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Abstract: Hand-reared (56) and parent-reared (76) juvenile Mississippi sandhill cranes (*Grus canadensis pulla*) were produced at the Patuxent Wildlife Research Center (Patuxent), Laurel, Maryland over a 4-year period (1989-92) and released at the Mississippi Sandhill Crane National Wildlife Refuge (Refuge), Gautier, Mississippi in a controlled experiment. Hand-reared survival rates proved higher than for parent-reared survival for each time category: 6 months, 86% versus 75%; 1 year, 77% versus 68%; 2 years, 66% versus 53%; 3 years, 55% versus 43%: partial data for fourth and fifth years were 57% versus 31% and 48% versus 37%.

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Even prior to its description as a separate subspecies (i.e., the Mississippi sandhill crane, *Grus canadensis pulla*: Aldrich 1972), the small, dark race of sandhill cranes (resident along the Gulf of Mexico coastal plain from Alabama as far west as mid-Texas) was considered to be in danger of extirpation (McIlhenny 1938, U.S. Fish and Wildlife Service 1991). The Refuge was created in 1975: thereafter efforts began to bolster the wild population and restore habitat.

Captive-reared sandhill cranes have been introduced to the wild in at least 15 other reported studies (see Nagendran et al. 1996 for a summary). Starting in 1980, juvenile Mississippi sandhill cranes were reared at Patuxent by their natural or conspecific foster parents (Fig. 1) for release in Mississippi (Ellis et al. 1992*a*). To date, over 300 birds have been released. The only comparably large release was the, now terminated, Grays Lake experiment which involved 289 eggs, not fledged birds.

One-year survival rates for the early releases in Mississippi averaged 62% (41 of 66 cranes: McMillen et al. 1987, Zwank and Wilson 1987, Ellis et al. 1992*b*). Comparable 1-year survival in other release studies varied from 0% ($n = 17$, Nesbitt 1979) to 56% ($n = 27$, Nesbitt 1988 unpublished, birds and infusions of 2 to 13 birds annually (total from Nagendran et al. 1996). Even with good survival of released 1981–89, 66 or 67 birds), the Mississippi sandhill crane population is believed to have never in recent decades exceeded 54 birds until the present study began.

Fig. 1. Adult Mississippi sandhill crane with a fostered chick at Patuxent. This process is termed parent-rearing. (Photo David H. Ellis.)

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Fig. 2. Costume-rearing is one type of hand rearing. For some projects, such birds are led afield and introduced to natural vegetation and wild foods. (Photo by David H. Ellis.)

In 1989, Patuxent began a concerted effort to produce and release about 30 chicks annually. This was accomplished both by increasing the number of parent-reared chicks and by releasing chicks hand-reared (Fig. 2) by costumed humans (costume-rearing). Five other studies reported success with releasing costume-reared sandhill cranes. Horwich (1989) had 4 of 5 costume-reared cranes survive to 1 year of age. Urbanek and Bookhout (1992) reported an average 1-year survival rate of 86% for 3 releases (n = 37) in Michigan. Nagendran (1992) raised 7 sandhill cranes in Texas and had 2 (29%) survive to 1 year of age.

Our goal was to conduct a long-term study to test the new technique of costume-rearing against the established method of parent-rearing. In this paper we compare known minimum survival rates of 56 hand-reared and 76 parent-reared chicks produced from 1989 through 1992 and released during their first winter. The value of this research was the comparison of the 2 rearing techniques in a side-by-side study where most other variables were controlled. We followed survival for 3 years for all birds and up to 5 years for 60 birds.

In a companion paper, our statistical estimates of survival rates were presented (Ellis et al. 2000) based on the same data set. Both studies are presented because we believe future students of crane conservation, and especially management agencies, will be interested not only in our best estimates (statistically calculated guesses [Ellis et al. 2000]) of crane survival, but also in the minimum number known to be alive, as presented here.

METHODS

We described our rearing techniques in detail in a previous paper (Ellis et al. 1992*b*). In general, parent-reared chicks were hatched under their own or foster parents and remained in their parents' pen until approximately 1 month after fledging. For hand-rearing we used (1) amorphous gray costumes to cover caretakers, (2) taxidermy mounts of crane heads to teach chicks to feed, (3) mounts of adults lying in brood posture with a heat lamp overhead, (4) sandhill crane brood calls (played by tape recorder during hatching and imitated by humans when interacting with chicks), (5) a live adult sandhill crane "imprinting model" penned adjacent to

young chicks, and (6) a group of 2–4 sandhill crane "socialization models" penned outdoors adjacent to the end of each chick pen. At 3–5 months of age, our hand-reared colts were pooled into release cohorts.

Birds were randomly assigned to release cohorts. Each year, 1 cohort was composed entirely of costume-reared chicks, another of parent-reared chicks, and a third group consisted of a combination of costume-reared and parent-reared chicks (hereafter, mixed cohort).

Chicks were held in release cohorts for 4–5 weeks, then crated and shipped by air to the Refuge in mid-November. A leg-mounted conventional VHF radio transmitter and wing brail (Ellis and Dein 1996) were attached when the chicks were introduced into their release pens. Each crane also was fitted with a numbered metal band attached just above the toes and a 7.6-cm-tall, colored, plastic band attached above the other hock joint. Each release experiment began when the wing brails were removed in December. Interaction with wild cranes (many of which were from prior releases) actually began before debrailing because wild birds often entered the release pen for pelletized food. After release, cranes were monitored 3 times per week using radiotelemetry and visual observations.

Many data conventions were followed. First, in measuring survival, day 0 was the date of debrailing. We deleted 13 cranes from the study prior to release because they were physically unfit. An additional 8 birds, with significant heart murmurs associated with congenital ventricular septal defects, were released but not included in the data set. Even with these deletions, 132 birds were included in the analyses. Because survival records are only through 31 January 1996, we present 5 years of survival data for birds reared in 1990 but only 3 years for birds reared in 1992.

Five of these 132 cranes were recovered emaciated or otherwise judged incapable of survival in the wild and removed from the study. Because these birds were captured by uncostumed humans, we judged them to be highly vulnerable to predation and used the date of capture as the "death date."

We present our results as number and percent of birds known to be surviving based on direct observations. For most wildlife populations, especially those of migratory species and species that otherwise have high rates of juvenile emigration, post-dispersal detection rates are low and highly variable, with the result that direct counts of marked individuals provide poor indicators of demographic parameters (Nichols and Pollock 1983). Because of these problems, in our companion paper (Ellis et al. 2000), we used complex statistical procedures to estimate survivorship. However, the Mississippi sandhill crane provides an extreme example of a population that can be directly censussed. The birds are large, very sedentary, gregarious, and they occupy a relatively small area. They also have no neighboring populations either to provide immigrants or to receive emigrants. All of these traits favor direct counts. Hence, we present our census data (minimum survival counts) here with confidence that they provide an excellent measure of survival, one that is, if not exact, only slightly conservative.

RESULTS

Presentation of our data 6 years after the release of the last birds and 5 years after termination of regular data gathering allowed time for birds that were lost to the study but still alive to be found. Thereby we minimized what would otherwise be a downward bias in our estimates of survival. Other complications in data analyses were caused by radio transmitter failure, band loss, and short distance dispersal of a few birds. For example, 3 cranes were relocated 4, 4.5, and 5 km from the Refuge. Two of our lost cranes reappeared on the Refuge after absences of 25 and 26 months. The extreme hiatus for a crane at the Refuge (but not in this experiment) was 64 months. We emphasize that few birds disappeared for more than one month.

Survival rates reported in Table 1 and Fig. 3 are very high. The sharp down-turn immediately after release was expected, but it was not expected that hand-reared juveniles (with 14% loss at 6 months post-release) would survive so much better than parent-reared juveniles (25% loss). From 6 months to 3 years, the slopes of the survivorship lines are linear for both hand-reared and parent-reared birds. After 3 years, survival rates were high both for hand-reared and parent-reared cranes. Seventeen of our cranes were found dead. Most of those necropsied died from traumatic injuries (i.e., predation).

DISCUSSION

Overall, survival of study birds was excellent: known 1-year survival for all cranes was 72% (77% for 56 hand-reared cranes, 68% for 76 parent-reared cranes), little different from our statistical estimate of 80% (Ellis et al. 2000). Most importantly, hand-reared cranes survived better than parent-reared birds.

A few comments are merited on the relative suitability of our two methods of handling survival information. The Kaplan Meir survival estimate was presented in a companion paper (Ellis et al. 2000). For populations with high rates of dispersal, it is obviously superior to estimate survival by censoring data for missing birds rather than treating such birds as dead. For the Mississippi sandhill crane, however, everything recommends using minimum or known survival as

Table 1. Post-release survival rates (% alive) for hand-reared (HR) and parent-reared (PR) Mississippi sandhill cranes reared from 1989 through 1992 and released during their first winter on the Mississippi Sandhill Crane National Wildlife Refuge.

Rearing Method	Time post-release (years)					
	0.5	1	2	3	4[a]	5[a]
HR and PR (n = 132)	80	72	58	48	42 (n = 92)	42 (n = 60)
HR (n = 56)	86	77	66	55	57 (n = 37)	48 (n = 25)
PR (n = 76)	75	68	53	43	31 (n = 55)	37 (n = 35)

[a]Termination of the formal study on 31 Jan 1996 resulted in fewer birds being involved in survival estimates in the fourth and fifth years.

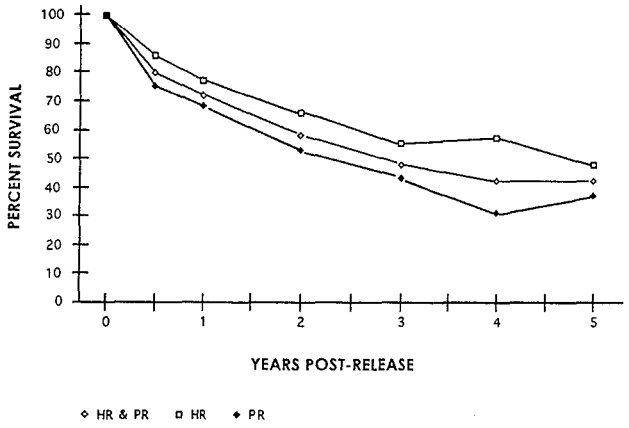

Fig. 3. Post-release survival of hand-reared and parent-reared Mississippi sandhill cranes (reared from 1989 through 1992).

the superior parameter in management decisions. Because cranes are at least seasonally gregarious and because the Mississippi sandhill crane is closely monitored, we have good reason to believe that birds missing long term are dead. To credit high portions of them as "alive but elsewhere" is to introduce a bias that overestimates survival. Our minimum survival treatment, presented in Table 1 and Fig. 3, is surely the more conservative measure of survival, and we believe it also to be the more accurate estimate.

The long-term goal in the Mississippi sandhill crane management program is to create a self-sustaining population. Although the survival rates (Table 1 and Fig. 3) for our fledged juveniles were very high and are believed to exceed the values necessary to provide sufficient birds to replace breeders, natural recruitment in this population (as measured by chick fledging rates) is very low. In some years, no wild chicks fledge and during the last 10 years, only 19 chicks have fledged.

Another way of assessing the results of our study is to compare survival of our cranes with wild crane populations. Unfortunately, no closely comparable data are available. The studies that do exist either involve small samples (e.g., Kuyt 1979, Drewien et al. 1999), different age categories (e.g., Toepler and Crete 1979, Littlefield and Lindstedt 1992), and/or widely dispersing migratory populations that are difficult to monitor (e.g., Drewien and Bizeau 1974, Bennett 1978, Boise 1979, Drewien et al. 1995). The most closely comparable study is Nesbitt's (1992) report of 82% (or 87%by another estimate) survival of 25 nonmigratory juvenile cranes in Florida over the interval from 80 to 290 days. Kuyt and Goossen (1987) reported a 1-year survival rate of 75% for whooping cranes banded as colts. Our overall minimum count for 1-year survival following debrailing was 72% for all birds, 77% for hand-reared birds, and 65% for parent-reared birds). Our estimated 1-year survival (Ellis et al. 2000) was about 80% for all birds. Most importantly, both our estimated and our known (or minimum) survival was higher for hand-reared than parent-reared birds.

MANAGEMENT IMPLICATIONS

During our study, the crane population on the Refuge (minimum counts, October 1993) increased dramatically to 133 birds. Prior to the study, the wild population (also based on autumn minimum counts) never exceeded 54 birds. Since 1993, fall counts have varied between 96 and 133. Our high survival rate for hand-reared birds not only allows the release of larger numbers of cranes, but may also obviate the need for maintaining a large captive colony of adult pairs (beyond what is needed to supply eggs) to support a parent-rearing program. However, the important survival benefits to hand-reared birds that resulted from mixing a few parent-reared cranes into some release cohorts (Ellis et al. 2000) recommends against totally doing away with parent-rearing.

ACKNOWLEDGMENTS

This paper is dedicated to Jake Valentine who died while it was in preparation and who, for over 30 years, followed population trends of the Mississippi sandhill crane. It was through his research, determination and guidance that the Refuge was created; truly, he can be cited as the father of the Mississippi Sandhill Crane National Wildlife Refuge. This study resulted in part from his urging that reintroduction efforts be redoubled.

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