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GEORGE F. GEE
USGS Patuxent Wildlife Research Center

JANE M. NICOLICH
USGS Patuxent Wildlife Research Center

STEPHEN A. NESBITT
Florida Fish and Wildlife Conservation Commission

JEFF S. HATFIELD
USGS Patuxent Wildlife Research Center

DAVID H. ELLIS
USGS Patuxent Wildlife Research Center

See next page for additional authors

Authors
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GEORGE F. GEE,[1] **USGS Patuxent Wildlife Research Center, 12011 Beech Forest Road, Laurel, MD 20708-4041, USA**
JANE M. NICOLICH, USGS Patuxent Wildlife Research Center, 12302 Beech Forest Road, Laurel, MD 20708-4022, USA
STEPHEN A. NESBITT, Florida Fish and Wildlife Conservation Commission, 4005 S. Main St., Gainesville, FL 32601-9099, USA
JEFF S. HATFIELD, USGS Patuxent Wildlife Research Center, 11510 American Holly Drive, Laurel, MD 20708-4017, USA
DAVID H. ELLIS, USGS Patuxent Wildlife Research Center, 11410 American Holly Drive, Laurel, MD 20708-4019, USA
GLENN H. OLSEN, USGS Patuxent Wildlife Research Center, 12302 Beech Forest Road, Laurel, MD 20708-4022, USA

Abstract: About 50% of the whooping cranes (*Grus americana*) released in Florida die within the first year of release. Most of these deaths and those in subsequent years result from bobcat (*Lynx rufus*) predation. Choosing release sites in open marshes away from bobcat habitat has improved survival. We hypothesized that exposure to ponds (water conditioning) at the rearing site would encourage birds to roost in deeper water marshes after release and such exposure would thereby reduce bobcat predation. In this study, we moved young birds (ca 50 days of age) to netted pens with large (15-m diameter), deep (30–60 cm) naturally vegetated ponds. We randomly assigned the costume-reared whooping cranes into 2 equal-sized groups at fledging. Some groups were placed in pens with a pond (experimental or ponded groups) and the others we reared without additional water exposure (control groups). All birds in the pens with ponds used the water. At night, they roosted at a depth of 36–46 cm. During the day, the birds used the ponds as well as other areas of the pen. We released 3 pairs of water-conditioned and control cohorts, 1 set in 1995 and 2 in 1996. No obvious behavioral differences were noted between the cohorts released in those years. Controls survived as expected (about 60% first year survival). The water-conditioned birds had much higher survival the first year (85%) and continued to survive better for the next 3 years.

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Key words: costume-rearing, Florida, *Grus americana,* parent-rearing, reintroduction, water conditioning, whooping crane.

The release of captive-produced animals to restore populations of endangered species has become a common conservation practice in the United States and other countries (Temple 1978, Gibbons et al. 1995). Few of these releases succeed. K-selected species (like cranes) are especially difficult to establish due to delayed sexual maturity and low reproductive rate. The probability of success for a species improves when the release takes place within the species' historical range and in high quality habitat, when sustained for a decade or more, and when the minimum number released exceeds 20 birds per year (Scott and Carpenter 1987, Griffith et al. 1989, Mirande et al. 1993.) The choice of microhabitat at the release site is important. Although conditions in previously occupied habitat can change, the professional consensus is that releases should occur in historically occupied habitat (Scott and Carpenter 1987, Griffith et al. 1989, IUCN/SSC 1988).

Investigators have often noted improper animal behavior as one factor that contributes to release failures (Ellis et al. 1978, Ellis et al. 1992*a*, Horwich et al. 1992, Urbanek and Bookhout 1992, Zwank and Dewhurst 1992, Drewien et al. 1997, Nesbitt et al. 1997). Obviously, behavioral and physiological conditioning is necessary for a bird to survive in the wild.

Wild birds translocated to a historic, but now unoccupied, site should persist if sufficient habitat exists. Although translocations are recommended, this method is seldom possible with an endangered species. Two of several species successfully translocated in the U.S. are the wild turkey (*Meleagris gallopavo*) (Harper 1968) and the Aleutian Canada goose (*Branta canadensis leucopareia*). Although captive-reared Aleutian Canada geese were released early in the program, real success came only after wild birds were translocated to new islands (Rees 1989). For both species, wild-caught birds survived the challenges of moving into a new area.

One strategy in endangered species programs is to keep animals alive in captivity until the habitat is recovered sufficiently to support releases. Captive-reared animals very often do not have the survival abilities of wild translocated animals. Often it is very difficult even to identify the factors responsible for the success or failure of a release. However, the lack of predator avoidance ability is a common feature in many failures. Rarely have researchers trained captive birds

[1]E-mail: george_f_fee@usgs.gov

to avoid predators. Ellis et al. (1978) taught masked bobwhites (*Colinus virginianus ridgwayi*) to avoid mammalian predators but found that these birds had effective innate responses to avian predators. McLean et al. (1999) taught New Zealand robins (*Petroica australis*) to fear predators. Young trained robins adjusted their responses to predators, but even with this training, none of the robins survived more than 6 months in the wild. Black-footed ferrets (*Mustela nigripes*) trained to avoid predators did not survive release nearly as well as animals exposed to natural-like environments while still in captivity. With training, releases have been made successfully (Vargas et al. 1998).

Establishing migratory crane populations involves risks not encountered with nonmigratory reintroductions (Horwich et al. 1992, Urbanek and Bookhout 1992, Drewien et al. 1997, Ellis et al. 1997, Lishman et al. 1997). As a result, the Whooping Crane Recovery Teams chose to proceed in establishing a nonmigratory population in Florida before attempting to establish a migratory population (U.S. Fish and Wildlife Service 1994). High mortality may occur when cranes are first released to the wild (Bizeau et al.1987, Ellis et al. 1992*b*, Nesbitt et al. 1997). Of course, many young cranes die even in wild populations, with the greatest mortality occurring before fledging (Nesbitt 1992, Ivey and Scheuering 1997).

The effort to establish a nonmigratory whooping crane population in Florida from captive stock started in 1993 (Mirande et al. 1993, Lewis 1995). We expect the Florida effort to continue until we establish a population of breeding-aged birds. Smaller releases may occur after that to adjust the genetic mix in the population and to replace losses until the population is self-sustaining (ca 2020).

Initial losses were expected to be high (40–60%) and it was anticipated that the primary source of mortality would be predation (Nesbitt et al. 1997). Losses were greatest during the first few months after release. Moving the release sites to more open habitat helped reduce these losses (Nesbitt et al. 1997). In this study, bobcats took most of the birds lost to predators (Table 1).

The propagation centers use 2 basic techniques to raise cranes for release (parent-rearing and costume-rearing) (Nagendran et al. 1996). In both rearing regimes, young birds are encouraged to imprint on other whooping cranes. The costume-reared birds get hydrotherapy and exposure to a very small pond early in life: the parent-reared birds do not.

We studied the influence of exposing fledgling crane chicks to large roosting ponds (Fig. 1) on the survival of these birds after release in Florida. Crane chicks of most species, soon after hatching, spend most of their time in or near water (Lewis 1995, Meine and Archibald 1996), so familiarity with, and experience in, roosting in water at night was tested as a means to improve crane survival.

Table 1. Causes of mortality Florida for whooping cranes reared at Patuxent, 1995, and released in Florida.

Cause of death	1995 Pond	1995 No pond	1996 Pond	1996 No pond	1995-96 Pond	1995-96 No pond
Bobcat	3	5	2	4	5	9
Alligator		1	1		1	1
Powerline				2		2
Other	1		1	6	2	6
Total lost	4	6	4	12	8	18
Total alive[a]	3	0	9	7	12	7
Total released	7	6	13	19	20	25

[a] Alive at end of study, 30 Jun 1999.

METHODS

We compared post-release survival of 3 groups of whooping crane chicks: parent-reared, costume-reared without ponds (controls), and costume-reared with water conditioning (experimentals). We raised the costume-reared birds separately and formed groups of 6–9 birds at 50-90 days of age. We randomly assigned the costume-reared birds to

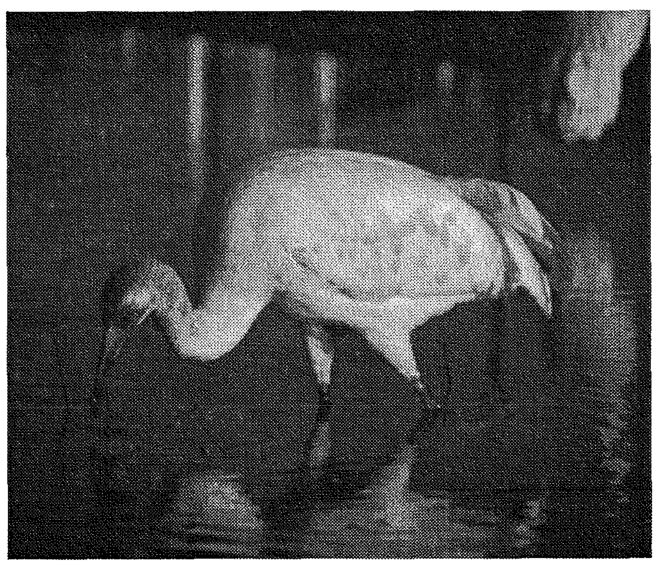

Fig. 1. Juvenile whooping crane in training pond at Patuxent. Note plastic crane decoy in background. (Photo by Jane M. Nicolich.)

pens with and without ponds. For quarantine and subsequent release, we formed cohort groups of 6–9 birds. We left the parent-reared chicks with their parents long term but formed them into a release cohort before the start of quarantine.

Three release cohorts of costume-reared birds contained a mixture of birds with and without water conditioning determined by a variety of other factors like sex, age, genetics, and compatibility. One release cohort contained 8 costume-reared birds with water conditioning and 1 release cohort contained 9 without water conditioning experience.

We held the parent-reared chicks in pens 14 x 17 m with cup waterers and gravity flow feeders. Birds scheduled for release were given a special diet, water, and prophylactic health treatments (Olsen and Langenberg 1996, Olsen et al. 1996, Wellington et al. 1996). The costume-reared chicks received the same food and water but a somewhat different prophylactic medication regime from the parent-reared birds. Medical regimes differed to accommodate the differences inherent in the 2 rearing techniques.

Each summer and fall, we held costume-reared control groups (no ponds in pens) in pens 12 x 31 m with cup waterers and gravity flow feeders. We kept the experimental, costume-reared groups in pens with naturally vegetated ponds (15-m diameter, 30–60 cm deep). A small shed placed in one corner of the control and experimental pens sheltered the gravity flow feeder. In the ponded pens, we observed the birds at night with infrared video cameras.

Before sending cranes to Florida, we moved the parent-reared and costume-reared birds to pondless pens (17 x 31 m) with cup waterers and gravity flow feeders for a 60+ day quarantine. To avoid introducing bias, the release team was not given the identity of the water-conditioned birds, and we purposely hid the identity from ourselves (a blind study). We evaluated the survival of the birds in the study 3–4 years later.

Statistical Methods

We used survival analysis (Lawless 1982, Blackwood 1991, Ellis et al. 2000) to test for differences among release years, rearing method, and water conditioning treatment. We used the nonparametric Kaplan-Meier product-limit method to compute the survival functions and the log-rank statistic to test for differences. Differences were considered significant when $P < 0.05$.

Study Area

Birds were raised at the USGS Patuxent Wildlife Research Center (Patuxent) in Laurel, Maryland. The release site was the Kissimmee Prairie in Osceola County, Florida. The area is dominated by open pastures, other agricultural lands, and abundant freshwater marshes. The area supports the largest and most productive populations of Florida sandhill cranes (*Grus canadensis pratensis*) (Bishop and Collopy 1987, Bishop 1988, Nesbitt et al. 1997) within the range of the subspecies.

RESULTS AND DISCUSSION

We know from earlier studies that pre-release conditioning plays an important role in the survival of reintroduced, captive-reared cranes. Nesbitt and Carpenter (1993) reported on the release of greater sandhill cranes (*G. c. tabida*), a migratory subspecies, in Florida to establish a nonmigratory population. Others previously demonstrated that the same subspecies could be added to a migratory population (Horwich et al. 1992, Urbanek and Bookhout 1992). We have even trained greater sandhill cranes to follow ultralight aircraft and trucks along preselected migration routes (Clegg et al. 1997, Ellis et al. 1997, Lishman et al. 1997). The largest crane restoration effort has been with the Mississippi sandhill crane (*G. c. pulla*) (nonmigratory). This program had early failures and recent successes (Zwank and Dewhurst 1992, Ellis et al. 1992*b*, Ellis et al. 2000), all related to conditioning.

While still at Patuxent, our water-conditioned birds roosted at night in the pond, often immersed up to the feathers of the shank. During the day, we observed them at times in water up to the belly. We made 3 releases of controls and 3 releases of water-conditioned birds. The releases were in the same general area, at the same time of year, but separate from one another. One of 3 releases contained only water-conditioned birds: this was the only cohort that had 100% 1-year survival. We also released 5 parent-reared cranes in 1996, but we had none for release in 1995. Because there were so few, we included the parent-reared cranes in the control group.

The water-conditioned cranes survived their first year after release at a rate that was greater than that for the control group (85% versus 52%). Survival benefits continued for the duration of the study (60% versus 28%: Table 2). There was no difference in survival between the 2 release years (chi-square = 0.6637, degrees of freedom = 1, $P = 0.4152$) or between the 2 rearing treatments (chi-square = 0.7511, degrees of freedom = 1, $P = 0.3861$). However, there was a significant difference between the water-conditioned cranes and the controls (chi-square = 6.1520, degrees of freedom = 1, $P = 0.0131$). Water-conditioned birds showed much higher survival (Fig. 2).

CONCLUSIONS

To maximize the post release survival of each whooping crane, it is critical that the cranes select the best available roosting sites upon release. Inappropriate roost site selection

Table 2. Survival after release of whooping cranes reared at Patuxent, 1995 and 1996, and released in Florida.

	No. released	No. survivors		% survivors	
		1 year	1999[a]	1 year	1999[a]
1995[b]	13	5	3	38	23
Pond[c]	7	4	3	57	43
No pond	6	1	0	17	0
1996	32	25	16	78	50
Pond[d]	13	13	9	100	69
No pond	19	12	7	63	37
Totals 1995–96	45	30	19	67	42
Pond	20	17	12	85	60
No pond	25	13	7	52	28

[a] Birds surviving as of 30 June 1999.

[b] Hatch year (HY) is year preceding release year (e.g., HY 1994 chicks were released early in 1995).

[c] 1995 release (HY 1994) birds spent 13 September to 22 November 1994 on ponds.

[d] 1996 release (HY 1995) birds spent 17 August to 14 November 1995 on ponds.

predisposes the cranes to predation. Water roosting is an innate behavior that, even without early experience, may develop if cranes are placed in appropriate habitat. However, our efforts to condition whooping cranes to roost in water during captive rearing at Patuxent and in release pens in Florida (Nesbitt et al. 1997) has demonstrably improved post-release survival. Early and prolonged exposure to an appropriate roosting environment during captive rearing should further enhance post-release roost site selection and survival.

As of June 30, 1999 (3–4 years after release) 2 of 5 (40%) parent-reared, 5 of 20 (25%) costume-reared control birds, and 12 of 20 (60%) water-conditioned whooping cranes survived (Table 2).

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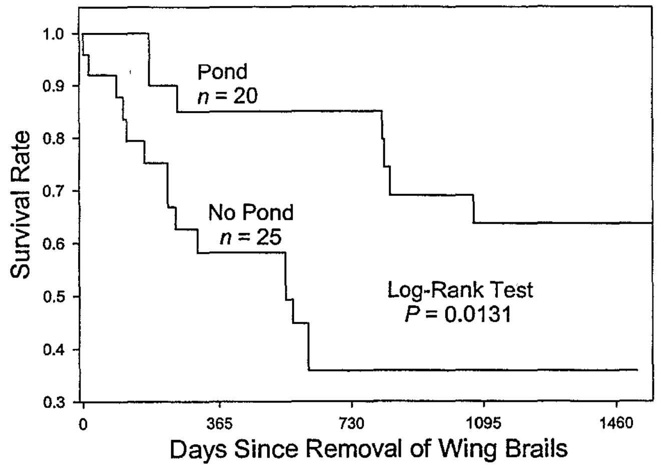

Fig. 2. Whooping crane survival in Florida as of 30 June 1999, Kaplan-Meier estimator.

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