WINTER RELEASE OF ISOLATION-READED GREATER SANDHILL CRANES IN SOUTH TEXAS

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Abstract: During the summer of 1988, 7 greater sandhill cranes (Grus canadensis tabida) hatched from 15 eggs collected at Seney National Wildlife Refuge (NWR), Michigan, were isolation-reared at Welder Wildlife Refuge (WWR) near Sinton, Texas, and fitted with radio transmitters prior to fledging. Because of severe drought conditions on WWR, 3 surviving juveniles were moved to Laguna Atascosa NWR (LANWR) in south Texas and released on 27 January 1989. On 12 March 1989 they left LANWR with 3 wild cranes. They were relocated on 4 April in Rosebud, Texas. The 3 cranes were captured and transported to Grand Island, Nebraska, and re-released on 7 April. They left the Platte River on 21 April with a large flock of wild cranes and migrated at least 160 km north before I lost radio contact with them. They reappeared in Waco, Texas, on 22 May, and in June they were 30 km from WWR. On 11 August, 2 surviving cranes returned to WWR; they were recaptured and transported to LANWR. In the absence of wild migrant cranes, the 2 remaining cranes began associating with domestic animals and humans. On 8 March 1990 they were removed from the wild because they displayed no intention to migrate with wild cranes. These birds showed a strong affinity for their natal area (WWR), suggesting that isolation-reared cranes should be released on breeding grounds rather than on wintering grounds.

Key Words: Grus canadensis, isolation-rearing, natal area, sandhill cranes, wintering grounds

PROC. NORTH AM. CRANE WORKSHOP 6:131-134

Reintroduction studies of cranes have been carried out on the species' breeding grounds, but not all of these studies have been equally successful. Cross-fostering, with chicks reared by congeners but not conspecifics, has so far not proven to be a viable reintroduction technique because whooping cranes (G. americana) raised by sandhill crane surrogates have not paired and bred in the wild (Drewien et al. 1989). Cranes hand-reared with extensive contact with humans are not good candidates for release to the wild (Nesbitt 1979). Cranes raised by conspecific parents in captivity have been successfully released to the wild (Zwank and Wilson 1987, Ellis et al. 1992). More recently, cranes hand-reared by humans using costumes, puppets, and crane vocalizations have been successfully released to the wild (Archibald and Archibald, in press; Ellis et al. 1992; Horwich et al., in press; Nagendran 1991; Urbanek and Bookhout 1992). Isolation-reared cranes have completed several successful migrations from their breeding grounds to wintering grounds and back, and in 1990, 1 of these cranes and his wild mate successfully raised a chick (G. W. Archibald, International Crane Foundation [ICF], pers. commun.). Reaches of migratory greater sandhill cranes into areas in Florida occupied by resident Florida sandhill cranes (G. c. pratensis) resulted in the former becoming resident and not migrating (S. A. Nesbitt, Florida Game and Fresh Water Fish Commission, pers. commun.). My major objective was to experimentally release isolation-reared sandhill cranes in south Texas, a wintering area with no resident sandhill cranes, to determine if cranes can be induced to learn migration routes from wintering conspecifics.

Sincere gratitude is extended to the following individuals and institutions who made this project possible: J. G. Teer, G. W. Archibald, J. W. Grier, S. Garner, C. M. Mirande, R. P. Urbanek, S. A. Nesbitt, R. Rauch, J. C. Lewis, J. L. Provost, B. M. Greenwood, F. Arenga, J. Langenberg, P. J. Currier, P. Nagendran, J. D. Bland, the staff at the International Crane Foundation, the staff and students at Welder Wildlife Refuge, and the staff and personnel at Laguna Atascosa NWR. This project was funded by the Institute of Museum Services and the Roger Tory Peterson Institute. Logistical support was provided by North Dakota State University, the ICF, WWR, and LANWR. G. Septon reviewed an earlier draft of this paper and provided helpful comments.

STUDY AREA AND METHODS

The Welder Wildlife Refuge, located on Highway 77 near Sinton, Texas (Fig. 1), was the hatching and rearing site. WWR was chosen because several hundred sandhill cranes usually winter on and around this refuge. Greater sandhill crane eggs (n = 15), collected from nests on Seney NWR in the Upper Peninsula of Michigan, 21–23 May 1988, were transported by air to Texas in a portable incubator on 23 May. Eggs were kept warm with hot water bottles during transportation.

At WWR the eggs were further incubated in an automatic incubator until hatching. Chicks were hand-reared in audio-visual isolation from humans using
costumes, hand puppets resembling sandhill crane heads, taped sandhill crane vocalizations, and realistic brooding models; chicks were in audio-visual contact with each other (Horwich 1989). They were initially reared in a facility adjacent to the refuge headquarters. Each chick had an individual corral approximately 2.5 m × 1.5 m. Daily routine included weighing the chicks, general physical examination, and exercising the chicks together. When young chicks were together, they were under constant vigil to avert any fatalities/injuries as young chicks are aggressive toward each other. Chicks were fed an artificial crane starter diet in crumble form for the first 2 weeks. They also consumed grasshoppers and other insects captured in the exercise yard, where they spent most of each day. When the chicks were about 2–3 weeks old they began eating the crane starter in pelleted form.

In early August the chicks were split into 2 groups and moved to 2 release sites near Big Lake on WWR, an area where wild, wintering sandhill cranes traditionally roost. In September—October the chicks were fitted with leg-hold or backpack radio transmitters (Telonics Telemetry Systems, Mesa, AZ). Chicks were sexed behaviorally (Archibald 1976) or by size comparisons.

RESULTS

May – August 1988

The first chick hatched on 24 May, followed closely by 10 more chicks, with the last chick hatching on 16 June. Four of these chicks died, 2 presumably killed by snakes, 1 from an eye injury, and 1 from unknown causes. The 7 remaining chicks were very aggressive towards each other during the first 10 days, but by 1 month of age this aggression had dissipated and a hierarchy was established with the oldest chick most dominant.

The chicks were very attached to the costumed "parent" (henceforth parent) during the first few weeks. They followed closely behind the parent during walks, especially when the taped brood call was played, and remained next to the parent while it hunted for grasshoppers. Only 1 chick had health problems soon after hatching; it had to be tube fed on 2 successive days and administered saline subcutaneously to prevent dehydration. All chicks fed and drank without parental assistance when they were 3–4 days old. When 1 month old they spent considerable time foraging and less time following the parent. Chicks spent more than 50% of their time in a plastic baby pool during the many hot Texas days. Chicks responded to armadillos (Dasypus novemcinctus) by squealing and approaching with great curiosity, and to the taped sandhill crane unison calls by immediately assuming an alert posture.

The oldest chick had a badly twisted hock which could not be corrected, although I tried every reasonable therapy. Although the chick managed to lead a normal life and remained dominant over others, I decided not to further handicap it with a transmitter and harness.

September – December 1988

By mid-August the chicks (hereafter project cranes) were fledging age and were moved to the release site. Due to extended drought, Big Lake became dry at the end of September. Without water the lake would not attract any wild cranes, and a successful release of the project cranes would be impossible. A hurricane brought 7.5 cm of rain to the refuge, barely sufficient to muddy the lake bed for a few days. Wild sandhill cranes began arriving in late September, but none roosted at WWR. It became apparent
that another release site was needed, and an active search for a new site began in October. The project cranes had become extremely attached to their parents and stayed next to them for more than 8 hours each day, completely ignoring the occasional wild sandhill crane that would land nearby. It was very important to transfer this attachment to wild cranes.

On 17 November the project cranes were moved to a private ranch near Seadrift, Texas (near Refugio, Fig. 1), where hundreds of wild sandhill cranes and waterfowl roosted. The first night 1 project crane disappeared. On 18 November the remaining 6 project cranes were moved back to WWR rather than risk another loss. The missing crane was located on 21 November by radio telemetry and recaptured while she was walking along a street in the town of Seadrift. When I approached her in my costume playing a tape recorded brood call, she ran up to me. I returned her to her cohort at WWR.

I located a third potential release site 25 km from WWR in early December and moved the project cranes to this site on 7 December. Heavy rainfall washed out our camp site, forcing me to release the project cranes abruptly and earlier than planned. Three project cranes were killed by a bobcat (Felis rufus) during 2 successive nights. The remaining 4 cranes were captured and brought back to WWR. Permission was obtained to move them to Laguna Atascosa NWR, 200 km southwest of WWR (Fig. 1), where 600–1,000 sandhill cranes were wintering.

January - December 1989

On 6 January 1989, the 4 remaining project cranes were moved to LANWR from WWR, and exposure to wild sandhill cranes began immediately. The temporary night holding pens, each approximately 1 m², were a few hundred meters away from Lake Atascosa, the roost site of wild sandhill cranes. On 9 January a project crane died from gout. I forced the remaining 3 to interact with wild cranes by attracting wild cranes to an area heavily baited with corn and sorghum. This forced association was necessary because project cranes had little time remaining to bond with wild cranes before spring migration northward, which could begin by late February. Hand-reared cranes needed to identify with their wild counterparts so that they could migrate successfully.

The wild cranes flew to corn and sorghum fields away from the refuge to feed. By baiting I was able to induce 300–400 cranes to remain on LANWR, thus enabling the project cranes to associate with wild birds for extended periods of time. On 27 January they roosted with wild cranes on Lake Atascosa for the first time. During February and March, 3 wild adult cranes were captured and fitted with radio transmitters so that I could also monitor the movements of associated wild cranes.

On 12 March the 3 project cranes migrated to the northwest from LANWR with 3 wild cranes. These 6 cranes were the last to leave LANWR. I lost radio contact outside LANWR and spent the afternoon radio-tracking by aircraft, attempting to ascertain whether they had left the area. From 13 to 18 March I searched by vehicle with a receiver for these birds between south Texas and Grand Island, Nebraska. By 3 April, all 3 wild cranes with transmitters were on the Platte River, but there were no radio signals from the project cranes. On 4 April the project cranes were found in Rosebud, Texas, approximately 600 km north of LANWR (Fig. 1). I returned to Texas, and on 6 April I donned my crane costume and used my tape player to retrieve the cranes, placed them into compartments in my enclosed pickup truck, and drove 1,100 km north through the night to Nebraska. I arrived in Grand Island (Fig. 1) at 0700 hours, and the 3 project cranes were re-released on the Platte River before 0900 hours. After a few moments of hesitation, they joined wild cranes.

One of the project cranes separated from the other 2 on 11 April. On 15 April she appeared to head north with a small flock of cranes. That night she did not roost on the Platte River, but she was back the following night. The 3 cranes reunited on 20 April. At 1102 hours on 21 April, they left the Platte River with a large flock of wild cranes. The temperature was >28°C, and there were strong south-easterly winds. I followed the cranes for approximately 160 km and then lost radio contact with them north of Burwell, Nebraska (Fig. 1). They were migrating at a ground speed of 72 km/hour. I returned to the Platte but had no radio contact along the river the next morning. The cranes had left the area.

There were no reports of the project cranes until 22 May, when they were seen in Waco, Texas, approximately 72 km north of Rosebud (Fig. 1). In June I received a report that the project cranes were seen on the Herd Ranch near Refugio, approximately 32 km from WWR. On 26 July, 1 of the females was killed by a bobcat just before 1930 hours (Texas Parks and Wildlife Department, pers. comm.). The remaining 2 project cranes (1 male and 1 female) moved adjacent to WWR and started visiting a horse barn to feed. I retrieved them when they returned to WWR on 11 August, and I transported them once again to LANWR, where roosting and foraging habitats far exceeded those at WWR. I hoped that the project cranes would be able to survive at LANWR without too much human intrusion and would associate with wild cranes again in the fall of 1989. In the absence of wild cranes, they foraged with domestic animals and associated with people living near the refuge, but they
apparently continued to roost at LANWR. For a short period after the wild cranes arrived, the 2 project cranes stopped these foreign associations and remained in the company of wild cranes, but this did not last very long. They did, however, continue to roost at LANWR, according to the people they visited during the day. Efforts to discourage people from feeding and taming the project cranes produced mixed results, with some residents wanting to retain the cranes as pets, some complying with my request, and 1 particular individual wanting to shoot them.

January – March 1990

In January 1990 I returned to LANWR and changed the radio transmitter on the remaining male project crane. The female was very wary of me and could not be captured. During this visit I contacted many people and distributed fliers requesting them to discourage the 2 cranes from visiting their yards. One individual did heed this request and further tamed them. On 8 March, because they had become too tame and displayed no intention to migrate, the 2 subadult hand-reared sandhill cranes were removed from the wild and shipped to Rio Grande Zoo in Albuquerque, New Mexico.

DISCUSSION

Availability of crane habitats at WWR was at an all-time low because of drought conditions during the project, making it difficult to properly test the release of cranes on wintering grounds. Notwithstanding, this experiment suggests that the natal area plays a significant role in the movements of cranes. The ability of the isolation-reared cranes to navigate accurately back to their natal area (WWR), even after making a significant portion of their northbound journey in an enclosed pickup in the dark, raises intriguing questions about cranes’ migratory behavior. I believe the following factors severely affected the experiment: (a) the absence of an adult sandhill crane for early imprinting purposes, (b) Big Lake becoming dry for the first time in recent years, (c) frequent handling of these cranes by humans to change release sites, and, most serious of all, (d) the resultant postponement of the release from October 1988 to January 1989. Without these extenuating circumstances the results might have been different, and only a similar experiment carried out under more suitable conditions would answer questions on migration and homing by released cranes.

The importance of the natal area to cranes suggests that releases would best be accomplished on the species’ breeding or staging areas (in the north). A stable body of water for roosting and a stable wild crane population with which the hand-reared cranes can integrate are crucial requirements. The time of release and the length of the acclimation phase are crucial factors for successful release because the longer the cranes remain with their costumed parent, the more difficult it is to transfer this attachment to wild cranes.

LITERATURE CITED


TECHNIQUES FOR REARING AND RELEASING NONMIGRATORY CRANES: LESSONS FROM THE MISSISSIPPI SANDHILL CRANE PROGRAM

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Abstract: Captive-reared Mississippi sandhill cranes (Grus canadensis pulla) reared at the Patuxent Wildlife Research Center (Patuxent) have been released at the Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR) since 1981. Of 131 birds released through December 1990, 103 were reared by foster parents. The remaining 28 were experimentally hand-reared in 1989 and 1990. After refining release procedures, parent-reared birds have integrated into the wild flock, many have survived, and some have bred. Releases of hand-reared cranes elsewhere in the 1970’s were largely unsuccessful, at least in part due to the lack of a lengthy acclimation period. A new hand-rearing protocol holds promise in producing release-worthy birds. The technique employs some features first used in the 1960’s (e.g., a costume for the human caretaker and model crane heads used to train chicks to feed). In the mid-1980’s, the following features were added: (1) the costumed caretaker was given a visor and feathers, (2) a taxidermic crane head or a hand puppet was held or suspended from the ceiling for use in stimulating chicks to feed, (3) a taxidermic mount of a brooding crane supplied warmth, (4) a full-sized live crane was maintained in an adjacent pen and in visual contact with neonatal young to provide an imprinting model, and (5) a small group of adult (or subadult) cranes was penned adjacent to the outdoor chick pens to provide socialization models. Recent releases of Mississippi sandhill cranes hand-reared according to this protocol and released in Mississippi have had high first-year survival rates. The now-operational technique holds promise for producing large numbers of release-worthy birds.

Key Words: captive breeding, Grus canadensis, reintroduction, sandhill crane

Reintroduction techniques for fledged cranes were described by Konrad (1976), Derrickson and Carpenter (1983), Horwich (1986, 1989), Horwich et al. (in press), Urbanek (1990), and Urbanek and Bookhout (1992) and are outlined below.

PAIRING OF CAPTIVE AND WILD CRANES

In Hokkaido, Japan, flightless male red-crowned cranes (Grus japonensis) lured females into their enclosures (Konrad 1976). The resulting pairs produced chicks that fledged into the wild flock. Occasionally, captive cranes of other species have lured wild mates (Hyde 1957; G. W. Archibald, International Crane Foundation [ICF], pers. commun.). A variation of this technique was tried twice with cross-fostered whooping cranes (Grus americana) at Grays Lake National Wildlife Refuge (Grays Lake), Idaho (Drewien et al. 1989). Because adult male whooping cranes in this experimental flock failed to return to the marsh with female mates, several attempts were made to capture and translocate adult females that had dispersed into neighboring states. When this also failed to produce viable pairs, 2 hand-reared females (1 each in 1981 and 1989) from Patuxent were introduced to the adult males. Both females were courted and although both pairs seemed to be forming lasting bonds, neither pair produced eggs and neither pair migrated together (Derrickson and Carpenter 1983, Drewien et al. 1989).

Another variation of pairing captive-reared and wild cranes occurred in northern China: chicks of the white-naped crane (Grus vipio) and the red-crowned crane were hand-reared and fed long-term until they became semi-wild in the marshes at Zhalong (Jie et al. 1989). In subsequent years, these semi-domestic birds paired with wild mates and nested in the marshes near their natal area. Offspring resulting from these tame-wild matings were reportedly much more tolerant of human approach...
and therefore better able to live in a human-dominated environment.

Either variation of this technique, although logistically difficult with a large number of birds, seems (at least from the experiments in Japan and China) to hold promise for forming small numbers of pairs.

**ABRUPT RELEASES**

The first sizable release of captive-reared cranes occurred in 1971, when 14 juvenile Florida sandhill cranes (G. c. pratensis) reared at Patuxent were transported to a site near Lake Okeechobee, Florida, and released without acclimation (Nesbitt 1979). None of these hand-reared birds integrated into the wild flock, and within a few months all had died of exposure, starvation, or accident. A single parent-reared crane released at Paynes Prairie, Florida, survived 3 years.

Following the experiment with hand-reared cranes in Florida, abrupt releases of parent-reared greater sandhill cranes (G. c. tabida) were attempted at Grays Lake in 1976 (n = 1) and 1980 (n = 11) (Drewien et al. 1982). Of 7 young that survived to migrate south, none reappeared at Grays Lake the following spring. These results, especially when compared with results from the gentle releases described next, further demonstrate the need for pre-release conditioning at the release site.

**GENTLE RELEASES OF PARENT-REARED CRANES**

In gentle releases in Mississippi, cranes (usually juveniles) were brailed (i.e., rendered temporarily flightless by having a plastic strap bound around 1 wing; Ellis and Dein 1991) and confined in large pens at the release site for about 30 days. Thereafter, they were debailed and allowed to come and go at will.

Since 1981, more than a dozen gentle releases have been made using parent-reared cranes from Patuxent. Survival rates have varied greatly. Only 9 of 21 (43%) greater sandhill cranes released at Grays Lake in summer 1984 survived to migrate (Bizeau et al. 1987). These birds were held on site for less than 1 week in a small net-topped pen before release. However, 15 of 27 (56%) Florida sandhill cranes released after a longer acclimation period survived their first winter in a nonmigratory situation (Nesbitt 1988). Higher survival rates (Table 1) have sometimes been achieved in Patuxent's extensive release program with Mississippi sandhill cranes; about 2/3 (41 of 66) of the birds released from 1981 through 1989 survived for at least 1 year (McMillen et al. 1987, Zwank and Wilson 1987, unpubl. data). Nearly all Mississipi birds surviving more than a few months have successfully integrated into the wild flock. Details of the rearing procedures for these cranes are presented later in this paper.

**GENTLE RELEASES OF HAND-REAURED CRANES**

Various attempts have been made to increase post-release survival rates for hand-reared birds (Horwich 1986, 1989; Nagendran 1992; Archibald and Archibald, in press; Horwich et al., in press; Urbanek and Bookhout 1992, unpubl. data). These experiments included work at the ICF (with releases in Texas and Wisconsin), at Seney National Wildlife Refuge, Michigan, and at Patuxent (with releases in Mississippi and Florida). In all of these experiments, sandhill crane chicks were reared in relative isolation from uncostumed humans. In the 1960's, silhouetted heads (2 dimensional) were first used at Patuxent to train chicks to feed. A puppet head was first used in 1982 (Archibald and Archibald, in press). In 1985, Horwich (1986, 1989) combined the devices used in previous hand-rearing attempts and applied concepts from classical ethology (e.g., age-specific learning, sign stimuli, and imprinting) to introduce a small number of sandhill cranes into a migratory flock. His method included a mounted crane model in brooding posture with a heat source and crane maternal vocalizations, hand puppets for feeding, puppet heads with bills dangling in the food, and a feathered costume allowing a human caretaker to lead the chicks afield to learn natural foods, the features of their natal area, and to socialize with wild cranes. These devices and a mock attack by an uncostumed human prevent imprinting and attachment to humans.

Today, chicks are fed using a terry cloth puppet (ICF and Michigan) or a taxidermic mount (Patuxent). In addition, some chicks are penned in visual and auditory (but not physical) contact with adult cranes.

Pledged birds released in Wisconsin, Michigan, and Mississippi have survived well, many birds have effectively socialized, and several have paired with wild cranes (Urbanek and Bookhout 1992, unpubl. data; G. W. Archibald, ICF, pers. commun.). Some juveniles released in northern latitudes have also completed fall and spring migrations unassisted, while others have required assistance to move them to staging areas after they failed to move south unaided (Urbanek and Bookhout 1992; Horwich et al., in press). Recent releases have largely solved the problems of integrating hand-reared sandhill cranes into wild flocks in time for migration (Urbanek and Bookhout 1992, pers. commun.). Although no conclusions can yet be drawn for less gregarious species, hand-rearing is now a proven technique for introducing sandhill cranes in both migratory and nonmigratory situations.
Table 1. Fate of hand-reared (HR) and foster parent-reared (PR) Mississippi sandhill cranes released in Mississippi.

<table>
<thead>
<tr>
<th>Winter of release</th>
<th>No. cranes released*</th>
<th>No. surviving 6 months</th>
<th>No. surviving 1 year</th>
<th>No. breeding by 1991</th>
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<td></td>
<td>HR (M)</td>
<td>PR (S)</td>
<td>HR (%)</td>
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<td>1980-81</td>
<td>0 9</td>
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<td>9 (100)</td>
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<td>1981-82</td>
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<td>1982-83</td>
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<td>1983-84</td>
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<td>4 (100)</td>
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<td>1984-85</td>
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<td>9 (90)</td>
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<td>1985-86</td>
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<td>6 (86)</td>
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<td>1986-87</td>
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<td>2 (100)</td>
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<td>1987-88</td>
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<td>8 (89)</td>
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<td>1988-89</td>
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<td>10 (77)</td>
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<td>1989-90</td>
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<td>12 (100)</td>
<td>14 (82)</td>
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<td>1990-91</td>
<td>16 20</td>
<td></td>
<td>14 (88)</td>
<td>17 (85)</td>
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</table>

*Not included are 2 birds that died before they flew from their release pen and 3 birds with severe heart murmurs. We did include 1 overly tame bird and 4 birds that were captured injured, sick, or emaciated after release. For these last 5 birds, date of removal from the wild was treated as death date.

We appreciate the essential contributions of the many animal caretakers, technicians, graduate students, and volunteers who have helped in either rearing or releasing cranes. R. C. Erickson, the founder of our program at Patuxent, and J. Valentine, the father of the Mississippi sandhill crane studies, were the prime movers in inspiring early releases in Mississippi. T. J. Logan played a major role in organizing systematic data gathering for release birds. C. Ellis and J. Dennis helped with clerical chores. S. Swengel, R. Horwich and R. P. Urbanek made useful suggestions on the manuscript.

REARING AND RELEASE METHODS

This section details Patuxent's rearing program for Mississippi sandhill cranes intended for release. Of the chicks that were hatched at Patuxent (1989-91), about 70% of those intended for release were alive and otherwise suitable at time of shipment to the refuge.

Hand-rearing

Birds in the hand-rearing program are held in audiovisual isolation from humans, but with exposure to conspecific crane chicks, mounted crane brooding models, stuffed crane head feeding models, a live adult or subadult crane (imprinting model) penned next door to neonates, and a group of adult cranes in outdoor community pens (socialization models). Carcapers are disguised by gray cotton costumes and are often further hidden behind screens.

Chicks were exposed to the above listed stimuli according to the following schedule:

1. Live Imprinting Model in adjacent pen Day 0-20
2. Stuffed Broodcr Model Day 0-10
3. Feeding Model (puppet head) Day 0-10
4. Live Socialization Model in outdoor pens Day 0-75+

The caretaker's costume covers the wearer from head to knee, with a viewing port covered by camouflage netting to obscure the face. The costume prevents chicks from recognizing and becoming attached to individual caretakers. In addition to the costume, screens covered with cloth or carpet are used when a costumed caretaker teaches a chick to feed to further reduce the chances that they will imprint on costumed caretakers.

Caretakers normally lock chicks outdoors when they clean pens and exchange food and water. Otherwise, caretakers do all chores while costumed. All visitors enter the rearing area only in costume. Even the veterinarians are costumed while performing health checks and other tasks. When a chick is removed from the pen for examination, it is frequently hooded to allow caretakers or veterinarians to remove their hoods.

Care of Late Term Eggs.—A rigorous rearing protocol is imposed even prior to hatching. At Patuxent, the eggs of
endangered cranes are incubated by poultry, cranes, and artificial incubators. When eggs that are not incubated by cranes approach hatching (ca. 27 days of incubation), taped brood calls of sandhill cranes are played to the eggs at ca. 0800, 1100, 1400, and 1630 hours for 5–15 minutes.

**Care of New Hatchlings.**—After a Mississippi sandhill crane chick hatches, it undergoes the same medication regime whether it is intended for release or not (M. M. Wellington, A. Burke, ICF; and J. M. Nicolich, Patuxent; in prep.). It is weighed, examined by a veterinarian, given prophylactic antibiotic injections, and placed in its own separate pen (about 8 × 8 feet) with a carpet mat. A stuffed brooder model with partly spread wings is located directly under a heat lamp to allow the chick under the wing for brooding. A water jug is placed in the pen and the bil of the stuffed brooder model is placed in the water.

The taxidermic mount crane head (including about 32 cm of the neck and a posteriorly protruding wire handle) is suspended from a hook in the ceiling and dangles in a bowl filled with granulated chick food. After removing the head from the string, the caretaker manipulates it through the hole in the screen as though it were the head of a parent crane feeding its chick. The caretaker dips the bill in water, then in the food, and then holds the food-laden bill near the chick while purring or playing the tape recording of a brood call. Most chicks show great interest in the moving head and eagerly peck crumbles from the bill. Eventually they learn to peck into the food bowl where the head is probing. As soon as the chick learns to eat from the bowl, caretakers no longer enter the pen to manipulate the head; rather they stand outside the pen behind a screen and bob the head using the suspending string which terminates on the pen wall. The head is similarly used to lure the chick to the water jug to train the chick to drink. Chicks that are reluctant to approach the head are enticed to do so by wrapping red tape around the tip of the bill. Mississippi sandhill crane chicks normally respond well without the red tip.

**Imprinting and Socialization Models.**—For the first 10–20 days, chicks are penned next door to a live adult or subadult conspecific to facilitate proper imprinting. To prevent aggression, chicks are protected from this crane by a vinyl-coated, welded-wire barrier with a sheet of clear plexiglass along the bottom 60 cm. These barriers permit unlimited viewing of the imprinting model.

After day 10, chicks can be moved away from the imprinting model if necessary to accommodate younger birds. At 4 days, chicks gain access to an outdoor run where they have visual and audio contact with a group of conspecifics (socialization models) in an outdoor community pen.

**Human Avoidance Conditioning**—Beginning around 20 days of age, release chicks are subjected to several bouts of human avoidance conditioning. After the chicks are locked in their outdoor pens, an uncostumed human runs through the corridor at the end of these pens while producing loud noises (e.g., banging pots, yelling). Another observer simultaneously plays a tape recording of a sandhill crane guard call. In addition, the imprinting models are locked outside during the attack and encouraged to guard call. Chicks that show little or no reaction are captured, jostled, and then released. After the chicks are formed into release cohorts in community pens, 1 or 2 mock attacks are staged wherein 1 or 2 uncostumed caretakers pursue the chicks for about 5 seconds.

**Parent-rearing**

The parent-rearing process involves the captive rearing of a chick by a pair of conspecific foster parent cranes or rarely a single crane. We used Florida sandhill crane foster parents to care for early Mississippi sandhill crane chicks and greater sandhill crane foster parents to care for late-season chicks. Some Mississippi sandhill cranes are also employed as foster parents. This process closely parallels the rearing of a chick in the wild. At appropriate times the chick learns to drink, forage, avoid humans and fear predators, and learns how to interact with other cranes. Cranes reared by their own species should imprint properly. Parent-rearing is less labor intensive than conventional hand-rearing, but requires extensive facilities to maintain breeding pairs and their replacements.

Because parent-reared chicks are raised in an environment in close contact with other cranes, they are more subject to certain hazards than are hand-reared chicks. They are exposed to foul weather, parasites, and are at a greater risk of predation than birds raised in buildings. Because they have much greater contact with uncostumed humans and motorized vehicles, they become acclimated to both.

Several factors are considered when choosing pairs to raise chicks. Not all captive cranes make good parents; some kill or neglect chicks. Before a pair is allowed to raise a genetically valuable or endangered crane, it is given at least 2 years of experience raising cranes of a common taxon. The parenting performance of each pair is closely monitored and evaluated. Preferred pairs are tolerant of routine disturbances. They do not redirect aggression to eggs or chicks or tred on chicks when disturbed. Good pairs are constantly attentive to their chicks, and both adults share in incubation and brooding. About 80% of the pairs that are evaluated eventually prove suitable to rear Mississippi sandhill crane chicks.
Cross-fostering, the parent-rearing of a chick by adults of another species, results in near-normal behavioral development; however, if a chick is not exposed to species specific imprinting cues, it may prefer its foster parent species when it is an adult (Mahan and Simmers 1992). Cross-fostering is never used for Mississippi sandhill crane chicks.

Careful planning is required to provide a suitable pair of foster parents on the projected hatch date. Normally, eggs of 2 or more potential parents are manipulated to ensure that a suitable pair is ready.

Five different methods of adoption have been used at Patuxent and are chosen in various circumstances. In the preferred method, a pair hatches an egg it has been incubating and raises the resulting chick. A second alternative is to introduce a pipped egg in exchange for an egg that has been incubated at least 21 days, but preferably 28–30 days. This method is consistently used when a pair’s incubation performance has been poor or is unknown.

The final 3 fostering methods involve introducing a small chick to surrogate parents. These methods are risky and are not used routinely. In 1 approach, a pair’s chick is replaced by a similar-aged chick. This technique, used when the pair’s first chick becomes sick or dies, allows for movement of an ill chick to an intensive care area while still making use of a valuable pair of foster parents. Because the success of this technique depends largely on the behavior of the chicks, only chicks that have had previous exposure to live cranes are used. In another method, a pair’s egg is replaced with a young chick, usually under 4 days of age. Generally only experienced parents tolerate such an abrupt change. The final, and most extreme, adoption method has only been used a few times at Patuxent. Non-endangered chicks as old as 7 days have been introduced to pairs that were not then incubating eggs or rearing chicks. Both experienced and inexperienced pairs have adopted chicks in this way. Six of 7 adoption attempts (1989–91) using these 3 chick introduction methods were successful.

Newly hatched parent-reared chicks are given medical treatments according to a schedule similar to that of hand-reared chicks (M. M. Wellington, A. Burke, ICF; and J. M. Nicoll, Patuxent; in prep.). Fresh food and a fountain waterer are placed near the nest daily until the chick is mobile (2–3 days). At Patuxent, parent-reared chicks are handled days 0–4, 6, 9, 12, 15, 18, 21, 25, 32, 46, 53, 60, 67, and every 2 or 3 weeks thereafter. Chicks are observed daily for signs of injury, panting, and lethargy. In addition, they are periodically caught, examined, weighed, and given prophylactic treatment for parasites and other medications or treatments as needed. Fresh fecal samples are taken at scheduled intervals and examined for parasites.

Natural foods provided by the parents supplement commercially prepared crumbles or pellets. After the first few days, the feed bowl and waterer are placed near the parents’ feeder to familiarize the chicks with this location. Daily provision of chick feeders and waterers is discontinued when the chicks are large enough to reach those used by the adults.

Forming Release Cohorts and Releasing Colts

Until 1989, all Mississippi sandhill cranes intended for release were parent-reared. In 1989 we modified our elaborate costume rearing regime to prepare chicks for release. These birds appear as 1990 release birds in Table 1. In 1990 and 1991, 3 types of experimental release cohorts were used each year: 1 cohort consisted entirely of parent-reared birds, the second consisted of a mixture of hand-reared and parent-reared birds, and the third type consisted entirely of hand-reared birds.

Hand-reared Mississippi sandhill cranes are kept at the chick rearing facility until they are 55–60 days. At this age they are formed into temporary juvenile cohorts in netted community pens. Normally these cohorts are penned next door to a small group of parent-reared (i.e., wildacting) adult conspecifics. Parent-reared chicks remain with their foster parents somewhat longer. Because most of the parent-rearing pens are without nets, the flight capability of parent-reared chicks is closely monitored after about 55 days. When they are capable of flight, the chicks are bailed until mid-October when they are removed from their foster parents’ pen, debrailed and randomly assigned to a release cohort, and released in a net-covered community pen. Cohorts are then randomly (or restricted randomly) assigned to a release pen in Mississippi.

Hand-reared and parent-reared colts remain with their release cohorts until mid-November when they are bailed, crated, and shipped to the MSCNWR. After a month in 1 of 3 large release pens (ca. 2 ha each), the brails are removed and the birds are allowed to come and go at will. Food is provided in the release pens for 2–3 months. Wild cranes also take advantage of the food available in the release pens and serve as trainers for the release birds.

Monitoring Survival of Release Birds

Survival of parent-reared Mississippi sandhill cranes has been under study since 1981 (Zwank and Wilson 1987, unpubl. data). Radio telemetry and color banding are used extensively to monitor survival after release. Each bird released in 1990 and 1991 carried a transmitter which also
included a mortality sensor.

Some aspects of survival for all birds released through January 1991 are presented in Table 1. After experiencing poor success integrating release birds into the wild flock in 1981 and poor survival for the birds released in 1982, we adjusted cohort formation time and the pre-release acclimation period to about 1 month each. Following these changes, release birds readily integrated into the wild flock and survived well (survival to 1 year post-release was 65% for 52 birds released from December 1982 through January 1989).

We hoped that survival rates for hand-reared Mississippi sandhill cranes would approach those of parent-reared birds, but the rates experienced so far for hand-reared birds have been unexpectedly high. All (12) of the 1989 hand-reared birds released in January 1990 survive to the present (late 1991). Of the hand-reared birds from the following year (released in December 1990), 1 died prior to leaving the release pen; 14 of 16 (88%) chicks that actually flew from the release pen survived to 6 months.

Of 16 birds that have been alive at least 4 years after release (and are therefore of breeding age), 10 have participated in 26 breeding attempts (eggs observed). Of these, at least 15 attempts have resulted in fertile eggs, at least 9 of which led to hatching, and 6 chicks fledged. Of course, no hand-reared birds have been involved in these attempts; it will be 1 or more years before anything is known of the reproductive performance of reintroduced hand-reared Mississippi sandhill cranes.

CONCLUSIONS

Survival rates for parent-reared Mississippi sandhill cranes released as 6-month-old juveniles have risen to acceptable levels during the 11 years that releases have been conducted at the MSCNWR. Many of the birds surviving to breeding age have also bred. Hand-reared birds (28) have been released for only 2 years so our conclusions about their survival are at best tentative. However, 6-month survival rate pooled for both years was 96%, and 1-year survival was 93%. These data bode well for the continued use of hand-rearing as a reintroduction tool, especially for nonmigratory cranes.

LITERATURE CITED


POPULATION RECOVERY OF THE WHOOPING CRANE WITH EMPHASIS ON REINTRODUCTION EFFORTS: PAST AND FUTURE

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Abstract: The U.S. Fish and Wildlife Service (USFWS) began building a captive whooping crane (Grus americana) colony at Patuxent Wildlife Research Center (Patuxent), Maryland, in 1966. From 1976 to 1984, 73 eggs from this colony and 216 eggs from Wood Buffalo National Park (Wood Buffalo), Canada, nests were placed in sandhill crane (G. canadensis) nests at Grays Lake National Wildlife Refuge (Grays Lake), Idaho, the site of the first whooping crane reintroduction attempt. Although 84 chicks fledged from the 289 eggs, the egg transfer program has been discontinued because of inordinately high mortality (only ca. 13 birds remain in the wild in 1991) and lack of breeding in survivors. In recent decades new methods have emerged for introducing captive-produced offspring to the wild. Surrogate studies with sandhill cranes, particularly the endangered Mississippi sandhill cranes (G. c. pulla), have shown that young cranes, raised either by captive, conspecific foster parents, or by costumed humans and in close association with live cranes and lifelike crane taxidermic dummies, have high post-release survival rates. These techniques will likely be used in future whooping crane reintroduction programs. Current recovery objectives for the whooping crane include expansion of the 2 captive colonies, establishment of a third captive colony in Canada, and reintroduction of 2 additional wild populations. The Kissimmee Prairie in central Florida has been selected for the next release experiment. Evaluation of this site began in 1984, and risk assessment is expected to begin in 1992 with the transfer and monitoring of a group of captive-reared, juvenile whooping cranes. These "tests of the environment" will, if results are favorable, be followed by a full-scale reintroduction effort of at least 20 birds/year beginning in 1994 or 1995.

Key Words: captive breeding, Grus americana, Grus canadensis, recovery, sandhill crane, whooping crane

PROC. NORTH AM. CRANE WORKSHOP 6:142-150

Of the 15 species of cranes worldwide, 6 species and 2 subspecies are listed as endangered (U.S. Fish and Wildlife Service 1988). All 15 species have been bred in captivity, and during the last 20 years, several reintroduction projects have been initiated. Herein, we relate past and potential efforts for recovery of the whooping crane.

We deeply appreciate the editorial, secretarial, and data handling support provided by L. Miller, C. Ellis, and J. Dennis. Many people have assisted in propagating and caring for cranes at Patuxent; all have our heartfelt thanks.

The manuscript benefitted from reviews by R. Eisler, G. M. Haramis, D. K. Dawson, S. Swengel, and M. Mossman.

WHOOPING CRANE POPULATION DECLINE

Historically, the breeding range of the whooping crane extended from Illinois northwest through Iowa, Minnesota, and North Dakota into southern Manitoba, Saskatchewan, and Alberta (Allen 1952) with a disjunct population nesting in the Great Slave Lake region (U.S. Fish and Wildlife Service 1986). In 1939, a small, widely disjunct population was also found breeding in the marshes north of White Lake, Louisiana (Lynch 1984). Breeding may have also occurred at other locations, but information is limited. Wintering populations ranged from the Rio Grande delta eastward along the Gulf Coast to Florida and along the Atlantic Coast as far north as New Jersey (Allen 1952). In the 1800's, a combination of habitat destruction, human disturbance, hunting, and egg and specimen collection for museums and private collectors contributed to a rapid population decline. By 1870, fewer than 1,400 individuals remained (Allen 1952). In 1945, the population consisted of 2 disjunct flocks totaling about 21 birds (Fig. 1) (U.S. Fish and Wildlife Service 1986); only 3 birds remained of the small (soon to be extinct) sedentary flock in Louisiana. The remaining 18 birds comprised a flock that wintered at Aransas along the Texas Gulf Coast and nested in Wood Buffalo, Northwest Territories, Canada (Allen 1956) (Fig. 1). Following this nadir, the whooping crane population began its slow increase.

PATUXENT'S CAPTIVE COLONY

The ponderous expansion of the whooping crane population beginning in the late 1940's (Fig. 1) prompted a search for management schemes to bolster the wild population. Captive breeding was attempted for many years with isolated pairs at Audubon Park Zoo in New Orleans (1948–66), in confinement at Aransas (1948–51), and at the San Antonio Zoo (1967 to present) (McNulty
The notion of establishing a sizable captive flock by removing young whooping cranes from the Aransas-Wood Buffalo population was first proposed by Lynch (1956). Theoretically, whooping cranes produced by the captive flock could be released to augment the wild population as a hedge against catastrophic loss of the wild population. Hyde (1957) noted that sandhill cranes and whooping cranes usually lay 2 eggs but rarely raise 2 young. He suggested that a captive flock could be established without detriment to the wild population by removing 1 egg from each clutch. Erickson (1968) recommended first developing a surrogate flock of nonendangered sandhill cranes. In 1961, the USFWS established a captive flock of sandhill cranes at Monte Vista National Wildlife Refuge in Colorado to develop crane husbandry and propagation techniques. In 1966, the surrogate flock and a flightless male whooping crane recovered in Canada in 1964 were moved to Patuxent. In 1967, the second eggs from 6 nests in Wood Buffalo were taken to Patuxent. Egg taking has continued sporadically ever since (Table 1), with eggs sent either to Patuxent, to Grays Lake, Idaho, or, more recently, to the International Crane Foundation (ICF), Baraboo, Wisconsin. Management agencies and researchers generally believe that this egg harvest has not adversely affected, and may have actually increased, the number of chicks fledged each fall in Canada (Kuyt 1987; F. G. Cooch, pers. commun.).

During the colony's first decade at Patuxent, many disease and nutritional problems that initially impaired survival of whooping cranes in captivity were resolved (Erickson 1975, Carpenter 1977, Carpenter and Derickson 1982, Serafin 1981). It then became possible to address more subtle problems such as failure of neonatal young to feed, failure of pairs to bond and breed, and sexual imprinting of chicks on human caregivers (Kepler 1977). In 1975, the first fertile eggs were produced by a captive female at Patuxent. As problems with artificial insemination, incubation, and chick rearing were addressed, annual productivity increased (Archibald 1974, Kepler 1977, Gee 1979). The first chick fledged in 1976. Between 1975 and 1991, the Patuxent flock produced 255 eggs, of which 73 (61 known to be fertile) were transferred in an attempt to establish a second wild flock at Grays Lake. The captive population slowly expanded (Fig. 2), although it occasionally suffered major declines, as in 1984, when a major epizootic, eastern equine encephalitis (EEE), killed 2 males and 5 females. This outbreak and 2 other epizootics led to the decision to establish a second captive breeding flock at a site remote from Patuxent. In November 1989,
Table 1. Destination and fate of whooping crane eggs taken from Wood Buffalo National Park, 1967–91.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of eggs collected</th>
<th>Patuxent Wildlife Research Center</th>
<th>Grays Lake National Wildlife Refuge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of eggs received</td>
<td>No. of young fledged</td>
</tr>
<tr>
<td>1967</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>1968</td>
<td>11</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>1969</td>
<td>14</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>1970</td>
<td>7 (5 viable)</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>1971</td>
<td>10</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>1972</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1973</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1974</td>
<td>13 (11 viable)</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>1975</td>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1976</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1977</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1978</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1979</td>
<td>19</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1981</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1982</td>
<td>16</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1983</td>
<td>18</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1984</td>
<td>25</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1985</td>
<td>25 (23 viable)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1986</td>
<td>24 (24 viable)</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>1987</td>
<td>19</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>1988</td>
<td>26</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>1989</td>
<td>9 (3 viable)</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>1990</td>
<td>12* (11 viable)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1991</td>
<td>16 (9 viable)</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Totals</td>
<td>341 (320 viable)</td>
<td>121</td>
<td>48</td>
</tr>
</tbody>
</table>

* An additional 73 eggs (61 fertile from which 17 young fledged) from Patuxent were transferred to Grays Lake from 1976 to 1984.

b All 12 eggs were sent to ICF. Eleven hatched; 8 chicks fledged.

22 birds representing all families in the captive flock were transferred to the ICF.

The following factors compound the difficulty of propagating whooping cranes in numbers sufficient to build 3 captive colonies while supporting future reintroduction projects: (1) delayed sexual maturity (i.e., captive females at Patuxent first laid at 5 (2 females), 6 [2], 7 [3], 8 [3], 9 [2], 10 [1], 11 [1], and 18 [1] years of age: only 2/3 laid eggs by 8 years of age, Fig. 3), (2) moderate fertility levels (only 3/4 of captive-produced eggs are fertile), (3) moderate hatchability rates (only 3/4 of the fertile eggs hatch), (4) low fledging success (only 3/5 of the chicks fledge), and (5) demographic anomalies characteristic of small populations (e.g., unequal sex ratios and differential mortality). From these demographic factors, in Fig. 3 we project the size of the future captive population. However, unforeseen infusions of eggs from Canada and/or major mortality events can drastically alter these predictions.

REINTRODUCTION ATTEMPTS

The Translocation of a Single Bird

By 1947, only 1 wild bird remained in the marshes near White Lake, Louisiana (Fig. 1) (McNulty 1966, Doughty 1989). In an effort to retain the genetic contribution of this bird, the crane was captured by helicopter on
11 March 1950 and translocated by truck to join the Aransas-Wood Buffalo flock. On arrival, the dangerously weakened crane was penned and force fed for 2 days, then released into a freshwater marsh; later, it was attacked by 2 wild cranes. It was recaptured, fed, and released at a freshwater lake some distance from other whooping cranes. It survived through the spring and summer but was found dead in September. If nothing else, this attempt demonstrated some of the problems inherent in translocating adult cranes.

According to plan, the sandhill crane foster parents incubated the eggs and reared the young whooping cranes that hatched. The chicks also accepted their foster parents and followed them on migration. However, only 209 (72%) of the 289 whooping crane eggs transferred to Grays Lake hatched, and only 84 chicks (40% of the 209 that hatched or 29% of the original 289 eggs) fledged. High egg and chick mortality rates were associated with inclement weather and coyote (Canis latrans) predation (Drewien and Bizeau 1978, Drewien et al. 1985). Most cranes that managed to fledge died from powerline and other wire strikes (Brown et al. 1987) or from avian tuberculosis (Doughty 1989). Recruitment has not kept pace with mortality, and the Grays Lake whooping crane flock declined from a high of 33 birds in 1984–85 to 13 birds in 1991 (Drewien et al. 1989, Lewis 1990).

Low survival rates in young birds at Grays Lake were accompanied by the failure of surviving whooping cranes to form pair bonds and breed. Among breeding-age birds a preponderance of males caused by differences in male and female mortality contributed to this failure. More importantly, the few females that reached breeding age failed to pair with males on the wintering ground or the

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Fig. 2. Size of the captive whooping crane flock at Patuxent Wildlife Research Center, 1966 – 91.

The Grays Lake Experiment

The only reintroduction effort thus far attempted consisted of placing nearly 300 whooping crane eggs in greater sandhill crane (G. c. tabida) nests at Grays Lake. This experiment was designed to create a disjunct population of whooping cranes that, like their sandhill crane foster parents, would nest in Idaho and winter along the Rio Grande in west-central New Mexico (Drewien and Bizeau 1978). Beginning in 1975, each egg from Patuxent or Wood Buffalo was placed alone in nests of greater sandhill cranes.
spring staging areas and then scattered on northward migration, thereby further diminishing their chances of finding mates. Yearly attempts were made to capture these wandering females and transport them back to pair with wild males at Grays Lake. Because no pairing occurred naturally, 2 Patuxent-reared females were introduced to males at Grays Lake in 1981 and 1989 to see if cross-fostered males would pair normally. Both females seemed to form temporary pair bonds with wild males, but neither pairing resulted in eggs or in pairs that migrated south together (Drewien et al. 1989).

From projections of conservative values for age-specific mortality rates at Grays Lake, Garton et al. (1989) concluded that at best only 6 pairs of whooping cranes would be breeding after infusions of 30 eggs per year for 50 years. The future of the project had been under question since the mid-1980's. In March 1990, a decision was made to de-emphasize the Grays Lake experiment. The last egg transfer was in 1988, and no further transfers of captive-reared females are anticipated. Because of fear of transmitting avian tuberculosis to other flocks, captive or wild, there is little likelihood that any of the surviving birds in the Grays Lake flock will be added to any existing captive colony. Some or all could go to a separate facility.

The 13 birds remain under study in hopes of learning as much as possible for future experiments, and a decision concerning their fate is expected late in 1991. The Grays Lake population will either languish, then disappear, or be removed.

CHOOSING THE NEXT EXPERIMENTAL REINTRODUCTION SITE

Factors such as high mortality rates during migration (which may account for about 80% of the losses for birds in the Aransas- Wood Buffalo flock [U.S. Fish and Wildlife Service 1986]), disease hazards, and demographics, all recommend that the next reintroduction site have the following characteristics: (1) extensive suitable habitat, (2) geographical isolation from other wild populations (to limit effects of a single catastrophic mortality event [oil spill, storm, epizootic]), (3) a southern location that would discourage migration (and thereby limit migration related mortality and negate the need to teach birds to migrate), and (4) a location within the historic range of the species. Using these criteria, an obvious choice for the next reintroduction of a sedentary population would be the marshes north of White Lake in southern Louisiana. It seems logical to return the birds to the wild where they most recently lived. The creation of a nonmigratory population is also preferred because of risks noted during migration in the Grays Lake experiment.

In recent decades White Lake appeared to be unavailable as a reintroduction site because state and federal wildlife management agencies had strong reservations (Gomez 1992). The state feared that the declaration of critical habitat would impair waterfowl hunting and other forms of wildlife use. Federal agents feared that local customs, especially wildlife harvesting practices, would endanger any released birds. As a consequence, 3 other sites were evaluated from 1984 to 1987 (McMillen et al., in press): (1) the Upper Peninsula of Michigan (McMillen 1988), (2) Okefenokee Swamp in southern Georgia (Bennett, in press; Bennett and Bennett, in press), and (3) the Kissimmee Prairie region in central Florida (Bishop, in press). All areas have extensive wetlands, are somewhat removed from urban areas, and currently support sizable sandhill crane populations. Whooping crane breeding, however, has never been documented for any of the 3 areas, although Allen (1952) and Nesbitt (1982, 1988) report evidence that the species occurred and perhaps summered in Florida even into the present century.

In 1988, the USFWS decided to proceed with a whooping crane introduction experiment in Florida. Reasons favoring the Kissimmee Prairie include the extent of wetland habitat, the potential for establishing a nonmigratory flock, the high degree of state and local support for the project, favorable land use practices, and favorable human demographics.

Unfortunately, the Kissimmee Prairie poses risks of Venezuelan equine encephalitis and avian tuberculosis; an EEE zone is also nearby. Although EEE outbreaks have been reported for southwestern Michigan, Carpenter et al. (1989) concluded that of the 3 areas being evaluated, the risk of contact with EEE was least likely for birds breeding in northern Michigan. Cranes breeding there would
probably visit southern regions only in winter, when EEE transmission is less likely because of reduced activity of the mosquito vector.

REINTRODUCTION TECHNIQUES

Reintroduction techniques for fledged cranes were described by Konrad (1976), Derrickson and Carpenter (1983), Horwich (1986, 1989), Horwich et al. (in press), Bizeau et al. (1987), Ellis et al. (1992), and Urbanek and Bookhout (1992). The techniques most likely to be employed in future whooping crane introduction attempts are listed below.

High survival rates have been achieved in releases of parent-reared Mississippi sandhill cranes. Two-thirds of the birds released from 1981 to 1989 survived for at least 1 year (McMillen et al. 1987, Zwank and Wilson 1987, Ellis et al. 1992). During the past 5 years, at least 13 captive-reared Mississippi sandhill cranes have paired or bred in the wild.

Although various attempts have been made to release hand-reared birds, until the mid-1980's hand-reared birds generally proved unsuitable. For example, none of 14 hand-reared birds released without acclimation near Lake Okeechobee, Florida, integrated into the wild flock, and within a few months all had died (Nesbitt 1979). In recent experiments, sandhill crane chicks have been reared in relative isolation from humans. In addition, some chicks are penned in visual and auditory (but not physical) contact with adult cranes. These chicks are handled by costumed caretakers, are taught to feed using either a puppet head (ICF) or a taxidermic mount crane head (Patuxent), and are brooded by a taxidermic brooder mount. From these rearing regimes fledged birds released in Wisconsin, Michigan, and Mississippi have survived well, and many birds have paired with wild cranes (Urbanek 1990, unpubl. data; Archibald and Archibald, in press; Ellis et al. 1992; G. W. Archibald, pers. commun.). It is, of course, important for release birds to have an extended on-site acclimation period (ca. 1 month is recommended for birds transferred from an off-site captive-rearing center) if they are to survive well. Even parent-reared birds survive poorly if released without acclimation (Drewien et al. 1982).

FUTURE RECOVERY GOALS AND SCHEDULE

The USFWS and Canadian Wildlife Service (CWS) have separately published recovery plans for the whooping crane (U.S. Fish and Wildlife Service 1986, Cooch et al. 1988). Common goals in the recovery plans are increases in the size of current wild and captive flocks and establish-

ment of at least 2 additional, disjunct, wild flocks in the near future. The 2 agencies also operate under a 1990 Memorandum of Understanding (MOU) that dictates cooperative decision-making in the day-to-day management of captive and wild whooping crane populations.

Increasing the Size of the Aransas-Wood Buffalo Flock

Both USFWS and CWS recovery plans agree on the need to increase the Aransas-Wood Buffalo flock. Because increases in the wild flock depend primarily on natural recruitment, recovery plans stress the need to reduce mortality. Specific concerns include identifying and evaluating disturbances and developing contingency plans for rapid containment of hazards such as oil spills, disease, and human or "pest" disturbances. Plans also call for identifying and preserving essential habitat for use in winter, during migration, and during the breeding season.

Although extraordinary efforts have been made to build captive whooping crane colonies and to create a wild flock at Grays Lake, we emphasize that the expansion of the Aransas-Wood Buffalo flock (Fig. 1) has been due entirely to endogenous production. Not 1 egg or crane has come from the captive colonies. This statement is not meant to demean human efforts in the crane's behalf; for surely, without intensive efforts to create refuges and to educate hunters along the flyway, the population would not have grown to its present number (about 140 birds) (Fig. 1). Furthermore, beginning in 1984, the second fertile eggs from many nests in Canada were moved to nests where pairs were incubating infertile eggs. This type of manipulation should result in more pairs fledging chicks than would have occurred naturally (F.G. Cooch, pers. commun.).

Captive Populations

Recovery goals to be achieved by 1995 include increasing the size of captive breeding flocks to 15 breeding pairs at Patuxent and 10 breeding pairs at the ICF and establishing an additional captive flock at the Calgary Zoo in Alberta, Canada. Pen construction began at Calgary in 1991 and will be completed by summer 1992. The staff will work with sandhill cranes in 1992 and will probably receive their first whooping crane eggs from Patuxent, ICF, or perhaps Wood Buffalo in 1993.

Recovery plans also emphasize maximizing genetic diversity in the captive flocks by selectively harvesting eggs from the Wood Buffalo flock and utilizing other genetic management techniques. The plans also call for research to enhance captive reproduction by further refining incuba-
tion, hatching, and rearing procedures, and by behavioral management of pairs.

Establishing Additional Wild Flocks

Long-term survival of whooping cranes can be ensured by establishing disjunct captive and wild populations. Before the bird is "down listed" from endangered to threatened status, the USFWS recovery plan calls for at least 2 additional wild flocks (each flock with a minimum of 25 nesting pairs) (U.S. Fish and Wildlife Service 1986). "Delisting" could occur as even more flocks are established.

After the decision was made to discontinue the Grays Lake experiment, it became urgent to choose alternate destinations for the eggs from Wood Buffalo. In 1989-90, most of the second eggs in each clutch were sent to the captive colonies although a few clutches were left with 2 eggs. Another likely use of these eggs is to establish new wild flocks. In 1988, the USFWS, with the concurrence of the CWS, agreed on the Kissimmee Prairie for the next whooping crane reintroduction experiment. Additional reintroduction experiments are also likely in Canada during the present decade.

Long-term survival of any reintroduced wild flock depends on the same factors that Griffith et al. (1989) associated with successful translocation of other avian groups: (1) large founder populations, (2) suitable habitat, and (3) high fecundity. These conditions can be only partially met in any whooping crane release.

PROJECTIONS, GOALS, AND CONCLUSIONS

With the expansion of the Aransas-Wood Buffalo population to over 140 birds, the growth of the Patuxent flock to about 40 birds, the establishment of the ICF flock with 30 birds, and the construction of a new propagation facility at the Calgary Zoo in Alberta, we are optimistic about whooping crane recovery. This optimism is reflected in the previously mentioned MOU signed in April 1990 by the USFWS and the CWS calling for joint cooperation in (1) enhancing and preserving habitat, (2) increasing bird survival rates, (3) improving bird and egg transfer practices, (4) establishing new captive flocks and wild populations, (5) determining disposition of specimens and handicapped birds, and (6) deciding on the best uses for wild and captive-produced birds and eggs.

The USFWS recovery plan (U.S. Fish and Wildlife Service 1986) calls for expansion of the Aransas-Wood Buffalo population to 40 breeding pairs by the turn of the century and the establishment of 2 additional wild populations by 2020. The CWS (Cooch et al. 1988) calls for a separate population of 25 pairs in the United States and another population of at least 5 pairs in Canada by 2010.

A recent draft appendix to the CWS plan (F.G. Cooch, pers. commun.) provides a 5-year action plan governing the fate of eggs from Canada and the captive flocks. The young surviving from eggs harvested in Canada in 1992 and from captive production are to be transferred to Florida to begin reintroduction experiments. The 1991 and 1993 eggs from Canada are to be used to help build the captive flocks. Beginning in 1994, captive colonies are to provide 20 young each year for 10 years to establish a wild flock in Florida. Some eggs from Canada may provide chicks to supplement the early Florida releases. A new 5-year action plan will be developed for the 1995–2000 period. If all proceeds satisfactorily, another release may begin in Canada in the late 1990's while the Florida release is still underway.

As in the past, all increases in the Aransas-Wood Buffalo population will be from natural reproduction and recruitment. Although no eggs or birds are to go to Wood Buffalo from captive flocks, fertile eggs in the nests in Wood Buffalo will be distributed so that nesting pairs have at least 1 viable egg.

In the 1940's, the whooping crane teetered on the brink of extinction; fewer than 30 birds remained in the world. In the intervening 5 decades, the wild population has expanded 7-fold, while sustaining a massive effusion of 349 eggs to build the Grays Lake flock and captive flocks. The recovery of the whooping crane, although not yet complete, stands as a singular marvel in the annals of wildlife conservation.

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SEXUAL SIZE DIMORPHISM AND SIZE INDICES OF SIX SPECIES OF CAPTIVE CRANES
AT THE INTERNATIONAL CRANE FOUNDATION

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Abstract: Sexual size dimorphism and size indices in captive cranes were studied to learn dimorphism patterns and size relationships that could be used in the management of captive cranes. In 6 species of captive cranes, Siberian (Grus leucogeranus), eastern sarus (G. antigone sharpii), white-naped (G. vipio), common (G. grus), hooded (G. monacha), and red-crowned (G. japonensis), males averaged 14.5–22.5% heavier than females (P < 0.05) in all species. Males had longer culmens, tarsi, and wing chords in all species. Males had significantly longer culmens (P < 0.05) in 4 of 6 species and had significantly longer tarsi than females (P < 0.05) in 3 of 6 species. Culmen and tarsus lengths both averaged 7% longer in males than females when the 6 species were combined. Wing chord length was not significantly dimorphic (P > 0.05) in any of the 4 species measured (Siberian, white-naped, hooded, and red-crowned cranes), averaging only 1.3–3.3% longer in males than in females. Body weight correlated significantly with culmen length, culmen + tarsus length, and culmen × tarsus length in 5 of 6 species (P < 0.05). Weight covaried significantly with culmen length in 4 species, and with wing length in 1 species (P < 0.05). Sex-specific linear regression models predicted weight from linear measurements more accurately than when both sexes were combined, suggesting differences in body scaling between sexes in some species. The best regression formulae used linear measurements to predict crane weights at the International Crane Foundation (ICF) within 1.2–4.2% of actual weight for 5 of the 6 species. Because ICF cranes weighed more than cranes from 3 other zoos sampled, these regression formulae were poor predictors of crane weights at those zoos. Body weight was the best index of overall size within a site, followed by culmen + tarsus and culmen × tarsus. Culmen + tarsus and culmen × tarsus are probably the best indices of overall size among sites. Wing chord and weight measurements vary over time, so caution should be used when comparing these among individuals. All species gained weight between September and November. Red-crowned and Siberian cranes undergo large fall weight gains and remain heavier than normal all winter. Sexual size dimorphism could be used to determine the sex of some crane species. Using normal weights of cranes may help detect potentially unhealthy weight changes (usually losses) in captive or rehabilitated cranes.

Key Words: crane, Grus, sexual size dimorphism, size indices

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Cranes are monomorphic in plumage, with slight sexual size dimorphism (Walkinshaw 1973, Johnsgard 1983). Several studies of wild cranes (Blackman 1971, Aldrich 1979, Tacha et al. 1989) have demonstrated that males average larger than females, but that much size overlap exists. Among wild pairs of brolgas (G. rubicunda), males were larger than their mates in 20 of 20 cases (Blackman 1971), suggesting assortative mating by size.

Murata et al. (1988) developed a method of predicting the sex of most captive red-crowned cranes by discriminant analysis. Soviet researchers used body measurements to develop a discriminant function that can correctly assign sexes to nearly all wild common cranes they have captured (Y. Markin, Oka State Nature Reserve, pers. commun.). There are few published data on normal weights and measurements of captive cranes (e.g., Johnsgard 1983), so crane breeders and wildlife rehabilitators are often unable to determine whether their cranes are heavier or lighter than normal. Crane weights vary over time. Therefore, weights from different seasons are needed in order to assess a species’ weight variation pattern.

I examined sexual size dimorphism in 6 species of cranes and generated models to predict crane weights from body measurements. I also compared different size indices in an effort to determine which measurements best describe a crane’s overall size. I quantified fall weight changes in several species in order to characterize part of the annual weight cycle of captive cranes. I then compared sexual size dimorphism patterns and relationships among size measurements of cranes at the International Crane Foundation (ICF) to those of captive cranes at 3 widely disparate localities to learn whether trends I observed at ICF were general or site-specific.

I gratefully acknowledge the ICF staff, who collected many of the measurements used in this study. V. Panchenko (U.S.S.R. Rare Crane Center), the Korat Zoo, Thailand, and J. Barzen provided additional measurements of cranes. I thank G. Archibald, M. Fuller, J. Harris, J. Langenberg, C. Mirande, G. Olsen, and an anonymous reviewer for their valuable comments on earlier drafts of this paper.

STUDY AREA

Cranes housed on ICF’s 2 sites (43°29'–43°32'N, 89°45'W) were used in this study. The ICF is a non-profit foundation started in 1973 with the purpose of protecting
the world's cranes and their wetlands. During the study period ICF housed a captive breeding flock of 125 individuals of 14–15 species of cranes. Cranes at ICF have a constant supply of fresh, pelleted food. Because they live in 275-m² pens, the cranes are unable to exercise as much as wild cranes. I also used published and unpublished measurements of captive cranes from a variety of latitudes, including The U.S.S.R. Crane Center at the Oka Nature Reserve (Oka Center) (55°N), Japanese zoos (35°N), and the Korat Zoo, Thailand (15°N), to corroborate or test some of my results.

METHODS

I compiled tarsus, wing chord (distance from the wrist to the tip of the longest unflattened primary), and exposed culmen lengths (Pettingill 1970;446) of Siberian, common, hooded, and red-crowned cranes measured during annual physical exams at ICF in October 1980. I took the same measurements on eastern sarus cranes (of Australian origin) in August 1986 and on white-naped cranes in October 1989. Within a species, all measurements were taken by the same personnel to minimize measurement bias. I collected all weights that were recorded on these measured cranes' medical records from 1980 to 1990, but excluded weights taken when cranes were ill or injured, or when cranes were less than 16 months old (i.e., not fully adult weight). The largest sample of weights (up to 11 per individual because I collected weights from 11 calendar years) was gathered in October during the annual physical exam. Samples were only 1–2 per individual for other months, so I used October weights as baseline values. I used the mean October weight of each individual for statistical analyses. Male Siberian cranes measured in 1980 weighed less than other conspecific males at ICF, so I included weights of all adult Siberian cranes for comparing males to females. Different species of cranes differ in sizes and body shapes, so all comparisons were intraspecific.

Cranes at ICF weigh more in winter than in summer, so I examined seasonal weight variation. I compared weights taken in October to those taken in the months immediately preceding or following October. Only months pairs that included October had large enough sample sizes for statistical analyses. I also examined seasonal weight changes in 13 Siberian cranes from the Oka Center (V. Panchenko, Oka Center, unpubl. data).

I tested for correlations (multiple coefficient of correlation, $R$) among weight, culmen, tarsus, and wing chord measurements. The results suggested that an index combining tarsus and culmen lengths would be a good size descriptor, so I tested for correlations between culmen + tarsus length (culfans) and culmen × tarsus length (tars-

cul) vs. wing chord length and body weight.

To determine whether one can accurately predict crane weights from linear measurements, I calculated regression formulae and ANOVA's for tarsus length vs. weight, culmen length vs. weight, culfans vs. weight, and tarscul vs. weight for 3 groups: all cranes of a species, males of each species, and females of each species. Using these regression formulae, I calculated 8 predicted weights (4 regressions on all cranes of that species and 4 sex-specific regressions) for each crane. I calculated the deviation of predicted weight from actual weight for each crane and each formula, and determined which formula predicted weight most accurately for all cranes of a species, males, and females.

To test whether the weight prediction models developed from ICF's cranes are applicable to captive cranes in general, I used the models to predict weights of red-crowned cranes from zoos in Kobe, Okayama, and Osaka, Japan (Murata et al. 1987), Siberian cranes from the Oka Center (V. Panchenko, unpubl. data), and eastern sarus cranes from the Korat Zoo, Thailand (J. Barzen, ICF, unpubl. data). I compared weights of cranes from all these captive centers to learn the degree of weight variation found in captive cranes at different sites. All statistical analyses were performed by the SYSTAT (SYSTAT, Inc., Evanston, Illinois) database program.

RESULTS

Sexual Size Dimorphism

Male cranes of all 6 species averaged larger than females for every measure of size (Table 1). October weight was the most dimorphic character; males were significantly heavier than females in all 6 species ($P < 0.05$, independent t-test) (Table 2). Culmen and tarsus measurements exhibited significant sexual dimorphism in 4 and 3 species, respectively ($P < 0.05$, independent t-test). Wing chord length exhibited small, non-significant differences between sexes in Siberian, white-naped, hooded, and red-crowned cranes.

The degree of weight dimorphism, ranging from 14.5% to 28.5%, was larger than the dimorphism in linear measurements in all 6 species (Table 2). Culmen and tarsus lengths each averaged 7% larger in males than females. The magnitude of linear measurement dimorphism was greatest in the species that had the most weight dimorphism.

There were interspecific differences in the magnitude of sexual size dimorphism. The most dimorphic species were the common, eastern sarus, and white-naped cranes, and the least dimorphic were hooded and red-crowned
### Table 1. Linear measurements (mm) and October weights (g) of males and females of 6 species of cranes at ICF.

<table>
<thead>
<tr>
<th>Species</th>
<th>Culmen</th>
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<th>Tarsus</th>
<th></th>
<th></th>
<th></th>
<th>Wing chord</th>
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<th>October weight</th>
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<td>Range</td>
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<td>Range</td>
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<td>$\bar{x}$</td>
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<tr>
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<td>277.6</td>
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</tr>
</tbody>
</table>

* Grand mean of mean October weights.

Cranes. The Siberian crane exhibited an intermediate amount of sexual size dimorphism. In eastern sarus, white-naped, and hooded cranes there was no overlap in mean October weight of males vs. females. The lightest male averaged at least 5% heavier than the heaviest female. In the other 3 species, 1 large female weighed more than at least 2 males. Even in the 3 species where all males had higher mean October weights than all females, however, single female weights (most individuals were weighed in several different Octobers) were sometimes higher than the lowest individual male October weight.

### Seasonal Weight Variation

An individual crane's weight varied as much as +10% from its mean between Octobers in consecutive years. Cranes weighed less during the warm months preceding October and continued to gain weight after October (Table 3). Between September and November, mean weights increased 15% in Siberian cranes, 9% in white-naped cranes, and 10% in red-crowned cranes. Wherever the sample size was larger than 5, October weights were significantly higher than September weights and lower than November weights ($P < 0.05$, paired $t$-test). More than 95% of individual November weights were higher than the crane’s mean October weight.

Siberian and red-crowned cranes remained heavier than average into the winter. Red-crowned cranes at ICF weighed 34% more, and Siberian cranes 23% more, in December than in July. Similarly, Siberian cranes at the Oka Center (V. Panchenko, unpubl. data) averaged 23.0% heavier (range 11.5–36.0%, $n = 13$) ($P < 0.001$, paired $t$-test) in January 1983 than in August 1982.

### Relationships Between Linear Measurements and Weight

Weight was significantly correlated with tarsus length in 5 of the 6 species ($P < 0.05$, Pearson's product-moment correlation matrix) (Table 4). Weight covaried strongly
Table 2. Percentage that males averaged larger than females in 6 species of cranes at ICF. Probabilities* are from independent t-tests.

<table>
<thead>
<tr>
<th>Species</th>
<th>Culmen</th>
<th>Tarsus</th>
<th>Wing chord</th>
<th>October wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siberian</td>
<td>11.7*</td>
<td>6.3</td>
<td>1.9</td>
<td>16.3***</td>
</tr>
<tr>
<td>Eastern sarus</td>
<td>11.6**</td>
<td>8.6**</td>
<td>2.3</td>
<td>27.9***</td>
</tr>
<tr>
<td>White-naped</td>
<td>7.4*</td>
<td>7.5**</td>
<td>3.3</td>
<td>23.6***</td>
</tr>
<tr>
<td>Common</td>
<td>5.1*</td>
<td>11.1*</td>
<td>28.5**</td>
<td></td>
</tr>
<tr>
<td>Hooded</td>
<td>2.6</td>
<td>3.3</td>
<td>1.3</td>
<td>14.5***</td>
</tr>
<tr>
<td>Red-crowned</td>
<td>4.3</td>
<td>4.2</td>
<td>2.0</td>
<td>19.4*</td>
</tr>
</tbody>
</table>

* *P < 0.05, **P < 0.01, ***P < 0.001.

with culmen length in 4 of the 6 species (P < 0.05, Pearson's product-moment correlation matrix). Weight was more highly correlated (multiple coefficient of correlation, R) with tarsus length than with culmen or wing chord lengths in all 6 species. Weight correlated significantly with wing chord in only 1 species and had a weak negative correlation with hooded crane wing length.

Cultars and tarscul, which combine culmen and tarsus lengths, each correlated more highly with weight than the other 3 measurements in at least 5 of the 6 species (Table 4). Cultars and tarscul were about equally correlated with weight. Since body weight appeared to be geometrically related to linear measurements, I examined the correlation between cultars², cultars³, tarscul², and tarscul³ and body weight. In several cases (some common and eastern sarus cranes, and male white-naped cranes) some of these 4 size indices were significantly correlated with October weight, but they were never as highly correlated with body weight as the best of the other linear measurements or their derivatives I examined.

Culmen length correlated significantly with tarsus length in 3 species and with wing chord length in 2 species (Table 4). Wing chord length covared strongly with tarsus weight in 2 species, with cultars in 3 species, and with tarscul in 2 species (Table 4). Culmen length generally correlated more highly with tarsus and wing chord lengths than did the latter 2 measurements with each other.

Sex-specific Size Relationships

The 2 sexes of a species generally had similar scaling among measurements, but there were several sex differences. For example, in male Siberian cranes tarsus length correlated more highly with culmen and wing lengths than it did in females.

Female measurements correlating significantly with October weight were culmen (P = 0.026), cultars (P = 0.030), and tarscul (P = 0.012) in Siberian cranes, and tarscul (P = 0.025) in hooded cranes. Male common cranes showed significant relationships between October weight and tarsus, cultars, and tarscul measurements (P = 0.014, 0.004, and 0.001, respectively). Male Siberian cranes had significant correlations between October weight and culmen, tarsus, cultars, and tarscul (P = 0.048, 0.039, 0.042, and 0.043, respectively). Probabilities were derived from Pearson's product-moment correlation matrix.

Predicting Weight from Linear Measurements

Many regression models produced statistically significant estimators of weight from linear measurements, especially in Siberian, eastern sarus, white-naped, and common cranes (ANOVA, significance levels are the same as for the correlations in Table 4). Cultars and tarscul typically produced the best regression model estimators of body weight. Sex-specific models produced more accurate estimates of weight from measurements than models combining both sexes in 43 of 48 comparisons. Because of their smaller sample sizes, however, sex-specific relationships among size measurements were statistically significant less often than in all-crane models.

The best 2–4 estimators of body weight for each species and sex had mean errors from actual weight of 1.2–3.0% in Siberian cranes, 1.3–3.5% in eastern sarus cranes, 2.3–3.3% in white-naped cranes, 2.7–4.2% in common cranes, 2.3–3.0% in hooded cranes, and 5.7–9.7% in red-crowned cranes. Averaging the predicted weights from the best 3 or 4 regression models sometimes produced more robust predictors of weight from measurements. This technique reduced the mean error of weight predictions in female Siberian cranes from 1.7% to 0.7%.

Table 3. Seasonal weight variation in 6 species of cranes at ICF. October weight = 100. Probabilities* are from paired t-tests comparing October weight to weights from other months.

<table>
<thead>
<tr>
<th>Species</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siberian</td>
<td>90.6</td>
<td>93.6**</td>
<td>100.0</td>
<td>108.1***</td>
<td>111.7</td>
<td></td>
</tr>
<tr>
<td>Eastern sarus</td>
<td>96.7</td>
<td>94.9</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-naped</td>
<td>96.5*</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common</td>
<td>89.2**</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hooded</td>
<td>97.4</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red-crowned</td>
<td>92.5</td>
<td>95.8*</td>
<td>100.0</td>
<td>105.7**</td>
<td>124.2*</td>
<td></td>
</tr>
</tbody>
</table>

* *P < 0.05, **P < 0.01, ***P < 0.001.
Table 4. Multiple coefficients of correlation (R) among linear measurements and between linear measurements and mean October weight in 6 species of cranes at ICF. Probabilities* are derived from Pearson's product-moment correlation matrix.

<table>
<thead>
<tr>
<th>Species</th>
<th>Culmen</th>
<th>Wing chord</th>
<th>Tarsus</th>
<th>Culmen + tarsus</th>
<th>Culmen × tarsus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siberian</td>
<td>0.893**</td>
<td>0.442</td>
<td>0.908**</td>
<td>0.919***</td>
<td>0.911**</td>
</tr>
<tr>
<td>Eastern sarus</td>
<td>0.873**</td>
<td>0.751**</td>
<td>0.914**</td>
<td>0.976***</td>
<td>0.968***</td>
</tr>
<tr>
<td>White-naped</td>
<td>0.751**</td>
<td>0.665</td>
<td>0.841***</td>
<td>0.825***</td>
<td>0.809**</td>
</tr>
<tr>
<td>Common</td>
<td>0.776**</td>
<td>0.304</td>
<td>0.830***</td>
<td>0.868***</td>
<td>0.893***</td>
</tr>
<tr>
<td>Hooded</td>
<td>0.397</td>
<td>-0.205</td>
<td>0.463</td>
<td>0.546</td>
<td>0.570</td>
</tr>
<tr>
<td>Red-crowned</td>
<td>0.395</td>
<td>0.586*</td>
<td>0.612*</td>
<td>0.587</td>
<td></td>
</tr>
<tr>
<td>Siberian</td>
<td>0.583</td>
<td></td>
<td>0.881**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern sarus</td>
<td></td>
<td></td>
<td>0.680</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-naped</td>
<td>0.862**</td>
<td></td>
<td>0.902***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common</td>
<td>0.614</td>
<td></td>
<td>0.636*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hooded</td>
<td>0.369</td>
<td></td>
<td>0.111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red-crowned</td>
<td>0.853**</td>
<td></td>
<td>0.376</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siberian</td>
<td>0.492</td>
<td></td>
<td>0.384</td>
<td>0.398</td>
<td></td>
</tr>
<tr>
<td>White-naped</td>
<td>0.732*</td>
<td></td>
<td>0.808**</td>
<td>0.838**</td>
<td></td>
</tr>
<tr>
<td>Common</td>
<td>0.842*</td>
<td></td>
<td>0.826*</td>
<td>0.790</td>
<td></td>
</tr>
<tr>
<td>Hooded</td>
<td>-0.176</td>
<td></td>
<td>0.054</td>
<td>0.066</td>
<td></td>
</tr>
<tr>
<td>Red-crowned</td>
<td>0.349</td>
<td></td>
<td>0.636*</td>
<td>0.740**</td>
<td></td>
</tr>
</tbody>
</table>

* **p < 0.05, ***p < 0.01, ****p < 0.001.

but did not improve weight predictions for male Siberian cranes.

Application of Results to Cranes From Other Zoos

Siberian cranes at the Oka Center exhibited the same degree of sexual size dimorphism as ICF cranes. Males (n = 10) had significantly larger weights and culmen lengths than females (n = 4) (P = 0.020 and P = 0.005, respectively, independent t-test). Oka males had nearly significantly longer tarsi (P = 0.052, independent t-test) than females. Unlike the ICF Siberian cranes, the Oka birds had no significant correlations between linear measurements and weight. Tarsus and culmen lengths were the only measurements of Oka cranes that covaried strongly (P = 0.036, Pearson's product-moment correlation matrix). Mean weight of Oka cranes was 0–5% lower than for ICF cranes of the same sex.

Weight of eastern sarus cranes in the Korat Zoo, Thailand, was significantly correlated with culmen, culmars, and tarscul (P = 0.016, 0.030, and 0.020, respectively), and nearly correlated with tarsus length (P = 0.060) (all probabilities derived from Pearson's product-moment correlation matrix). These results were similar to those of the ICF cranes. The Korat cranes exhibited larger linear measurements than ICF cranes, but the ICF cranes weighed an average of 0.8 kg (>14%) more than the Korat cranes.

Regression models developed from the ICF data were inaccurate at predicting weights of cranes at other sites from linear measurements. My weight predictions of Siberian cranes at the Oka Center had an average error of 12% from the cranes' true weights. This was in part because the regression model overestimated the weight of both sexes of Oka Siberian cranes by 3.8%. My regression model overestimated the weight of red-crowned cranes from Japanese zoos (Murata et al. 1987) by 18% for males and 24% for females. The regression model overestimated weights of eastern sarus cranes in the Korat Zoo, Thailand, by 31%. The Korat eastern sarus cranes were of Asian origin, whereas their conspecifics at ICF were of Australian stock; this difference in genetic background, however, is of unknown significance. In summary, among birds having similar linear measurements, ICF birds weighed slightly more than Oka (55°N) birds, a large amount more than Japanese zoo (35°N) birds, and an
even larger amount more than captive birds in Thailand (15°N).

DISCUSSION

Value of Different Body Measurements

October weight was the best index of size in the 6 species of cranes I examined, because it correlated more highly with linear measurements than did linear measurements with one another. Murata et al. (1988) used culmen, tarsus, tail, and wing chord lengths in their discriminant function for predicting red-crowned crane sexes. In that study, as in this one, culmen and tarsus lengths were the linear measurements exhibiting the highest correlations with other measurements. Y. Markin and V. Krever (Oka State Nature Reserve, pers. commun.) use body length, culmen, and tarsus measurements to predict wild common crane sexes. Wing chord and tail measurements can be at least 10% smaller than normal on captive cranes due to feather wear, especially in aggressive male cranes. Tail wear in captive cranes results in shorter than normal body lengths; therefore, body length data are not as useful. Culmen and tarsus lengths, which remain relatively stable, are the best size indices among linear measurements for captive cranes. Cullars and tarsus combine these 2 size measurements and are therefore better size indices than either culmen or tarsus length alone. In captive cranes having overgrown bills, culmen length is not a reliable size index.

Magnitude of Sexual Size Dimorphism

The degree of sexual size dimorphism I found in captive cranes is similar to that found in wild sandhill cranes (G. canadensis) by Aldrich (1979) and slightly less on average than that exhibited by wild brolgas (Blackman 1971). Compared to wild birds (Walkinshaw 1973, Johns-gard 1983), I found significantly more sexual size dimorphism in common cranes, slightly to moderately more sexual size dimorphism in Siberian, eastern sarus, and white-naped cranes, and a similar degree of size dimorphism in red-crowned and hooded cranes. Captive red-crowned cranes in Japan had an average of twice as much sexual size dimorphism in tarsus, culmen, and wing chord lengths (Murata et al. 1988) and 1.5 times as much weight dimorphism (Murata et al. 1987) as their conspecifics at ICF.

Ecological Correlates of Sexual Size Dimorphism

I could detect no taxonomic, ecological, or geographic-
**Latitudinal Weight Variation**

Although I believed that the tropical eastern sarus crane would exhibit less seasonal weight variation than the high latitude nesting cranes, there were not enough weight data on the eastern sarus crane to test this hypothesis. The nonmigratory Florida sandhill crane (G. c. pratensis), however, experiences smaller fall weight gains at ICF than the 3 species for which I had adequate data to compare September and November weights (Table 3). This crane weighed an average of only 7.7% more in November than in September (n = 8) at ICF.

Captive crane weights were positively correlated with latitude. ICF (43.5°N) and Oka (55°N) Siberian cranes weighed about the same. ICF red-crowned cranes weighed 18-24% more than their conspecifics having the same linear measurements in Japanese zoos (35°N). The raw weights of ICF cranes were only 8-15% larger than those of the Japanese zoo cranes, however, since the Japanese cranes had larger average linear measurements than the ICF cranes. Similarly, the Korat, Thailand (15°N), eastern sarus cranes had longer measurements than ICF cranes but weighed substantially less. ICF cranes had raw weights of 14% more than the Korat cranes, but were 31% heavier when I applied my regression models to cranes having similar linear measurements. Since these weight comparisons among pairs of sites each employed a different species of crane, I urge caution in interpreting the relationship between crane weights and latitude. Different diets and husbandry among the captive sites could greatly affect crane weights. There might also be geographical differences in cranes that make size indices difficult to apply over 9 wide geographic areas. For example, condition indices of wild sandhill cranes developed in 1 study (Iverson and Vohs 1982) do not always agree with those from another study (Johnson et al. 1985), nor do they necessarily produce accurate estimates of fat content of cranes in other studies (Tacha et al. 1985a).

**MANAGEMENT IMPLICATIONS**

**Robustness of Size Indices**

No single measure of size correlates well with all other size indices. Therefore, one must use several measures of size when measuring sexual size dimorphism or developing models to predict weight from measurements in captive cranes. Models predicting the mass of fat reserves in wild cranes are more reliable when body weight is combined with structural size indices (e.g., tarsus, wing chord, culmen, keel, or body length) than when weight alone is used (Iverson and Vohs 1982, Johnson et al. 1985). Weight, tail, body, and wing chord lengths vary greatly over time in captive cranes. Weight was the best index of size among these 4 variables because, unlike the others, it varies on a predictable annual cycle. However, crane weights are accurate size indices only when they are taken at the same time of year. Culmen and tarsus measurements are reliable size indices at any time. I recommend that weight, cultrum, and tarsus be used as size indices in captive cranes within a site. Among sites, cultrum and tarsus are better indices than weight for comparing crane sizes. In wild birds, which may have less feather wear than captive birds, wing, body length, and tail measurements can be useful indicators of size.

Since captive crane weights change rapidly during the spring and fall, comparisons of their weights should consider what time of year the weights were taken. Captive cranes in temperate to high latitudes will be heaviest in winter and lightest in summer. Most cranes at ICF lose weight during March—May (pers. observ.), mirroring their fall weight gains.

**Sex Determination Based On Size**

There is potential for developing discriminant functions to identify sexes of several species of cranes, but this task is beyond the scope of this paper. The red-crowned crane, which has only moderate sexual size dimorphism among cranes, was dimorphic enough in Japanese zoos for Murata et al. (1988) to determine the sex of most individuals based on size. Two of 14 females, however, were classified as males by the discriminant function. Eastern sarus cranes at ICF exhibited sexual size dimorphism by the time they were 100 days old and displayed no overlap in weights of the 2 sexes (Hesch 1987) (P < 0.001, independent t-test done by me; sex of the largest "female" is now known to be male).

**Weight Variation and Health**

Ill or injured cranes are frequently underweight (Carpenter 1979). Veterinarians, crane managers, and wildlife rehabilitators could more accurately assess crane weights if there were normal published values. However, the large seasonal variation in some species can make single weights less useful clinically, until more data on seasonal weight variation can be obtained. The weight data and discussion of seasonal weight changes in this paper give some indication of the normal range of crane weights. Crane weights vary among sites due to environmental and dietary differences. As noted above, cranes in temperate zoos probably weigh more than cranes in subtropical zoos.

When a crane weighs less than usual but shows no
signs of illness or injury, one should reweigh the crane at a reasonable interval. Sometimes a second weighing confirms that the crane is abnormally light and should be examined further. Ideally, one should compare the crane’s weight with its previous weight at the same time of year. Comparing its weight to that of another crane is useful and can be used if no previous weights for that individual crane are recorded. Crane weights change rapidly during spring and fall, such as a red-crowned crane that weighed less than average in October but had gained 3.1 kg (37%) and was at his highest recorded weight by the time we reweighed him in December. The plumpness of the crane’s keel indicates its nutritional status as well. Comparisons of keel condition to other cranes of the same species can indicate whether a crane is malnourished. Individual cranes of a species vary in their normal keel plumpness as well as in weight, however, and it is best to have data from the same individual. Some individual Siberian, sarus, brogoa, whooping (G. americana), wattled (Bugeranus carunculatus), black crowned (Balaeniceps rex), and gray crowned cranes (B. regulorum) normally have very thin keels during summer and relatively thin keels the rest of the year (pers. observ.). Conspicuous of these individuals are consistently plumper.

A poor appetite sometimes indicates that a crane is ill, but cranes sometimes fast when they have large fat reserves and the weather becomes warm. Red-crowned and Siberian cranes at ICF frequently eat little or no food for several days during warm spells from February to April (pers. observ.). Weighing a crane can indicate whether the crane is ill or simply fasting due to warm weather. If the crane is at the low end of its weight range and still fasts, it might be ill. This is another instance in which established normal weight criteria would be invaluable.

LITERATURE CITED


