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Abstract: In 1995 and 1996, we trained 2 groups of costume-reared greater sandhill cranes (*Grus canadensis tabida*) (10 in 1995, 14 in 1996) to follow a truck. Thereafter we led 10 in 1995 and 12 in 1996 from Garland Prairie, northern Arizona, to the Buenos Aires National Wildlife Refuge, southern Arizona (ca. 620 km). These techniques were being developed to create additional, disjunct populations of the whooping crane (*G. americana*). The cranes taught the migration route in 1995 did not follow the desired migration route in 1996 but did travel north 140 km along the route in spring 1997. By the summer of 1997, we did not know the locations of any of these birds. Results were better for the 1996 trucking cranes. Between 1997 and 1999 there was a 92% (11 of 12) success rate for the 1996 trucking cranes with known locations flying unassisted from the summering to wintering grounds. Through 1999, 7 of the 12 cranes became lost on flights from the wintering to summering grounds. (Some of the trucking cranes apparently followed wild cranes to or toward breeding grounds.)

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There is currently only one self-sustaining, and therefore viable, population of the whooping crane in the wild. To create additional migratory populations of this federally-listed, endangered species, several techniques have been tested to lead captive-reared birds along a predetermined migration route. One such technique is having wild cranes act as guide birds that lead conspecifics along a predetermined migration route. In 1994 and 1995, 3 wild, cross-fostered adult whooping cranes from the Grays Lake cross-fostering experiment (Drewien and Bizeau 1978, Drewien et al. 1985) were captured and placed in pens near Grays Lake National Wildlife Refuge (GLNWR) (Drewien et al. 1997). Five whooping crane chicks were placed in enclosures with the adult whooping cranes for approximately 2 months before both the adult and juvenile whooping cranes were released from the pens. The objective of the experiment was to have the adult whooping cranes adopt and lead the juvenile whooping cranes on a predetermined migration route from the GLNWR to the Bosque del Apache National Wildlife Refuge (BdANWR). Though the adults and juveniles were thought to have established bonds while in the pens, after their release the adults did not maintain the social bonds with the juveniles and migrated without the young whooping cranes. Injuries and death of the juveniles from vehicle transportation to the target wintering grounds constrained evaluation of this technique of having guide cranes teach conspecifics a desired migration route (Drewien et al. 1997).

A second approach to creating a migratory population of cranes involves teaching fledged birds to fly after an ultralight aircraft that leads the birds along a desired route. During 1993–95, Canada geese (*Branta canadensis*) (1993 = 18; 1994 = 38; 1995 = 30) were led by ultralight aircraft on 3 migrations from Ontario to wintering sites in either Virginia or South Carolina (Lishman et al. 1997). Of 86 geese, 61 returned unassisted to the Ontario rearing location the following spring. Following this success, greater sandhill cranes were used as a surrogate species for the whooping crane to determine if cranes could also be taught to migrate by following an ultralight aircraft. In 1995, 7 of 11 sandhill cranes were successfully led by ultralight along a 1,204-km route from southern Idaho to the BdANWR, New Mexico (Clegg et al. 1997). The following spring 4 of these birds remained alive and migrated north. Two were found 53 km from the rearing location. The locations of the other 2 birds were unknown. In 1997, another experiment was conducted where greater sandhill cranes were led along a desired migration route with an ultralight aircraft (Duff et al. 2001). In this experiment, 7 greater sandhill cranes were led from Ontario to Virginia. The following spring, 6 of 7 of these cranes returned to Ontario.

A third approach, one now being tested, is the stage-by-stage method where birds are transported in a motorized vehicle and released at 25- to 50-km intervals for brief flights to orient themselves along a desired migration route (Ellis et al. 2001*a*). For this method to work, cranes must "connect-

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the-dots" with landmarks as they migrate independently after a training stage-by-stage migration.

The fourth approach is teaching cranes to fly after a motorized ground vehicle and leading the cranes along a desired route. In this manner, 8 of 10 sandhill cranes in 1995 and 10 of 12 in 1996 were successfully led along a 620-km route from Garland Prairie, northern Arizona, (Table 1) to a wintering site at the Buenos Aires National Wildlife Refuge (BANWR), southern Arizona (Ellis et al. 1997, 2001*b*). This paper describes the survival and movements of these sandhill cranes after their truck-led migration, and the lessons we learned that may be helpful in future attempts to teach cranes a migration route.

METHODS

The rearing and training of these sandhill cranes has previously been documented by Ellis et al. (1997). To summarize, the sandhill cranes were costume-reared at Patuxent Wildlife Research Center (Patuxent) where they were exposed to such imprinting stimuli as tape recordings of engine noises of the converted army ambulance (cranemobile) used during the training migration, walking after costumed caretakers, exposure to the sound of whistles and flapping flags used on the cranemobile, riding in the cranemobile, and eventually flying after the cranemobile. Approximately 70 days after the cranes hatched, we shipped the cranes to Arizona where the birds' training continued by having them fly after the cranemobile on the Camp Navajo Army Depot near Flagstaff, Arizona. When the birds were approximately 110 days of age, the migration from northern to southern Arizona began.

After the truck-led migrations, we followed the movements of the cranes. In the winter and spring of 1995–96, the 1995 trucking cranes were kept in pens on the BANWR. Throughout the spring of 1996, we released the birds weekly from their pen to determine if the birds would independently initiate northern migration. On the first day of each release, we transported the birds to a pond. The second day was spent waiting for the birds to initiate migration. The third day was spent waiting through the morning until the birds became inactive. At this point, we returned the birds to their pen until the following week when the next spring release took place. When the birds failed to go north on their own, we intervened as described below. The following year, we again kept the 1995 trucking cranes in pens for the winter, and in the spring of 1997, we transported the cranes to the same pond we used the previous year for spring releases. Instead of weekly releases, however, we set up a feeding station and allowed the birds to stay at the pond for the entire spring. We visited the birds weekly to refill the feeder.

With the 1996 trucking cranes, we used other manipulations. Soon after this second truck-led migration was completed, we transported the 1996 trucking cranes 300 km northwest to a section along the Gila River that was approximately halfway along the migration corridor. At this location, we released the 1996 trucking cranes into a wild flock of conspecifics. In spring 1997, we captured 5 of the 1996 trucking cranes and placed them in a pen. We left the remaining 7 trucking cranes free on the Gila River.

Table 1. Timeline for greater sandhill cranes of the 1995 truck-led migration experiment, Arizona.[a]

Time Period	Buenos Aires NWR[b]	Mormon Lake[c]	Unknown Location	Crane Deaths
Nov 1995–May 1996	8			
Jun–Aug 1996		9[d]		
Sep–Oct 1996		4		5
Nov 1996–Apr 1997	4	4		
May–Jun 1997			4	

[a] Values indicate the number of birds in each category.
[b] Target wintering grounds.
[c] Target summering grounds.
[d] Includes 1 crane that dropped out during migration.

RESULTS

1995 Trucking Migration

The October 1995 migration involved 10 costume-reared sandhill cranes (Table 1). One bird died after it collided with a powerline. Another bird was lost on migration but lived. The 8 birds that successfully completed the route wintered in a pen at BANWR. In the spring of 1996, they did not fly north when we gave them weekly opportunities. We, therefore, transported the birds to the desired summering area, Mormon Lake in northern Arizona. All of these 8 cranes from the BANWR and 1 bird that wintered elsewhere survived the summer, but in the fall of 1996, 5 died with the likely cause of death being predation by coyotes (*Canis latrans*) at the summering grounds after their marsh dried up. The 4 survivors did not initiate migration in October 1996, and when "jump-started," flew south but not along the target migration corridor. Further, because the birds continually approached humans, we felt they were too tame to remain in the wild. We, therefore, placed them in a pen until spring

1997.

In spring 1997, we released the 4 birds at BANWR. In early April, the 4 flew north 140 km following the target migration route, but we were obligated to remove them after they landed on a golf course. We relocated the 4 birds to a nearby location along the migration route that had fewer opportunities to contact humans. One bird was injured, probably from a coyote or bobcat (*Felis rufus*) attack, 8 days later. The 3 remaining cranes apparently became disoriented after we moved them; they flew 125 km east (not north) and landed in a state penitentiary. When they were released from jail, they flew west and were never seen again.

1996 Trucking Migration

In October–November 1996, we released the 12 survivors of our 1996 truck-led migration (Table 2), using the one-by-one release technique (Ellis et al. 2001*c*), into a wild flock of approximately 150 greater sandhill cranes on the Gila River, halfway along the migration corridor. We saw this as a way to prevent the birds from becoming overly tame toward humans. At the end of winter, all 12 cranes were still alive and unapproachable by uncostumed humans. In spring 1997, we captured 5 of the trucking cranes by helicopter or in costume and placed them in a pen, concerned that our trucking cranes would follow the neighboring wild sandhill cranes on migration to Nevada or Oregon.

We did not capture 7 trucking cranes. After the wild sandhill cranes departed, we could not locate 1 of the 1996 trucking cranes. We think this crane migrated with the wild sandhill cranes. In mid-March 1997, we did not know the locations of 3 of the remaining 6 trucking cranes that we had left on the wintering grounds. The other 3 birds flew north to within 75 km south of the desired summering grounds, where they encountered deep snows and responded by returning to the wintering grounds. In April, these 3 trucking cranes again flew north landing in a town approximately 75 km southeast of the desired summering area. Because the cranes approached human habitations, we transported these 3 birds in a truck to the desired summering area. Once at the summering area, these 3 trucking cranes and the 5 trucking cranes we released from the holding pen commenced frequent flights in 2 groups to towns within a 100-km radius around the desired summering area. In late May 1997, we clipped 3 primaries from each wing of the dominant bird of 1 group and brailed (wrapped athletic, adhesive tape around 1 wing) the dominant bird of the second group to stop these flights. Afterwards, all 8 trucking cranes stayed at the desired summering grounds through the summer and early fall.

In mid-fall 1997, 7 trucking cranes remained alive at the summering area. (The crane whose primaries we clipped died in early fall.) Mormon Lake dried up in late fall, and 3 trucking cranes flew unassisted from the summering area to the desired wintering grounds. The remaining 4 trucking cranes flew east (not south), 200 km off the desired migration course. We returned these 4 cranes to Garland Prairie, the starting terminus of the migration route, and the birds flew 60 km in the correct southern direction, landed, and spent several weeks using the site as a mid-elevation staging area. In November 1997, we found 3 of these 4 trucking cranes, plus an additional bird whose location had been unknown for 7 months, on the target wintering grounds, making a total of 7 cranes that successfully flew to the target wintering grounds for the 1997–98 winter.

In spring 1998, we knew the locations of only 4 of these birds. Three flew to within 40 km of the desired summering grounds. One crane flew south from the wintering grounds, 180 degrees off course. We collected and transported 4 of these birds to the desired summering area. In October 1998, these 4 cranes left the summering area and flew unassisted to

Table 2. Timeline for greater sandhill cranes of the 1996 truck-led migration experiment, Arizona.[a]

Time Period	Holding Pen	Gila River[b]	Mormon Lake[c]	Unknown Location	Crane Deaths
Nov 1996–Feb 1997		12			
Mar 1997	5	3		4	
Apr–Aug 1997			8	4	
Sep 1997			7	4	
Oct 1997			7	4	1
Nov 1997–Mar 1998		7		4	
Apr 1998		4		7	
May 1998–Sep 1998			4	7	
Oct 1998–Mar 1999		4		7	
Apr 1999			3	8	
May–Jul 1999			4	7[d]	
Aug 1999–Feb 2000	3[e]			8	

[a] Values in table are for the number of birds in each category.
[b] Target wintering area.
[c] Target summering area.
[d] One of these birds was later found to be in Victorville, southern California from 12 May-26 October 1999.
[e] These 3 cranes were permanently placed in zoos.

the desired wintering area. All 4 survived the winter, and in spring 1999, 2 flew unassisted to the desired summering area, 1 flew to within 40 km of the summering area, and the fourth bird, apparently followed the wild flock of sandhill cranes and landed in west-central Nevada. A fifth bird, we later discovered, was in Victorville, southern California from mid-May until late October 1999 and thereafter could not be relocated. We placed 3 of these birds in zoos because we felt the cranes were too tame to remain outside of captivity. In spring 2000, 4 cranes were seen in the mountains north of Mormon Lake, and 1 crane was reported in the White Mountains in 2001. Because breeding cranes were extirpated from these areas several decades ago, we believe, but cannot be certain, that these were survivors of the trucking experiments.

DISCUSSION

Our experiments in 1995 and 1996 demonstrated that costume-reared sandhill cranes could be trained to follow a truck along a migration route. We also found that some of these trucking cranes could survive and later independently return to desired wintering and summering grounds during appropriate time periods. We did encounter several problems that provided valuable lessons for future experiments.

In November 1995, we placed the birds in pens too near to human contact. We think this made the cranes excessively tame. In spring 1996, our release method (i.e., waiting near the cranes in hopes they would migrate) probably prevented the birds from migrating north. After we transported these 8 cranes to the summering grounds, only 4 survived the summer and fall. This high mortality rate was likely due to the combination of inexperience with predators and the drying of their roost lake.

The 1996 trucking cranes had higher survival rates and were more successful in following the migration route. We felt that the one-by-one release of these cranes into a flock of wild sandhill cranes for their first winter allowed the captive-reared cranes to develop a wariness of humans and predators, while possibly also learning from the wild cranes other survival skills such as efficient foraging and safe roosting. As a result, we knew of only 1 trucking crane from this flock that died after the training migration, even though the lake used by these birds on the summering grounds also evaporated completely and these birds were exposed to an abundant coyote population throughout this experiment. We also had greater success with the 1996 trucking cranes returning to and from desired summering and wintering grounds. From 1997 to 1999, 92% (7 out of 8 in 1997; 4 out of 4 in 1998) of the cranes for which we knew their location flew unassisted from the summering to wintering grounds. Problems of our not being able to locate many of the 1996 trucking cranes stemmed mostly from the birds' disappearing while on migration and radio failure. During the time when the cranes were on the wintering grounds or migrating to the summering grounds, we were unable to locate 58.3% (7 out of 12) of the cranes between 1997 and 1999. This is probably related to the climatic differences between the wintering grounds at 230 m in elevation and the summering ground elevation at 2,200 m. Because of this elevational gradient, the cranes would leave the wintering grounds in March when the summering grounds were still snowbound. The birds eventually learned to use a mid-elevation staging area before continuing to the summering grounds. Before this was learned, however, we were unable to locate 7 of the 12 cranes after the birds attempted to fly directly to the summering grounds and subsequently flew to an unknown location after encountering snow in the high elevations of northern Arizona. Although we were frequently unable to locate some cranes, 60% (3 out of 7 in 1997; 3 out of 4 in 1998; 3 out of 4 in 1999) of the birds with known locations returned to within 75 km of the northern summering grounds.

We also learned that, when our cranes flew from a desired summering ground to adjacent populated areas, we could eliminate this behavior by impairing the flight of the dominant crane in the group. We tried 2 techniques to impair flight. We grounded 1 leader by clipping 3 primaries from each of its wings. This discontinued flights to populated areas but still allowed the bird to fly distances of up to 1 km and therefore escape predation as necessary. However, this bird died from unknown causes 3 months after we clipped its wings. Because of this bird's inability to migrate until molt (the time until molt being unknown at the time of clipping), we do not encourage this technique in future experiments. The second method we used to prevent flight of a flock was brailing. This prevented all flight and rendered the bird vulnerable to predation. However, we could restore the bird's flight by simply removing the braile. We therefore found this technique (i.e., brailing a dominant bird) the preferred method to keep the entire flock at a desired location.

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