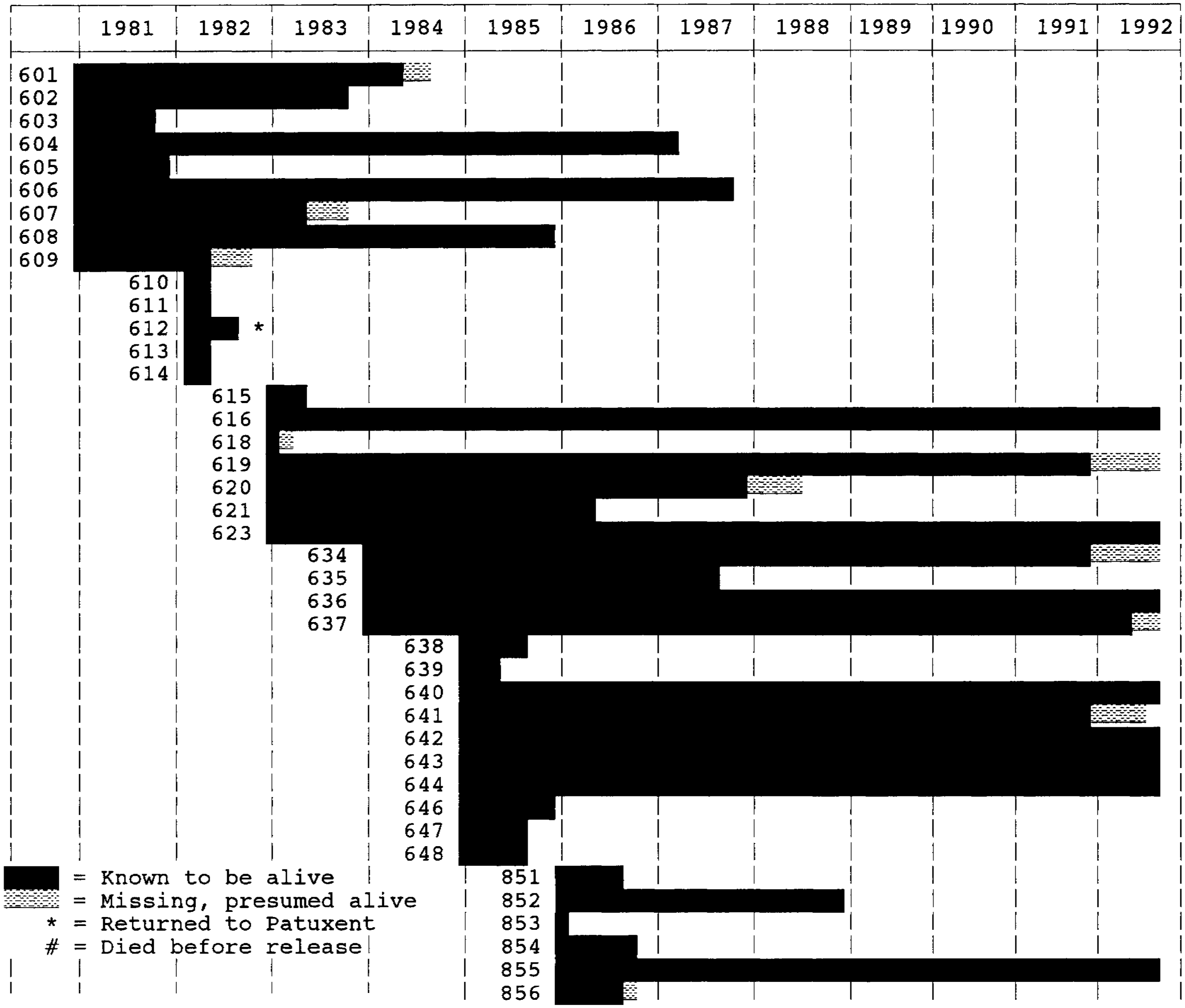
Dec 1991 35 **21 survived of release group to 09/92**

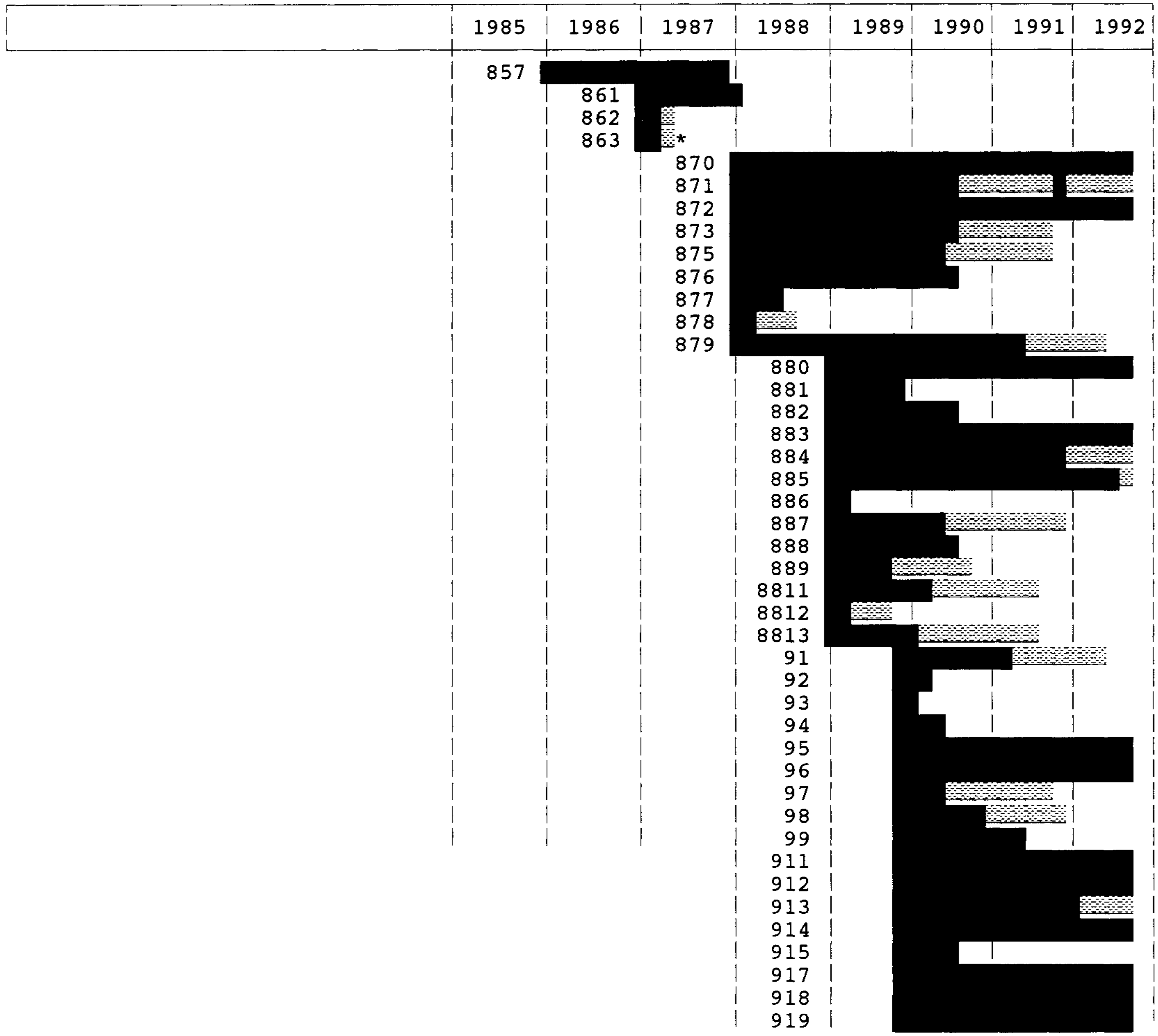
101 died of predation 1-92
111 died 4-92 of unknown causes
117 died 5-92 of coccidiosis, etc.
120 died 9-92 of unknown causes
124 died 3-92 of unknown causes
131 died 4-92 of trauma
132 died 12-91 of predation
133 died 2-92 of heart defect
134 died 12-91 of predation
138 died 2-92 of unknown causes
140 died 2-92 of lead poisoning
141 died 2-92 of predation
143 died 12-91 of predation
144 died 7-92 of predation

Only 3 of 12 in Ben Williams parent-reared release cohort survived.

Mortality in released birds is discussed in Diseases Section.

Figure 3. Survival plot of 169 cranes raised at Patuxent Wildlife Research Center and sent to Mississippi Sandhill Crane National Wildlife Refuge for release.

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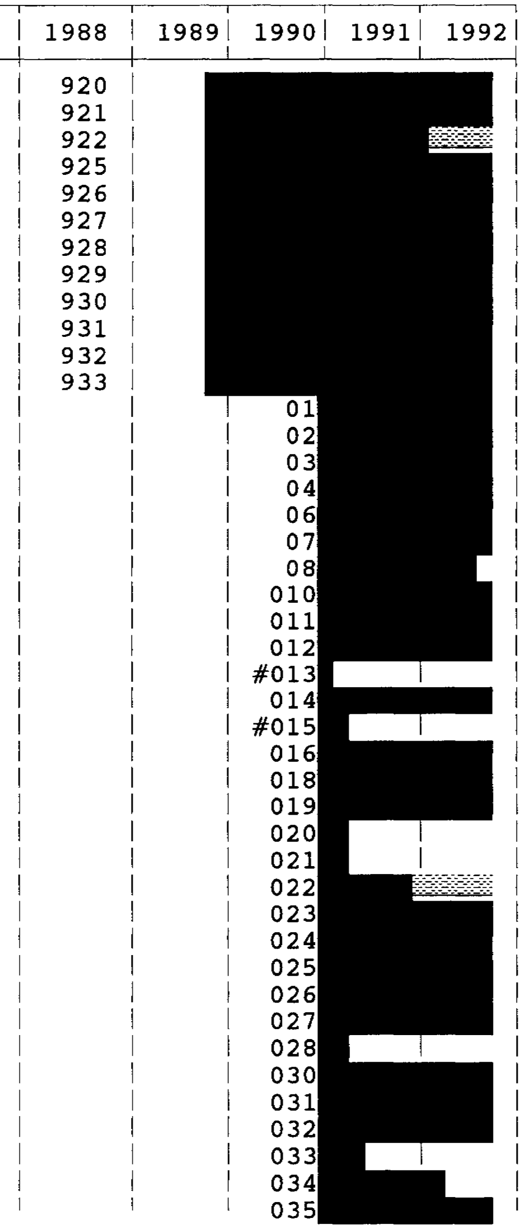
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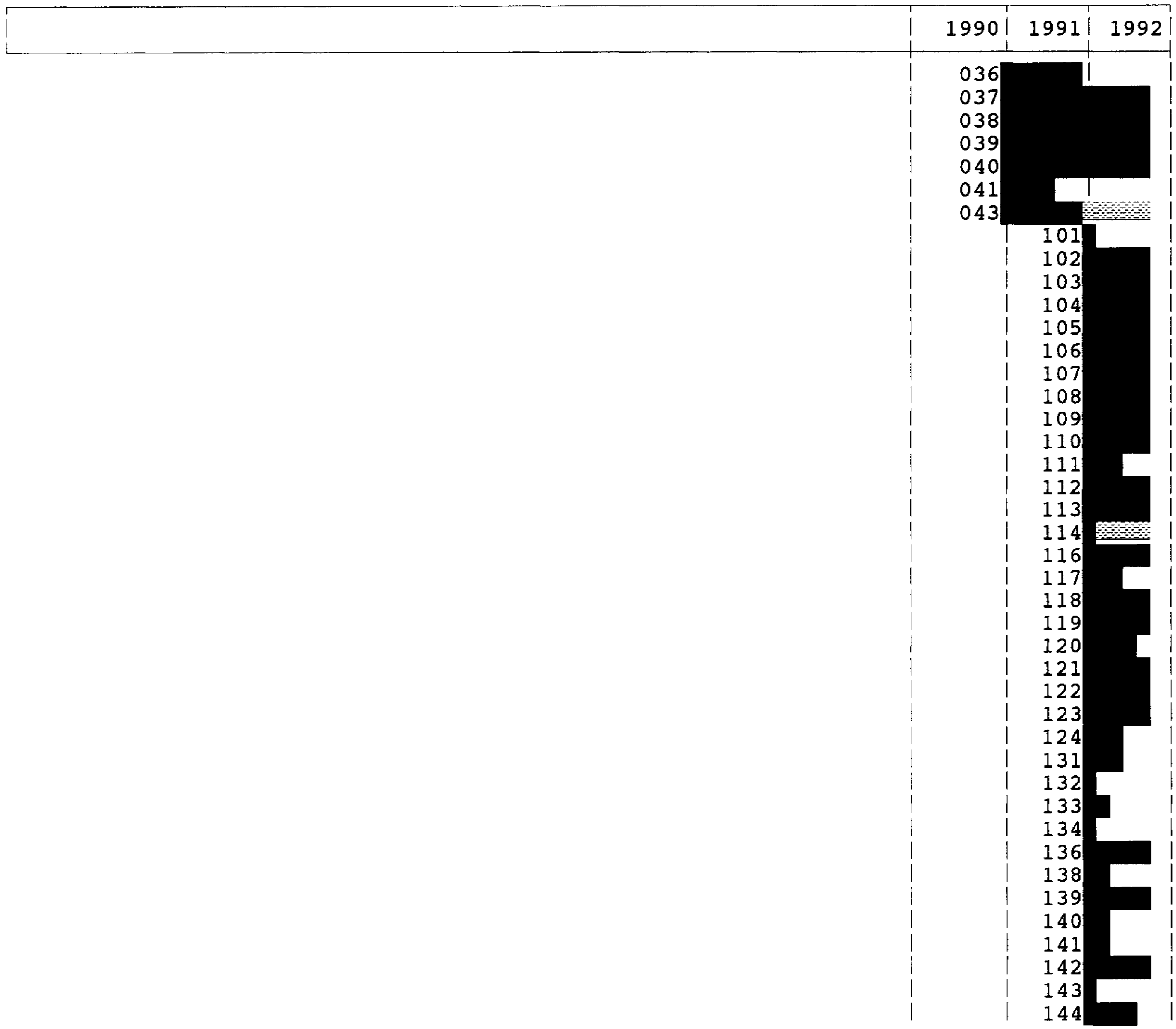
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Table 12. Released birds - *53 of 96 survived to 1990.*

Birth Released Band Comments
Month-Year/ # #/sex

1979 Jan-1981 / 1 **0 survived of year class to 1990.**
#608-M Died in 1985 due to massive internal hemorrhage.

1980 Jan-1981 / 8 **0 survived of year class to 1990.**
#607-F (May 1983) disappeared, 2 died of unknown reasons.
#602-F was shot.
#604-M Jan. 1987 died of head & neck injuries, shipped to PWRC and died.
#606- paired with #623 in 1986.

1981 Feb-1982 / 5 **0 survived of year class to 1990.**
Within 6 weeks 4 were dead of predation, 2 from dogs/coyotes, 1 from vehicle, 1 parasites. 1 returned to PWRC due to wounds and starvation.

1982 Oct-1982 / 8 **3 survived of year class to 1990.**
In less than a year 1 disappeared. 1 killed by a truck. In April 1986 1 died due to complications from a tumor. 1 nested & produced eggs.
#616-M
#619-F
#621- (died)
#623- paired with #606 in 1986, then with a wild crane and 6 Apr.1987 hatched a chick, which died.

1983 Dec-1983 / 4 **3 survived of year class to 1990.**
In 1987 on dead of dog/coyote.1 (1 nested & produced eggs)

1984 Dec-1984 / 10 **5 survived of year class to 1990.**
(3 nested & produced eggs)
#640-F paired with a wild male, than paired with #632-M and produced 2 eggs May 1987.
#643- and #644- formed a pair in April 1987 produced 2 eggs.
#644- and #643- formed a pair in April 1987 produced 2 eggs.

Among 14 juveniles released at the Ocean Springs pen during 1984 and 1985, 7 were killed in the vicinity of the enclosure: one by a hawk or owl; 4 by bobcats; 1 by a dog/coyote; and one was accidentally killed by a M-44 coyote "getter."

1985 Dec-1985 / 4 **1 survived of year class to 1990.**
Within 2 days one was killed by a bobcat. One female paired with a wild male. (Ocean Springs pen)

1985 Dec-1985 / 3 **1 survived of year class to 1990.**

1 was returned to PWRC due to wrist stiffness in 1987. (Gautier pen)

#854-M Killed 8 months after release.

Among 6 released in 1985 and 1986 at the Gautier pen, 2 disappeared within 6 months and are presumed dead. One was returned to PWRC and 3 survived into 1987.

1986 Dec-1986 / 3 **0 survived of year class to 1990.**

1 died in Feb 1987. 3

1987 1988 / 10 **7 survived of year class to 1990.**

1988 1989 / 13 **7 survived of year class to 1990.**

1989 1990 / 29 **26 survived of year class to 1990.**

#627-F wild female paired with #616-M, later with #608-M.
#634 and wild mate raised one chick (switched)

Mortality of released birds

26 of 45 (1981-1986)

10 - 1985, 1981(4)predation
7 - 1980(2)unknown
4 - diseases-parasites
4 - accidents
1 - 1980 shot
2 - 1985, 1981 returned to PWRC

1987 - 50 Cranes in captivity:

9 - breeding females
5 - pairs
15 - young of the year

Egg collection:

1965 -1977, 1981-1982, 1985-1987

Overview of Current Research

1. Research to determine the causes of nest loss in wild Mississippi Sandhill Cranes.

A. The closed-circuit TV camera (CCTV) was fitted with an infrared beam to allow 24-hour observation at each nest.

B. Because of the small number of crane nests in 1991, only one nest (Ben Williams) was studied (three were monitored in 1990).

C. The Ben Williams pair incubated normally for an apparent full incubation period, but abandoned a substituted Patuxent egg just prior to its hatching.

D. Results to date indicate:

i). three of four monitored nests have failed, and the fourth nest would have failed without timely intervention.

ii). all nests failed (or would have failed) for different reasons: inexperienced pair lacking behavioral synchrony (1990), flooding (1990), abandonment due to human (our) disturbance (1990), eggs failing to hatch (1991), and possible extended incubation period using substituted (PWRC) eggs (1991).

iii). low Mississippi Sandhill Crane recruitment is probably due to a multitude of causes rather than any one predominant factor.

2. Research to determine if carcinogenic airborne contaminants may be affecting the Mississippi Sandhill Crane.

A. Twenty air samples were collected from two sites on the Mississippi Sandhill Crane National Wildlife Refuge in 1991. Samples will be analyzed in 1992.

B. Six nonviable Mississippi Sandhill Crane eggs from 1990 contained only trace amounts of dioxins and furans. The eggs will be analyzed from PCB congeners in 1992.

3. Research to determine any difference in survival between juvenile Mississippi sandhill cranes that are hand-reared or parent-reared.

A. Beginning in late 1989 and to continue on for 4 years Birds randomly assigned to 1 of 3 cohorts sent to refuge, radio-tagged, released, and monitored.

B. 100 juveniles have been released so far. Hand-reared are surviving as well or better then the parent-reared. The last group of forty will be released in late 1992.

Interference of Nesting by Young Cranes at Release Sites

Comments by Scott Hereford: One concern regarding the recent large release cohorts is potential disturbance to neighboring breeding pairs. All three release sites are near potential nesting areas. However, actual disturbances probably differ depending on the site, pair, and proximity of nesting savannas. The Gautier release pen was built and first used. in 1981. There are approximately 8 active and potential nesting areas within a mile of the pen. North and east of the pen are the Valentine nesting areas. Although the North Valentine pair interacts with juveniles and subadults and the latter are observed infrequently on the periphery of the nesting savanna, this pair is one of the two most successful pairs in the population over the last five years. The other successful pair over that period, the South Valentine pair, is rarely seen at the pen site and appear unaffected by any disturbance, even though subadult groups seem to share some of the same feeding areas. South of the pen are four potential areas that may be affected. Only one has been used for nesting in the last six years. The abandonment of that nest is attributed to disturbance, but to that due to activity associated with the first year of the video monitoring study. New pairs have been observed on these nesting areas as well as the release site. One territory seems effectively isolated by thick intervening vegetation. There is probably some correlation between activity at the pen and lack of nesting on the nesting area directly south and adjacent.

The Ocean Springs release pen was first built and used in late 1984. There is probably more year-round use of this site than the other two. There are about ten active or potential nest areas within one mile of this release pen. The adjacent Cottonmouth territory was used from 1987-1989. Disturbance may be related to lack of nesting since. However, it may also be due to a prescribed burn. A number of new areas have been created north of the pen. One pair has nested two of the last three years. West of the pen, there have been numerous nest attempts in the Utah territory. Potential disturbance is unlikely other than Cottonmouth because most of these areas are well isolated visually.

The third release pen (Ben Williams) has been used only since late 1989. At the adjacent nest territory, a pair has nested two of the last three years and appear unaffected. There have been no other birds old enough yet to consider.

MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Section 5

POPULATION BIOLOGY

Population Biology

Introduction

The Mississippi Sandhill Crane was classified as a distinct subspecies in 1971. This population appears to have numbered less than 100 birds for at least 65 years and probably less than 50 for 20 years until supplementation with captive reared birds was undertaken beginning in 1981. The population numbered 108 in 1992, of which 88 were from a captive propagation program, as a result of a program for release of birds hatched from wild-laid eggs and release of captive bred birds. Recruitment from wild-reared birds has been 0-2 fledged chicks per year for the past 10 years. The low recruitment appears to result from low nesting success and loss of chicks prior to fledging.

Data on the population biology - life history, demography, and genetics - of the Mississippi sandhill crane provided at the workshop and later updates is current through September 1993. Data on the Florida sandhill crane was obtained from Nesbitt (1992) and for the whooping crane from Mirande et al. (1993). Life history and population information on the Mississippi Sandhill Crane gleaned from the literature, reports, and the recovery plan is summarized in Table 20. Consensus of workshop participants was obtained from the workshop participants on the likely values, or the range of plausible values that could not be estimated from existing data. One of the objectives of the workshop was to indicate the values for breeding and mortality parameters that would be needed for the wild population to grow through natural recruitment. Data for the whooping crane and the Florida population of the sandhill crane were used for estimation and modelling of likely ranges of demographic values. These analyses can provide tests of suggested priorities for management and research programs to assist recovery of this crane population.

Population Size and Structure and Carrying Capacity

Population estimates in 1929, 1949, and 1969 indicate a population of less than 100 since 1929 with evidence of continuing decline through 1980. Supplementation of the population began in 1981 and has continued every year since (Table 13). Approximately 81% of the free ranging population is from captive hatched or captive bred birds. All of the released birds are marked and some are radio-tagged so that more detailed data on individual known pedigree birds is becoming available. The sex and age structure of the population (Figure 4) is partially known. Adults (about 29 birds) comprise 27% of the population which is about 1/2 the proportion in a stable or growing population (60-65% adults). The adult sex ratio is close to equal.
Thus there are 12-14 breeding pairs in the population which appears to be the maximum number present over the past 10 years.

Mapping of the habitat requirements of the crane (Section 3) indicated that a population of about 130-150 birds is the maximum capacity of the refuge even with intensive site management. We used this value for K in all of the simulations. The modelled population is truncated when this level is exceeded during the simulations. Ultimately the carrying capacity will limited by the habitat available for nesting territories. These are currently estimated at 22-26 on the refuge. Tentatively, 150 birds in the total population was set as an upper limit to the carrying capacity in the models to allow for a growing population. However, at this size population 1/3 to 1/2 of adult birds will not have breeding territories in the Refuge based upon current estimates.

Genetics

Electrophoretic studies indicate that the sandhill crane subspecies are closely related although an allele of one enzyme appears to be unique to this population. Measures of heterozygosity indicate this population (0.024 ± 0.014) is like other crane species and like the Florida sandhills in the Okefenokee Swamp (0.028 ± 0.016) but less than the heterozygosity in the Florida sandhill in Florida (0.125 ± 0.069) and greater sandhills in the Rocky Mountain population (0.067 ± 0.028). The potential for inbreeding depression in this population was evaluated from studies of the captive hatched wild laid eggs. Pedigree analyses of captive bred red-crowned cranes indicate that species is subject to inbreeding depression, so evaluation of this effect was included in the modelling scenarios.

Table 13. Estimated Numbers of Mississippi Sandhill Cranes

Source	Year	Total	Wild-Hatched	Released Captives
Leopold	1929	50 to 100		0
Walkinshaw	1949	>50		0
Strong	1969	50 to 60		0
Valentine	1975	30 to 50		0
Refuge*	1978	40 to 50		0
Refuge	1979	40 to 50		0
Refuge	1980	50		0
Refuge	1981	50	41	9
Refuge	1982	50	41	9
Refuge**	1983	43	34	9
Refuge	1984	40	27	13
Refuge	1985	32	13	19
Refuge	1986	41	23	18
Refuge	1987	33	17	16
Refuge	1988	44	21	23
Refuge	1989	54	21	33
Refuge	1990	73	24	49
Refuge	1991	92	19	73
Refuge***	1992	108	20	88

* 1978-1982, from Annual Narrative.
** 1983-1991, minimum population estimate from October semi-annual census.
*** September, calculated from attrition since January 1992 semi-annual census.

Figure 4.

AGE PYRAMID
Mississippi Sandhill Crane
September 1992

Age	Males	Females	
10	XX		?
9	X	X	?
8	XX	XX	
7	X		
6	X		
5	XX	X	
Adults, Unk Age	XXXXX	XXXXXXXX	
4	XXX	X	
3	XXXXXXXXX	XXXXXXXXXXX	??
2	XXXXXXXXXXXXXXXX	XXXXXXXXXXXX	
1	XXXXXXXXXXXXXXX	XXXXX	??
Unk Age, unpaired	??	??	

20 15 10 5 | 5 10 15 20

Number of Cranes

X>>>Specimens of known sex

?>>>Specimens of unknown sex

Reproduction

The average age of first reproduction, in the wild population, is 4 years for females with and 5 years for males. About 70% of captive females have laid eggs at 3 years and 40% of males have produced semen so that the birds can reproduce at an earlier age in captivity than in the wild. The mean clutch size in the wild population has been 1.6 $\pm$ 0.2 (Tables 15 & 16, Figure 5) and a second clutch may be produced if the first is lost or removed. Multiple clutching, with artificial or surrogate incubation is used in captivity to amplify the productivity of the captive flock. Pairs in the wild rarely raise more than one chick. The birds are monogamous in a season. Reproduction is likely to be limited by the amount suitable nesting areas available so that there is an upper limit to the population size in the refuge. The sex ratio is probably 1:1 at hatching and fledging and in the current adult population. The number of adult males could become limiting for breeding in the models if the age of first reproduction of males is set 1 year older than the females and the sex ratio is equal in all adult age classes.

Reproduction in the whooping crane and in the Florida population of sandhill cranes (Table 14) indicates an average per female (or pair) of about 1 offspring reaching 1 year of age every 2 years for whooping cranes and every 3 years for the sandhill cranes. The fraction of hatched chicks appears to be the same in both species. Most of the difference appears to be in higher post hatching mortality, prior to fledging, in the Florida sandhill cranes.

Table 14. Comparison of demographic traits for wild populations of Whooping Cranes, Florida Sandhill Cranes, and the Mississippi Sandhill Crane.

Variable		Crane Population	
	Whoopers[1]	FL Sandhills[2]	MS Sandhills[3]
Reproduction:			
Possible Pairs	390	117	214
Nests	310 (79%)	-	89 (42%)
Hatched	236 (61%)	69 (59%)	54 (25%)
Fledged	-	46 (39%)	9 (4%)
1 Year Survival	172 (44%)	41 (35%)	? 8 (4%)
Mortality:			
H - 1 Year	27%	41%	30.1%
1 - Adult	7.7	13.3	12.9
Adults	7.7	13.3	8.7

[1] Data from Mirande, C., R. Lacy, and U. S. Seal (eds). 1993. Whooping Crane (*Grus americana*) Conservation Viability Assessment Workshop Report. CBSG, Apple Valley, MN.
[2] Data from Nesbitt, S.A. 1992. First reproductive success and individual productivity in sandhill cranes. J. Wildl. Manage. 56:573-577.
[3] Data from Scott Hereford (Mississippi Sandhill Crane PHVA Workshop). Mortality data from released captive hatched or captive bred birds - Table 10.

Mortality

The viability of eggs in wild nests is estimated at 65 $\pm$ 14% (Table 16, Figure 5). However eggs removed from nests to PWRC had a 79% (53 of 67 eggs) fertility rate. Survival to hatching in the wild was 50% (31 of 61 eggs followed). The hatching rate at PWRC was 83%

(or 44 of the 53 fertile eggs) and 31 chicks fledged (75%) so that 46% of eggs received (58% of viable eggs) produced fledged chicks at PWRC. In contrast, only 20% of hatchlings or 10% of viable eggs survived to fledging in the wild (Table 16, Figure 6). The net result in the wild population is that only 10% of females have produced a fledged young in a year. The potential based upon captive data would be that at least 50-60% of pairs could produce a fledged chick in a season.

Mortality rates were initially estimated at 9.3% for 1-2 year olds, 7.5% for 2-3 year olds, and 5.0% for 3-4 year olds. However data from released birds indicates an average mortality rate of 12.9% over these age classes. Adult mortality was modelled at 7.7, 8.7, and 9.7%. This range of values brackets the estimated mortality rate of 8.7% in the free ranging population.

Comparison of these mortality estimates with the wild population data for whooping cranes and the Florida sandhill crane, Table 14, indicates substantially lower rates for the whooping crane. Estimates for first year mortality are from the time of hatching to 1 year for all 3 populations since this was the only common data point available. The estimates for both species were pooled for the ages 1 year to adult because of the lack of age structured information for 2 of the populations. The estimates for the Mississippi sandhill crane in this table are from data collected on released birds (Table 10).

The life span of several crane species is known to reach 70 years. The oldest known Mississippi sandhill crane is 21 years. In the preliminary scenarios we used a 20 year life span for the wild birds. Given the adult mortality rates of 8-10% per year the number of older birds would be a small part of the population.

Table 15. **Egg Fertility Over Time**:

Eggs taken from wild birds on MS Sandhill Crane National Wildlife Refuge (Comments written by Scott Swengel and George Gee)

Source of Egg Data: Valentine (1982) Breeding Ecology of Mississippi Sandhill Cranes in Jackson County, Mississippi. <u>Crane Research Around the World</u>; also from the MS Sandhill Crane Recovery Plan 1991.

Results From Wild Nests

Clutch size 1.86 (N= 79) 1965-81

Clutch size 1.61 (N= 88) 1979-92 (also 1.61, 1982-92)

1.23 eggs; percent of eggs hatched at refuge 1965-81 64 % (50/78)

1.2 eggs; percent of eggs hatched at refuge 1979-92, ca. 40% (result from 64 % viable eggs, 62 % hatch)

Even when lower number of eggs left per nest in the years 1965-81 (due to collection of eggs) is corrected for, the higher success rate for the earlier group is clear. Because--
0.79 eggs/1.23 possible eggs hatched vs 0.48 eggs/each 1.2 possible eggs

Egg quality of wild birds has not however, declined over time. ca. 80 % fertility (79.1 %) and 83 % hatch rate for those eggs when sent to PWRC late in the incubation period (after 20 days approx.) and these rates have stayed consistently high to the present.

This means that the lower hatching success of wild eggs is extrinsically caused and this is accounted for by the results of the last 1/3 of incubation time by wild birds (post day 20).

Disturbance could cause this poor incubation.

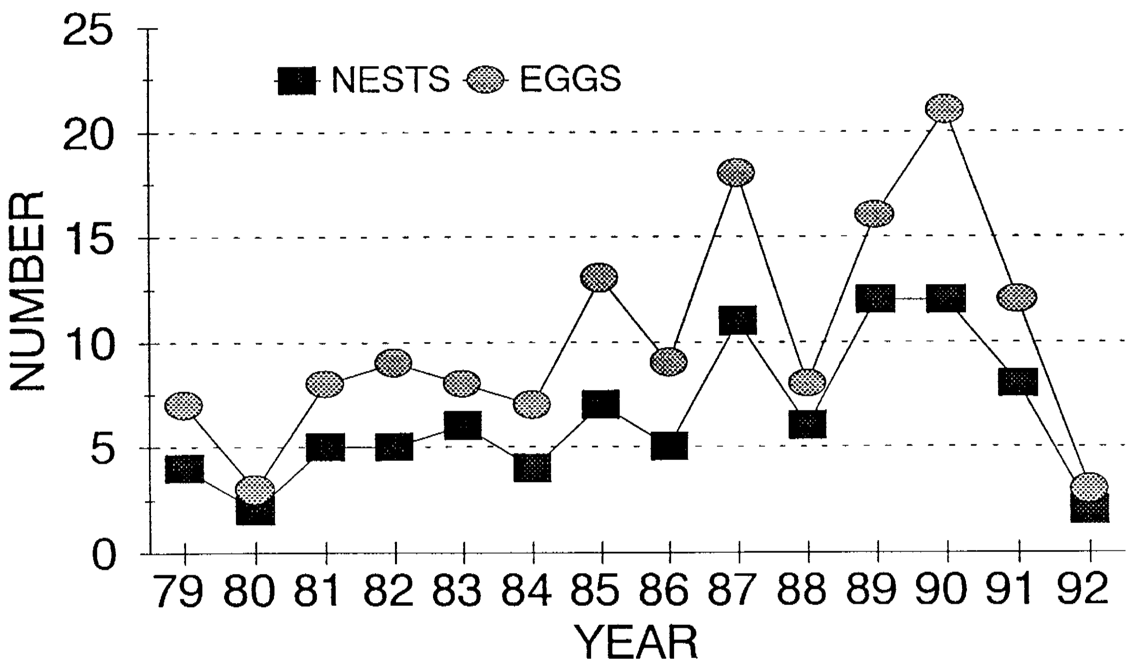
Summary

Egg fertility (79 %) and hatchability (83 %) of eggs taken from the refuge falls within normal limits for reproductive sandhill cranes. The decreased hatch (approximately 40 % vs. 66%) of eggs on the refuge results from exterior (non-physiological) factors associated with the last third of the incubation period.

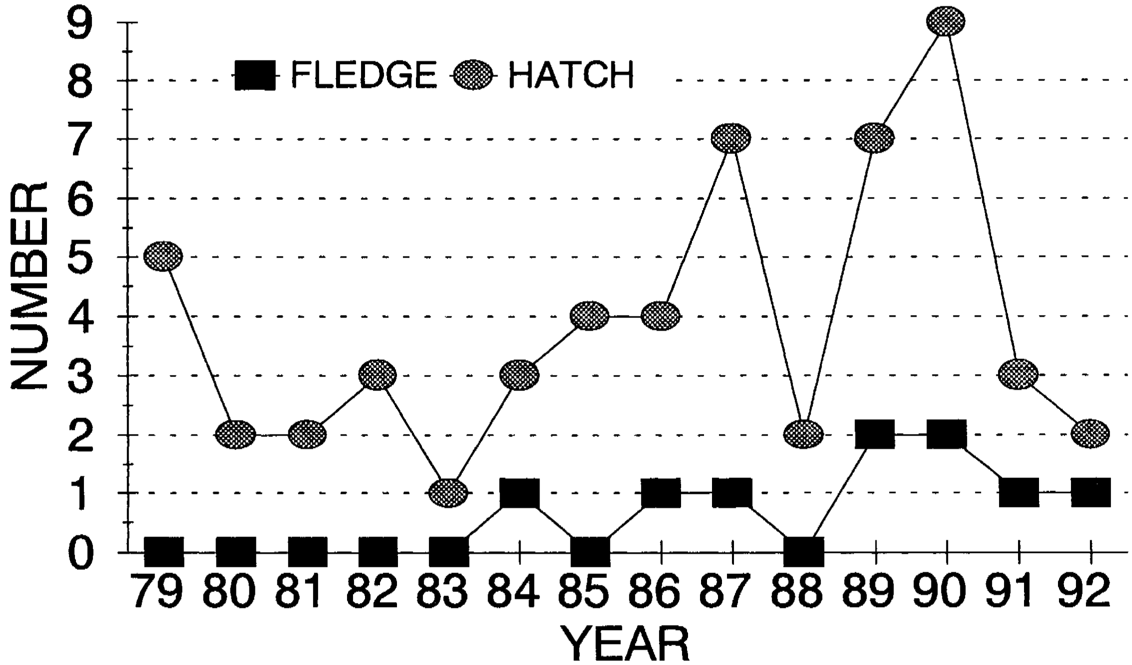
Table 16. Mississippi Sandhill Cranes Nesting Success

Year	Nests	Eggs	Clutch	Viabl	%Viable	Hatch	%Hatch	Fledge
79	4	7	1.8	5	71	5	100	0
80	2	3	1.5	2	67	2	100	0
81	5	8	1.6	5	62	2	40	0
82	5	9	1.8	4	44	3	75	0
83	6	8	1.3	1	12	1	100	0
84	4	7	1.8	4	57	3	75	1
85	7	13	1.9	5	55	4	80	0
86	5	9	1.8	6	67	4	67	1
87	11	18	1.6	8	44	7	88	1
88	6	8	1.3	4	50	2	50	0
89	12	16	1.3	10	62	7	70	2
90	12	21	1.8	15	71	9	60	2
91	8	12	1.5	5	42	3	60	1
92	2	3	1.5	3	100	2	67	1
SUM	89	142	22.4	77		54		9
MEAN	6.3	10.1	1.6	5.5	57	3.8	73.7	0.6
S.D.	3.2	5.1	0.2	3.4	19.1	2.3	17.9	0.7

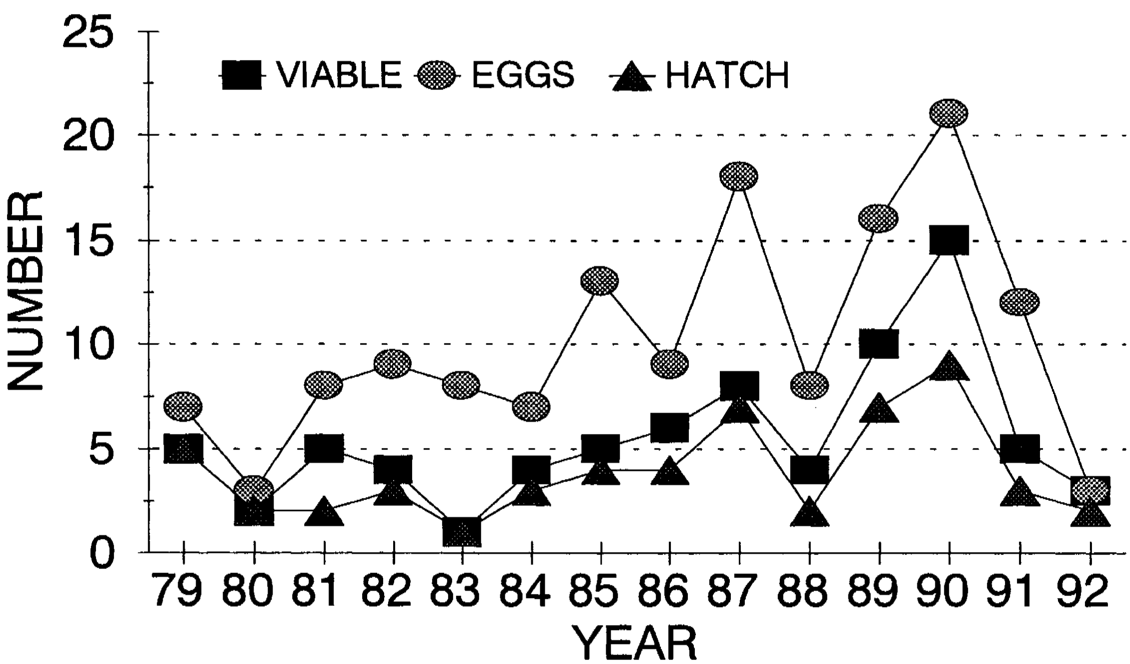
MISSISSIPPI SANDHILL CRANES
ANNUAL NESTS & EGGS



MISSISSIPPI SANDHILL CRANES
ANNUAL CHICKS FLEDGING



MISSISSIPPI SANDHILL CRANES
ANNUAL NUMBERS HATCHING



Catastrophes

Two types of more extreme environmental events were included in the models. Droughts occur about every 10 years (10% frequency) and may result in a 50% reduction in reproduction in that year but with no effect on survival. Similar effects of drought have been reported for the Florida sandhill crane. Severe hurricanes occur in this area with a frequency of about 3% and could result in a total loss of reproduction for the year and a 50% reduction in survival.

Genetics

The estimated generation time for the crane is about 10 years based upon the scenario developed. Population numbers were below 50 with no more than 10 breeding pairs for 3 or more generations. The effective population size may have been about 10 during this time. The remaining wild born birds in the wild population have had essentially no reproduction (about 0.6 fledged chick per year) for more than 10 years. Electrophoretic studies (Section 8) found heterozygosity at levels comparable to some other crane species but less than those found in the Florida and greater sandhill crane. However these studies can not directly address whether inbreeding depression has occurred.

An analysis of captive pedigree data for the red-crowned crane indicates that inbreeding depresses reproductive success in this species (Table 17). However since calculations of the number of lethal equivalents in this population have not been made we used a medium estimate of 3.41, based upon estimates that have been made in other species. All scenarios for the sandhill crane were run with and without inbreeding depression included. Note however that the fertility (79%) and hatching (83%) rates in the captive colony of Mississippi sandhill cranes are higher than those for the out bred red-crowned cranes. The total productivity was 64% in comparison with the 40.4% for the red-crowned crane. It is difficult to make a case for inbreeding depression as a basis for the failure of recruitment in this wild population of sandhill crane. However, the evidence for higher mortality, when released into the wild population, of fledged birds with heart murmurs detected on at least one examination suggests that a more careful analysis of pedigree records might be helpful.

Table 17. Effects of inbreeding on reproductive traits in captive red-crowned cranes. (Data from the World Register of Red-crowned Cranes, 1972-1989). Adapted from a figure prepared by Scott Swengel.

Trait	Not Inbred		Inbred	
	N	%	N	%
Fertility Rate	768	57	222	28
Hatching Rate	310	72	29	49
Total Production		40.4		13.1

Supplementation of the Wild Population

One objective of the management program for the wild and captive populations is to provide captive reared 1 year old birds on a continuing basis to maintain the population near carrying capacity until the problem of reproductive failure in the wild population has been resolved. The modelling was used to estimate the number of 1 year old birds that need to be released annually based upon no natural recruitment, the estimates of 50% mortality in the wild of the released birds, prior to reaching reproductive age, over the past 10 years, and the 8.7% adult mortality rate.

POPULATION MODELLING

All of the scenarios modelled here started with an initial population of 150 birds in a stable age distribution and equal sex ratio. All adult males were assumed as available for breeding. The carrying capacity was set at 150 with no variance from year to year and no trend of change. The drought and hurricane catastrophes were included. Each scenario was run 100 times using version 5.1 of VORTEX and 500 times with version 6. The runs were for 100 years with statistics calculated at 10 year intervals. The calculated generation time was about 10 years for females and males.

The data in the tables (Tables 18 & 19) include the deterministic and stochastic population growth rates (r values) and the estimates of probability of extinction (Pe) and population size (mean and S.D.), for 20, 50, and 100 years. The calculated remaining heterozygosity (H) is included for 50 and 100 years. The mean or mode time to first extinction (Te Years) is in the last column. The data in Table 19 are organized to systematically evaluate the effects of adult mortality, juvenile mortality, and inbreeding at different levels of annual hatchling production.

Risk of Extinction: Current Conditions and Minimum Survival Scenarios

The interaction of annual adult mortality (post 1 year to death) at 7.7%, 8.7%, and 9.7%, of juvenile mortality (post hatching to 1 year of age) at 20 and 30%, and rates of hatchling production per adult female over the range of 10 to 60% were modelled to identify a set of interactions that would produce a positive stochastic growth rate and reduce the risk of extinction to less than 5% in 50 years (Figures 8-10 and Table 19). The results in Figures 8-10 are arranged with 2 groups of 3 values for each level of hatchling production. The two groups are for 20 and 30% juvenile mortality respectively. Within these juvenile mortality groups, the results for 3 levels of adult mortality (7.7, 8.7, and 9.7%) are shown.

Table 18. CRANE POPULATION COMPARISONS - 60% of Adult Females Produce Hatchlings

File	Comment	Mortality H-1 %	Mortality 1-Ad %	Mortality Adlt %	Results: Population Growth Deter r	Population Growth Stochastic r	Population Growth Stochastic SD	20 years PE %	20 years N	50 years PE %	50 years N	100 years PE %	100 years NSD	100 years NSD	100 years H	TE
Population Comparisons																
18	Whoop	27	7.7	7.7	.053	.030	.052	0	146	0	147	0	146	6	.939	-
19	FL SC	41	13.3	13.3	-.026	-.076	.150	0	45	33.4	10	100				57
20	MS SC	41	12.9	8.7	.006	-.032	.106	0	86	.2	48	43.6	16	14	.776	84
21	MS SC	30	12.9	8.7	.024	-.006	.073	0	112	0	100	3.8	69	40	.892	89
Mississippi Population - 41% Mortality H-1 Yr																
22	No Inbr	41	12.9	8.7	.006	-.024	.096	0	87	0	54	25.8	26	22	.800	84
23	+ Catas				-.006	-.047	.132	0	72	3.6	28	81.0	8	6	.718	77
24	♂ Br 4Y				.006	-.018	.086	0	100	0	76	15.6	38	31	.846	88
25	♀ Br 5Y				-.010	-.040	.167	0	78	.8	36	63.4	10	9	.736	81
Mississippi Population - 30% Mortality H-1 Yr																
26	No Inbr	30	12.9	8.7	.024	.000	.068	0	115	0	107	.6	96	38	.906	81
27	+ Catas				.012	-.025	.106	0	93	.4	62	29.8	30	27	.812	83
28	♂ Br 4Y				.024	.007	.064	0	131	0	129	0	115	30	.924	-
29	♀ Br 5Y				.006	-.015	.081	0	106	0	81	9.0	42	30	.860	87

The risk of extinction is 1 (100%) at the present 10% annual fledgling production rate is essentially 100% over all values of adult and juvenile (1 year to adult) mortality studied, with or without inbreeding depression effects included. Under these mortality schedules, the 50 year risk of extinction is less than 5% at annual hatchling production rates of 40% or more. However the 100 year risk of extinction ranges from 5 to 85% for the 40% hatchling production rate. The 100 year probability of extinction is less than 5% for all scenarios without inbreeding at the the 50% hatchling production rate. However many of these populations are also in a slow decline.

The stochastic population growth rates, Figure 9, offer some insight. The mean growth rates are negative for all conditions until a 50% hatchling production rate is reached. Here only the scenarios with 20% (or less) juvenile mortality have a positive mean stochastic r value. Populations with a negative growth rate will all eventually become extinct. Comparison of the deterministic and stochastic growth rates, Table 19, indicates that the stochastic values are usually lower, become negative first, and have a large S.D. so that there is substantial variation from one year to the next.

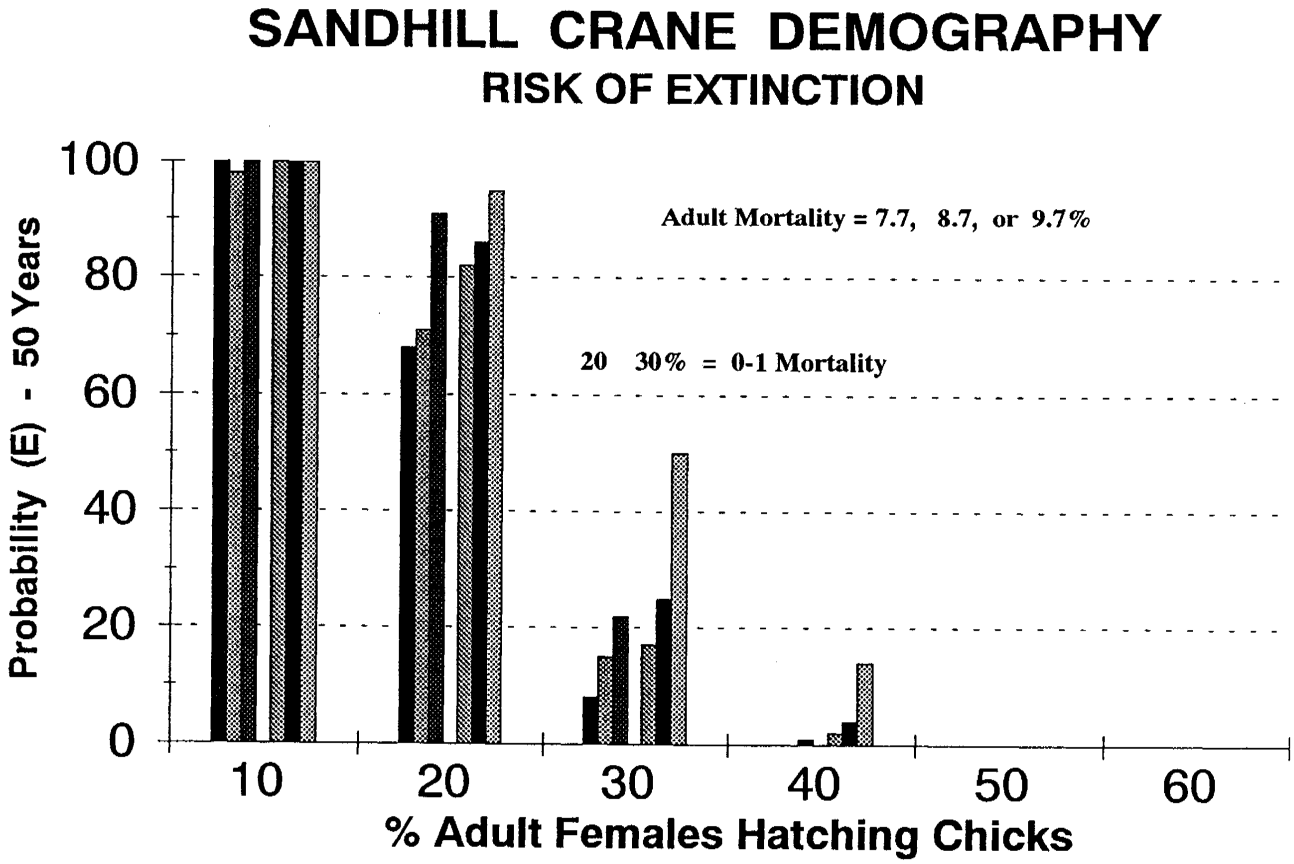
Surviving mean population sizes (Figure 10) reflect the same trends. It is only at 60% hatchling production that the 50 year population sizes are consistently near the carrying capacity. The mean population sizes at lower hatchling production rates are lower and show trends with respect to both juvenile and adult mortality. Thus at 50% recruitment, all of the populations with 30% juvenile mortality appear to be in decline despite the fact that none went extinct by 50 years.

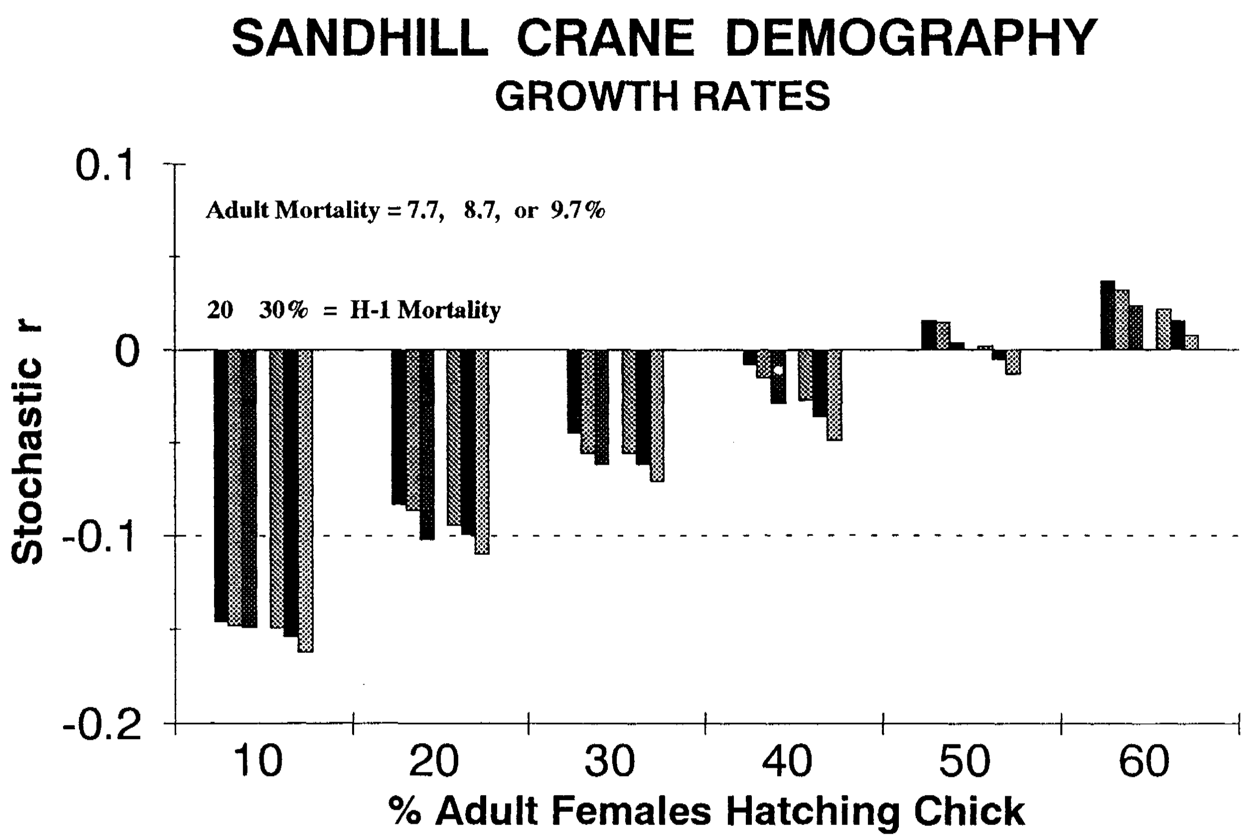
Effects of Inbreeding Depression

Inbreeding depression was added to the model, with hatchling production set at 50% of females producing hatchlings annually, on average (Figure 11 and Table 19). In the figure each pair of bars represents the population with no inbreeding and the population with 3.14 lethal equivalents added. Population size projects for 20, 50 and 100 years indicates a gradually increasing effect with lower population sizes. The effect is most pronounced at the higher mortality rates. The average expected heterozygosity, as a fraction of a beginning value of 1.00 (100%) ranged from .94 to .96 at 50 years and from .83 to .93 at 100 years. Thus under the best of these conditions (20% juvenile and 7.7 or 8.7% adult mortality) the loss of heterozygosity was estimated at 7-8% which is more than a suggested maximum of 5% loss in 100 years or 10 generations.

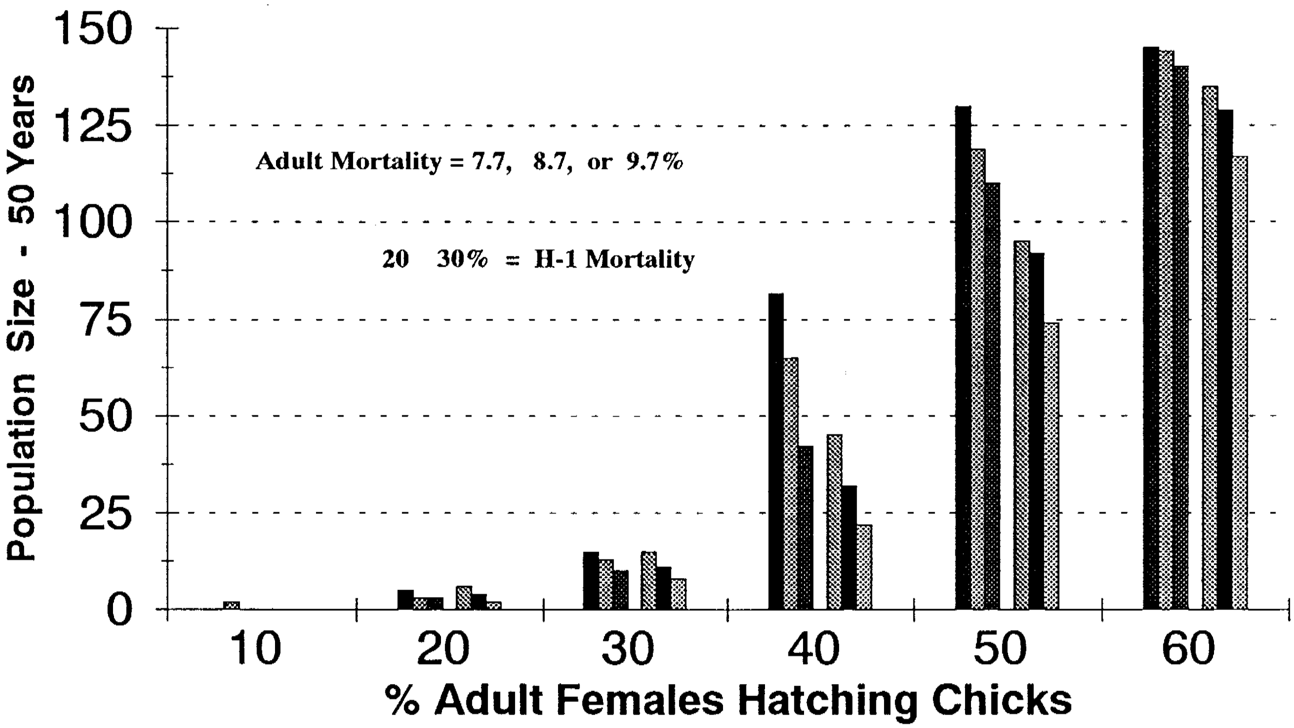
Comparisons with Other Populations

The whooping crane population has a growth rate of 3-5% under the prevailing conditions for that population, Table 18. The values used to fit these parameters provided estimates that fit the 50 year history of the whooping crane population. Note that the mortality rates are lower in all age classes for the whooping crane despite the fact that this is

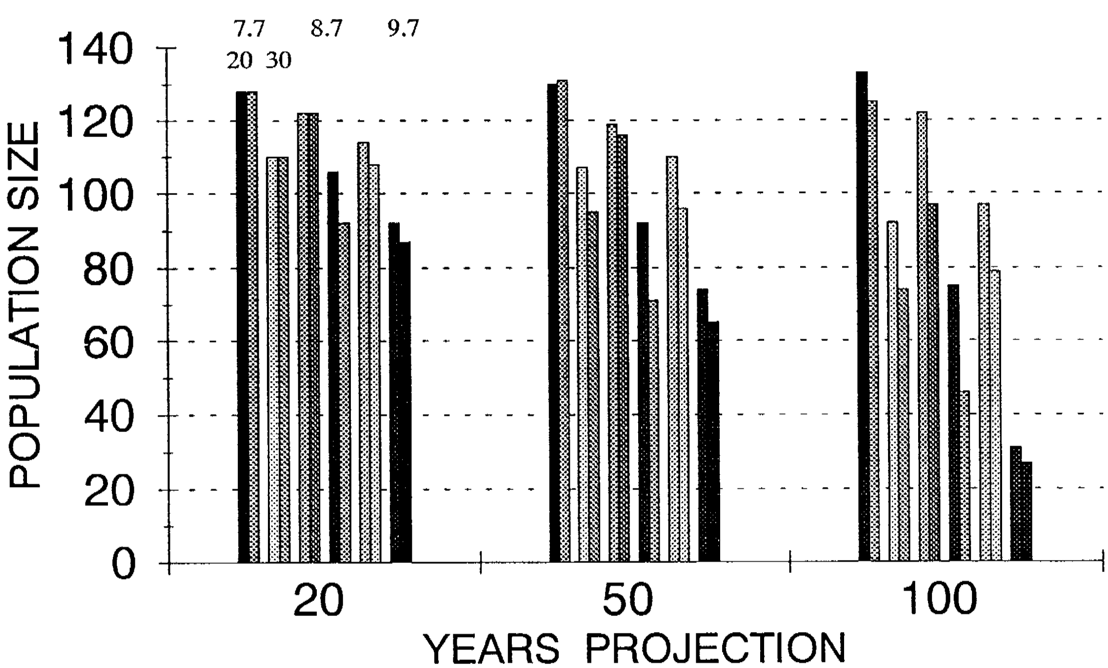

SANDHILL CRANE DEMOGRAPHY
RISK OF EXTINCTION
Adult Mortality = 7.7, 8.7, or 9.7%
20 30% = 0-1 Mortality
Probability (E) - 50 Years
100
80
60
40
20
0
10
20
30
40
50
60
% Adult Females Hatching Chicks


SANDHILL CRANE DEMOGRAPHY
GROWTH RATES
Adult Mortality = 7.7, 8.7, or 9.7%
20 30% = H-1 Mortality
Stochastic r
0.1
0
-0.1
-0.2
10
20
30
40
50
60
% Adult Females Hatching Chick

SANDHILL CRANE DEMOGRAPHY
POPULATION SIZE



MISSISSIPPI SANDHILL CRANES
INBREEDING, MORTALITY, AND N



a migratory population and the 1 year old birds make the flight from Wood Buffalo Park in Canada to the Aransas in Texas. The production of hatched chicks is comparable in the whooping crane and the Florida sandhill crane but the mortality rates from hatching to 1 year are sufficiently higher to result in a 3 year interval in 1 year old chick production in the Florida population rather than the 2 year interval in the whooping crane. The average nesting rate of the Mississippi crane is significantly less than that of the whooping crane. However, in several years (1987, -89, -90; Table 16) nesting appears to include at least 80-90% of the 12-14 potential breeding pairs. These low nest years appear to be the result of environmental events rather than an infect of inbreeding since several of the high nest years are recent.

Hatched chicks appear at the same rate in the Florida population in comparison to the whooping cranes (Table 14), but the rate is reduced by half in the Mississippi population. There is little further loss of chicks in the Florida population to fledging but virtually all of the chicks have disappeared in the Mississippi population. Thus nesting failure in some years and egg loss and chick mortality in most years combine to almost completely eliminate recruitment in the Mississippi population. The hatching to 1 year old 41% mortality rate reported for the Florida population, in combination with the average 13.3% mortality rate for birds 1 year and older (Table 14) produces negative deterministic and stochastic growth rates when combined with the reproductive rates described (Table 14). Reduction of the mortality rates in all 3 age classes (H-1, 1-adult, adult) to the values described for the released Mississippi cranes resulted in a population with a positive deterministic growth rate ($r = 0.024$) but the stochastic rate was weakly negative ($r = -0.006$), Table 18. Thus even these conditions are marginal and produce a slowly declining population with a 3.8% risk of extinction at 100 years.

Removal of the effects of inbreeding from the models had no effect on the deterministic growth rate, but increased the stochastic growth rate slightly. Addition of catastrophes to the model (these were not included in most of the scenarios in Table 18 while variations in mortality were being tested to define a set of conditions yielding a growing population) resulted in a significant decrease in the deterministic and stochastic growth rates. The only set of conditions, within the constraints of the mortality rates used in these models, that resulted in a modestly growing Mississippi sandhill crane population allowed the males to breed at 4 years implying that in some years the number of 5 year old male breeders would be limiting the number of breeding pairs in these small populations.

Supplementation

Given the carrying capacity of about 150 birds, the number of birds that will need to be added to the population each year, with no recruitment from the wild breeders, will determine the number of fledglings that will need to be produced each year in the captive population for this purpose. Estimation of this number can be made from an estimate of the annual loss rate of birds in the current wild population (including the previously added birds) and the expected mortality of released captive reared birds during their first year post release.

These sources are incorporated in the estimated free ranging population annual mortality of 8.7%. This yields an estimate of about 14 birds per year. This number may be further reduced if the excess mortality contributed by the heart murmur birds can be removed. Since current production is capable of producing about 40 birds for the release program, an analysis of this program should allow projection of the number of breeding pairs needed. Special attention will be given to the genetic management of the captive flock since it will overwhelm the composition of the remaining wild bred birds over time and potentially lead to unnecessary genetic impoverishment.

Summary

The whooping crane data yielded a growing population. Modelling the data on the Florida sandhill crane population yielded a negative growth rate and declining population. This may be a result of the fact that the data from a bad year were pooled with the other years to yield average values for the demographic variables. This bad year might usefully be treated as a catastrophic event in a model with the data from the other years recalculated to yield new averages with the influence of the outlier year removed. This approach can allow a closer fit to the observed events and the population has an opportunity to recover in the better years.

For the Mississippi sandhill crane, the data and the models indicate nesting failure, egg loss during incubation, and chick loss before fledging are the key events in the failure of the Mississippi sandhill crane to recruit new birds into the population. The data from the captive propagated wild eggs indicating normal fertility, hatching, and fledging rates, the occasional years of high nesting success, and the survival of the released birds indicate that the primary factors are environmental and may be related to nest disturbance and predation. The models provide an indication of the reproductive and mortality rates that will need to achieved for the recovery of this population. A further reduction of the mortality rates in the 1year to adult age classes would produce a further increase in the growth rates into the ranges observed with the whooping crane population. A growth rate of 5% per year would result in a population doubling time of about 14 years. The modeling process also allows a continuing test of the predictions made of carrying capacity and the limits that available nesting territories place on the growth of the population.

Table 19. SANDHILL CRANE - STOCHASTIC POPULATION MODELS

File	Input Values			Results														
	Adl Mor	0-1 Mt	Inb H	Population Growth			20 years			50 years				100 years				TE Yr
				Deter r	Stochastic r	SD	PE %	N	SD	PE %	N	SD	H	PE %	N	SD	H	
	90%=0 | 10%=1 Females Reproducing																	
1.001	7.7	20	3.1	-.113	-.138	.17	8	9.6	4.4	98	2.0		.69	100				29
1.002			0	-.113	-.146	.18	13	9.6	5.0	100								28
1.003		30	3.1	-.124	-.155	.18	11	7.0	3.5	99	4		.38	100				25
1.004			0	-.124	-.149	.18	9	7.7	4.6	100								27
1.005	8.7	20	3.1	-.121	-.145	.17	13	8.7	4.5	99	2		.50	100				27
1.006			0	-.121	-.148	.18	10	8.8	4.6	98	2		.62	100				26
1.007		30	3.1	-.131	-.156	.17	21	6.8	4.1	100								25
1.008			0	-.131	-.154	.17	14	7.3	4.2	99	2			100				26
1.009	9.7	20	3.1	-.128	-.159	.18	15	7.8	4.7	100								25
1.010			0	-.128	-.149	.18	13	8.0	4.4	100								27
1.011		30	3.1	-.139	-.168	.18	31	6.8	3.7	100								24
1.012			0	-.139	-.162	.17	21	6.3	3.0	100								25
	80%=0 | 20%=1 Females Reproducing																	
2.001	7.7	20	3.1	-.056	-.088	.15	0	28	10.5	67	5.6	3.4	.75	100				46
2.002			0	-.056	-.083	.15	0	27	10.3	68	5.4	3.4	.72	100				44
2.003		30	3.1	-.068	-.098	.16	0	21	9.2	78	4.2	2.6	.74	100				42

Table 19. SANDHILL CRANE - STOCHASTIC POPULATION MODELS

File	Input Values			Results															
	Adl Mor	0-1 Mt	Inb H	Population Growth			20 years			50 years				100 years				TE Yr
				Deter r	Stochastic r	SD	PE %	N	SD	PE %	N	SD	H	PE %	N	SD	H	
2.004			0	-.068	-.094	.16	1	22	9.1	82	5.6	3.1	.74	100				41
2.005	8.7	20	3.1	-.063	-.095	.15	0	25	9.5	82	3.2	1.2	.72	100				40
2.006			0	-.063	-.086	.15	0	26	10.3	71	5.0	2.2	.75	100				43
2.007		30	3.1	-.075	-.103	.15	0	18	8	91	3.3	1.2	.73	100				38
2.008			0	-.075	-.099	.16	0	20	9.5	86	4.0	2.2	.68	100				38
2.009	9.7	20	3.1	-.070	-.099	.15	0	21	10	83	3.4	1.2	.69	100				39
2.010			0	-.070	-.102	.16	1	20	9.8	91	2.9	.6	.69	100				39
2.011		30	3.1	-.082	-.112	.16	0	16	7.4	95	2.6	.9	.48	100				35
2.012			0	-.082	-.110	.16	0	17	7.9	95	2.4	.6	.68	100				36
	70%=0 | 30%=1																	
3.001	7.7	20	3.1	-.019	-.050	.13	0	59	18	8	22	19	.88	91	8.7	6.8	.62	72
3.002			0	-.019	-.045	.13	0	59	18	8	22	15	.89	80	9.6	8.5	.69	79
3.003		30	3.1	-.031	-.064	.14	0	44	18	25	11	6.6	.84	99	4			61
3.004			0	-.031	-.056	.13	0	49	20	17	15	13	.85	95	4.8	2.6		65
3.005	8.7	20	3.1	-.025	-.058	.14	0	51	21	15	17	14	.87	97	4	1		68
3.006			0	-.025														
3.007		30	3.1	-.038	-.069	.14	0	42	16	33	8.6	5.1	.82	100				57

Table 19. SANDHILL CRANE - STOCHASTIC POPULATION MODELS

File	Input Values			Results														
	Adl Mor	0-1 Mt	Inb H	Population Growth			20 years			50 years				100 years				TE Yr
				Deter r	Stochastic r	SD	PE %	N	SD	PE %	N	SD	H	PE %	N	SD	H	
3.008			0	-.038	-.063	.14	0	41	17	25	11	8	.82	98	7			60
3.009	9.7	20	3.1	-.032	-.065	.14	0	44	16	22	10	8	.80	100				60
3.010			0	-.032	-.062	.14	0	44	17	22	9.9	7.4	.80	95	4.6	2.4		58
3.011		30	3.1	-.045	-.078	.15	0	34	13	54	6.2	3.6	.78	100				50
3.012			0	-.045	-.071	.14	0	35	14	50	8.3	5.1	.79	99	3			50
	60%=0 | 40%=1																	
4.001	7.7	20	3.1	.010	-.016	.09	0	100	29	0	77	39	.95	15	39	32	.86	86
4.002			0	.010	-.008	.09	0	100	28	0	82	36	.95	5	61	40	.87	93
4.003		30	3.1	-.004	-.033	.11	0	76	28	2	42	30	.92	54	17	14	.72	97
4.004			0	-.004	-.027	.11	0	75	24	0	45	27	.92	32	21	24	.75	83
4.005	8.7	20	3.1	.003	-.025	.10	0	89	28	1	55	32	.93	30	25	26	.80	81
4.006			0	.003	-.015	.09	0	90	25	0	65	35	.94	10	40	36	.82	87
4.007		30	3.1	-.010	-.042	.12	0	64	25	3	30	20	.91	76	11	12	.73	81
4.008			0	-.010	-.036	.12	0	68	24	4	32	22	.89	57	16	13	.74	92
4.009	9.7	20	3.1	-.003	-.037	.12	0	77	24	2	39	24	.92	63	15	14	.76	95
4.010			0	-.003	-.029	.11	0	78	26	1	42	25	.92	37	17	18	.73	79
4.011		30	3.1	-.017	-.054	.14	0	59	23	12	20	17	.85	90	6	3	.63	69

Table 19. SANDHILL CRANE - STOCHASTIC POPULATION MODELS

File	Input Values			Results														
	Adl Mor	0-1 Mt	Inb H	Population Growth			20 years			50 years				100 years				TE Yr
				Deter r	Stochastic r	SD	PE %	N	SD	PE %	N	SD	H	PE %	N	SD	H	
4.012			0	-.017	-.049	.14	0	54	20	14	22	14	.88	85	7	7	.64	76
	50%=0 | 50%=1																	
5.001	7.7	20	3.1	.033	.013	.07	0	128	26	0	131	26	.96	0	125	28	.93	
5.002			0	.033	.106	.07	0	128	23	0	130	22	.96	0	133	21	.93	
5.003		30	3.1	.019	-.005	.08	0	110	27	0	95	39	.95	4	74	48	.88	85
5.004			0	.019	.002	.08	0	110	26	0	107	36	.96	0	92	42	.90	
5.005	8.7	20	3.1	.027	.004	.08	0	122	24	0	116	28	.96	1	97	39	.92	86
5.006			0	.027	.015	.08	0	122	26	0	119	32	.96	0	122	34	.92	
5.007		30	3.1	.012	-.018	.10	0	92	31	0	71	37	.94	23	46	37	.86	82
5.008			0	.012	-.005	.08	0	106	31	0	92	35	.95	4	75	42	.89	86
5.009	9.7	20	3.1	.020	-.003	.08	0	108	30	0	96	34	.95	4	79	43	.89	90
5.010			0	.020	.004	.08	0	114	29	0	110	36	.95	1	97	39	.90	82
5.011		30	3.1	.006	-.021	.10	0	89	28	2	65	34	.94	19	27	24	.83	80
5.012			0	.006	-.013	.09	0	92	30	0	74	33	.94	4	31	34	.83	83
	40%=0 | 60%=1																	
6.001	7.7	20	3.1	.053	.033	.07	0	143	13	0	144	10	.97	0	143	13	.94	
6.002			0	.053	.037	.08	0	144	11	0	145	11	.96	0	144	11	.94	

Table 19. SANDHILL CRANE - STOCHASTIC POPULATION MODELS

File	Input Values			Results																
	Adl Mor	0-1 Mt	Inb H	Population Growth			20 years			50 years				100 years				TE Yr
				Deter r	Stochastic r	SD	PE %	N	SD	PE %	N	SD	H	PE %	N	SD	H	
6.003		30	3.1	.038	.018	.08	0	130	21	0	132	22	.96	0	131	25	.93	
6.004			0	.038	.022	.08	0	135	16	0	135	18	.96	0	138	19	.94	
6.005	8.7	20	3.1	.047	.026	.07	0	140	16	0	140	12	.96	0	139	17	.93	
6.006			0	.047	.032	.07	0	141	14	0	144	9	.96	0	144	10	.93	
6.007		30	3.1	.032	.010	.08	0	132	22	0	123	28	.96	0	114	33	.92	
6.008			0	.032	.016	.08	0	125	24	0	129	25	.96	0	128	24	.93	
6.009	9.7	20	3.1	.041	.018	.08	0	133	24	0	134	23	.96	0	129	23	.93	
6.010			0	.041	.024	.08	0	133	21	0	140	16	.96	0	140	12	.93	
6.011		30	3.1	.026	.003	.08	0	116	30	0	113	37	.95	4	93	40	.90	
6.012			0	.026	.008	.08	0	114	28	0	117	32	.96	1	115	35	.91	94
	50%=0 | 50%=1																	
7.001	7.7	40	3.1	.003	-.027	.11	0	83	29	3	56	32	.94	35	23	23	.80	82
7.002			0	.003	-.019	.10	0	86	28	1	60	35	.94	19	36	31	.82	80
7.003		50	3.1	-.015	-.050	.13	0	62	29	14	24	20	.87	86	8	5	.76	70
7.004			0	-.015	-.041	.13	0	63	24	4	30	23	.90	66	12	15	.72	76
7.005	8.7	40	3.1	-.003	-.039	.13	0	74	31	5	36	25	.91	68	16	14	.79	78
7.006			0	-.003	-.030	.12	0	61	31	4	44	30	.92	43	20	22	.74	77

Table 19. SANDHILL CRANE - STOCHASTIC POPULATION MODELS

File	Input Values			Results														
	Adl Mor	0-1 Mt	Inb H	Population Growth			20 years			50 years				100 years				TE Yr
				Deter r	Stochastic r	SD	PE %	N	SD	PE %	N	SD	H	PE %	N	SD	H	
7.007		50	3.1	-.022	-.060	.14	0	51	21	22	16	12	.86	97	4	3	.69	63
7.008			0	-.022	-.052	.14	0	50	20	18	19	14	.87	88	8	7	.64	70
7.009	9.7	40	3.1	-.010	-.044	.13	0	69	28	5	30	23	.90	78	11	9	.70	80
7.010			0	-.010	-.035	.12	0	69	25	4	34	24	.90	60	20	27	.75	94
7.011		50	3.1	-.028	-.062	.15	0	49	22	27	14	12	.84	98	2.5	.7	.56	61
7.012			0	-.028	-.058	.15	0	49	23	16	13	10	.83	95	8	4	.60	64
	50%=0 | 50%=1																	
8.001	7.7	60	3.1	-.036	-.066	.15	0	43	21	31	12	11	.83	98	12	6	.80	58
8.002			0	-.036	-.065	.15	0	43	20	29	10	8	.81	97	5	3	.59	60
8.003		70	3.1	-.062	-.095	.17	0	26	16	80	9	11	.81	100				42
8.004			0	-.062	-.093	.17	1	26	15	79	6	4	.77	99	6		.74	40
8.005	8.7	60	3.1	-.043	-.080	.15	0	34	15	66	8	5	.81	100				45
8.006			0	-.043	-.073	.16	0	37	17	47	8	5	.80	100				51
8.007		70	3.1	-.069	-.101	.17	2	23	14	80	5	3	.72	100				38
8.008			0	-.069	-.106	.18	2	21	15	85	5	4	.77	100				37
8.009	9.7	60	3.1	-.050	-.084	.16	0	31	16	65	6	4	.76	100				47
8.010			0	-.050	-.081	.17	0	30	16	69	8	6	.78	100				44

Table 19. SANDHILL CRANE - STOCHASTIC POPULATION MODELS

File	Input Values			Results														
	Adl Mor	0-1 Mt	Inb H	Population Growth			20 years			50 years				100 years				TE Yr
				Deter r	Stochastic r	SD	PE %	N	SD	PE %	N	SD	H	PE %	N	SD	H	
8.011		70	3.1	-.076	-.110	.18	3	19	11	88	3	1	.73	100				34
8.012			0	-.076	-.106	.18	3	21	14	88	4	2	.72	100				36
	50%=0 | 50%=1																	
9.001	7.7	80	3.1	-.096	-.131	.20	10	15	11	100								31
9.002			0	-.096	-.123	.20	12	16	9	98	2		.62	100				32
9.003		90	3.1	-.150	-.175	.21	38	7	5	100								23
9.004			0	-.150	-.182	.21	48	8	5	100								21
9.005	8.7	80	3.1	-.103	-.143	.20	26	12	9	98	4	3	.71	100				27
9.006			0	-.103	-.141	.21	19	13	10	98	4	1	.64	100				27
9.007		90	3.1	-.158	-.178	.20	42	7	4	100								22
9.008			0	-.158	-.185	.21	42	7	4	100								22
9.009	9.7	80	3.1	-.111	-.148	.20	28	12	9	100								25
9.010			0	-.111	-.153	.20	30	11	9	99	3		.50	100				25
9.011		90	3.1	-.165	-.194	.21	51	7	5	100								20
9.012			0	-.165	-.190	.20	51	6	5	100								20

Table 20. Mississippi Sandhill Crane. Population Viability Analysis Data

Species: *Grus canadensis*

Species distribution:

Jackson County MS, with possible migrants in Baldwin County MS.(Valentine 1981)

Study taxon: *G. canadensis pulla*

Study population location:

Wild population confined to Jackson County MS, from the Pascagoula River west to about the Harrison County line. The northern limit runs on an east-west line (Lat. 30 35') about 6.4 km north of Vancleave. The southern limit is Simmons Bayou and Graveline Bay, nearly to the Gulf of Mexico.(Valentine 1981)

Metapopulation:

Single wild population and a captive population.

Specialized requirements:

Savannas, or other openings at edges of swamps, forests, or plantations. Fresh water is necessary in the maintenance of preferred habitats and for drinking. (Smith & Valentine 1987)

Age of first reproduction for each sex:

a) Earliest: 3 yr. (Valentine & Logan 1988)
b) Mean: 5 yr for males, 4 yr for females - (S. Hereford, pers. comm.)

Clutch size (N, mean, SD, range):

1.7 (MSCRP

	Captive PWRC 1986-90	Wild - 1990	
Number fertile:	74%	61%	
Number hatch:	73%	64% - before '82	36% - '82 and after
Number fledged:	72%	46% - Florida sandhills	

Captive information - See attached PWRC production records for more information -J.Nicolich pers. comm.

Wild information, Table 6 - Florida information - MSCRP

Laying season:

Late March thru mid-May. Earliest: late February. Latest: June (S. Hereford, pers. comm.)

Laying frequency (interclutch interval):

About two days between eggs. (J.Nicolich pers. comm.)

Are multiple clutches possible?

Yes, if first clutch is lost, 13 of 119 clutches laid were reported as renestings (MSCRP)

Duration of incubation:

30 days including the day of laying, but not including the day of hatching. (Valentine 1982)

Hatchling sex ratio:

1:1 Male to females - Sandhills generally (MSCRP)

Egg weights:

Average weight 147.9 g (Walkinshaw 1981)

Hatchling weights (male and female):

Average weight 113.0 g (J.Nicolich, Pers. comm.)

Age(s) at fledging:

About 75 days - Sandhills generally (MSCRP)

Adult sex ratio: 1 male 5 years & older: 1 female 4 years & older (S. Hereford, pers. comm.)

Adult body weight of males and females:

Captive - Females 4.19 kg, Males 4.19 kg (J.Nicolich, pers. comm.)

Reproductive life-span (male & female, Range):

Unknown, Oldest Mississippi sandhill crane in captivity is 21 yrs.

Other species, male Siberian - sperm in late 70's, pair of White-naped breeding in their late 60's (ICF data)

Life time reproduction (mean, male & female):

Lowest recruitment rate for any sandhill crane population; 2.4 juveniles per 100 total cranes in October censuses, 1983-1992 (S. Hereford, pers. comm.).

Social structure in terms of breeding:

Monogamous pair bond will change if mate is ill, dies, or if pair is unsuccessful. Young birds may re-pair several times before staying with a mate.

Proportion of adult males and females breeding each year:

45% of adult (4 years old) females and males (5 years old) breeding (S. Hereford, pers. comm.).

Dispersal distance (mean, sexes)

Migrations (months, destinations)

The Mississippi sandhill crane probably doesn't migrate, but most birds fly to small cornfields or pastures to feed during the winter. The maximum flight distance to the feeding area is about 16 km. (Valentine 1981)

Territoriality (home range, season):

Greatest distance between nesting areas was 25 km and the shortest distance 2.5 km. (Valentine 1982). Nesting territories average 180 (±71) ha (MSCRP)

Age of dispersal:

About 290 days after hatching - Sandhills generally (MSCRP)

Maximum longevity:

Unknown

Captivity = 21 yrs.

* 2 White-naped at least in their 60's. Siberian died at - 80 years.

Population census-most recent. Date of last census. Reliability estimate.:

80-90, 1989. In addition 29 young of the year were released in 1989 and not included in the census number. 26 of these birds survived to 1990.

The January 1992 census yielded a population estimate of 122. As 80%+ are marked this is reliable. Since then, another 15 are considered dead and 1 thought dead reappeared, bringing the population at time of PHVA to 108 (S. Hereford, pers. comm.).

Projected population (5,10,50 years).:

Preliminary models suggests a goal of 130-170 cranes in a 10 year period of time. (MSCRP)

Past population census (5,10,20 years-dates, reliability estimates):

See attached wild census

Population sex and age structure (young, juvenile, & adults)-time of year.:

Winter counts 2.3 juveniles per 100 adults (MSCRP)

Source of mortality % (natural, poaching, harvest, accidental, seasonal?).: (MSCRP)

predators poaching pollutants
cranes vehicles tumors
flooding fire\arson parasites
droughts powerlines diseases

Habitat capacity estimate (Has capacity changed in past 20,50 years?):

From 1942-1981 using 6,475 ha: Savanna declined 74% to 14%. (Smith & Valentine 1987) Using 180 ha (MSCRP) as nesting territories, 1942 could have 26 territories and 1981 could have 5 territories.

Present habitat protection status.:

By 1992 almost 20,000 acres of Jackson County, MS have been placed under the control of the USFWS in the form of the Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR).

Projected habitat protection status (5,10,50 years).:

A goal of 22,000 acres, possibly more depending on what is required for a self-sustaining population. Unknown time frame. (MSCRP)

Environmental variance affecting reproduction and mortality (rainfall, prey, disease, snow cover?).:

Habitat loss, altered hydrology, Fire, dense tree growth, flooding, hurricanes, droughts, disease, pollution, predation, and parasites.

Is pedigree information available?:

Captive Mississippi Sandhill Cranes through PWRC.

Date form completed and revised: November 18, 1993

References:

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Valentine, J.M., and R. Lohoefener. 1991. Mississippi sandhill crane recovery plan (Third revision). U.S. Fish and Wildl. Serv., Atlanta, Georgia. Typewritten Manuscript. 42 pp.

Walkinshaw, L.H. 1981. The Sandhill Cranes. Pages 151-162 in J.C. Lewis and H. Masatomi, eds. Crane research around the world. Int. Crane Foundation, Baraboo,WI

VORTEX -- simulation of genetic and demographic stochasticity

SANDHILL.026 Sun Dec 26 20:59:08 1993

1 population(s) simulated for 100 years, 500 iterations
No inbreeding depression
First age of reproduction for females: 4 for males: 5
Age of senescence (death): 20
Sex ratio at birth (proportion males): 0.50000

Population 1:
Monogamous mating; all adult males in the breeding pool. 100.00 percent of adult males in the breeding pool. Reproduction is assumed to be density independent.

40.00 (EV = 12.65 SD) percent of adult females produce litters of size 0
60.00 percent of adult females produce litters of size 1
0.00 percent of adult females produce litters of size 2

30.00 (EV = 10.00 SD) percent mortality of females between ages 0 and 1
12.90 (EV = 3.00 SD) percent mortality of females between ages 1 and 2
12.90 (EV = 3.00 SD) percent mortality of females between ages 2 and 3
12.90 (EV = 3.00 SD) percent mortality of females between ages 3 and 4
8.70 (EV = 3.00 SD) percent annual mortality of adult females (4<=age<=20)
30.00 (EV = 10.00 SD) percent mortality of males between ages 0 and 1
12.90 (EV = 3.00 SD) percent mortality of males between ages 1 and 2
12.90 (EV = 3.00 SD) percent mortality of males between ages 2 and 3
12.90 (EV = 3.00 SD) percent mortality of males between ages 3 and 4
12.90 (EV = 3.00 SD) percent mortality of males between ages 4 and 5
8.70 (EV = 3.00 SD) percent annual mortality of adult males (5<=age<=20)
EVs may have been adjusted to closest values
possible for binomial distribution.
EV in mortality will be correlated among age-sex classes
but independent from EV in reproduction.

Frequency of type 1 catastrophes: 10.000 percent
with 1.000 multiplicative effect on reproduction
and 1.000 multiplicative effect on survival

Frequency of type 2 catastrophes: 3.000 percent
with 1.000 multiplicative effect on reproduction
and 1.000 multiplicative effect on survival

Initial size of Population 1:
(set to reflect stable age distribution)
Age 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
19 20 Total
7 7 5 5 4 3 3 3 3 2 2 2 1 2 1 1 1 1 1

0 54 Males

7	7	5	5	4	4	3	3	2	3	2	2	1	2	1	1	1	1	1

1 56 Females

Carrying capacity = 150 (EV = 0.00 SD)

Deterministic population growth rate (based on females, with assumptions of no limitation of mates, no density dependence, and no inbreeding depression):

r = 0.024 lambda = 1.024 R0 = 1.256
Generation time for: females = 9.65 males = 10.41

Stable age distribution:

Age class	females	males
0	0.083	0.083
1	0.057	0.057
2	0.048	0.048
3	0.041	0.041
4	0.035	0.035
5	0.031	0.030
6	0.028	0.026
7	0.025	0.024
8	0.022	0.021
9	0.020	0.019
10	0.018	0.017
11	0.016	0.015
12	0.014	0.013
13	0.012	0.012
14	0.011	0.011
15	0.010	0.009
16	0.009	0.008
17	0.008	0.008
18	0.007	0.007
19	0.006	0.006
20	0.006	0.005

Ratio of adult (>= 5) males to adult (>= 4) females: 0.834

Population1

Year 10
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 500, P[S] = 1.000
Population size = 116.41 (0.84 SE, 18.82 SD)
Expected heterozygosity = 0.988 (0.000 SE, 0.001 SD)
Observed heterozygosity = 0.999 (0.000 SE, 0.003 SD)
Number of extant alleles = 110.05 (0.55 SE, 12.21 SD)

Year 20
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 500, P[S] = 1.000
Population size = 114.95 (1.08 SE, 24.23 SD)
Expected heterozygosity = 0.980 (0.000 SE, 0.003 SD)
Observed heterozygosity = 0.993 (0.000 SE, 0.008 SD)
Number of extant alleles = 75.74 (0.47 SE, 10.52 SD)

Year 30
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 500, P[S] = 1.000
Population size = 113.32 (1.24 SE, 27.71 SD)
Expected heterozygosity = 0.972 (0.000 SE, 0.006 SD)
Observed heterozygosity = 0.986 (0.001 SE, 0.012 SD)
Number of extant alleles = 57.67 (0.43 SE, 9.51 SD)

Year 40
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 500, P[S] = 1.000
Population size = 111.10 (1.31 SE, 29.32 SD)
Expected heterozygosity = 0.964 (0.000 SE, 0.008 SD)
Observed heterozygosity = 0.978 (0.001 SE, 0.017 SD)
Number of extant alleles = 46.50 (0.38 SE, 8.44 SD)

Year 50
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 500, P[S] = 1.000
Population size = 107.30 (1.41 SE, 31.56 SD)
Expected heterozygosity = 0.955 (0.001 SE, 0.013 SD)
Observed heterozygosity = 0.970 (0.001 SE, 0.020 SD)
Number of extant alleles = 38.59 (0.35 SE, 7.75 SD)

Year 60
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 500, P[S] = 1.000
Population size = 104.79 (1.50 SE, 33.46 SD)
Expected heterozygosity = 0.947 (0.001 SE, 0.017 SD)
Observed heterozygosity = 0.962 (0.001 SE, 0.025 SD)
Number of extant alleles = 32.98 (0.31 SE, 7.04 SD)

Year 70
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 500, P[S] = 1.000
Population size = 101.43 (1.54 SE, 34.53 SD)
Expected heterozygosity = 0.938 (0.001 SE, 0.023 SD)
Observed heterozygosity = 0.956 (0.001 SE, 0.025 SD)
Number of extant alleles = 28.69 (0.30 SE, 6.72 SD)

Year 80
N[Extinct] = 1, P[E] = 0.002
N[Surviving] = 499, P[S] = 0.998
Population size = 99.82 (1.65 SE, 36.86 SD)
Expected heterozygosity = 0.928 (0.002 SE, 0.037 SD)
Observed heterozygosity = 0.943 (0.002 SE, 0.041 SD)
Number of extant alleles = 25.30 (0.29 SE, 6.45 SD)

Year 90
N[Extinct] = 3, P[E] = 0.006
N[Surviving] = 497, P[S] = 0.994
Population size = 97.06 (1.68 SE, 37.50 SD)
Expected heterozygosity = 0.917 (0.002 SE, 0.040 SD)
Observed heterozygosity = 0.935 (0.002 SE, 0.043 SD)
Number of extant alleles = 22.68 (0.28 SE, 6.16 SD)

Year 100
N[Extinct] = 3, P[E] = 0.006
N[Surviving] = 497, P[S] = 0.994
Population size = 95.53 (1.72 SE, 38.29 SD)
Expected heterozygosity = 0.906 (0.003 SE, 0.057 SD)
Observed heterozygosity = 0.926 (0.002 SE, 0.053 SD)
Number of extant alleles = 20.50 (0.26 SE, 5.81 SD)

In 500 simulations of Population1 for 100 years:
3 went extinct and 497 survived.

This gives a probability of extinction of 0.0060 (0.0035 SE),
or a probability of success of 0.9940 (0.0035 SE).

3 simulations went extinct at least once.
Of those going extinct, mean time to first extinction was 81.33 years (2.73 SE, 4.73 SD).
No recolonizations.

Mean final population for successful cases was 95.53 (1.72 SE, 38.29 SD)

Age 1	2	3	4	Adults	Total	
5.61	5.01	4.37	3.95	28.32	47.26	Males
5.75	4.88	4.37		33.28	48.27	Females

Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was 0.0000 (0.0003 SE, 0.0677 SD)
Final expected heterozygosity was 0.9061 (0.0025 SE, 0.0567 SD)
Final observed heterozygosity was 0.9265 (0.0024 SE, 0.0532 SD)
Final number of alleles was 20.50 (0.26 SE, 5.81 SD)

MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Section 6

DISEASES: MANAGEMENT AND RESEARCH

SUMMARY OF DISEASES AND DISEASE ISSUE RECOMMENDATIONS

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Mortality rates are a significant negative factor for the status of the Mississippi Sandhill crane (MSC). Based on data from wild and captive birds, disease is a significant and insufficiently investigated factor adversely affecting the successful recovery of the subspecies. Non-infectious disease conditions (congenital heart defects, tumors) are of particular concern with the MSC. The following have been identified as disease concerns; specific research and management needs are outlined.

Health Issues For The Wild Flock

Based on the information gleaned from examination of carcasses/samples submitted to the National Wildlife Health Research Center (NWHR) between 1981 and 1992, the major health issues for the wild flock include tumors (carcinomas of respiratory origin) and associated biliary hyperplasia, disseminated visceral coccidiosis/other parasites, exteriorized yolk sacs, heart defects, and necrotizing dermatitis. (See Appendix 1 for details.) The prevalence of Salmonella found in these cranes is also of concern, especially its potential as a limiting factor for reproductive success.

Summary of Tumor Problem in Mississippi Sandhill Cranes at the MSC National Wildlife Refuge

Five adult Mississippi sandhill cranes from the MSCNWR have been diagnosed with tumors. All five of these cranes, and one other from the refuge, also had a biliary lesion in the liver. The prevalence of tumors in wild MSC far exceeds that expected in birds or mammals. Tumors were diagnosed as the cause of death for three of these cranes. The cause of death of the other two was actually trauma, one was killed by a golden eagle, and the other died after crashing into a fence.

Three of the cranes with tumors were hatched in the wild and the other two at PWRC. All were 4 years or older. The first crane with a tumor was found in 1974, two were found in 1984, one in 1986 and one in 1987. Only two adults were submitted for necropsy between 1975 and 1983, and no cranes old enough to have developed tumors have been found suitable for necropsy since 1987. The ten year gap between the first and second tumor cases, and the sporadic presentation of dead birds old enough to be at risk for tumor development suggest that this could be an ongoing problem for the wild MSC flock and not just a finite historical problem. Additionally the significant frequency of tumors in this flock may be merely a relatively easily observable sign of a much greater threat to flock health, e.g. sublethal effects on reproduction and fitness.

The most common identified causes of tumors include infectious agents such as viruses or parasites, chemical or natural toxins, or genetic predisposition. No viruses nor parasites known to cause tumors have been recovered from these cranes. Because cranes at PWRC have not developed tumors, genetic predisposition alone does not appear likely.

Studies by FWS (Daphne, AL) and Mississippi State University have detected polycyclic aromatic hydrocarbons (PAHs) and aflatoxins, respectively, in the environment at the refuge. Both PAHs (manmade toxin) and aflatoxin (natural toxin) are known carcinogens.

Refuge staff captured almost 300 other vertebrates on the refuge for examination for tumors, none have been found to date in any of the other birds, mammals, or fish examined.

Research needs to continue in order to determine the role of PAHs and aflatoxins in causing these tumors. Continued monitoring of air at the refuge and analysis of eggs and tissues from dead cranes should give us a better understanding of what potential carcinogens are present and may play a role in the demise of the Mississippi sandhill crane.

In addition, research is needed to determine the affect these toxins have on cranes, both directly as causes of morbidity and mortality, and affects on reproductive success. Feeding trials, or experimental exposure studies, need to be undertaken to address this concern. Once the cause of the tumors is identified, management steps can be taken at the refuge to reduce exposure to the cranes.

Summary of Findings of SALMONELLA spp. at the Mississippi Sandhill Crane NWR.

Mississippi State University Researchers recovered the potentially hazardous bacteria, Salmonella arizonae and S. muenchen, from the water drainages on the refuge that originated from the Ocean Springs sewage treatment plant. In 1989, 3 Salmonella spp. (S. give, S. miami, and S. muenchen,) were isolated from 3 of 5 healthy cranes captured for banding on the refuge. Salmonella bareilly was cultured from a sick crane found near the refuge. Salmonella spp. are potential egg pathogens which can cause poor hatchability and/or formation of skin lesions in embryos. Three of five dead chicks or full-term embryos collected at the Mississippi Sandhill Crane National Wildlife Refuge in 1989 had a necrotizing skin disease of uncertain etiology.

Salmonellosis causes problems in domestic poultry similar to those experienced by the Mississippi sandhill cranes. Extensive research has been done to demonstrate the relationship between Salmonella spp. and reproductive failure in adult chickens and turkeys such as infertility, reduced hatchability, and poor hatchling performance. Other studies have demonstrated the capability of salmonella organisms to remain in the environment for long periods of time. Studies have also demonstrated the carrier state and spread of pathogenic salmonellas through waste products from large and small mammals (human and non-human).

Research needs to be undertaken to evaluate the virulence of Salmonella spp. that have been recovered from cranes on the Refuge as one of the causes of reduced hatchability of the crane eggs and early chick mortality. If salmonellosis is determined to be a reproductive problem for MSCs and the source determined, then management steps can be undertaken to eliminating the source or reduce crane exposure to the bacterium.

Health Issues For The Captive Flock

Appendix 2 is a complete quantitative summary of the mortality seen in the captive MSC flock at Patuxent Wildlife Research Center (PWRC) from 1985-1992. The most important health risks to captive MSC vary by age group.

Chicks (pre-fledging): Anatomic abnormalities, most commonly congenital heart defects, are an important cause of morbidity and mortality in chicks (15 of 58 deaths, 26%). This problem is discussed in more detail below. Trauma caused the deaths of 11 of 58, or 19% of chicks. Most of the trauma was parent-associated, either direct attacks or inadvertently stepping on chicks. Infectious respiratory disease, and infectious and non-infectious yolk sac conditions have also been identified as significant problems for chicks.

Juveniles (between fledging and one year): Wing and leg fractures and subsequent complications were the most common mortality factors in juvenile birds (4 of 19, 21%). Patuxent staff need to continue to search for ways to reduce this problem. Trauma, respiratory infections, predation and disseminated visceral coccidiosis each caused the death of two birds (11% of the mortality), and should be considered as significant diseases to be managed for the captive flock.

Adults (greater than one year of age): Trauma, either due to conspecific aggression, predation, or accidents was by far the most common mortality factor identified (10 of 12 deaths, 83%). Infectious diseases are uncommon in adult birds; parasites occur at a low frequency, but rarely cause clinical illness and are successfully treated.

Summary of Heart Defects (Heart Murmurs)

There is significant evidence that congenital heart defects, resulting in detectable heart murmurs, are a major health problem for the MS sandhill crane. Eight deaths of chicks in the captive flock have been attributed to heart defects, accounting for 14% of deaths in downy chicks and 9% of all deaths. (see Appendix 2) Three of the 36 wild birds (8%) submitted for necropsy were found to have heart defects. (see Appendix 1) These heart defects are not universally lethal; from 1988-1991 23 chicks hatched at PWRC were found to have heart murmurs, and presently 12 of these are surviving either at PWRC or on the MSCNWR.

On necropsy, the congenital heart defects have been identified as ventricular or atrial septal defects. Clinical evaluations including EKG analysis and radiographs suggest right-sided heart enlargement. Chicks are variably affected; transient murmurs are detected in some birds only in the first few weeks, other birds have persistent murmurs.

Potential causes for this type of congenital cardiovascular anomaly include developmental defects at the critical stage of embryonic growth (2-7 days), environmental insults such as improper incubation temperatures or egg rotation frequencies, or toxins, and genetic factors. Developmental defects and environmental factors have been explored at PWRC, and no apparent pattern has been found. Initial analysis of the pedigrees of the affected birds has not elucidated any simple pattern of inheritance; 12 females and 7 males have been identified as parents of affected chicks. (see Table 27, Appendix 3) However, the relationships of these 10 parents have not been completely delineated, and there is a strong suspicion that this is an inherited problem, either polygenic or involving both genetic and environmental factors. It is important to consider that the observed heart defects may be part of a complex of more subtle inherited problems.

One of the most important questions is the significance of the heart defect problem for the overall performance of the captive and wild flocks. Specifically, does the presence of a heart murmur in an individual affect that bird's performance and survival? Analysis of weight gain data at PWRC has not shown evidence of stunted growth in affected chicks. However, analysis of mortality data on birds released at the MSCNWR shows a reduction in survival for birds affected with heart murmurs: between 1989-1991, 7 of 11 affected birds died (64%) and only 9 of 53 unaffected birds died (17%). (see Table 26, Appendix 3)
For many of the affected chicks who died, the proximal cause of death was not the heart defect, but trauma, predation, parasites, or other infectious or toxic diseases. (see Appendix

1) Potentially, congenital heart abnormalities of a less severe nature may be a debilitating factor in more birds than already identified.

The prevalence of the heart abnormalities and the demonstrated negative effect on survivorship suggest that serious consideration be given to management changes and research needs related to this health issue. Our recommendations are given below.

Health Issue Management Recommendations

1. **Heart defects**: There is a mortality rate almost 4 times greater for released birds with a history of a heart murmur compared to normal released birds. Given the monetary and manpower resources needed to raise and release each of these chicks, and the unknown impact of this possible genetic problem on the genetic health of the population, we recommend that (a) birds identified as having a heart murmur no longer be considered for release, (b) analysis of the pedigrees of the entire flock be undertaken to evaluate a possible genetic basis for the murmurs and to determine the risk of losing genetic diversity by removal of these birds from the potential wild breeding pool, and (c) consultation with experts on the genetics of cardiovascular disorders be sought. This would include both birds with transient and persistent murmurs, as the data on decreased survival do not indicate a difference between these two groups. There needs to be additional consideration of the management needs of the captive flock (e.g. genetic diversity, surrogate rearers, research birds) before a decision is made whether these affected birds should be euthanized or maintained in captivity.

It is important that there be continued good documentation of the pedigrees of affected birds. Additionally, if eggs are collected from the wild for addition to the captive flock, every effort should be made to identify the wild parents.

2. **DVC/Salmonella**: Birds destined for release need to be routinely screened specifically for Salmonella and coccidia. Additionally, a program for long term surveillance of birds in the release pens should be initiated to evaluate how introduction of captive birds, continued use of the same pens, and increased density of birds at release sites are affecting the prevalence of coccidia and Salmonella infections. The existent management plan to control build-up of pathogens in the release pens should be reviewed and systematically implemented. Presently used release pen should be moved to new ground. If birds are to be transferred to new captive propagation sites, protocols to clear the birds of coccidia before transfer should be developed and implemented. (Experience with transfer of a portion of the whooping crane flock suggests that this is a realistic option.)

3. **Trauma/fractures**: The etiologic factors and management techniques for the trauma and fracture problems seen in the captive flock should be investigated. Management modifications, such as changes in pen design, handling techniques, and nutritional programs should be considered to minimize the impact of these problems.

4. There needs to be thorough evaluation of the protocols used for release of cranes at MSCNWR to determine health risks associated with the release program. Protocols for quarantine and health screening before transfer to the MSCNWR for release (and before transfer to future captive flock sites) need to be reviewed and systematically implemented. Periodic health checks of the captive flock for potential pathogens should be continued. The release pens should be managed to minimize survival of pathogens and potential spread of disease agents to the free-flying cranes at the refuge.

5. The program of intensive necropsy evaluation of all birds dying in the captive and wild flocks to ascertain cause of death and collect tissues for retrospective contaminant analysis needs to be continued. It would be preferable if all birds were necropsied by one institution (NWHR), to maximize consistency and make best use of the existent expertise. However, if this is not possible, a necropsy protocol should be developed for use by all institutions and a format developed for exchange, discussion, and comparison of findings.

Prioritized Health Issue Research Needs

1. **Heart defects/murmurs**: The genetic basis of the problem needs to be explored by computer analysis of the pedigrees of affected MSC. A program of more extensive clinical diagnostic evaluation should be designed to better describe the functional abnormalities and help elucidate the pathogenesis. Once the results of these investigations are available, breeding studies to confirm the inheritance pattern could be considered.

2. **Tumors/Contaminant Exposure**: We do not believe that the dramatic prevalence of tumors and associated biliary hyperplasia in adult MSC was a finite historical event, but instead is probably an ongoing problem that potentially is a sentinel of more insidious sublethal effects such as decreased reproduction. Research needs to be done to explore the effects of identified contaminants on reproduction as well as on the source of tumors in adult cranes. The studies in progress (see Project list in general appendices) should be continued. Additionally, feeding/exposure trials should be done with the identified potential carcinogens (polycyclic aromatic hydrocarbons, aflatoxins) in an attempt to produce tumors, cause mortality, or depress reproduction. There is also a need for other insightful projects to try to identify contaminants, point sources, or other causes for the tumor problems.

3. **Salmonella**: Research needs include screening of eggs, eggshells, nests and trapped birds to determine the prevalence of Salmonella spp., and virulence testing of the isolated Salmonella serotypes to determine morbidity and mortality for eggs and nestlings. Virulence testing could be expanded to investigate the much more complicated and harder to detect effects of Salmonella serotypes on reproduction. The ongoing study investigating the prevalence of Salmonella and other potentially pathogenic bacteria in the environment should be completed.

4. **Disseminated visceral coccidiosis**: The source of the parasite causing DVC is unknown, but the prevalence of coccidia caused morbidity/mortality in the MSC flock appears to be greater than in other species of cranes in the wild. The two species identified, Eimeria gruis and E. reichenowi and the disease has been established with oocysts isolated from feces collected in the wild. It is not clear whether DVC occurred in the wild flock before the release of captive birds; releases started in 1980 and the first known mortality from DVC in a wild bird occurred in 1985. A study of PWRC necropsy records should be done to look for evidence that DVC occurred in wild MSC before 1980. If PWRC continues to hold MSC, further research is needed to develop effective coccidiostats to rotate for control of DVC in this flock since cocci develop resistance to drugs.

5. **Exteriorized yolk sacs**: Because the cause of this disease is unknown research needs include investigation into determining whether or not this condition is a result of disease/contaminants or behaviorally induced. Additionally, the development of a photographic/keyed aging chart for sandhill crane embryos would be helpful in the evaluation of this embryo problem.

Appendix 1

Health Issues Of The Wild Flock

I. Causes of morbidity/mortality in MSC diagnosed at the National Wildlife Health Research Center

Thirty-six carcasses suitable for necropsy have been submitted to NWHR between 1981 and 1992. Five of these were nestlings, 12 were adults, and the remaining 19 were immatures.

Fifteen of the 31 adult and immature cranes submitted were in good body condition, 5 were in fair condition, 3 in poor condition, and 5 were emaciated. Generally those birds in poor/emaciated body condition had chronic diseases/parasites associated with the cause of death. The sex composition of the 36 crane carcasses was 20 males, 14 females and 2 undetermined (scavenged).

Trauma was involved in almost half of the carcasses submitted. However, many of these had predisposing disease factors associated with cause of mortality.

Tumors were found in 4 of the carcasses examined at NWHR, plus retrospective searching yielded a fifth tumor case in a Mississippi sandhill submitted to PWRC prior to establishment of NWHR. This is an extremely high prevalence of tumors compared to other species examined and a major cause of concern. The five cranes with tumors were 4 1/2 years of age or older, two were females and three were males. Tumors were detected in 1974, 1984 (2), 1986, and 1987. No adults known to be old enough to develop tumors have been found since then in a condition suitable for post mortem exam.

Tumors have not been found in any of the MSC at PWRC. The source of the tumors has not been determined although 2 known carcinogenic sources have been identified on the refuge, a polycyclic aromatic hydrocarbon (benzo [a] pyrene) and aflatoxin. These were found in studies by FWS (Daphne, AL) and Mississippi State University respectively.

Disseminated visceral coccidiosis was diagnosed in 5 of the cranes (4 males, 1 female) submitted to NWHR, one in each of 1985, 1986, and 1991 and 2 in 1992. One of the cranes in 1992 actually died of trauma, and the one in 1985 died from cyanide poisoning (coyote bait). Another had a tumor and one had aspergillosis and a heart defect diagnosed along with the coccidiosis. The fifth suffered from typhlitis (probably a manifestation of intestinal coccidiosis) and avian pox.

Hemorrhagic enteritis, with a massive Ascarid parasite infection, probably initiated by an intestinal coccidial infection, was diagnosed in one carcass, as was lead poisoning. Gizzard lesions were severe in some birds with **Capillaria sp.** Infection and emaciation was prevalent as probable complications. Other mortality factors noted in carcasses submitted were capture myopathy, septicemia, emaciation (of unknown cause) in one bird, and asphyxiation.

The eggs/nestlings submitted also had various disease problems. Exteriorized yolk sacs were seen in five cases, the cause was not determined. Necrotizing dermatitis was also found in 3 of 5 nestlings, the cause of which could not be determined. Differential diagnosis for these could be infectious agents, (e. g. **Salmonella** bacteria), behavioral problems of the parents, or, in the case of necrotizing dermatitis; fire ants.

The concern for overall health status prompted MSCNWR and NWHR staff to survey cranes captured for banding in 1989. Three Salmonella spp. (S. give, S. miami, and S. muenchen were isolated from 3 of 5 "healthy" cranes captured that year. A similar survey is planned for fall 1992.

Ventricular or atrial septal defects were found in 3 immature cranes in 1991 and 1992. Two of these were male and one was a female. One was killed by a predator and another had hemorrhagic enteritis, coccidiosis, and aspergillosis. No other cause of morbidity/mortality was detected in the third carcass having the heart defect.

II. Based on the information gleaned from examination of carcasses/samples submitted to NWHR the major health issues include the tumor problem, disseminated visceral coccidiosis, parasites, exteriorized yolk sacs, heart defects, and necrotizing dermatitis. The prevalence of Salmonella found in these cranes is also of concern, especially its potential as a limiting factor for reproductive success.

Appendix 2.

Mississippi Sandhill Crane Mortality At Patuxent Wildlife Research Center, 1984-1992.
Glenn H. Olsen

Between July 1984 and September 1992, 89 Mississippi sandhill cranes (Grus canadensis pulla) died at Patuxent Wildlife Research Center, Laurel, Maryland (Table 21). Fifty-eight of the dead cranes were chicks (hatch to fledging), 18 were juveniles (fledging to 1 year) and 12 were adult birds (Tables 2, 3, 4). Trauma associated with aggression, pneumonia/air sacculitis, predation, yolk sac disorders, and congenital anatomic abnormalities account for 58 (65%) of the cases seen (Table 21). Another 19 cases had no definitive diagnosis. Five cases in recent years (1989-1992) died or were euthanized because of fractured long bones. No deaths of Mississippi sandhill cranes were recorded from July-December 1984 and this year is not included in all tables.

As would be expected from the large number of deaths in chicks, most mortality occurs in May (15%), June (37%), and July (22%) (Table 25). More deaths occurred in the fall as compared to the winter and early spring because the young birds have not yet been shipped to their namesake state.

Trauma caused by aggression was the most common cause of death identified. It occurred in both adults and chicks. In chicks that are parent-reared by foster parent sandhill cranes of other subspecies, we occasionally saw trauma caused by the parent bird attacking the chick. Less often seen was the situation where the parent bird accidentally injured the chick, usually by stepping on it.

In older birds trauma is associated with pair formation in community pens. When a pair forms in the confines of the pens, the two members of the pair often became aggressive towards other pen mates. The last common situation where aggression was seen occurred when a crane flew or jumped from its normal pen to a nearby occupied pen. Almost always the trespasser was the seriously injured or dead bird.

Of the 3 common trauma/aggression types, only the first, aggression against chicks, probably causes death with any frequency in the wild. In the other two cases, involving adult or sub-adult cranes, the defensive bird would have infinite space in which to retreat from the aggressive individual(s), making death of a crane an unlikely outcome of such encounters.

A fourth type of trauma, was seen when a crane ran/flew into the fencing and died from cervical fracture or spinal trauma. This type of trauma caused the death of 3 cranes in the last 8 years. Similar causes of death may occur in the wild as cranes fly into fences or powerlines, but the incidence may not duplicate the captive situation numerically.

Pneumonia/air sacculitis or other respiratory diseases cased 8% of the mortality seen a Patuxent in the study period. If appeared that the young cranes were especially prone to respiratory infections as 5 of 7 infected birds were chicks and the other 2 were juveniles (Table 22, 23). Because no etiological agent has been identified in these cases, it appears to be a disease syndrome of young birds that would be expected to occur with similar frequency in the wild population.

Another disease complex of chicks was omphalitis/ruptured yolk sac/yolk peritonitis. Various etiological agents and causes, from bacterial infections (E. coli most commonly) to suspected trauma, have been identified in the 7 cases. There is no reason to suspect that this is only a problem in captive birds. Indeed, these figures can be used to compare with the known incidence of yolk sac problems in wild chicks.

Congenital or developmental anatomical abnormalities were very common, accounting for 17% of all deaths and 26% of deaths in chicks. Almost half of these abnormalities were heart defects, primarily ventricular or atrial septal defects. These heart defects seem to be genetically linked. Three chicks suffered from severe scoliosis. Other lesions seen included a 3-legged chick, curled toes/clubbed foot, and severely exteriorized yolk sac. Again, the assumption is that a similar mortality rate may occur in the wild population.

Disseminated visceral coccidiosis (DVC) has only resulted in 3 deaths in the past 8 years (Table 22). Two of the deaths occurred in 1988, the year we recognized the failure of the coccidiostat amprolium to continue to protect captive birds. In 1989 Patuxent switched to Monensin. Only one death from DVC has occurred since then and this was in a parent-reared chick. We believe, the parents were too successful at capturing prey for the chick and therefore did not feed enough pellets. The status of DVC in the wild population is uncertain at this time. It is difficult to extrapolate from the captive situation given the concentrated in which birds are penned.

In the past 8 years 6% of the deaths have been associated with complications or fractures of long bones. This problem has only occurred since 1990. It may be related to the increased number of chicks being raised or to other factors in the captive environment. Further discussion on this topic are planned at Patuxent this year. In any case, this appears to be an artifact of captive propagation at this time.

Predation seems to claim one known loss each year. There are other, undocumented as to cause, disappearances of chicks each year. There were 3 cases in 1992, where predation is suspected. In all cases, avian predators, especially great horned owls, are suspect. Most likely, similar losses occur among wild birds.

Seasonally, we see most deaths in May, June, and July (74%) (Table 25). This is not unexpected, given that 65% of recorded deaths are in chicks and another 21% in juvenile cranes. Other deaths are scattered throughout the year. This pattern of occurrence probably reflects the situation in the wild, also.

Other disease conditions occur in the captive flock, but do not always result in death. A low incidence of capillaria, ascarids, gapeworm, and coccidia has been observed in the cranes. Clinical signs of illness (upper respiratory disease) are seen with gapeworm, but treatment has been very effective. Ocular lesions, primarily traumatic corneal lesions of unknown origin, are seen occasionally. One female crane has several small neoplasias of the iris that are causing no appreciable problem for the 16 year-old bird. One crane continues to do quite well despite suffering a leg amputation following a fracture several years ago. Generally, at this time there is no ongoing medical problems existing in the flock that are not reflected in the mortality figures given above.

Table 21. Review of causes of mortality of all Mississippi sandhill cranes at Patuxent Wildlife Research Center, Laurel, Maryland, July 1984-September 1992.

Cause of Mortality	Year										
	84	85	86	87	88	89	90	91	92	Total	%
Aggression/trauma	0	1	2	1	3	2	5	1	1	16	18
Cervical or spinal trauma	0	1	0	0	1	0	0	0	1	3	3
Pneumonia/resp. disease	0	1	1	1	0	2	1	1	0	7	8
Predation	0	0	1	1	1	1	1	0	1	6	7
Yolk sac conditions	0	0	0	1	2	0	1	2	1	7	8
Disseminated visc. coccid.	0	0	0	0	2	0	1	0	0	3	3
Anatomical abnormalities	0	0	0	1	0	3	3	5	3	15	17
Scoliosis	0	0	0	0	0	1	1	1	0	(3)	(3)
Heart defect	0	0	0	1	0	0	1	3	3	(8)	(9)
Fracture complications		0	0	0	0	0	0	1	2	2	56
Colibacillosis	0	0	0	1	0	0	0	0	0	1	1
Cloacal prolapse/septicemia	0	0	0	0	0	0	1	0	0	1	1
Capture myopathy	0	0	0	0	0	0	1	0	0	1	1
Maggot infestation/wounds	0	0	0	0	0	0	1	0	0	1	1
Intestinal adhesions	0	0	0	0	0	0	0	1	0	1	1
Drowning	0	0	0	0	0	0	0	1	0	1	1
Cloacal impaction	0	0	0	0	0	0	0	0	1	1	1
Head caught in water handle		0	0	0	0	0	1	0	0	0	11
No diagnosis/open	0	0	4	4	1	2	4	3	1	19	21
Total by year	0	3	8	10	10	11	20	16	11	89	

Prepared by Glenn H. Olsen, Patuxent Wildlife Research Center, Sept. 1992.

Table 22. Causes of mortality in Mississippi sandhill crane nestling chicks (hatch to fledging) at Patuxent Wildlife Research Center, Laurel, Maryland, 1985-1992.

Cause of Mortality	Year 85	86	87	88	89	90	91	92	Total	%
Aggression/trauma	0	0	1	1	3	5	0	1	11	19
Pneumonia/resp. dis.	0	1	1	0	1	1	1	0	5	9
Predation	0	0	1	0	0	0	0	1	2	3
Yolk sac conditions	0	0	1	2	0	1	2	1	7	12
Dissem visc. coccid.	0	0	0	0	0	1	0	0	1	2
Anatomical abnorm.	0	0	1	0	3	3	5	3	15	26
Scoliosis	0	0	0	0	1	1	1	0	(3)	(5)
Heart defect	0	0	1	0	0	1	3	3	(8)	(14)
Colibacillosis	0	0	1	0	0	0	0	0	1	2
Capture myopathy	0	0	0	0	0	1	0	0	1	2
Maggot infest. wounds	0	0	0	0	0	1	0	0	1	2
Intestinal adhesions	0	0	0	0	0	0	1	0	1	2
Cloacal impaction	0	0	0	0	0	0	0	1	1	2
Prolap. cloaca/septic.	0	0	0	0	0	1	0	0	1	2
No diagnosis/open	0	2	2	1	1	3	1	1	11	19
Total by year	0	3	8	4	8	17	10	8	58	

Prepared by Glenn H. Olsen, Patuxent Wildlife Research Center, Sept. 1992.

Table 23. Causes of mortality of juvenile Mississippi sandhill cranes (fledging to 1 year of age) at Patuxent Wildlife Research Center, Laurel, Maryland, 1985-1992.

Cause of Mortality	Year 85	86	87	88	89	90	91	92	Total	%
Aggression/trauma	0	1	0	1	0	0	0	0	2	11
Pneumonia/resp. dis.	1	0	0	0	1	0	0	0	2	11
Predation	0	1	0	0	0	1	0	0	2	11
Dissemin. visc. coccid.	0	0	0	2	0	0	0	0	2	11
Fracture complications	0	0	0	0	0	1	1	2	4	21
Drowning	0	0	0	0	0	0	1	0	1	5
No diagnosis/open	0	2	2	0	0	1	1	0	6	32
Total by year	1	4	2	3	1	3	3	2	19	

Prepared by Glenn H. Olsen, Patuxent Wildlife Research Center, Sept. 1992.

Table 24. Causes of mortality of adult Mississippi sandhill cranes at Patuxent Wildlife Research Center, Laurel, Maryland, July 1984-September 1992.

Cause of Mortality	Year 84	85	86	87	88	89	90	91	92	Total	%
Aggression/trauma	0	1	0	1	1	0	0	1	0	4	33
Cervical or spinal trauma	0	1	0	0	0	0	0	0	1	2	17
Predation	0	0	0	0	1	1	0	0	0	2	17
Fracture compl.	0	0	0	0	0	0	0	1	0	1	8
Head caught: water handle	0	0	0	0	0	1	0	0	0	1	8
No diagnosis/open	0	0	1	0	0	0	0	1	0	2	17
Total by year	0	2	1	1	3	1	0	3	1	12	

Prepared by Glenn H. Olsen, Patuxent Wildlife Research Center, Sept. 1992.

Table 25. Mortality of 89 Mississippi sandhill cranes by month at Patuxent Wildlife Research Center, Laurel, Maryland, Jan. 1985-Sept. 1992.

Year	Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	0	0	0	1	0	1	0	1	0	0	0	0
1986	0	0	0	0	1	2	2	1	0	0	1	1
1987	0	0	0	0	2	5	0	1	1	0	0	1
1988	0	0	0	0	2	2	3	0	0	3	0	0
1989	0	1	0	0	0	5	3	1	1	0	0	0
1990	0	0	0	0	3	6	6	2	1	1	0	1
1991	0	0	1	0	4	5	4	0	0	1	1	0
1992	0	0	0	0	1	7	2	1	0	-	-	-
Total	0	1	1	1	13	33	20	7	3	5	2	3
%	0	1	1	1	15	37	22	8	3	6	2	3

Prepared by Glenn H. Olsen, Patuxent Wildlife Research Center, Sept. 1992.

Appendix 3

Table 26. Heart Murmurs in Mississippi Sandhill Cranes-Effects on release bird survivorship. A=birds affected by heart murmurs, U=birds without heart murmurs.

"A" Birds

YEAR	hatched at PWRC	# Released	# Died Post Release	# Died at PWRC
1988	1	0	0	1
1989	7	3	1	2
1990	10	5	4	3
1991	3	3	2	0
1992	2	___	___	___
TOTALS	23	11	7	6

YEAR	# Released		# Died		Percentage	
	U	A	U	A	U	A
1989	6	3	3	1	50	33
1990	20	5	0	4	0	80
1991	27	3	6	2	22	67
TOTALS	53	11	9	7	17	64

*Table generated during workshop by Julie Langenberg

Appendix 3.

Table 27. Parents of MSC Chicks Affected with Heart Murmurs.

	Studbook #	Patuxent ID #
Females (12)	T1018	71002 (Mrs Stubby)
	T1024	74002 (Banshee)
	T1028	75001 (Aunt Bea)
	T1031	76003 (Sweetie)
	T1066	81001
	T1135	84008
	T1136	84007 (Valentine)
	T1138	85008 (Charlotte)
	T1149	85010
	T1151	85011
	T1163	86038
	T1168	86056
Males (7)	T1020	72001 (Stubby)
	T1022	73001 (Peg Leg)
	T1034	76001 (Willie)
	T1128	84006
	T1137	84009
	T1148	85009
	T1152	85012

Appendix 4. Table 28. Ultimate Causes of Mortality in Released Mississippi Sandhill Cranes

Proportion of carcasses found: 55 of 80 birds (68.8%) that are presumed dead.

Causes of Death When Carcass Found	Number	Percent
Known/Suspected	39	70.9
Unknown	16	29.1
Total	55	100.0

Breakdown of Known Mortality	**Number**	**Percent**
Predation	12	30.8
Trauma (mostly fence/pen collisions)	4	10.3
Probable powerline collision	4	10.3
Leg-hold trap related injury	2	5.1
Capture-related (1 trauma, 1 suffocation due to aspirated corn)	2	5.1
Trauma--intra(?)specific aggression	1	2.6
Hit by vehicle	1	2.6
Hit by vehicle/internal parasites	1	2.6
Internal parasites	1	2.6
Gunshot wounds	1	2.6
Predation/Heart defect	1	2.6
Predation/internal parasites	1	2.6
Internal hemorrhage/intern. parasites	1	2.6
Tumor/Biliary hyperplasia	1	2.6
H-44 coyote getter cyanide poisoning	1	2.6
Emaciation	1	2.6
Suffocation--aspirated corn	1	2.6
Coccidiosis	1	2.6
Heart defect	1	2.6
Lead poisoning	1	2.6
Total	39	100.0

31/39 known causes of death were for birds <1 year old. For birds >1, causes were trauma 3, predation 2, powerline 1, intra(?)specific aggression 1, Suffocation (corn) 1, total=8.

Notes: Predation is the largest cause of death; reducing this could be the most important way to improve the birds' survivorship. Powerline marking at critical locations is a possible way to marginally improve survivorship. Internal parasites contributed to 3 deaths. Heart defects are possibly under represented as mortality factors in these data.

MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Section 7

CAPTIVE POPULATION

CAPTIVE MANAGEMENT

(Working Group: George Gee, Gloria Lee, Susan Mikota, Jane Nicolich, George Ranglack, Peter Shannon, Scott Swengel)

Background and Needs

Captive-release research on Mississippi sandhill cranes (MSC) was begun by the U.S. Fish and Wildlife Service's (Service) Patuxent Wildlife Research Center (PWRC) in 1966. The PWRC has approximately 40 MSC in captivity. Of these, there are 15 breeding pairs (several cranes are just now reaching reproductive age). Using the MSC's and surrogates (primarily Florida sandhill cranes), PWRC produces MSC's for release to the wild. The PWRC's work on MSC's has now evolved into what is primarily an operational breeding program, however, research to indicate the fate of costume versus parent-reared birds once they have been released on the Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR) has not been completed. To allow PWRC to focus on other high-priority endangered species research, the Service has proposed phasing out the involvement of PWRC and transferring the crane propagation to the Southeast Region as a management activity.

To realize this proposal, the Service's southeast Region must find or develop a facility (or facilities) capable of producing 15-20 MSC's per year for release to the wild until the recovery goal of a population of 160-170 MSC's containing at least 30 consistently successful breeding pairs is met. Captive breeding of cranes suitable for release requires experienced personnel and quality facilities. The birds produced must be healthy and capable of surviving and reproducing in the wild.

Captive Considerations

The main reason for the existence of the captive flock has been the production of birds for the release program. Therefore, it should be stressed that any transfer of birds into, out of, or between captive flocks or exchanges into or out of the wild population must not compromise the recovery of the wild population.

Various scenarios for this flock are presented below. Although there may be additional possibilities, these seem to be the most likely courses of action. The captive flock currently consists of 20.19 at Patuxent Wildlife Research Center (PWRC) and 2.2 at Front Royal.

<u>Captive rearing of chicks for expansion of wild population</u>

1. Production of 15 to 20 chicks per year will be required to maintain current wild population numbers.

2. Production of 40 chicks per year for release is currently used to expand the wild population.

3. Additional genetic material is needed from the existing wild flock. Most of the current captive flock is derived from the Gautier population. Ocean Springs needs additional founder representation. Other Unit territories may also need representation in the captive flock.

Strategies of captive rearing for the development of a second wild flock

1. To maintain a stable wild population while establishing a second wild population will require production of 40 chicks per year.

2. Reduce expansion rate of existing wild population with more chicks devoted to establishing the second wild population.

3. Cease introduction of chicks into existing wild population with all chicks going into second wild population.

Options for the captive flock

1. Single flock

   a. One option is to leave the captive flock at PWRC and not split it.

   b. One option is to move the captive flock to another location and not split it.

2. Multiple flocks

   a. One option is to split the captive flock in two: half at PWRC and half at another facility.

   b. One option is to split the captive flock in two or three at new facilities.

   c. One option is to split the captive flock into multiple smaller flocks. Greater than 3 captive flocks is NOT a recommended option.

Development of a second captive flock (contingent upon locating a second participant)

Development of a second captive flock MUST NOT compromise the recovery of the wild population. It is assumed that release of birds will continue during the development of a second captive flock.

1. Rationale for split:

a. Reduces likelihood of loss of entire captive flock to catastrophe such as natural disaster, disease, predation, etc.

b. Reduces costs to any one facility.

c. Enables retention of genetic variability in captive flock.

2. Drawbacks to split flock:

a. Movement of animals will decrease reproduction in the short term. Decrease will be greatest if all birds are moved.

b. Variability in husbandry and management techniques between institutions could compromise the goals of the program.

c. Greater overall costs to maintain multiple facilities and the associated needs (staff, incubators, pens, etc.).

d. Production may decline due to: initial movement of birds, disruptions in the options with the AI program (fewer donors at each facility resulting in less AI options), staff expertise, diversification of duties at alternate sites may restrict time dedicated to the cranes.

e. Risk of mortality in transport.

f. At the present time Region 4 has no funding or FTEs for operations required for captive propagation.

Means for creating second captive flock

1. Split the existing flock in two. This will result in reduced breeding from the moved birds initially. Both facilities will need to have the capability of holding and rearing birds based on the needs of the reintroduction plan. If puppet rearing or surrogate rearing is needed, additional space and resources will have to be provided at both facilities.

2. For consistency of rearing for release, one facility could be designated to receive all captive produced eggs for incubation and isolation rearing. This facility would not necessarily have to maintain breeding birds. Isolation rearing should allow for production of 3 chicks per pair.

3. The ideal would be to house 10 potential breeding pairs of MSCs and 3 pairs of surrogate cranes at each of the two sites. This should allow for production of 20 parent-reared chicks per year (1 chick per pair) plus a number of costume-reared birds based on the number of clutches possible from the MSCs. However, at present there are only 15 breeding pairs of MSCs at Patuxent. A build up of the captive flock over time and the transfer of surrogate pairs of Florida sandhill cranes from patuxent will be required to meet this goal.

Facility recruitment

At the present time, the facilities that may be involved in future captive propagation of the Mississippi sandhill crane are PWRC, Audubon Institute, and Noxubee National Wildlife refuge. It is recommended that Patuxent retain some portion of the captive flock, at least temporarily, due to the expertise developed there through extensive research. As soon as the Audubon Institute facility is available, it is recommended that 6 or 7 pairs of MSCs be moved there from PWRC.

Financial commitment: These are dependent on rearing technique and the costs associated with parent rearing vs. surrogate rearing vs. model rearing. The assumption is that each facility will be responsible for its own costs of participating in the program (bird maintenance, staff, transportation costs, medical/lab costs), however it seems reasonable to assume that Region 4 would have to provide some support.

Facility requirements

1. Institutional commitment
2. Evaluation of potential disease risks
3. Availability of start-up and maintenance costs
4. Incubation capability
5. Rearing facilities
6. Adequate number of pens
7. Socialization pens
8. Veterinary services
9. Personnel expertise

Climate factors. They probably do not matter if the facility is adequate. Climate might have some sort of effect on the development of the chicks in terms of adaptability to release site.

Geographic separation to prevent common catastrophe.

Management considerations

1. The representation of each breeding line in the captive flocks will need to be carefully monitored. A Recovery Coordinator and a Recovery Committee consisting of all parties involved in captive propagation and Service personnel would probably be the most effective strategy for managing the flock. Avenues of communication between captive propagation facilities will be essential, especially during the transition period. Behavior of certain genetic lines may be unsuitable for captivity.

2. Recommend that birds with heart murmurs not be released, however, the fate of these birds needs to be addressed. In the short term, chicks with heart murmurs can be used to create/supplement the surrogate flock. Options for disposition of these chicks include euthanasia and placement in other facilities for education or research. Continued presence of these individuals in the captive population may be important to the preservation of some portion of the gene pool.

3. In future years, the captive population may need manipulations to balance sex ratios in both captivity and the wild.

4. An attempt should be made to locate one facility to perform necropsies and maintain all records and tissues to ensure consistency of procedures.

5. Both the wild and captive flocks require management to balance genetic representation of all potential founder lines.

Disease factors relevant to captive population

1. History of disease at new site.

2. Standardized guidelines to minimize disease transmission between captive populations.

3. Routine screening of captive flocks for various health factors to be strictly adhered to among the participants.

4. Protocols have been developed for whooping cranes: transfer between facilities, quarantine, pre-release, etc. These should be used as models for similar protocols for the MSC.

Recommendations for Captive Flock

1. Establish second captive flock as soon as possible at the Audubon Institute.

Develop another captive propagation facility at Noxubee National Wildlife Refuge.

or

Leave half the captive flock at PWRC and move other half to Audubon Institute facility. PWRC has a proven track record with all aspects of this program. Questions still remain about the effect of transfer on the adults' subsequent reproductive success. Movement of the entire flock could jeopardize recovery of the species if the birds do not breed at other facilities or are not able to meet production goals.

2. Stage the movement to minimize loss of production.

3. PWRC would be designated a parent-reared facility and Audubon Institute a costume-reared facility.

4. To maintain the wild population at its present level about 14-20 birds will be needed for release each year.

5. Develop protocols for routine health screening and disease detection based on whooping crane recommendations.

6. Preserve 50 semen samples from each founder line.

7. Establish second wild flock.

Transfer of MSCs

1. Recommended time table for transfer of MSCs: USFWS Region 4 has been mandated to take over responsibility for captive propagation from PWRC.

January 1993 Identify second facility. (Audubon Institute/Species Survival Center has expressed interest in receiving half the captive flock from PWRC).

January 1994 Have facility operational.
Have sufficient number of surrogates in place to test facility.

October 1994 Transfer half the captive flock to facility.

January 1994 Identify third facility.

January 1995 Have facility operational.
Have sufficient number of surrogates in place to test facility.

October 1995 Transfer MSCs to facility. Number of pairs to be transferred will depend on whether or not the Patuxent Wildlife Research Center continues its involvement in the captive propagation program.

If a third facility is not identified by January, 1994, the entire timetable may be delayed one year.

2. Transfer of captive propagation should occur in phases to ensure continued production of chicks for release. The second transfer should be delayed until birds from the first transfer have begun breeding at the new facility.

Research Recommendations for Captive Flock

1. Need further research on increase in germ plasm banking and preservation of ova, embryos, and tissues.

2. Faster turn-around in genetic identification.

3. Need research on microclimate of wild and captive nests.

4. Develop screening techniques for diseases prior to release.

5. Feasibility of pairs raising 2 chicks in captivity.

6. Continue research on development of rearing techniques that result in release birds breeding in the wild.

7. Improve artificial incubation of eggs.

Appendix 1. Patuxent Captive Population Data.

Summary of Mississippi Sandhill Crane Captive Flock at PWRC. Jane Nicolich.

1. Present population 20.19.43 = 82

2. January flock size at PWRC 1967-1992

1967	5	1975	9	1985	36
1968	4	1976	11	1986	40
1969	4	1977	14	1987	39
1970	7	1978	16	1988	33
1971	8	1979	19	1989	36
1972	9	1980	24	1990	40
1973	7	1981	26	1991	40
1974	8	1982	24	1992	40
		1983	20		
		1984	21		

3. Average mortality 1985-1991 = 4%

4. Breeding females: 9 in AI program; 7 natural breeders

5. Six semen donors

6. Age at first egg production: 2 yrs. 25%; 3 yrs. 50%; 4 & 5 yrs. 12.5% n=16

7. Age at first known semen production: 3 yrs. 25%; 4 yrs. 42%; 5 yrs. 25%; 6 yrs 8% n=12

8. Mean # eggs/female = 5.9

9. Last 10 years: Hatchability 80%, Fledgling success 74%

10. Number birds sent to refuge

1980-81	9	1984-85	10	1988-89	13
1981-82	5	1985-86	7	1989-90	29
1982-83	7	1986-87	2	1990-91	38
1983-84	4	1987-88	9	1991-92	35

11. Number birds sent per number productive females (last 3 yrs.) = 2.4

12. Predictions for future releases (maintaining present location and management of flock): 1993:41, 1994:46, 1995:48.

Table 29. Demographics of MS Sandhill Cranes, PWRC captive flock, September 1992.

HY	71-90	14.14	Producing pairs
HY	75	0.1	Productive female
HY	78	1.0	Semen donor
HY	79	1.0	Semen donor
HY	89	1.1	Productive female
HY	90	1.2	
HY	91	2.1	
HY	92	0.0.43	

Table 30. Mississippi Sandhill Crane annual mortality summary of captive flock at PWRC 1985-1991

Year	Flock Size (AHY)	# Died	% Mortality
1985	26	1	4
1986	33	1	3
1987	35	1	3
1988	39	3	8
1989	33	1	3
1990	36	0	0
1991	40	3	8
Mean	34.6	1.4	4

Table 31. 1992 Summary of Mississippi Sandhill Crane Pairs in artificial insemination program at PWRC.

Pair M	F	Semen Prod./Quality	Egg Production	Incubation	Parenting
85012	85008	Very Poor	6	Fair	Good
82005	85011	Fair	5	Good	Good
84011	84007	Very Poor	0	Good	Good
72001	71002	Excellent	3	Excellent	Excellent
73001	74002	Good	7	Poor	Good
76002	76003	Very Poor	8	Excellent	Excellent
85016	85010	Fair	8	Excellent	Excellent
79003	86056	Very Poor	8	Fair	Fair
78001		Fair			
79002		Good			
75001			8	Good	

Table 32. 1992 Summary of the Naturally Fertile Mississippi Sandhill Crane Pairs at PWRC.

Pair M	F	Egg Production	% Fertility	Incubation	Parenting
84006	81001	7	86	Good	Excellent
82006	81002	8	50	Fair	Excellent
84009	86038	8	100	Excellent	Excellent
85009	84008	4	75	Excellent	Good
89118	89069	4	50	Good	Fair
87023	90019	2	100	Good	----

Table 33. Production of Mississippi Sandhill Cranes at PWRC: Mean number of eggs per female.

Year	Number Eggs	Number Prod. Females	Mean number Eggs/ Prod. Female
1970	8	1	8.0
1971	14	1	14.0
1972	3	1	3.0
1973	10	2	5.0
1974	13	2	6.5
1975	13	4	3.3
1976	12	4	3.0
1977	20	4	5.0
1978	24	4	6.0
1979	35	5	7.0
1980	38	6	6.3
1981	40	7	5.7
1982	34	5	6.8
1983	26	5	6.2
1984	32	5	6.4
1985	24	5	5.6
1986	32	7	4.6
1987	47	9	5.2
1988	53	12	4.4
1989	78	14	5.6
1990	86	13	6.6
1991	88	14	6.3
1992	87	15	5.8

Table 34. Mississippi Sandhill Crane Fertility 1983-1992

	Artificial	Insemination	Natural	Breeding
Year	Ratio	% Fertile	Ratio	% Fertile
1983	24/24	100		
1984	27/27	100		
1985	22/23	96		
1986	17/20	85	3/4	75
1987	28/28	100	5/13	38
1988	26/28	93	3/12	25
1989	46/47	98	10/17	59
1990	44/50	88	23/27	85
1991	42/45	93	20/25	80
1992	39/43	91	25/29	86

Table 35. Mississippi Sandhill Crane Captive Flock (PWRC) Hatching and Fledging Success 1983-1992.

	Hatching		Fledging	
YEAR	Ratio	% Hatched	Ratio	% Fledged
1983	18/20	8/18	44	
1984	20/25	80	17/20	85
1985	19/22	86	17/19	90
1986	15/21	71	9/15	60
1987	22/33	67	16/22	73
1988	19/27	70	12/19	63
1989	44/56	78	35/44	80
1990	56/67	84	45/60	75
1991	53/65	82	40/53	75
1992	56/65	86	43/56	77

Table 36. Number of Mississippi Sandhill Cranes sent to Refuge per Number Productive Females at PWRC.

Year	Number Birds Sent	Number Productive Females	Birds Sent/ Prod. Female
1982	7	5	1.8
1983	4	5	1.6
1984	10	5	3.4
1985	7	5	3.2
1986	2	7	1.1
1987	9	9	1.6
1988	13	12	1.0
1989	29	14	2.1
1990	36	13	2.8
1991	35	14	2.5
Mean (Last 3 Years)	33.3	13.7	2.4

Table 37. Predictions for Future Releases

Year	Number Prod. Females		Mean Number Released/ Prod. Female		Release Potential
1993	17	X	2.4	=	41
1994	19	X	2.4	=	46
1995	20	X	2.4	=	48

MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Section 8

GENETICS AND MANAGEMENT

Genetic Characteristics And Studies Of The Captive Mississippi Sandhill Crane Flock
George Gee

Territorial Representation

The captive flock contains individuals with genetic contributions from 24 of the 40 territories sampled since 1967. One pair [#2 (Brown's trail X Ben Williams 3) X (Ben Williams 4A)] produced 7 birds in the captive flock and continues to produce birds for release (Figure 1). The bird (Brown's trail X Ben Williams 3) is over represented in the captive flock, 13 of 39 birds (Figure 2). Also, the Ben Williams territories are over represented (Figure 3) in the captive flock, 22 of 39 birds. This results in an over representation of the Ben Williams territories in release birds but most of these birds contain more genetic material from other territories and no birds are inbred (Figure 4).

Genetic Characteristics

Apparent genetic characteristics that distinguish the Mississippi sandhill cranes from other sandhill cranes include physiological, morphological, and blood protein differences. Aldrich (1972) describes the morphological characteristics like size and color of the Mississippi sandhill crane. The birds mature earlier than any other sandhill crane especially when compared to the Florida sandhill crane. About 70% of captive female Mississippi sandhill cranes lay eggs by three years of age but about 70% of the Florida sandhill cranes lay by 5 years of age. Also, egg production begins about six weeks later Mississippi sandhill cranes than in Florida sandhill cranes kept in the same place. Immature Mississippi sandhill cranes wander less than the Florida sandhill cranes and adults spend most of their lives in much smaller areas than Florida sandhill cranes. The flock also contains a possible genetic defect (heart murmur) that can lead to death in some young birds.

Recent electrophoresis studies (Dessaurer et al. 1992) indicate a reasonable level of diversity in the wild populations (Table 39), especially in a population with a limited number of breeding pairs. The population contains one allele unique to sandhill cranes (MPI=Mannose-6-phosphate) and one other allele different from Florida sandhill cranes (PGM=phosphoglucomutase)(Table 40). Using Roger's Distance or the Modified Cavalli-Sforza and Edwards Chord Distance to construct systematic trees, sandhill cranes are closely related. The Mississippi sandhill crane appears to be more closely related to the greater sandhill crane (Rocky Mountain population) than the Florida sandhill crane, but the differences are small (Figure 5).

Genetic Studies

At least 4 genetic areas need more study: relatedness in the flock and the other sandhill subspecies, diversity in the major histocompatibility complex, heart murmur and effects of hybridization with other subspecies.

Relatedness - Mitochondrial DNA (MtDNA)

Mitochondrial DNA (MtDNA) can be used to trace maternal linages. It has been used to identify disjunct populations as a part of the whole. Aleutian Canada geese discovered on a distant island in the Aleutian Island chain were determined to be nearly identical to the remnant Buldir population in the late 80's and afforded protection under the Endangered Species Act based on the striking likeness of MtDNA. It might be useful in distinguishing Mississippi sandhill cranes from other cranes and from other sandhills. A survey of other cranes would be needed to interpret the results. MtDNA is preserved better than most any other segment of DNA and is possible to use museum type specimens for studies.

Nuclear Minisatellite DNA

Nuclear DNA is used to determine relatedness and paternity and maternity in some cases. DNA RFLPs (DNA fingerprinting) have been used extensively in recent years to identify individual animals and their offspring. We used it to establish paternity in some whooping cranes. Unfortunately, whooping crane samples were not available from birds that had died and several paternities are still in doubt.

Nuclear Microsatellite DNA

A new nuclear DNA approach is evolving using DNA microsatellites. It will be especially effective for determining maternity, paternity, and sibship from poorly preserved tissues. It will provide the same fingerprint type data but from poorly preserved tissues like mounted specimens. It requires very small samples of DNA because the DNA is amplified through PCR.

Microsatellite clones are retrieved from recombinant DNA libraries. These clones come from a good tissue sample, contain a few repeat fragments (10 to 20 oligonucleotides). The clone is sequenced to establish the primer nucleotides at either end (small gene like fragment) and amplified using the polymerase chain reaction (PCR).

Dr. Jonathan Longmire at the National Laboratories in Los Alamos and Drs. Travis Glenn and Mike Braun suggested using microsatellites to compare nuclear diversity estimate in the captive whooping crane flock with diversity from pre-bottle neck museum specimens. Travis Glenn and Mike Braun at the Smithsonian have agreed to start such a project with the whooping crane as a part of another funded project. We will be supplying whooping crane samples to start the development this fall. They are working with Carey Krawjewski on MtDNA as well. Carey's work will concentrate on the D-loop in MtDNA because it is better preserved than most DNA.

Major Histocompatibility Complex (Mhc)

The Mhc interests biologists because of the role for Mhc encoded proteins in immunity, and because of the unusually high number of Mhc alleles generally maintained in normal populations. In populations with high Mhc polymorphism but undergoing population decline, diversity may be lost through genetic drift.

Maintenance of Mhc polymorphism in natural populations suggests a role in population viability. Selection for Mhc diversity and heterozygosity in captive populations and especially in the individuals founding reintroduced populations, will maximize the Mhc within the population.

Mhc Multigene System

Mammalian studies provide much of the knowledge of the organization and function of the Mhc. The Mhc was first discovered in the mouse and later (1948) in the chicken by Briles. For some time the chicken was the only avian species in which the Mhc had been studied.

The Mhc is a multigene system. Many genes within the Mhc encode molecules involved in processing and presentation of antigen in the immune system. Most species maintain many Mhc alleles (polymorphism) in a freely breeding population. Similar to the Mammalian Mhc, the chicken Mhc encodes class I (B-F) and class II (B-L) molecules. There are multiple B-F and B-L genes within the chicken. The two types of genes are interspersed and closely positioned with respect to one another. In addition to the Mhc B-F and B-L molecules, another class of molecules called G-G (Mhc class IV) have been found within the MHC of chickens. While the function of B-G molecules is not known, they interest us because of they are highly polymorphic, expressed on many cell types, and are members of the immunoglobulin super gene family.

Mhc and Vitality

The Mhc has been conceptualized as a disease resistance system, and the allelic frequencies in populations are thought to be influenced by the selective pressures of pathogens. The existence of protective alleles in infectious diseases such as malaria in humans and Marek's disease in chickens supports this idea. It appears likely that Mhc polymorphisms within a population may be maintained at some critical level that benefits lone-term survival.

Immunologists do not understand how Mhc polymorphism is maintained. Mice can sense phenotypes determined by genes of the H-2 complex from chemosensory signals in the urine. In female mice mating choice is influenced by Mhc-incompatibility in males.

Because of the apparent impact of Mhc diversity on population survival, we added the Mississippi sandhill crane to our crane study this year. As a part of a larger study of cranes, condors, pheasants and chickens at the Beckman Research Institute, we should find the level of polymorphism in the Mississippi sandhill crane and if we can select to improve the diversity in the population. Where we use very small numbers of breeding cranes to sustain the population, maximum genetic diversity in the Mhc is critical.

Mhc Studies

Using studies of chicken Mhc as a foundation, we are using serological and recombinant DNA methods to investigate the Mhc in cranes and other birds. A minimum of 27 B haplotypes have been serological-defined in experimental chickens, 14 in pheasants, and 16 in Florida sandhill cranes. We applied the immunogenetic techniques developed for the production of Mhc specific antisera and analyses of Mhc haplotypes in chickens to cranes.

The recombinant DNA based methods of evaluating Mhc diversity in chickens can be applied to cranes too; sometimes through the direct application of chicken Mhc probes and sometimes through first isolating these from conspecific cranes. The cDNA clones from B-F, B-L and B-G chicken subregions can be used as probes for RFLP analyses of chicken DNA. Chicken Mhc subregion-specific probes have been found to cross-hybridize to the homologous Mhc genes in other closely related bird species (pheasant, quail, turkey, and peafowl) and are used to distinguish Mhc haplotypes. DNA from cranes hybridize with chicken CDNA probes only under low stringency conditions, producing weak banding patterns. Our cooperators, Sue Jarvi, Marcia Miller and Elwood Briles, have clones several fragments of genomic DNA containing B-G genes from the whooping cranes. We found the RFLP studies useful not only in whooping cranes but the other 14 species of cranes as well. Also, we found probes made from portions of Mhc class I and class II genes cloned by PCR from pheasants, whooping cranes, and Andean condors useful in genotyping by RFLP analyses. These PCR-generated fragments also prove useful in screening genomic libraries for full gene sequences of the Mhc.

Heart Murmur

See notes from the health report in this PVA.

Hybridization

Some investigators have suggested hybridizing the Mississippi Sandhill Crane with another closely related subspecies to produce a more robust genetic diversity. They reason that the increased diversity would increase fertility, hatchability and fledgling success in the Mississippi sandhill Crane. We need to take a very cautious approach to hybridization. The very diversity could make the Mississippi Sandhill Crane less adapted to this unique habitat. The hybridization should be done in captivity and the offspring followed for two or three generations. The birds should be raised and kept in the same environment. We could monitor such things as age at first egg, average date of lay and fertility. If the hybrids were superior to Mississippi Sandhill Crane in captivity, then a few could be tested in the field with other Mississippi Sandhill Cranes. I would not recommend this approach. Captive birds show no signs of reduced vitality. In fact, Mississippi Sandhill Cranes produce as well as any crane in our captive colony.

Table 38. Mississippi Sandhill Crane Listing of Territories

Number	Territory	Number	Territory
1	*BRW TRL 1A	21	*SIMMS RD 9
2	*BRW TRL 1A	22	*SIMMS RD 9
3	*BRW TRL 1B	23	*FTBAYOU 11
4	*BRW TRL 1B	24	*FTBAYOU 11
5	BRW TRL 2	25	BOURNE 12
6	BRW TRL 2	26	BOURNE 12
7	BEN WMS 3	27	ELGIN 13
8	BEN WMS 3	28	ELGIN 13
9	BEN WMS 4A	29	VICKERS 15
10	BEN WMS 4A	30	VICKERS 15
11	*BEN WMS 5	31	*REGIS 16A
12	*BEN WMS 5	32	*REGIS 16A
13	*BEN WMS 6	33	REGIS 16B
14	*BEN WMS 6	34	REGIS 16B
15	BENWMS 6A	35	WEBER 19
16	BEN WMS 6A	36	WEBER 19
17	BEN WMS 7	37	N VAL 21A
18	BEN WMS 7	38	N VAL 21A
19	PERIGAL 8	39	DBL TREE 25
20	PERIGAL 8	40	DBL TREE 25

* No birds in captive flock

Table 39. Indices of diversity detected at 24 loci in population samples of cranes.

Taxon & Number[D]		Heterozygosity Direct Count[A]	Alleles/ Estimate[A,B]	Polymorphism Locus[A]	Percent[C]
AME	14	0.048+0.024	0.045+0.023	1.17+0.08	20.9
CAM	7	0.024+0.014	0.050+0.033	1.17+0.1	12.5
CAG	17	0.067+0.028	0.071+0.031	1.38+0.13	29.2
CAO	10	0.028+0.016	0.037+0.022	1.13+0.07	12.5
CAF	2	0.125+0.069	0.111+0.052	1.17+0.08	27.2
LEU	9	0.032+0.016	0.031+0.015	1.17+0.08	16.7
ANT	6	0.028+0.019	0.036+0.026	1.13+0.09	8.3

[A]Mean+/-standard error; wild population only. [B]Unbiased estimate. [C]0.99 criterion; wild and captive bred animals. [D]AME (whooping crane), CAM (Mississippi sandhill crane), CAG (greater sandhill crane), CAO (Florida sandhill crane - Okefenokee population), CAF (Florida sandhill crane), LEU (Siberian crane), ANT (sarus crane).

Table 40. Crane Polymorphic Genotypes

Enzyme	*sIDHP*	*GK*	*PGM*	*EST-1*	*PEPB*	*PEPC*	*MPI*	*PGDH*	*ESTD*
Mississippi Sandhill (CAM)									
Allele	b	f	a/c	c	c/b	b/a	b/d/c	b	b
Greater Sandhill Crane (CAG)									
Allele	b/a	f/e	a	b/c	c/b/d	b/a	d/b/e	b	b
Georgia-Florida Sandhill Crane									
Allele	b	f/e	a	c	b/a	b/a	d	b	b
Florida Sandhill Crane (CAF)									
Allele	b/a	f/e	a	c/d	c/a	a/b	d/e	b	b
Whooping Crane (AME)									
Allele	b/a	c/b	b/a/c	a	c	d	d	b/c	a/b
Siberian Crane (LEU)									
Allele	b/a	c/b	b/e/d	a	c	b/a	d	b	b
Sarus Crane (ANT)									
Allele	b	e/d/f	a/c	c/b	c	c	d	b	b

Table 41. Alloenzyme Summary

UNIQUE alleles at MPI and PGM compared to the Florida sandhill

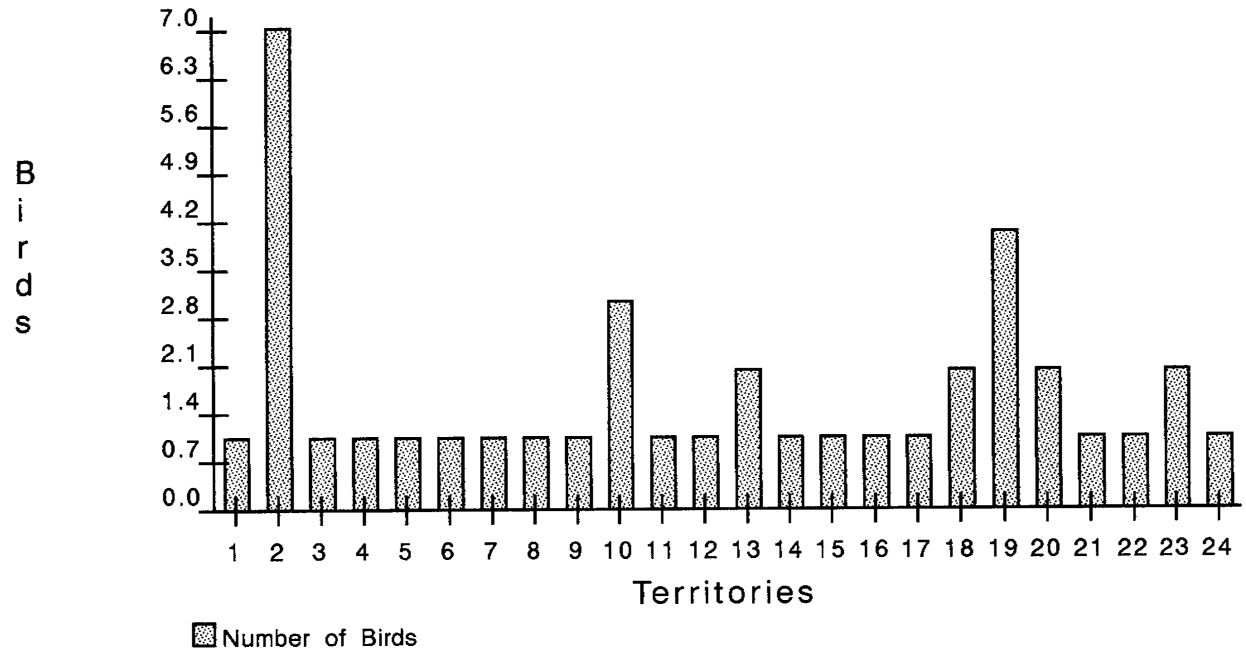
MODERATE heterozygosity estimate (0.05)

Polymorphism about 1/2 of Greater or Florida sandhill cranes

Systematics place all sandhills CLOSE together

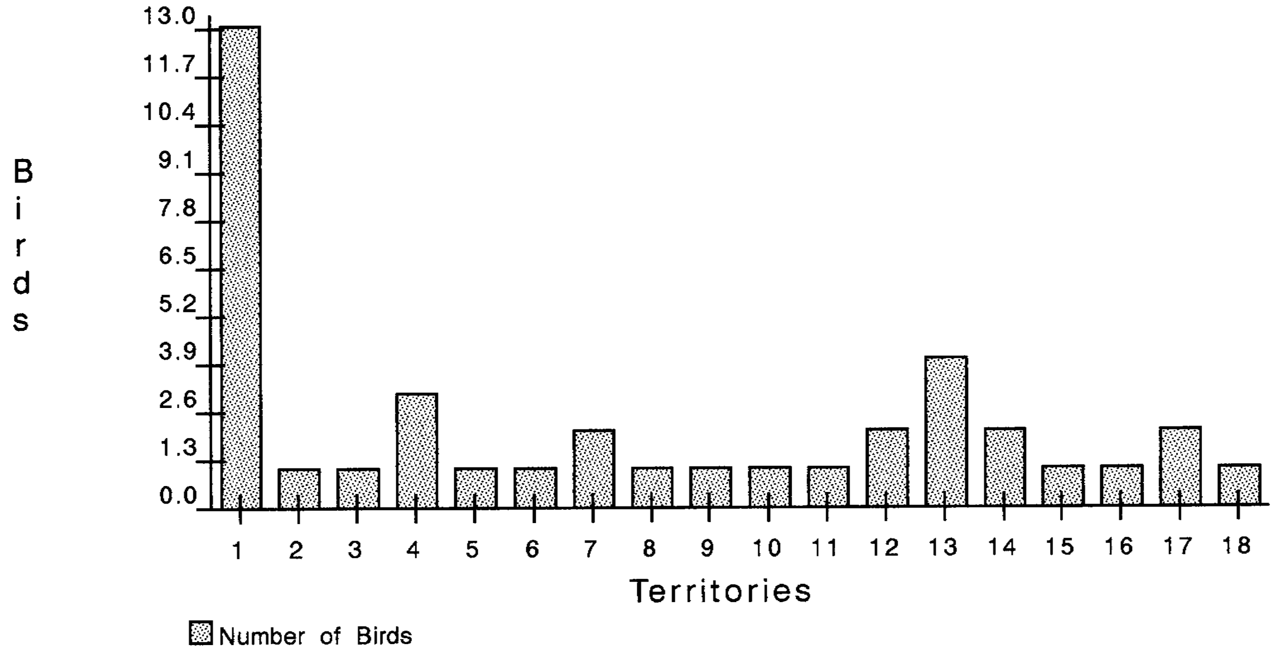
Systematics place CAM CLOSER to CAG

Figure 1. Mississippi Territories In Captivity In 1992



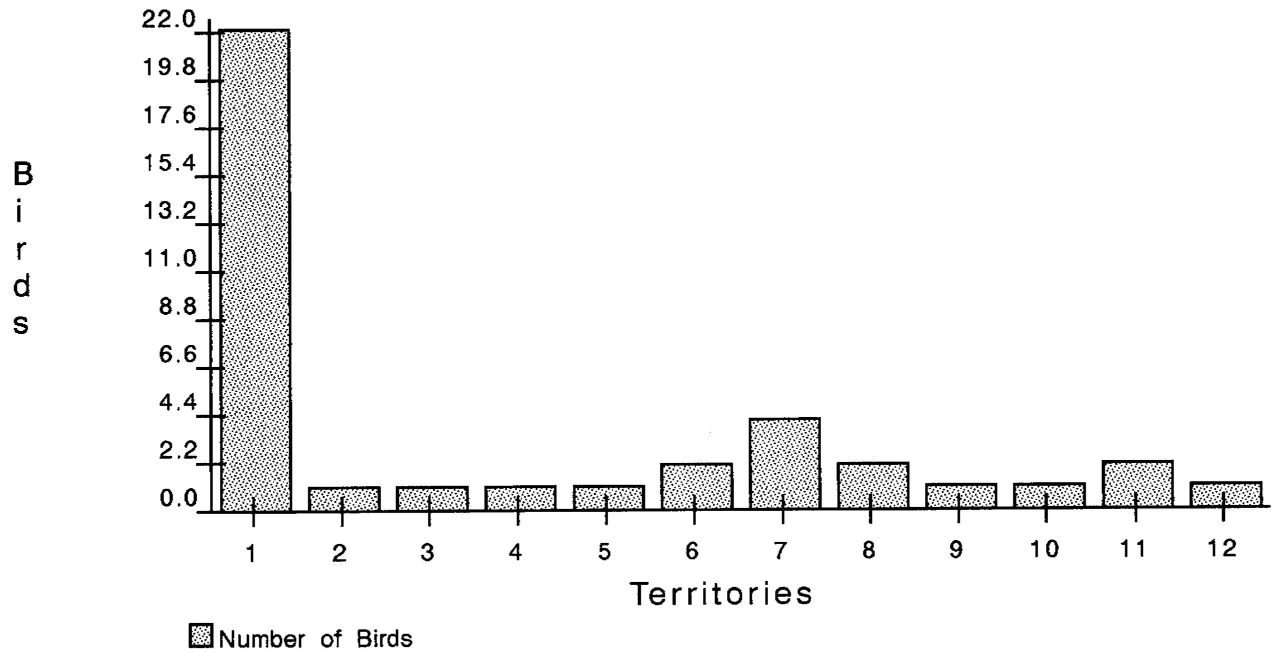
1 = 5+6,7+8 2 = (5+6,7+8)9+10 3 = (5+6,7+8)17+18
4 = (5+6,7+8)25+26 5 = (5+6,7+8)298+30 6 = (5+6,7+8)?
7 = [(5+6,7+8)9+10]25+26 8 = 9+10 9 = 9+10,17+18
10 = 9+10,27+28 11 = 15+16 12 = 17+18 13 = 17+18,19+20
14 = 19+20 15 = 19+20,29+30 16 = 25+26 17 = 25+26,?
18 = 29+30 19 = 29+30,? 20 = 33+34 21 = 33+34.? 22 = 35+36
23 = 37+38 24 = 39+40

Figure 2. Mississippi Territories In Captivity In 1992



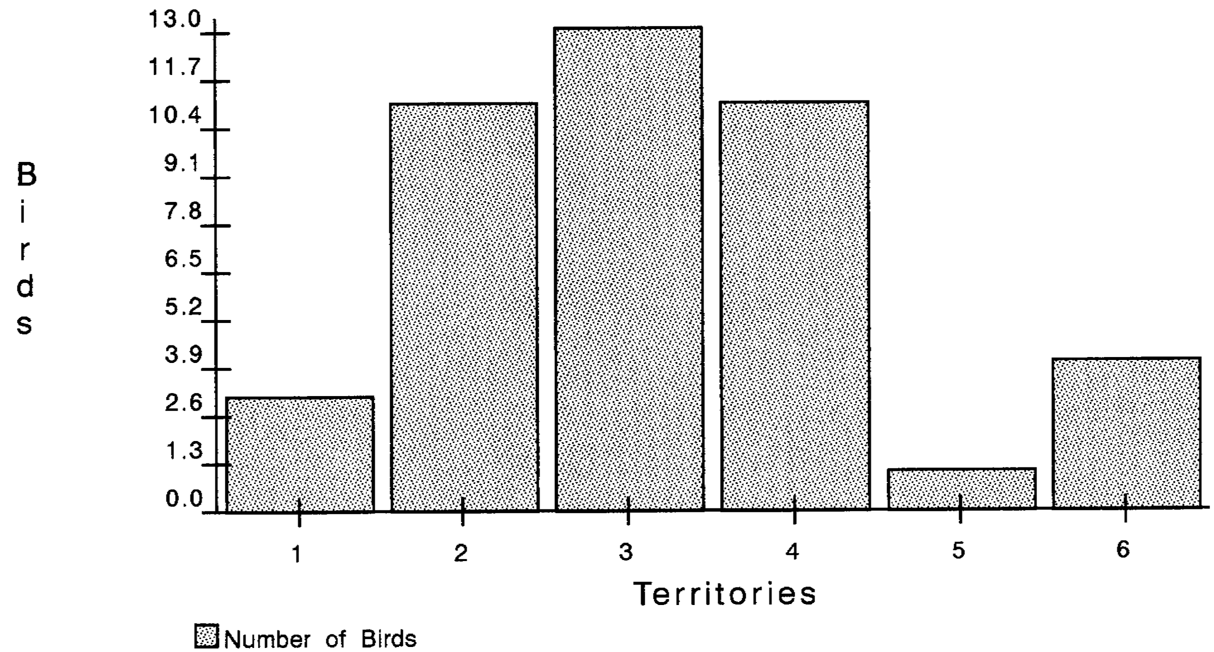
1 = all birds containing 5+6,7+8 2 = 9+10 3 = 9+10,17+18
4 = 9+10,27+28 5 = 15+16 6 = 17+18 7 = 17+18,19+20
8 = 19+20 9 = 19+20,29+30 10 = 25+26 11 = 25+26,?
12 = 29+30 13 = 29+30,? 14 = 33+34 15 = 33+34.? 16 = 35+36
17 = 37+38 18 = 39+40

Figure 3. Mississippi Territories In Captivity In 1992



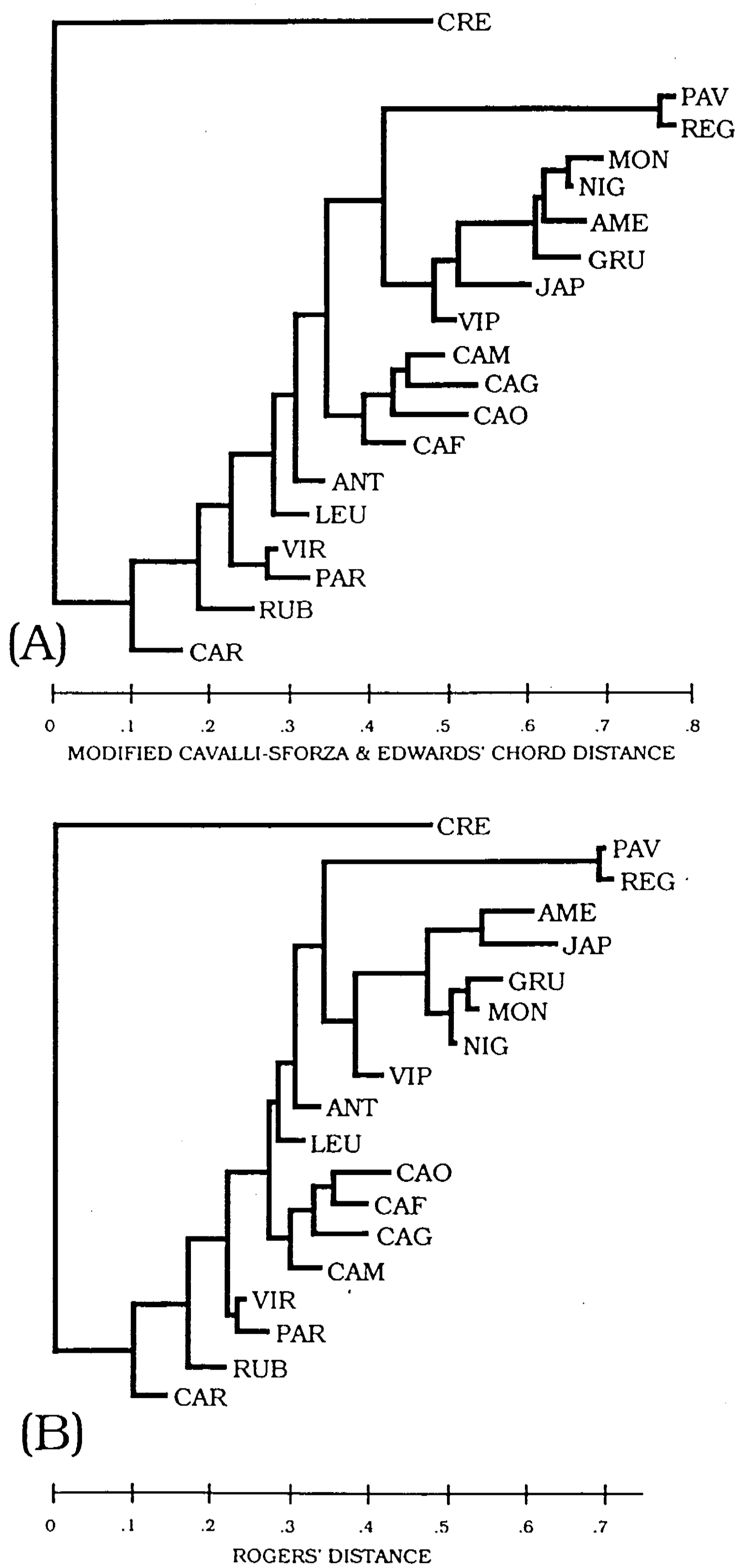
1 = all birds from Ben Williams 2 = 19+20 3 = 19+20,29+30
4 = 25+26 5 = 25+26,? 6 = 29+30 7 = 29+30,?
8 = 33+34 9 = 33+34.? 10 = 35+36 11 = 37+38
12 = 39+40

Figure 4. Mississippi Territories In 1992 Release



1 = Both parents from Ben Williams Territory
2 = One parent from Ben Williams Territory
3 = One grandparent from Ben Williams Territory
4 = Two grandparents from Ben Williams Territory
5 = No ancestors from Ben Williams Territory
6 = Two great grandparents from Ben Williams Territory

Figure 5. Crane Systematic Trees From Allozyme Analysis



Genetic And Demographic Management Of Cranes (Scott Swengel)

I. Goals of genetic management

A. Large population
B. High genetic diversity

Steps To Achieve These Goals In Captive Cranes

II. Breed Bird Rapidly at First

A. Reduces probability of extinction in the short term

B. Larger population losses less genetic diversity to random genetic drift.

C. Large populations eventually create new genetic diversity through recombination during mating, offsetting or reversing genetic drift.

III. Avoid Inbreeding

A. Inbreeding reduces fecundity of Red-crowned Cranes 68%.

B. Inbreeding increases the expression of genetic defects in cranes.

C. Inbreeding depression could already be a factor in Mississippi Sandhill Crane biology, perhaps reducing their breeding success.

IV. Equalize Representation of Original Founders

A. Genetic diversity increases dramatically over normal populations

B. Prevents irretrievable loss of some rare gene combinations

C. Avoids artificial selection by humans for cranes that breed easily in captivity, yet might not be ideal for releases to the wild.

D. Enables managers to minimize inbreeding later, since more families have contributed offspring to the pool from which breeders are chosen.

E. To accomplish these goals requires extra effort in breeding some founders that are difficult to breed.

V. Use Demographic Management When the Population Achieves a Viable Size

A. Use survivorship and reproductive information to construct stable age distribution and calculate number of chicks needed for stable population.

B. Survivorship curve has the same shape as stable age distribution.

C. Captive Red-crowned Cranes survive much better (95-96%/yr) than wild Whooping Cranes (92.0% after 1st winter). See page 3.

D. Wild Mississippi Sandhills have poor survivorship, ca. 85%/yr. More offspring are needed for stable population as survivorship decreases.

E. Increasing populations have more young birds than a stable population does (see page 4). This is the Baby Boom effect.

F. Decreasing populations have more older birds than a stable population. This is the Baby Bust, which now affects wild Mississippi Sandhills.

G. Transferring these ideas to wild Mississippi Sandhills:
   1. As the wild population nears its estimated capacity of 120-170 birds on the refuge, it might be advisable to fine-tune the number, sex ratio, and years in which releases to the wild are made.
   2. Such fine tuning might optimize the sex ratio (1:1) and age distribution of wild Mississippi Sandhills.

VI. Genetic Management Cannot Solve Many Problems Facing Wild Mississippi Sandhill Cranes, however.

MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Section 9

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MISSISSIPPI SANDHILL CRANE

Grus canadensis pulla

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

Section 10

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