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RESULTS OF AN EXPERIMENT TO LEAD CRANES ON MIGRATION BEHIND MOTORIZED GROUND VEHICLES

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Abstract: Ten greater sandhill cranes (*Grus canadensis tabida*), trained to enter and ride in a specially-equipped truck, were transported at ca 80 days of age from their rearing site at Patuxent Wildlife Research Center (Patuxent), Maryland, to a reintroduction site located within the species' former breeding range in northern Arizona. After 5 additional weeks of training, these juvenile cranes were led south ca 600 km to a wintering area on the Arizona/Mexico border. Nine of the 10 survived the trek, 495 km of which were flown, although only a few cranes flew every stage of the route. Their longest flight was 77 km. Major problems during the migration were powerline collisions (3, 1 fatal), eagle attacks (none fatal), and overheating (when air temperatures exceeded ca 25 C). All cranes that entered training quickly learned to follow the truck, and their tenacity when following under unfavorable conditions (e.g., poor light, extreme dust, or heat) showed that cranes could consistently be led over long distances. We cannot predict if the cranes will retrace their route unassisted when adults, but 2 cranes returned 130 km to the starting point of the migration after the flock was scattered by an eagle during our migration south. Three other cranes were recovered 55 km from the attack site and on course toward the starting point.

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Key words: reintroduction techniques, migration, sandhill crane, whooping crane, *Grus* spp.

Because of the need to develop techniques for establishing additional migratory flocks of whooping cranes (*Grus americana*), 2 experiments were initiated in 1995 to lead sandhill cranes, as research surrogates, on migration. An ultralight experiment is described in a companion paper (Clegg et al. 1997). The first year of a 2-year experiment to lead cranes with a truck (Fig. 1) is described below.

Training birds to follow humans is far from new. For more than 5,000 years, falconers have trained raptors to return to their trainers (Burnham 1990). Sometimes this resulted in birds following pedestrian or equestrian trainers for several kilometers. By the mid-20th century, scientists understood the following response for some avian species and had trained neonatal waterfowl to follow humans (Lorenz 1952; see Immelman [1972] for a review of imprinting).

During the 1980's, 2 remarkable experiments were conducted in Washington state. In the first, Kenneth Franklin trained 2 prairie falcons (*Falco mexicanus*) to circle up and join an ultralight aircraft trailing a food-garnished lure (Franklin and Franklin 1985). Franklin later trained peregrine falcons (*F. peregrinus*) to follow him in free fall as he and the falcon sky-dived from a small fixed-wing aircraft (K. Franklin, Friday Harbor, Wash., pers. commun.). Less spectacular, but more pertinent to our crane experiments, in 1979 and 1980 John McNeely (Sharon, Conn., pers. commun.) trained a red-tailed hawk (*Buteo jamaicensis*) to fly with his hang glider. The bird also landed on the glider and received food from McNeely as he flew. A movie, *John McNeely and the Hawk*, resulted from the experiment. Also pertinent are the waterfowl training experiments of William H. Carrick (Toronto, Ont., pers. commun.), who trained geese and swans (1970–present) to follow boats and other craft. This pioneering work led to the spectacular successes of Bill Lishman and Joe Duff in leading Canada geese (*Branta canadensis*) on 3 migrations (1993–95) from eastern Canada to Virginia or to South Carolina (Lishman et al. 1997).

Probably all aviculturists who have reared cranes have noted that chicks are prone to follow their human caretakers. Beginning in 1973, George Archibald (International Crane Foundation, Baraboo, Wis., pers. commun.) trained sandhill cranes to fly and return to him. He added Eurasian cranes (*Grus grus*) in 1975 until he had a group of up to 20 cranes that would launch, climb to 100 m or more, fly for 5 minutes or more, then return. Probably the first to lead a crane chick with a motorized vehicle were Des and Jen Bartlett in 1971 (Bartlett and Bartlett 1975:69). They reared a sandhill crane chick with a flock of snow geese (*Anser caerulescens*) and trained all to follow an automobile. Because their primary goal was to photograph the birds in flight, they made no attempt to actually lead the birds along a migration route following the vehicle. They did, however, release the crane

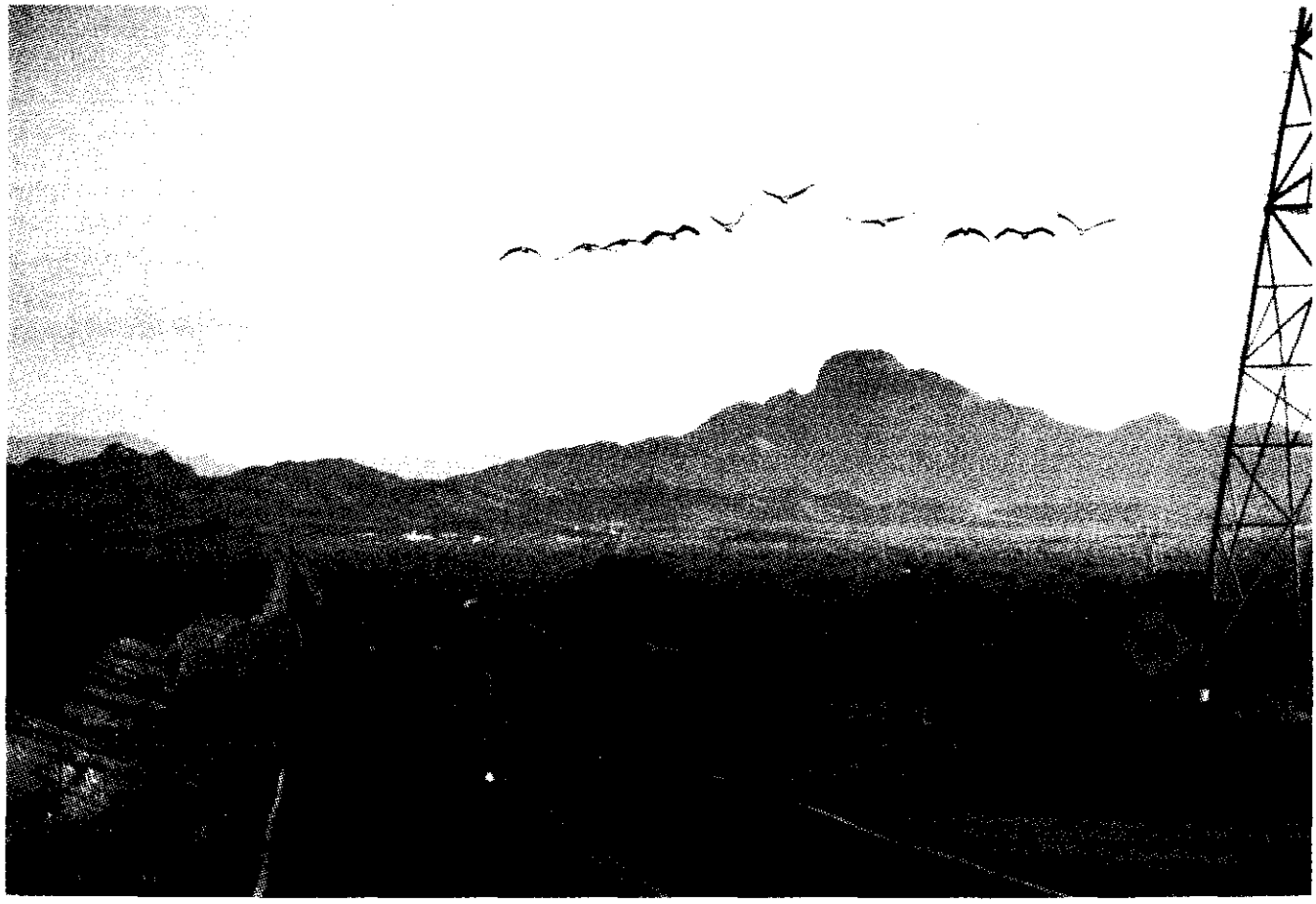

Fig. 1. A group of 10 greater sandhill cranes following the cranemobile on an early morning flight past the Vulture Mountains, 16 October 1996 (photo by D. H. Ellis).

and the geese periodically at refuges from southern Canada to Texas.

From 1990 through 1992, we at Patuxent, each year, trained 4–6 sandhill crane chicks to follow a motorized vehicle so we could observe their flight performance while they wore various backpack harnesses carrying satellite transmitters. Due to space constraints, these flights never exceeded 1 km. Beginning in 1983, Kent Clegg (Grace, Id., pers. commun.) led tame sandhill cranes behind all-terrain vehicles and automobiles. In 1994, 1 such flight extended to 61 km behind a pickup truck.

Occasionally sandhill cranes have been transported by truck to migration stopover sites after they failed to migrate on their own (R. H. Horwich, pers. commun.; Nagendran 1992; Urbanek and Bookhout 1992). In some of these attempts, the trucked cranes proceeded on their migration without further assistance. In none of these attempts did the birds actually follow the truck, and in all instances the trucked cranes had wild cranes to follow after their release.

We are greatly indebted to Colonel L. Triphahn for allowing our training on the Navajo Army Depot near Belmont, Arizona. Sergeant D. Hack coordinated all our activities on the depot and sponsored our stay. W. Shifflett, Manager of the Buenos Aires National Wildlife Refuge (BANWR), hosted our wintering cranes, and P. Landin, G. Jontz, S. Gall, and W. Kuvlesky assisted with bird care at the refuge. We greatly appreciate T. Kohler for transporting 6 of our cranes to Arizona, gratis. The Arizona Game and Fish Department (AGFD) greatly assisted us during the migration. They passed along locations of wayward (i.e., eagle-scattered) birds and provided an aircraft to search for birds by radiotelemetry. J. G. Goodwin, Jr., coordinated all of these efforts. P. Smith (AGFD) advised us in setting up the project. Important participants in the field include F. B. P. Trahan, who volunteered for the 1995 migration, and S. Thomas, who volunteered to help rear and train cranes in the 1994 pilot project. C. Van Cleave, Arizona's most noted raptor rehabilitator, donned another hat (i.e., gruid flock

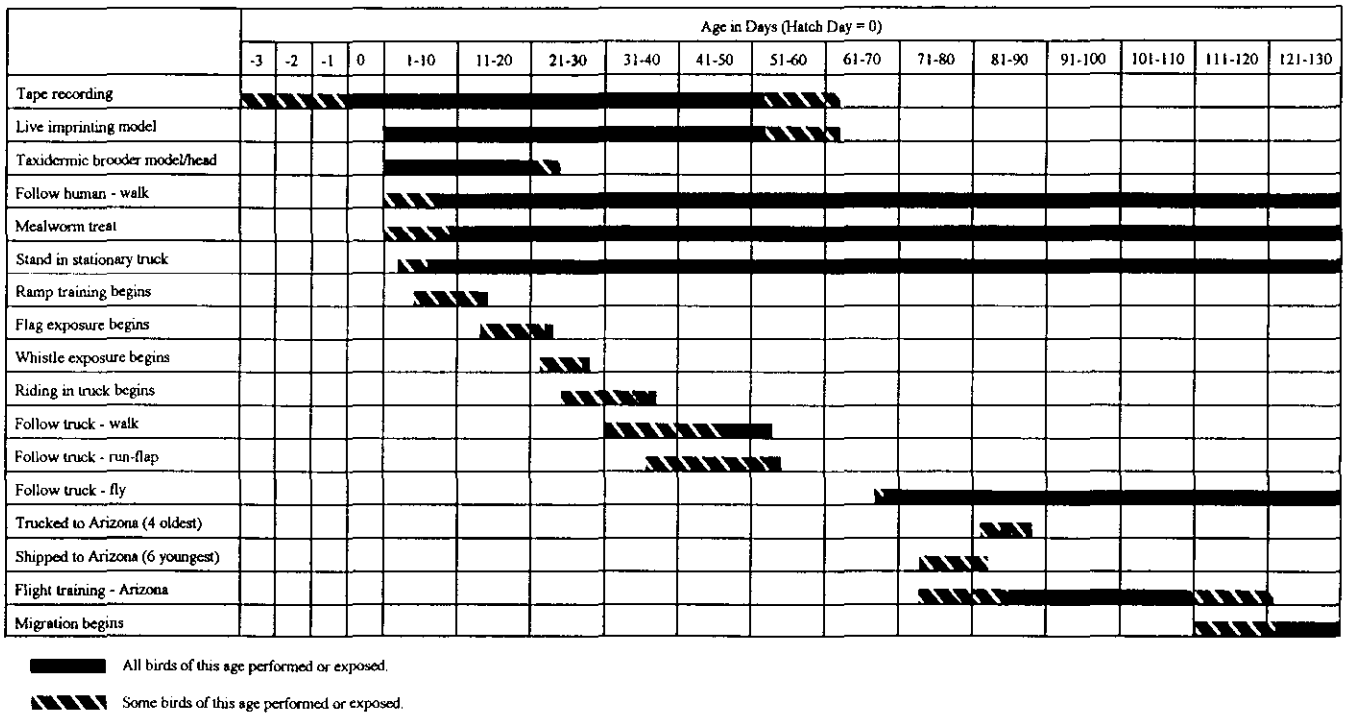

Fig. 2. Training timeline for greater sandhill cranes, trucking experiment, Arizona, 1995.

reassembler) during our odyssey. Most fundamental of all, we thank G. F. Gee, T. Fontaine, K. O'Malley, J. Nicolich, and all of the Patuxent rearing staff for making the project fly.

METHODS

In our 1994 pilot study, we trained 5 sandhill cranes to walk a ramp into a pickup truck. To lure the chicks up the ramp, we scattered mealworms (larvae of *Tenebrio* sp.) on the ground, up the ramp (2.4 m long with a 72-cm rise), and into the truck bed. The trainer on the ramp and in the truck bed also lured the chicks by imitating an adult brood call. Ramp training began at about 10 days of age. All chicks quickly learned to walk up and down the ramp and showed very little aversion to doing so or to riding in the truck. The only difficulty was preventing flightless chicks from walking off the edge of the ramp. The propensity of the chicks to do so necessitated stationing a caretaker on each side of the ramp. None of these birds was trained to fly behind the truck; however, from about 65 days of age, they did ride in the truck.

Also in 1994, we searched for a suitable migration corridor for a long-distance trucking study. We needed a site with good crane habitat, where sandhill cranes no longer bred, and, if possible, removed from sandhill crane migration areas. We reasoned that, if our sandhill crane migration study was to approximate conditions in the future whooping crane migration project, it was important that our sandhill crane chicks not have other sandhill cranes available to lead them on migration, either north or south. We considered and examined potential routes starting at northern termini in Maine, New York, and Ontario and leading south to the Atlantic Coast marshes, but finally settled on a route leading south from the mountains of northern Arizona to the BANWR on the Mexican border. The northern terminus was ideal because sandhill cranes had formerly bred there (Phillips et al. 1978:30), but they were now absent as breeders and unlikely even as migrants in this area. The winter terminus (BANWR) was selected because sandhill cranes never winter there and seldom migrate through. Also, facilities were available to overwinter the birds in a pen, safe from predation.

The Rearing Process

Birds used in the 1995 experiment were subjected to stimuli according to the schedule in Fig. 2. They were exposed to live adult imprinting models and were otherwise reared as described for hand-reared Mississippi sandhill cranes (*G. c. pulla*) intended for release (Ellis et al. 1992), except we substituted a blue and white jacket and red baseball

cap for the amorphous crane costume developed by Horwich et al. (1992). The senior author concluded that it was unreasonable to subject the crane rearing crew to the discomfort of wearing the full costume while rearing and training the chicks in Maryland and for 7 weeks in Arizona before we demonstrated that the southward migration was possible. Another departure from the Mississippi sandhill crane rearing regime was that the tape-recorded calls normally played for the chicks during hatching and rearing now included human imitations of a sandhill crane brood call, engine noises of our cranemobile, and the flapping sounds made by the flags that were later attached to the cranemobile during travel.

Table 1. Details of training sandhill cranes to fly behind a truck, Navajo Army Depot, Belmont, Arizona.

Total number of flights	53 on 23 days during 34-day period
Dates	30 Aug to 1 Oct 1995
Total flight distance	225 km
Total flight time	5 hr, 1 min
Average flock size	8 birds
Average altitude	19 m
Highest altitude	60 m
Lowest altitude	1 m
Average speed	49 km/h
Highest speed	72 km/h
Lowest speed	10 km/h

Training

Figure 2 presents most aspects of the training process. In 1994, our transport chamber for the birds consisted of the bed of the pickup truck with the floor lined with rubber matting, with 45-cm-tall sidewalls, and with white painted wood sidewall panels 41 cm tall. The box was covered by a nylon net (11-cm mesh length) to prevent birds from escaping while in transit.

During transport, cranes were thrown off balance by sudden changes in momentum, but drivers quickly learned to accelerate and decelerate gradually and to avoid severe bumps and rapid turns so cranes could be transported moderate distances with little discomfort. The transport maxima during the pilot year were ca 45 minutes and ca 100 km/h.

In 1995, our transport vehicle was a modified U.S. Army ambulance. The entry ramp was 3.1 m long, with a 1.3-m rise. When working with small chicks, we used a 43-cm-tall, vinyl-coated welded-wire fence attached to both sides of the ramp to prevent falling. After the chicks were about 30 days old, the ramp fence was removed, but trainers continued to guide the chicks as they traversed the ramp. During the migration, we manually lifted cranes into the truck bed, so the ramp was seldom used.

All aspects of training, except flying behind the truck, were initiated prior to transporting the birds west. Because leg and wing injuries regularly occur in groups of recently fledged chicks at Patuxent (Wellington et al. 1996), we decided to wait to transport the birds west until the youngest was 74 days old. Sandhill crane long bones are fully grown and growth plates are closed at about 70–84 days of age (J. Langenberg, International Crane Foundation, Baraboo, Wis., pers. commun.).

From 24 to 27 August, 4 cranes were trucked from Maryland to Arizona unfettered in the rear of the cranemobile. All were weak and wobbly toward the end of the trip. One bird (No. 86) sat most of the last 2 days. From his appearance upon arrival, we expected him to die. Within 2 days of arrival, all other birds were well-coordinated, active, and had begun flight training. No. 86 only gradually commenced flight training, and it was not until 9 days after arrival that he participated fully with the other cranes. Further, all 4 trucked birds subsequently showed a broad band of imperfectly formed barbs (fault bars or stress bars) on their back and scapular feathers, apparently coinciding with the time of transit and evidencing the physiological stress (Grubb 1989) associated with the journey west.

On 28 August 1995, the remaining 6 study birds were flown west in a small jet aircraft and spent only 8 hours in special crane shipping boxes (Swengel and Carpenter 1996). None of these birds exhibited physical damage after shipment other than temporarily mussed bustles. All were alert and ready to begin training upon arrival.

Flight Training

Training was conducted at the Navajo Army Depot, 20 km west of Flagstaff, Arizona. Because we hoped that our cranes would eventually breed where sandhill cranes had bred a century earlier (Phillips et al. 1978), on 13 September we trucked them to Mormon Lake and allowed them to wander in the marshes. We also encouraged them to capture grasshoppers (Locustidae) and aquatic animals in the marshes at the Navajo Army Depot.

Flight training is summarized in Table 1. At the onset, flights were short (1–4 km), but by the end of September the birds were making 15-km flights followed by a ca 10-minute rest, then a return flight of up to 15 km. The birds were trained to fly past fences and powerlines and through developed areas, prairies, and forests. During training, we locked the rear doors of the cranemobile open and 1 or more trainers sat on the elevated truck bed calling and waving to encourage the birds. Further visual and audio stimulation was provided

by 2 flags affixed above roof level.

The Migration

Prior to the migration, all 6 crew members traversed all or nearly all of the route once, and the 3 primary drivers had covered the route 2 or more times. Each vehicle carried a set of maps (scale 8:1,000,000 with powerlines marked in bold) and a 2-way radio. Coordination of widely separated vehicles and with cooperators was done by each of us calling C. Ellis at our Oracle, Arizona, base. Each crane was fitted with a VHF radio transmitter (solar powered) prior to migration. Radios were mounted on plastic leg bands with average total package weight of about 60 g.

Three vehicles participated in the migration. With few exceptions, the cranemobile was the middle vehicle during travel. Occupants of the lead vehicle, using their 2-way radio, advised of traffic conditions, announced hazards, and cleared intersections (so the cranemobile could drive through with speed unabated). The navigator in the third car announced, into his 2-way radio, data (e.g., concerning ground speed and altitude of cranes) for the recorder. This vehicle also dropped back to search for delinquent cranes.

RESULTS

The migration began midday on 2 October and ended on 14 October at 0915 hours (Table 2). Our southward passage included many unique and bizarre interactions between trainers, cranes, railroad trains, police, a jogger, eagles, bystanders, and oncoming vehicles. Brevity requires that we focus only on those experiences that best provide lessons for future attempts. The route is shown in Fig. 3.

Day 1: 2 October.—We tried to walk the flock through 4 km of forest to join a dirt road and begin the first flight. The cranes, already familiar with the area, flew back to camp, and we, left with only 1 crane, chose to regather the birds and truck them to a spot ca 7 km from camp. The birds then followed the cranemobile for 3 km until we stopped because of approaching darkness. As we began to set up camp, we inadvertently flushed the birds before they were penned and were able to call only some of them back to camp, so we spent the night with only 6 cranes, bemoaning our decision to use solar transmitters that disallowed nighttime searching.

Day 2: 3 October.—At dawn, all of the lost cranes flew back to camp. By 0800 hours we had gathered our search teams and began the flight into the forest. The first forest flight proceeded well, but the second terminated when the birds scattered and all but 1 were lost. Our telemetry equipment led us back to the open prairie where the migration began and there we camped with only 1 bird.

Table 2. Details of southward migration of sandhill cranes across Arizona behind a truck, October 1995.

Migration dates	2 Oct to 14 Oct 1995
Total number of migration days	13
Total number of flight days	8 (7 days of >5 km flights)
Total number of flights	29
Total migration length	589 km[a]
Total flight distance	495 km
Total flight time	11 hr, 58 min
Average altitude	30 m
Highest altitude	ca 600 m
Lowest altitude	1 m
Average speed	46 km/h
Fastest speed	78 km/h
Slowest speed	24 km/h
Longest flight	77 km
Total distance birds were trucked	124 km

[a] Garland Prairie to Buenos Aires NWR.

Day 3: 4 October.—The day was spent retrieving cranes (all but 1, No. 116, returned) and replacing a tire. In the evening, we drove our 9 cranes through the forest to camp beyond the tall ponderosa pines (*Pinus ponderosa*). In retrospect, our observations of golden eagles (*Aquila chrysaetos*) at 3 locations along the birds' path and subsequent observations of eagles attacking cranes led us to suspect that the scattering on 3 October was due to an eagle attack.

Day 4: 5 October.—Our cranes completed several excellent flights. All 9 birds were anxious to stay near the cranemobile. At 78 km/h, a 13-km flight descending from the mountains into Chino Valley was our fastest flight of the entire migration. To facilitate the transfer of the cranes across a canyon with an unsafe bridge, 2 trainers remained with the flock while the rest of the crew drove 2 vehicles on the long circuitous route to the other side. The 2 trainers then ran toward the canyon (with the cranes running in pursuit), hopped over the rim, and hid behind boulders. The cranes lifted off and circled down to join the team across the canyon ca 500 m away.

Our only fatality occurred about 110 km into the migration when 1 of the 3 males (No. 89) died upon impact with a powerline. About 10 km after the collision, an adult golden eagle swooped through the flock, scattering the cranes. No birds were injured, all regrouped by landing at the cranemobile, and the eagle was dispelled by firing 5 rifle slugs (22 caliber) near it.

During the final flight of the day, the birds soared up to about 300 m, followed us 23 km, then were lured down to the evening camp site in Skull Valley by 4 trainers calling

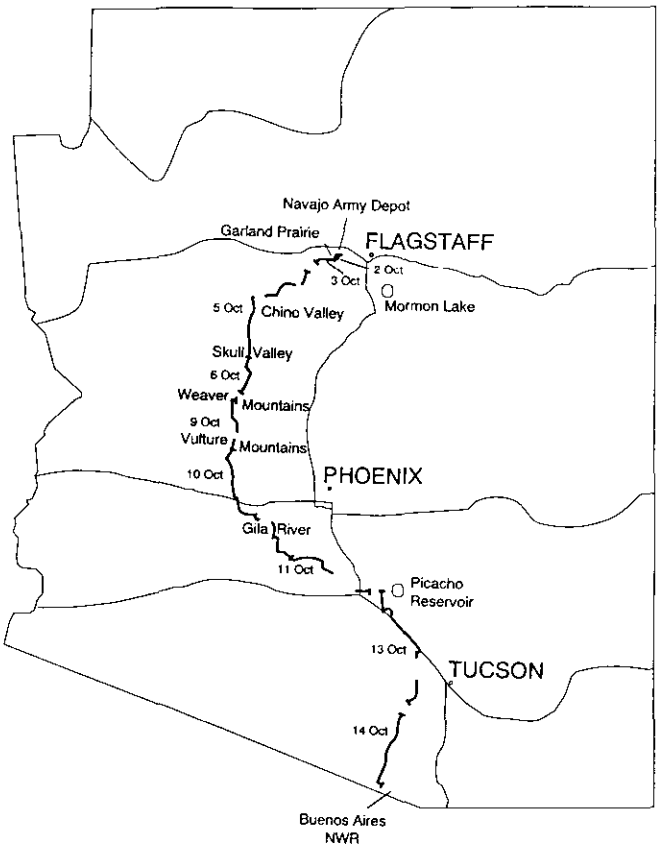

Fig. 3. Flown segments of truck-led sandhill crane migration, Arizona, October 1995.

and flapping.

Day 5: 6 October.—The day began with two excellent flights as the 8 cranes climbed over the Weaver Mountains. However, the second flight was terminated by another eagle attack scattering the birds. Only 1 crane stayed with the cranemobile. One more was recovered in the evening.

Day 6: 7 October.—Our telemetry search for the lost cranes continued; some signals were received. The crane lost on Day 2 (No. 116) was retrieved, and 3 more cranes were reported ca 55 km from the previous day's attack site.

Day 7: 8 October.—We recovered the 3 cranes (Nos. 94, 109, and 114) reported on 7 October. Later, we found 2 more cranes (Nos. 117 and 123) by radiotelemetry. Remarkably they had returned to Garland Prairie, near where we began the migration and ca 130 km from the eagle attack site.

Day 8: 9 October.—At noon, the migration resumed, but we were now in the Sonoran Desert where midday temperatures exceeded 30 C. The birds only managed 37 km in 5 short flights. More golden eagles were expected in the Vulture Mountains, so we passed below the beetling peaks after sunset with a shell cracker-loaded shotgun out the window of the lead car and a rifle at the ready.

Day 9: 10 October.—Our first flight (and our longest flight of the migration) began before sunrise and continued 77 km to the Gila River. One bird (No. 117), whose feathers had been damaged during retrieval operations the previous day, was lost at the onset of the flight (it reappeared by 28 October near where it was lost). South from the Gila River, the migration stalled due to heat. At sunset, we flew the birds again, and kept them moving until it was too dark to count them.

Day 10: 11 October.—Migration began at dawn with a 40-km flight. Two more flights fizzled during the heat of the day. We decided to truck the birds the last 13 km to Picacho Reservoir and rest them until 13 October.

Day 11: 12 October.—The final crane (No. 112), lost during the second eagle attack, was retrieved and joined the flock at Picacho Reservoir.

Day 12: 13 October.—The migration began again with 2 strong morning flights but terminated when all 8 cranes overheated. An evening flight resulted in 1 crane (No. 96) being lost near dusk. It was recovered 16 October.

Day 13: 14 October.—By 0915 hours, we completed the migration after 2 flights (totaling 60 km). The cranes, however, were overheated for the last 30 km. Only 6 birds actually arrived together at the southern terminus. The seventh (No. 86) dropped out, overheated, only 5 km from the BANWR headquarters but was immediately recovered.

DISCUSSION AND CONCLUSIONS

The migration is summarized in Fig. 4. The primary hazard during the migration was powerlines. We counted a minimum of 120 sets of powerlines along the route. Many near collisions, and 3 collisions, were observed: 1 fatal, 2 without injury.

We also encountered a minor difficulty in following winding roads through tall dense forest where it was nigh impossible to keep the birds in view. The result was that we slowed down when the birds were out of sight, only to have the cranes reappear ahead of the vehicles. These difficulties were compounded because the forested area occurred near the onset of the migration when the team was inexperienced and before the cranes were tenacious in following.

Another difficulty was eagle attacks. Our birds seemed able, from the onset, to avoid capture, but the second attack required 3 days to reassemble our flock. With experience, we probably could have avoided this problem, and, with more reliable and more powerful radio transmitters, we probably could have gathered our birds before they scattered so widely. Future routes should be chosen to minimize the potential for eagle attacks.

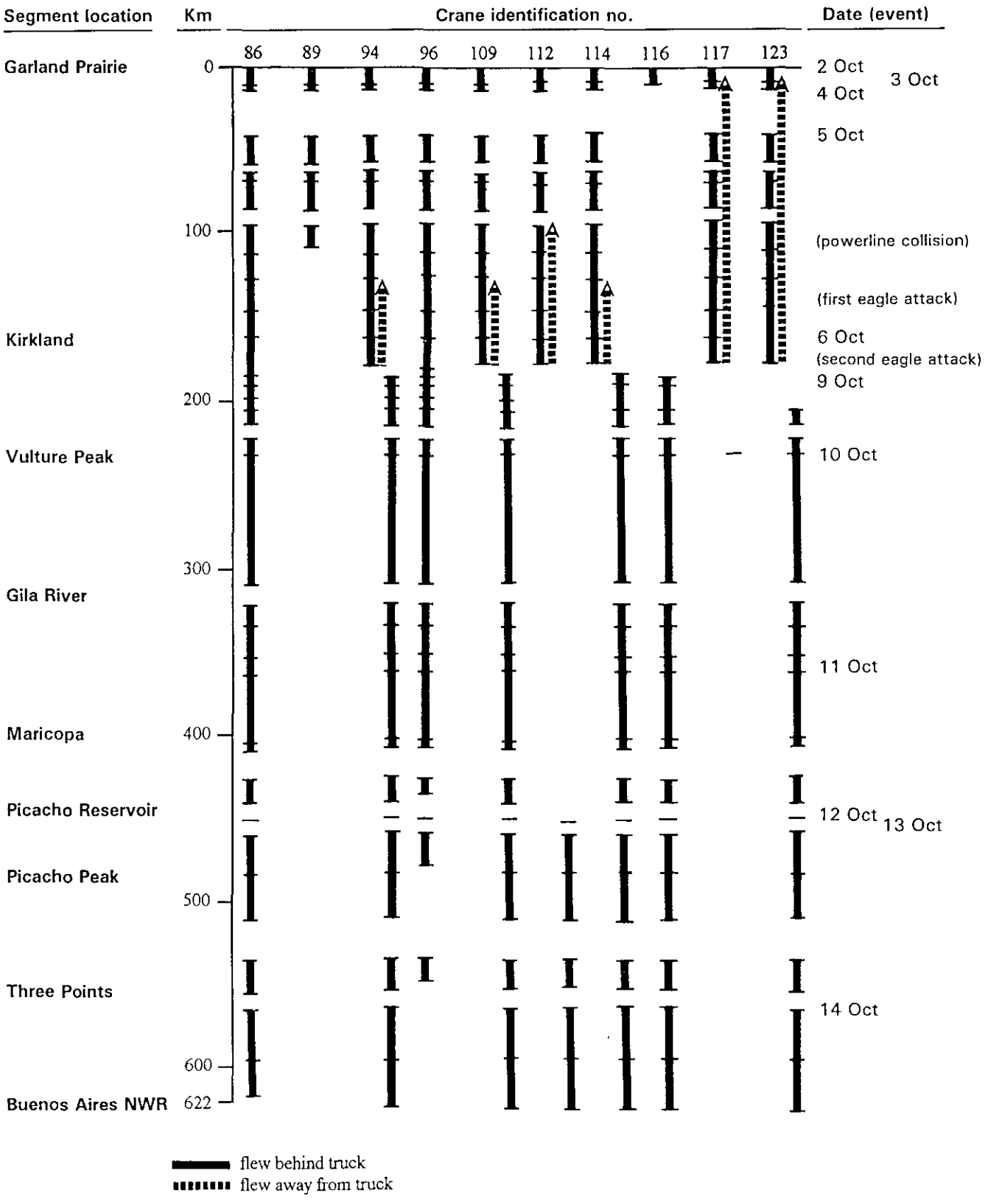

Fig. 4. History of greater sandhill crane truck-led migration: Garland Prairie to Buenos Aires NWR, Arizona, October 1995.

Our greatest difficulty was the unseasonably warm temperatures encountered as we traversed the Sonoran Desert, the final two-thirds of the route. We timed our departure from the high-elevation (ca 2,300 m) summering area by an appropriate environmental cue, the first hard frost. But, we should have led the birds to a mid-elevation staging area and maintained them there until November or at least until midday temperatures dropped below 20 C in the Sonoran Desert.

Other lessons included: (1) avoid flying fatigued birds through powerlines, (2) use a minimum crew of 7 people during migration (each of 3 drivers needs a navigator and a seventh person rides in the rear of the cranemobile calling to the birds), (3) transport cranes to the release site by air, and (4) costume-rear cranes unless they are to be integrated into a wild flock immediately after the migration.

A final lesson is that we should probably have given our birds "abandonment training" prior to departure. During flight training at the Navajo Army Depot, crane No. 109 was lost for 5 hours. After it was recovered, it changed from being one of our most adventuresome cranes to being the most tenacious (i.e., most attached to the trainers). Had we stranded each crane, solo, for a few hours in a pen guarded from a blind, and then arranged for it to "find" its keepers, we believe that all birds would have been more attentive at the onset of the migration. As the migration progressed, the cranes became more and more attentive (an observation consistent with the experiences of Urbanek and Bookhout [1992] and Lishman et al. [1996]), but the frustrations we experienced on Days 1 and 2 probably could have been avoided with such training.

Although our migration extended from 2 to 14 October (13 calendar days), we actually traversed our 622-km route (495 km of which were flown) in 8 days (days in which more than 3 km were flown). Only 3 days involved flights totaling more than 2 hours. Without the handicap of traveling in desert heat, we believe the same route could be traversed in 5 flight days.

In closing, we found that leading cranes long distances was feasible at least in unforested areas. We experienced 100% survival during training and good survival on migration (90%, although our birds had to be recovered following eagle attacks). With the lessons learned in 1995, we believe it is possible to have even greater success with fewer interruptions in future experiments.

The success of this project can be judged only in part by our ability to train cranes to follow a truck. Ultimately, we need to know if trained cranes can return unassisted to breed in the area where they fledged. Ironically, one of the greatest difficulties of our expedition (i.e., the second eagle attack) produced some premature, but favorable, results. Two of the birds were relocated on Garland Prairie where the migration started and ca 130 km from the attack site. Three others were found ca 55 km from the attack site and within 7° of direct course for Garland Prairie. A sixth bird was recovered ca 95 km from the attack site and 25° east of a direct vector to Garland Prairie. Although it is dangerous to make too much of these observations, the fact remains that 2 of 8 cranes scattered by the eagle returned to Garland Prairie and 3 others were nearly on course to that location when recovered.

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