

## DEVELOPING A MIGRATORY WHOOPING CRANE FLOCK

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**Abstract:** Research on crane reintroductions within the last 15 years has produced information necessary to effect a successful reintroduction of a migratory whooping crane (*Grus americana*) flock. There are 4 main problems to solve for such a reintroduction: (1) inducing a high survival rate of the reintroduced cranes, (2) encouraging normal reproduction with conspecifics, (3) teaching the reintroduced cranes the migration route, and (4) inducing fear of humans in the reintroduced cranes. Use of an isolation-rearing method by the author, using puppets, sounds, and costumes, has led to a consistent, over 80%, survival rate for the reintroduced young cranes after 1 year and migration. Such reintroduced sandhill cranes (*G. canadensis*) have followed wild cranes on the migration route and returned to their release area. They have learned to fear humans from their wild counterparts and have bred normally, raising fledged young. Results of 5 groups of experiments are reviewed: (1) cross-fostering has failed due to sexual imprinting on the wrong species, (2) releases of sandhill cranes have been successful and the survival rate has increased markedly with the costume method of rearing, (3) releases using the costume/isolation-rearing method have enhanced other programs, (4) creation of a nonmigratory flock of whooping cranes has met with some success but proper use of the costume method would enhance survival rates, and finally, (5) motorized vehicles have been used to teach young sandhill cranes a selected migration route. Recommendations for creating a migratory whooping crane flock include: (1) using as gentle a release as possible, (2) using young post-fledged chicks as the best candidates, (3) using developmental periods for enhancing releases, (4) using costumes to control the released chicks' behavior, (5) using costumes to enhance conspecific breeding, (6) considering habitat site imprinting, (7) avoiding human contact and consequent imprinting, (8) using the parent model and isolation-rearing for enhancing following of ultralight aircraft by the chicks, and (9) considering cost effectiveness in the reintroduction process. Procedures for effecting a successful reintroduction are elaborated.

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During the past 25 years, there has been a concerted effort by crane researchers to develop a technique for creating a second migratory flock of whooping cranes, a flock that is separate from the flock that flies from Wood Buffalo National Park in Canada to the Aransas National Wildlife Refuge on the Gulf of Mexico. This has been a goal for the protection of the species so that "all of their eggs would not be in 1 basket." Many different creative projects have resulted in sufficient information to develop such a flock. However, despite the profuse writing of research results, most workers in the field have ignored the successes resulting from these projects. Often we scientists become so involved in our own work and its "importance" that we miss the bigger picture. Although a review of crane reintroductions was published earlier (Horwich 1997), this paper goes beyond such a review and is an attempt to propose how a migratory flock of whooping cranes could be developed, based on the results of earlier research.

A major example of how pertinent research has been ignored is the research on cross-fostering a whooping crane flock at Grays Lake, Idaho. When Fred Bard suggested cross-fostering in 1956, it was a very creative idea, but by the time it was initiated in 1975, a profusion of research on the

imprinting process indicated that cross-fostering was risky at best (Hess 1973). Perhaps an experiment for 5 or 6 years would have been justified based on the lack of knowledge of imprinting in cranes. A better approach would have been a simple experiment which was done recently on captive parent-reared cross-fostered cranes (Mahan and Simmers 1992). Instead, the cross-fostering project lasted 15 years, cost millions of dollars, and used 289 endangered whooping crane eggs.

How do we generate a migratory whooping crane flock with the most efficiency (low cost of money and whooping crane eggs) that will persist indefinitely, use the best habitat, migrate to an appropriate wintering ground, breed with their own species, and fear humans? My premise is that we currently have the information to form such a flock and probably have had it for over 10 years. I wonder if crane researchers are not reading the research results, not talking to other knowledgeable researchers, not examining results critically, and/or are not emphasizing the solutions evolved. It is a puzzle we can easily assemble now: first we examine the lessons from recent experiments, then we identify those pieces of the puzzle which are yet to be found. Furthermore, this is not just about whooping cranes; our successes may

prove useful to many species of endangered birds.

## PROBLEMS IN DEVELOPING A MIGRATORY CRANE FLOCK

There are 4 main problems to be solved to form a migratory flock of cranes. What have we learned about these 4 problems which enable us to develop a viable migratory whooping crane flock for long-term survival of the species?

1. *Survival*.—Any cranes released into the wild, whether parent- or human-reared, young or old, must be able to survive. Survival entails protection from predators, disease, and manmade factors such as powerlines. We, as researchers, must strive for the highest survival level, both for the individual welfare of the experimental animals and to form a viable flock more rapidly, efficiently, and economically.

When reviewing survival rates, the costume/isolation-rearing method (Fig. 1) has proven itself to be the most successful technique with consistent levels of over 80% survival rates for released crane chicks after 1 year following migration (Horwich et al. 1992, Urbanek and Bookhout 1992). The careful, successful work on releases of nonmigratory Mississippi sandhill cranes (*G. c. pulla*) has been improved by using the costume method of isolation-rearing (Ellis et al. 1992, 2000). Do we know why? Not completely, but it doesn't matter. Nothing succeeds like success. The costume/ isolation-rearing technique has proven to be more efficient and effective than either captive parent-rearing or wild parent-rearing (as in the Grays Lake cross-fostering project). Cross-fostering had dismal survival rates (Drewien et al. 1989 unpublished, Garton et al. 1989) with few cranes ultimately surviving and only 1 breeding pair which produced a sandhill/whooping crane hybrid (Department of Interior 1992).

Nesbitt and Carpenter (1993) had 55% survival after 1 year with sandhill cranes released in Florida. Their attempts at foster-rearing were not very successful, with only 22% of nests fledging young from 1982–87. Nesbitt's initial releases of whooping cranes in Florida (Nesbitt et al. 1997) had even poorer survival rates, with only 38% surviving, over 3 years. Later survival rates, however, improved; survival rates through 2000 are 49% after 1 year post-release. However, survival rates were 84–85% after 2 years and 91–93% for 2–7 years post-release (Nesbitt et al. 2001, Wolff 2001a unpublished).

The costume-rearing technique has a much higher survival rate after 1 year post fledging. This technique lets us assume the role of the parent, giving us major control over the chicks. Thus, we can carry out careful plans for their protection, we can introduce them to food for their survival, and we



Fig. 1. Costume rearing as conducted in 1985 involved a puppet head and a costume with a scattering of feathers. (Photo by R. H. Horwich.)

might possibly play a role in teaching them to avoid powerline collisions. We can even teach them to fear humans, and we can prevent them from imprinting on humans.

2. *Normal Reproduction*.—Cranes released into the wild must be able to breed with their own species at rates approaching that of wild conspecifics. They must be able to react normally to their environment, form pair bonds, copulate, build nests, incubate, and hatch viable young. They must be able to raise their young approximating the natural survival rate and show their young the migration route.

Cross-fostering studies (Drewien et al. 1997) rule out cross-fostering as an option. No breeding with conspecifics occurred, and 1 hybrid was produced (Department of the Interior 1992). Studies by Mahan and Simmers (1992) on 4 captive cross-fostered sandhill cranes reinforce this. Two of their chicks were attracted to the foster species over conspecifics, and 2 cranes showed mixed reactions to foster species and conspecifics.

One initial reservation I had about hand-rearing was the problem of sociosexual imprinting where a species grows up "thinking" it is another species and consequently tries to socialize and ultimately to breed with the wrong species. But costume-rearing in groups has prevented that from happening. Birds from Urbanek's early study (Urbanek and Bookhout 1992) are currently breeding. Of 5 males that retained functional transmitters in 1993, at least 4 nested with wild mates, chicks were hatched from 2 nests (Urbanek and Bookhout 1994), and chicks fledged (R. P. Urbanek, U.S. Fish

and Wildlife Service, personal communication). Costume-rearing works: we do not really know why, we only know that it seems either neutral, or our feeble attempts at duplicating the sign stimuli of the correct species work. Despite their bizarre rearing, these costume-reared cranes seem to be growing up normally relative to their adaptability to their environment (Duan et al. 1997) and are properly socializing and breeding with their own species (Urbanek and Bookhout 1992, 1994).

**3. Migration.**—The cranes we release must be able to learn an appropriate migration route where they can survive winters in good health so that they can return and breed in the northern areas.

This may be the most difficult problem to solve, but we probably already have the solutions for it. By maintaining long-term control of released chicks and by using variations on the costume technique, Urbanek and Bookhout (1992) produced a chick which returned the following year and became a guide bird for other chicks. This is not the solution for the whooping crane situation because this guide bird had wild sandhill cranes available from which to learn the route. How would whooping cranes in a new migration route, far from wild whooping cranes, learn the route? Research with trucks and aircraft could presumably provide an answer (Ellis et al. 2001a), if these methods properly incorporate the holistic costume-rearing method with the truck or airplane. However, researchers must use a truck or an ultralight as just another tool and not as an end in itself. In other words, they must incorporate the airplane into the full isolation-rearing process so that the parent merely flies via an ultralight, but it is still the same parent which the cranes recognize and follow even after the parent appears in the machine.

However, improper use of the aircraft may produce other problems while attempting to solve the problem of migration. We do not know what effect it may have on adult behavior if researchers imprint the young cranes on the aircraft itself (Hilton 2001). Experiments performed on young animals have shown that we can produce adult birds that try to breed with almost anything. Chickens have been produced which try to copulate with strange colored forms (Vidal 1980), why not airplanes?

**4. Fear of Humans.**—In addition to displaying the proper conspecific mate choice, released cranes must ultimately show fear of humans so that they do not become nuisances and are not so tame that they become susceptible to human hunting or other life threatening experiences.

In many ways, this has been a difficult problem to solve, but it may not be as important as the other problems. If we can prevent the chicks from imprinting on humans and maintain high survival rates, the first groups of released cranes may develop fear on their own or in associations with

other bird species. From my study (Horwich et al. 1992), it became obvious that within a short time of joining wild cranes, my cranes became wild. Other studies also saw an increase in fear of humans once the cranes joined a wild flock (Ellis et al. 1992, Urbanek and Bookhout 1992). In addition, it became just as obvious how malleable young chicks were at specific ages. When a wild chick joined our chicks, I felt that this wild chick could have become tame if it had stayed with ours. But the attempt that Drewien et al. (1997) made at Grays Lake to use a cross-fostered whooping crane as a guide for isolation-reared whooping cranes, showed how intractable young birds can be at 3–5 months of age in relation to fear. From several projects (Clegg et al. 1997, Drewien et al. 1997, Ellis et al. 2001b), we learned how incredibly good wild cranes are at teaching fear of humans. These experiments were on the right track.

## CRANE RESEARCH RESULTS

In reviewing the various crane reintroduction research, I find 5 groups of research. Most of these are coordinated by the same researchers.

**1. Cross-fostering** (Drewien et al. 1997, 1989, 1982; Garton et al. 1997; Mahan and Simmers 1992).—Studies by Drewien and his colleagues showed cross-fostering to have a dismal survival record, with limited breeding only with the foster species. However, the cranes did learn the migration route and did have fear of humans. Drewien also showed that while these maladjusted whooping cranes might act as foster parents to hand-reared whooping cranes, they failed to act as guide birds. However, guide birds, if not cross-fostered, may have possibilities in guiding young cranes on a new migration route.

**2. Nonmigratory Mississippi Sandhill Crane Flock** (Ellis et al. 1992, 2000).—The Mississippi sandhill crane releases of parent-reared birds showed a fairly high degree of survival (66%) after 1 year. The survival rate improved to 93% when birds were reared by the costume technique. A further benefit of costume-rearing exhibited by the Mississippi sandhill crane experiments is that parent-reared birds survive better if mixed with costume-reared birds before release. Parent-reared crane survival increased from 58% for parent-reared birds alone to 90% when released with costume-reared birds (Ellis et al. 2001c). Breeding has been normal, and fear of humans has been normal due to interacting with wild cranes.

**3. Costume/Isolation-Rearing** (Horwich 1989, 1996; Archibald and Archibald 1992; Ellis et al. 1992; Horwich et al. 1992; Nagendran 1992; Urbanek and Bookhout 1992, 1994; Duan et al. 1997).—Survival with costume-reared birds has been consistently high (over 80% 1-year survival) and

breeding has occurred normally when the technique is used within an integrated rearing and release program. The most recent release, in 2000, had 100% survival and return to the release site (R. P. Urbanek, personal communication). Both fear of humans and migration have occurred normally because such birds have linked up with wild cranes and learned behaviors from them. Fear of humans can be enhanced by strict adherence to the isolation-rearing protocol. This is because the crane chicks see the costume as different from the human form. One winter release using the costume-rearing technique did not prove successful (Nagendran 1992) but others have (Ellis et al. 2001b).

**4. Nonmigratory Whooping Crane Flock** (Nesbitt and Carpenter 1993, Nesbitt et al. 1997).—While the releases have been somewhat successful, the survival rate has been low. Only 22% nests fledged young when greater sandhill crane (*G. c. tabida*) eggs were cross-fostered with Florida sandhill cranes (*G. c. pratensis*). By contrast, hand-reared birds had a 55% survival rate after 1 year. They showed normal dispersion around the release site without migration. A similar release of whooping cranes in Florida has thus far produced 84 surviving cranes, with an early survival rate of 38% for the first year (Nesbitt et al. 1997). Parent-reared birds survived at a 13% rate, while the costume-reared birds survived at a 43% rate. The survival rate could be enhanced by the continued use of costume/isolation-rearing during the release. Producing birds with a fear of humans was accomplished by preventing the birds from having contact with humans.

**5. Ultralight Aircraft and Terrestrial Vehicles to Establish a Migration Route** (Clegg et al. 1997, Ellis et al. 1997, Lishman et al. 1997, Ellis 2000, Duff et al. 2001a, Ellis et al. 2001a).—Most of the initial ultralight and truck experiments produced birds which were fairly tame to humans because there was too little emphasis on a strict costume-rearing protocol during flying practice. One experiment (Clegg et al. 1997), which imprinted the cranes on humans, showed some success; 6 of 15 birds followed the ultralight for a full 1280-km migration from Idaho to New Mexico. Lishman et al. (1997) and Duff et al. (2001a) initially only produced shorter flights of 64 km and 108 km respectively. Experiments using ground vehicles also showed some success, with birds completing a 640-km migration (Ellis et al. 1997, 2001a). Nevertheless, in some situations, following was not easily induced because some cranes were prone to break away in subflocks (Duff et al. 2001a), and some groups were willing to follow humans, costumed or uncostumed. Since most of the birds in these studies were taken back into captivity, there is not much record of survival or breeding. The Clegg experiment showed 27% survival of the chicks released on the wintering grounds; despite rearing by an uncostumed human caretaker, these 4 migrated back

with wild cranes and some showed normal escape responses toward humans.

A recent experiment in 2000 was much more successful. Using ultralights piloted by crane-costumed pilots and using crane sounds emanating from digital recorders, 11 of 13 sandhill crane fledglings completed a 2000-km migration from Necedah National Wildlife Refuge in Wisconsin to Chassahowitzka National Wildlife Refuge in Florida (39 days with 27 stopovers) (Archibald 2001, Hilton 2001). Nine of these returned to Wisconsin in the spring for a return rate of 69% (9 of 13) or 81% (9 of 11).

## RECOMMENDATIONS BASED ON RESEARCH

**1. Gentle Releases are Best.**—From the early work on translocating sandhill cranes, the survival rates of yearlings and adults released with no training and little preparation was 0% (Nesbitt 1979). Hard or abrupt releases are normally wasteful and inefficient (see Ellis et al. 1992). Even attempts to release some young chicks, which have been raised with costumes in isolation, are not helpful if a holistic program of gentle release is not used. Releases of whooping crane chicks in Florida (even costume-reared birds) initially had a survival rate of only 38% (Nesbitt et al. 1997). However, use of the costume largely ceased after transferring the birds to Florida. Even though costumes were not used consistently, the costume-reared birds actually survived better (Nesbitt et al. 1997). The survival difference between the rearing methods was dramatic, with only 13% of parent-reared birds surviving as compared to 43% of the costume-reared birds. By contrast, with using costume-rearing continually until autumn departure (Horwich et al. 1992, Urbanek and Bookhout 1992), survival rates have consistently been over 80% despite long fall and spring migrations. Recent releases of individual chicks, one-by-one, have proven very successful (Ellis et al. 2001b). In the most recent one-by-one release, all 8 chicks survived the winter and returned to the release site area in the spring. These birds were reared in natural habitat prior to the release (Ellis et al. 2001b).

The Mississippi sandhill crane work has established a nonmigratory flock and had consistently high survival rates (Ellis et al. 1997, 2000). The 1-year-survival rate with parent-reared birds from 1981–89 was 62%. Later releases from 1989–92 had a 76% survival rate (Ellis et al. 2000). Of these, the costume/isolation-reared birds survived at a higher rate of 82%, compared to 71% of the parent-reared birds (Ellis et al. 2000). As noted earlier, parent-reared birds benefit strongly from being reared with costume-reared birds (Ellis et al. 2000). In like manner, a properly planned, very gentle release with a long-term surrogate parent could promote even higher survival rates in the young Florida whooping crane flock. In a preliminary experiment using the

costume-rearing technique, higher rates were achieved. Why was this method not continued? How much larger would the population be today if costume-training had continued for each group long after release?

### 2. *Young are the Best Candidates for Release.*—

Costume-rearing (Horwich 1989, Horwich et al. 1992) showed that properly prepared and trained chicks can be hand-reared and make the best candidates for release because they are so malleable and trainable. This was repeated for 3 years with 38 chicks in another study (Urbanek and Bookhout 1992). Additionally, it should be noted that whooping cranes released in Florida when 1.5 years old instead of the usual 0.5–0.9 years of age showed an 80% mortality within 15 days of release (Nesbitt et al. 2001, Jones 2001), and all eventually died (S. R. Swengel, Baraboo, Wisconsin, personal communication).

### 3. *Time of Release Based on Ontogeny is Important.*—

Crane development goes through cyclic phases (Voss 1979; Horwich 1987, 1989; Hartup and Horwich 1994). Although the data on young cranes are limited, we can make some important inferences from studies on other birds. In cranes, there is an initial period during the first few weeks after hatching when the chicks follow the parent most closely (Horwich 1989). As with other species, the act of following the parent reinforces filial imprinting. It is believed that in this process, the young chick learns the parent's characteristics.

When the propensity to follow the parent diminishes during the next phase in a chick's life (4 to 10 weeks), foraging increases and remains high (Horwich 1989). Food preferences may also be formed by an imprinting-like process, and this may also be a crucial sensitive period for learning habitat. This foraging phase seems to become less important when the chick approaches fledging and shows an increasing tendency to be close to the parent again. Unfortunately, in our early studies, we were not able to collect data after we released the chicks at 16 weeks. However, data on a sandhill crane, cross-fostered by white-naped crane (*G. vipio*) parents, indicate that parental feeding, especially by the female, occurs at a high level during this foraging period, recedes, and then is again at a high level when the chick fledges. The chick reattaches to its surrogate parents at 11–13 weeks (Hartup and Horwich 1994). The data are suggestive that during this fledging period chicks are learning new foods and following the parents more closely. Intuitively, it is important that chicks become more closely associated with their parents just prior to and during the fall migration so they are not lost.

Other data indicate there may be an important period for acquiring vigilance. Common crane (*G. grus*) chicks in Spain show low vigilance during the winter, relying on their parents to watch for danger. By March when they cease

staying with their parents, vigilance levels triple, reaching adult levels (Alonso and Alonso 1993). Perhaps this explains why parent-reared birds make poorer release candidates. They have relied more on their parents for protection and are therefore less wary, while the costume-reared birds relied on themselves.

While filial imprinting takes place early and quickly to provide the hatchling a template for following, sexual imprinting takes place later and provides information needed when sexual maturity is reached. Evidence suggests that several precocial species start to restrict their sexual preferences long after their filial preferences. In general, the longer a bird is exposed to 1 object, the less likely it is to respond socially to another. However, this rule is complicated by developmental stages or sensitive periods (Bateson 1981).

Periods when rapid learning naturally takes place are probably sensitive periods. A sensitive period is a period during development when certain learning processes seem to be stronger (Immelman and Suomi 1981). These periods are not sharply defined but are gradual in onset and termination. Their length varies by species. Sexual imprinting probably occurs during a sensitive period. I feel that the post-fledging period at about 12–18 weeks may be one such sensitive period, the one which is important for sexual orientation. There may be other sensitive periods between the beginning of the fall migration and the spring migration. Hartup and Horwich (1994) noted a resurgence of pecking of the parental feathers at 16 weeks indicating a social reattachment at that time. Horwich (1989) showed a reattachment period toward a costumed surrogate parent at 11–14 weeks. Two red-crowned crane (*G. japonensis*) chicks similarly showed a period of concerted social interaction at 14–18 weeks (Horwich 1987).

We also know that natural stimuli, such as a conspecific parent, are the strongest stimuli for imprinting. It is my hypothesis that the costume allows some type of dual imprinting to occur by incorporating important sign stimuli of the conspecific from the surrogate in the costume and at the same time allowing close association with other chicks. Because there is no chance of costumed cranes occurring naturally, and because the costume can only be chosen when it is available and availability is completely controlled by the researchers, it is possible to control the degree of breeding attachment to a costumed human.

Studies of zebra finches (*Poephila guttata*) cross-fostered on Bengalese finches (*Lonchura striata domestica*) show that juveniles can revert to their conspecifics in mate choices under specific conditions dependent on 2 variables, age of the bird and duration of social contact with their own species. Short periods of intraspecific contact before day 40 had a permanent effect on sexual attachment (Immelman 1979,

Immelman and Suomi 1981).

Some aspects of sensitive periods are well known, especially those associated with sexual imprinting. However, within a species, there is a great deal of individual variation. Most species imprint most easily on their own species, more easily on similar species, and less easily on dissimilar objects like humans or inanimate objects. With unnatural things, imprinting preferences often take longer to develop and the animal remains receptive longer, as if awaiting for an appropriate parent to appear. Most phenomena that occur in sensitive periods can be altered, suppressed, or superseded given the appropriate experimental procedures. However, young animals are usually more resistant to modification if it stems from stimuli encountered outside the sensitive periods. Thus, cross-fostered finches retain their preference for their foster species after 7 years, a period of time greater than an average lifetime. Even when a cross-fostered crane encounters a potential mate of its own species, as in Drewien's cross-fostering experiment (Drewien et al. 1997), the old preference remains lifelong, even with little or no reinforcement. In the absence of the original preference, the animal may develop new preferences; however, new preferences are transient when the original stimulus is presented (Immelman and Suomi 1981).

**4. Control of Young Chicks Aids Survival and Migration.**—Use of the costume and parental crane sounds can give control over the young for as long as 2 years (Urbanek and Bookhout 1992). Costumes used consistently, along with staked-out, costumed dummies to keep the imprinted chicks close to the surrogate parents, help to maintain this control. Costumes have been used to retrieve chicks or to get them back on the proper migration route without undue stress (Horwich et al. 1992, Nagendran 1992, Urbanek and Bookhout 1992). Additionally, this method, produced chicks which had considerable site fidelity due to rearing on the release site. Seventy-four percent of Urbanek's chicks returned from the spring migration to within 50 km of the release site and many of them visited the site itself (Urbanek and Bookhout 1992).

**5. Control of Imprinting Encourages Conspecific Identification.**—Although the imprinting process is still not fully understood, it is apparent that there are sensitive periods in cranes (Horwich 1989). The initial phase of following a costume or parent can be greatly altered, as was shown by the most recent Grays Lake study (Drewien et al. 1997). We know that we can reverse the attachment process after 24 days and subsequently reattach the chicks to adult cranes. What we do not know is how much cross-fostering hampered whooping cranes (when adults) from staying with their "adopted chicks." How much did such adults' propensity to join sandhill crane flocks disrupt their bond with the chicks, and, to a lesser degree, did the adults' association with

sandhill cranes discourage the chicks from following the whooping crane adults?

We know that there is a reattachment period at 12 weeks, at about the same time as the first long-distance flights occur (Horwich 1989). This is a period of very strong social bonds during which the chicks opt first for the costume and next for their own species. However, if costumes and conspecifics are unavailable, there is some anecdotal evidence to suggest that they may reattach to another available species. Sexual imprinting has been demonstrated in at least 25 bird species (Immelman 1972, Mahan and Simmers 1992) with many cases cited where cross-fostered birds showed a strong preference for the foster species, directing courtship to them. This preference included chickens (Vidal 1980), raptors (Bird et al. 1985), and finches (Immelman 1972, Immelman and Suomi 1981). However, we also know that the imprinted attachment can be reversed during this period so that sexual orientation can be changed. Thus, if there are no adults available as imprinting models for young whooping cranes, the chicks which mature together will choose to breed with their own species. Because cranes apparently or probably avoid pairing with siblings, using small cohorts during rearing should facilitate a greater choice of mates and more efficient reproduction amongst the released chicks. This is also a crucial point in captive-rearing.

Depending upon the age of the bird, imprinting may be reversible or irreversible (Immelman 1972, Vidal 1980). In older birds, imprinting may be permanent and lifelong if the imprinting species is available as a choice. This explains the difficulty in force pairing the cross-fostered whooping cranes. Most species imprint most easily on their own species, and secondly on similar species. They imprint the least easily on very different species like humans or other non-bird-like objects. Complete irreversibility occurs most often in birds imprinted on closely related species (Immelman 1972). This explains why the cross-fostered whooping cranes would not breed with conspecifics.

Birds hand-reared without "foster siblings" are more prone to cross-imprint on another species. There is some evidence that male cranes are more susceptible to imprinting than females, although in other bird families the opposite may be true (Immelman 1972). This may explain why it was a male whooping crane that paired with a sandhill crane and produced the hybrid. The Mahan and Simmers (1992) data were suggestive of this concept as well. It may be pertinent to know that it is possible to imprint some species on more than 1 species: dogs, for example, can share an attraction for both dogs and humans (Sluckin 1964).

**6. Birds May Imprint on Food, Habitat, or Site and Should be Reared on Release Site.**—We know that birds can also imprint on food, nest materials, habitat, and other things (Immelman 1972). Food preferences and locality imprinting

may be a function of the rearing process. The importance of rearing birds on the release site may not be fully realized. The most successful migratory releases of cranes allowed the cranes to be gradually released just after fledging (Horwich 1989, Urbanek and Bookhout 1992, R. P. Urbanek, personal communication). Therefore, it is most important that young are reared on the release grounds so they have as much time in the original area with natural foods as possible. A successful reintroduction of peregrine falcons (*Falco peregrinus*) on natural cliffs along the Mississippi River occurred only when they were reared in naturalistic cliff nests and released from them. Previous releases on power plant towers produced birds with tendencies to nest on such unnatural structures (R. Anderson, Raptor Resource Project, Decorah, Iowa, personal communication).

**7. Avoid Contact with Uncostumed Humans to Avoid Tameness and Imprinting on Humans.**—Whenever procedures were lax in preventing cranes from seeing and hearing humans, there was a resulting tameness of the birds towards humans (Lishman et al. 1997, Nesbitt et al. 1997, Duff et al. 2001a). Operation Migration's first full crane migration with ultralights from Ontario to Virginia in 1997 resulted in birds returning north in the spring of 1998, but these birds readily approached people (Duff et al. 2001a). In some cases, the tameness caused potential problems, and the released birds were, of necessity, taken back into captivity. Tameness would obviously lead to extra mortality in areas where cranes are hunted. When black vultures (*Coragyps atratus*) were reared alone with much human contact, they imprinted on humans and preferred human company (Wallace 1983). With only a small difference in rearing procedure, sibling groups of turkey vultures (*Cathartes aura*) showed much less tameness toward humans (Wallace 1983).

**8. Use a Parent Model for Migration.**—There is evidence that early experience following an object encourages following at a later age (Hess 1973). Thus, costume-reared chicks will follow the costume or conspecifics more easily later in life. Costume-reared release birds, which returned to the release site from a previous year, have acted as guide birds to younger costume-reared birds (Urbanek and Bookhout 1992). These experienced, returning yearlings encouraged some of the fledglings at the release site to migrate with them. The chicks seemed reluctant to initiate migration, but once they were encouraged by the previous year's birds, they successfully migrated.

Any use of airplanes or ground vehicles to stimulate migration in young cranes should take advantage of the already successful costume/isolation-rearing technique. However, K. Clegg's rearing process showed promise even though he used an uncostumed human as a parent (Clegg et al. 1997). All 15 cranes followed the ultralight and 6 cranes

flew the entire route. In his experiment, he imprinted the chicks on himself using vocal imitations of crane brood calls. His cranes were understandably tame to humans. Although he did not use costumes, he used a parent-oriented philosophy similar to the philosophy used in costume-rearing. He led the juvenile cranes to an open field daily to allow them to forage without a caretaker; he used a plastic crane decoy as a daytime attractant when the caretaker was absent; and the birds were penned at night for protection.

Training the birds to follow him in an ultralight capitalized on the chicks' following behavior toward him in human form. At 20 days, the chicks were exposed to the sounds and the appearance of the ultralight which was flown over the pen at 2–3 day intervals and which was left idling nearby. After fledging, the chicks were encouraged to follow the ultralight. During initial flights, only 1–2 birds flew with the aircraft. Within 5 days, all 15 followed it. The pilot observed the birds for signs of exhaustion and gradually increased the flight distance until by migration time the cranes were flying 40 km daily.

Upon arrival at the wintering grounds, the birds joined the wild cranes. Then on seeing the ultralight aircraft from the air, they joined it. Consequently, the chicks were penned for the first night. Eventually, the chicks migrated back to Idaho, showing this to be a real possibility for whooping cranes as well. In fact in 1997, Clegg repeated the experiment with a mixed flock of whooping and sandhill cranes (Clegg and Lewis 2001).

While Clegg's migrations were somewhat successful, the chicks were very tame toward humans. Use of the costume-rearing technique would have prevented some of the potential imprinting problems on humans. There are 3 possibilities for the chicks Clegg released. First, there might have been a long-term effect with the chicks orienting to humans sexually and not breeding with conspecifics. If this happens, Clegg has solved 1 problem but created another. However, there is a second possibility; if human contact were eliminated once the chicks were released on the wintering grounds, they might have reoriented to the sandhill cranes during this reattachment period. A third possibility is that the chicks imprint on conspecific flockmates. The presence or absence of the various forms of reattachment would be extremely interesting to test, but even if reattachment occurred there would still be a problem for whooping crane chicks inasmuch as there would be no whooping crane flock for them to join during the early stages of a migratory reintroduction.

In another experiment, an army ambulance was used to lead 12 cranes along a 640-km migration through Arizona (Ellis et al. 1997). Because this team did not use the costume in the 1995 pilot project, many of the birds were very tame toward humans. In a subsequent migration using the costume, the cranes were better prepared for life in the wild

(Ellis et al. 2001*d*).

Initial experiments with ultralights by Operation Migration staff were less successful but reaffirmed the potential of using aircraft as guides. Lishman, despite losing a number of chicks during the initial rearing stages, had success with his remaining 2 crane chicks which followed his plane on a 64-km flight and return (Lishman et al. 1997). The chicks showed some desire to follow the principal caretaker who remained on the ground. However, once in the air, the birds followed well. When the birds appeared hungry, they did not drift more than 10 m from the plane. Lacking the necessary permits to actually migrate, the team was forced to place the birds in captivity in October.

For a subsequent experiment in 1997, Lishman isolation-reared his birds using the methods of Horwich (1989) and Urbanek and Bookhout (1992). The chicks were reared on site and walked with the costumed surrogate parent for 2 hr each day to reinforce the following response and to strengthen their legs. Aircraft sounds were played at those times. The chicks' outdoor pens were positioned so that the chicks could be trained on the runway with the ultralight craft. At 2–3 weeks, a smaller aircraft model was introduced to acclimate the chicks to the overhead wing. This continued until 5 weeks at which time the chicks were grouped together. The ultralight aircraft was then introduced at a distance and the motor was started by the surrogate. Once the chicks were comfortable with the aircraft, it taxied while a second parent ran under wing. The chicks followed the ultralight aircraft well at all distances and altitudes. One group of juveniles so trained, followed the aircraft on a 600-km migration, while a second group proved uncooperative and were trucked to the wintering site (Duff et al 2001*a*). In spring of 1998, the birds that had flown the route returned unassisted. The trucked birds were too tame by spring and had to be removed from the wild. While a preliminary success, even the flown birds became very tame due to exposure to human activity at the rearing and wintering sites (R. P. Urbanek, personal communication).

The 1998 study by Duff et al. (2001*b*) had better success in making birds wild. These birds were uncooperative in following the ultralight and were led on only a partial migration flight (108 km) within the state of South Carolina. The focus of this study was to promote wildness. The chicks were reared by a modified isolation-rearing technique. The method differed from that of Horwich (1989) and Urbanek and Bookhout (1992) by not allowing the chicks to follow the costumed surrogate, by using only 1 surrogate at a time, and by modifying the costume slightly. The chicks on 1 occasion flushed from humans at 50 m. However, at other times, they could be approached to within 5–30 m (R. P. Urbanek, personal communication). The inconsistent use of the costume and the lack of following are major deviations which

discouraged attachment to the surrogate parent and may have been the reason for their reluctance in following the surrogate in the aircraft at later stages in development. Although these birds flew north in the spring, none went north of Cape Hatteras and none returned to Ontario.

The most recent ultralight experiment using costume-rearing has been the most successful. Of 13 fledged cranes, 11 completed a 2000-km flight from Wisconsin to Florida. Nine of these cranes were sighted back in Wisconsin in the spring of 2001 (Archibald 2001, Duff 2001, Hilton 2001).

**7. Consider Cost Effectiveness.**—Another factor of concern is cost. Not only should we be concerned with survival rates as indicators of cost, but we also need to be concerned with the absolute financial cost. From gross budgets and the number of surviving cranes, we find that certain methods have been very cost effective and others very expensive. The initial 1985 project by Horwich (1989) was essentially a volunteer effort run on \$2,000. With 4 surviving birds, the cost per individual was \$500 per crane. Urbanek and Bookhout (1992) had a more realistic budget, which included creation of some rearing facilities and cost approximately \$2,500 per surviving bird. The cross-fostering project cost over \$2 million (May and Henry 1995), and at its most productive stage, with 33 surviving whooping cranes, still cost over \$60,000 per surviving bird. Although difficult to assess accurately, the 2000 ultralight migration probably cost much more. The use of ultralight aircraft in future migration experiments will also greatly increase the expenses.

## PROCEDURES TO FOLLOW TO DEVELOP A MIGRATORY CRANE FLOCK

Today, establishing a migratory whooping crane population is feasible using costume/isolation-rearing coupled with guide birds or airplanes. If the costume technique, which produces birds that can survive in the wild, can be combined with the use of ultralight aircraft to teach the migration route, an effective method for developing a migratory whooping crane flock can be accomplished (Lishman et al. 1997). Creating a migratory flock of whooping cranes should be based on capitalizing on the successes while identifying and eliminating the problems.

The basic philosophy in rearing crane chicks should be to parallel, as closely as possible, the parent crane's method, integrating whatever ideas and technology are needed. The parent is the object of the chick's attention for the first year. At certain times in its life, it is more closely bonded with the parent than at others. At fledging time, chicks can more easily lose the parent, so they are prone to follow very closely whether the parent is on the ground, in the water, or in the air. Airplanes and trucks are just devices for the surrogate



parent to teach the chicks. The chick will follow the surrogate almost anywhere, in almost any form, because the chick is the product of a system that has for eons had success.

#### A. Create a Strong Parent/Chick Bond by Encouraging Following

1. Start with costume-rearing using Urbanek's modifications (Urbanek and Bookhout 1992) and rear in absolute isolation from human sight and voices. Do everything in costume except if some fear is to be instilled.

2. Imprint the chicks on a costumed foster parent, using the puppet to interact with the chick. Chicks orient to a moving bill to greet the parent, to receive food from it, and to mimic it in foraging.

3. Use a costumed dummy planted in the center of the exercise yard. In addition, provide food at this same site, especially if you want to attract wild cranes to the released chicks. Use of the costume and field dummy eliminates the need for brailling the chicks.

4. If an airplane is to be used to show the chicks the migration route, then at some point, the pilot must become involved in leading the chicks; first walking and running, then leading them in the ultralight on the ground, and finally in flight. They will follow if they know they are following a familiar and trusted surrogate. Without question, chicks can distinguish various costumed surrogates. No attempt should be made to imprint the chicks on an ultralight or other vehicle (Hilton 2001), but rather continue imprinting and orienting the chicks to the costumed parent. During reattachment periods, chicks are strongly drawn to the surrogate parent and will follow it anywhere.

#### B. Induce Fear of Humans

1. Maintain the isolation-rearing technique as much as possible; this will enable control by the surrogate parent and will prevent tameness toward uncostumed humans.

2. One experiment might be to allow whooping crane chicks to join a sandhill crane flock for less than 2 weeks to increase their fear of humans. However, caution should be taken since allowing them to stay with sandhill cranes for too long may reverse their sociosexual choice as adults and inhibit them from eventually breeding with conspecifics.

#### C. Use of Ultralight for Migration

1. Pilots should be the parental models. Use the method developed by Duff (Hilton 2001) or Clegg et al. (1997) (except the pilots would abide by all the rules set up by Urbanek [Urbanek and Bookhout 1992]). Thus, the pilots should use the costume, puppet, and brood calls at all times

when leading the chicks.

2. Train the chicks to the airplane on the ground first, using the pilots in costume to acclimate the chicks to the pilots as surrogate parents: this is because the chicks respond differently to different surrogate parents.

3. After following the plane on the ground and after fledging, begin leading the chicks with the ultralight in the air on a regular basis.

4. There must be enough pilots and planes to assist all cohorts reared. During Lishman's first year with cranes (Lishman et al. 1997), there was inconsistent use of the aircraft with the result that cranes followed poorly.

5. When developing a migratory whooping crane flock, the major remaining concern involves the possibility that the reintroduced whooping crane chicks may reorient to sandhill cranes during the sensitive period following fledging, during the fall migration and the wintering period. Keeping the whooping cranes in an exclusive flock isolated from the wild sandhill cranes during this period may be most important, at least until the end of December. Data on preliminary breeding behavior in the Florida whooping crane reintroduction project indicates that young cranes from captivity, if released in areas with sandhill cranes, will show normal breeding behavior directed at conspecifics (Wolff 2001b unpublished). However, most of the releases have occurred between mid-December and mid-April. Of 5 birds released in 1998 in mid-November which survived over 3 years, only 1, a parent-raised bird, has shown breeding behavior with conspecifics (Wolff 2001a unpublished). Since these cranes are still young, they may be important to watch. To ensure the necessary control during sensitive periods, the chicks should be led during the fall migration and controlled at the wintering grounds by costumed parents, field dummies, and possibly supplementary feeding at least through December. The most conservative (involved) program would include leading the chicks back by costumed surrogates and aircraft to the release area. Whatever method proves successful, the first released whooping cranes can thereafter serve as guide birds.

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