SPRING HABITAT USE BY PEN-REARED MISSISSIPPI SANDHILL CRANES RELEASED ON A NATIONAL REFUGE

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Abstract: Diurnal habitat-use of pen-reared Mississippi sandhill cranes (Grus canadensis pulla) released into the wild was determined by monitoring movements of five radio-transmittered individuals. Seven habitat types were delineated: pine woodland, wooded drainage, hydric savanna, mesic savanna, pine plantation, agricultural land, and fallow land. A total of 176 telemetric locations was recorded from 3 March through 29 April 1982. Over 50% of locations were in hydric and mesic savanna. Thirty-two percent of locations were recorded from hydric savanna, whereas hydric savanna comprised only 4% of available habitat. Pine woodland was used the least. Only one crane survived more than two months after release. The remaining four cranes died in separate incidents occurring between 20-30 April. Because of the short duration of monitoring, more data are needed to adequately assess annual habitat-use of Mississippi sandhill cranes released into the wild.

PROCEEDINGS 1985 CRANE WORKSHOP

The Mississippi sandhill crane, described as a new subspecies (Aldrich 1972), consists of a single nonmigratory population of about 40 birds located in southern Jackson County, Mississippi. This deme is the only known representative of a breeding population once found from Louisiana east to Georgia and into peninsular Florida (Walkinshaw 1949, Valentine and Noble 1970). The Mississippi sandhill crane was officially listed as endangered in 1973 (38 Federal Register 14678, 4 June 1973). The Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR) was established in Jackson County in 1974. A recovery plan for the crane was approved by the U.S. Fish and Wildlife Service (USFWS) in September 1976 (Valentine et al. 1976) and revised in 1979 (Valentine et al. 1979).

Between 1965 and the present, Mississippi sandhill crane eggs were collected nearly every year from nests in the wild to establish a captive flock (Valentine 1981). From these eggs, a breeding flock of Mississippi sandhill cranes was established at the Patuxent Wildlife Research Center, USFWS, Laurel, Maryland (Carpenter 1977, Derrickson and Carpenter 1981).

Valentine et al. (1979) in the revised recovery plan suggested bolstering the depressed native population by releasing parent-reared Mississippi sandhill cranes into the wild. An initial release of eight juvenile and one 1-year-old Mississippi sandhill cranes occurred on the refuge in January 1981. All cranes survived the first five months after release (Zwank and Derrickson 1982), and four are known to have survived through December 1984. Based on the immediate results of the 1981 release, additional releases were planned.

Detailed knowledge of habitat use by cranes on MSCNWR is not available. The success of crane releases can be greatly enhanced by the availability of such information because this knowledge can be used to help select suitable crane release sites and to formulate habitat management plans for established and proposed release sites. The objectives of this study were to delineate diurnal habitat-use of pen-reared Mississippi sandhill cranes released on MSCNWR.

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STUDY AREA

The study was conducted on the 3200 ha Gautier Unit of MSCNWR, in southern Jackson County, in the southeastern corner of Mississippi. The area is within the 41,000-ha area comprising the known range of the Mississippi sandhill crane (Valentine 1982) and is typical of areas commonly referred to as "coastal flatwoods" or "pine flatwoods." Soils on the study area are loam to loamy sand in texture, low in natural fertility, and are strongly acidic (pH 4.0-5.5). The water table throughout the area is at or near the surface for much of the year. Topography of the southeastern three-fourths of the Gautier Unit ranges from nearly level to gently sloping, resulting in swales, wet savannas, and shallow, irregular drainages. The northwestern one-fourth of the study area consists of low ridges and moderately sloping land with drainages more constricted and well defined than those found to the south. Elevations on the Gautier Unit range from 6-12 m above mean sea level. Coastal Mississippi has a subtropical climate moderated by the Gulf of Mexico with mild, humid winters and uniform, very warm and very humid summers.

Open, wet savannas, pine meadows, and localized swamps were historically the dominant land features of the coastal flatwoods of southern Mississippi. Fires started by lightning or set by Indians, combined with the effects of sterile, wet soils, are thought to be responsible for the historically open nature of the savannas and pinelands (Valentine 1984). In the late 1800's, small-scale lumbering, turpentining, and open-range grazing became the dominant forms of land use (Valentine 1981, 1984). In conjunction with grazing, farmers burned the flatwoods to provide livestock with green winter forage. The burning and grazing inhibited pine and hardwood regeneration and contributed to maintenance of the open pine savannas and scattered pine stands (Valentine 1984).

The open-range grazing policy was abolished in Jackson County in the 1950's. Also in the 1950's, commercial timber companies began intensive timber management in the coastal flatwoods, planting the wet savannas and higher ground with slash pine (Pinus elliottii). Planting was accompanied by road-building and silvicultural activities, such as bedding to improve seedling microsite, and ditching to improve soil drainage in the wet savannas. Fire suppression programs were also initiated during the 1950's and are actively pursued to the present.

Following the creation of MSCNWR in 1974, Refuge staff began a savanna restoration program to improve habitat for the Mississippi sandhill crane. Aspects of this program include removal of pine plantations, prescribed burning, and water management (Valentine 1984). Current land uses on private land surrounding the study area are urban and commercial development, forest management, and farming.

Basic vegetation types found on the study area are savannas, swamps or wooded drainages, and pine woodlands. The savannas (natural and restored) are primarily open grasslands with ground cover plants including three-awns (Aristida spp.), toothache grass (Ctenium aromaticum), bluestem grasses (Andropogon spp.), panic grasses (Panicum spp.), and beakrushes (Rhynchospora spp.). Bitter gallberry (Ilex glabra) is widespread in the better-drained areas. Planted savannas have an overstory of slash pine. Scattered, relict longleaf pine (P. palustris) and pondcypress (Taxodium distichum var. ascendens) are also prominent in the savannas.

The swamps and wooded drainages support an overstory of pondcypress, swamp blackgum (Nyssa sylvatica var. biflora), and slash and longleaf pine. Edges and interior openings of the swamps and drainages are sometimes thickly vegetated with swamp cyrilla (Cyrilla racemiflora), buckwheat-tree (Cliftonia monophylla), and southern waxmyrtle (Myrica cerifera).

Open, scattered stands of slash and longleaf pine exist on the higher ground of the Gautier Unit and contain an understory similar to the adjacent savannas. The extreme northwestern one-quarter of the Gautier Unit is occupied by a slash pine-longleaf pine forest. The shrub-layer varies from thick to open and includes bitter gallberry, sweet gallberry (Ilex coriacea), yaupon (I. vomitoria), waxmyrtle, dewberry and blackberry (Rubus spp.), sweetbay (Magnolia virginiana), and winged sumac (Rhus copallina).

METHODS

The study area was divided into habitat types based on recognizable features on 1981 black-and-white aerial photographs and on-the-ground inspection. Areas were assigned to a particular habitat type according to factors that could potentially affect crane use of the type, such as presence and type of overstory canopy cover, land use, and recognizable moisture regimes.

We delineated seven habitat types on the study area:

1. Pine woodland: The pine woodland-type occupied the better-drained areas of the uplands and higher ridges in the savannas. The overstory was typically dominated by 30-50 year-old slash and longleaf pine.
2. Pine plantation: The pine plantation habitat type was characterized by areas of mesic or hydric savanna that had been artificially regenerated to slash pine by planting seedlings.
3. Hydric savanna: The relatively flat, poorly drained areas forming wet swales or borders along the swamps and drainages were classified as hydric savanna, based on a distinguishable water regime and a general lack of overstory. Soils of hydric savannas are saturated with water during most of the year.
4. Mesic savanna: The mesic savanna-type consisted of relatively open grasslands occupying the gently-sloping, better drained areas. A continuous overstory was lacking and surface water was generally present only during brief periods of the growing season.
5. Wooded drainage: This habitat type consisted of the swamps and drainage courses of the study areas. The primary classification characteristics of the wooded drainage-type were an overstory of swamp tupelo, pondcypress, and slash pine; and a semi-permanent or seasonally flooded water regime.
6. Agricultural land: Agricultural crop fields and pastures (improved or unimproved) were assigned to the agricultural land-type if the lands were used for growing crops or pasturing livestock during the 1981-1982 growing season.
7. Fallow land: Agricultural lands not farmed, or pastures left idle, during the 1981-1982 growing season were classified as fallow lands. This classification also includes upland areas of pine timber bulldozed and windrowed by MSCNWR staff. These areas supported vegetation atypical of the surrounding undisturbed areas and had a site history of soil disturbance similar to that associated with a fallow agricultural field.

We identified habitat use by pen-reared Mississippi sandhill cranes by monitoring movements of cranes fitted with solar-powered radio transmitters in the 164-MHz frequency range (Model HSPB-1600-3X, Wildlife Materials, Inc., R. R. 1, Carbondale, Ill.). Each radio transmitter weighed approximately 40 g and was equipped with a 20-cm whip antenna. The radio and base of the antenna were potted in dental acrylic. A 5- x 40-mm spring was sealed into the acrylic at the base of the antenna to reinforce the antenna and reduce stress caused by flexing.

The radio transmitters were attached to red, 8-cm plastic overlapping legbands similar in detail to those used by Melvin et al. (1983). Each radio was attached to the outer overlap of the band with epoxy cement, followed by layers of water-resistant cement. We roughened the surfaces of the band and transmitter back with sandpaper before glueing. The resulting bond was very secure and allowed the band to be easily opened by simultaneously pulling on the transmitter and the inside overlap of the band. Total weight of each radio transmitter with legband was approximately 60 g.

The band was placed on the crane's leg above the tibio-tarsal joint with the antenna oriented downward. The overlapping edges were glued together with epoxy, with care being taken to prevent the wet epoxy from coming in contact with the crane's leg or feathers.

Each crane was also marked with a red, 6.5-cm plastic neck collar inscribed with an individual identification number: 610, 611, 612, 613, and 614. Individual cranes will hereafter be referred to by neck collar number. Colored tape was added to all but one collar to aid in individual identification. After a collar was placed on a crane, the overlapping edges of the collar were riveted together at the top. The bottom of the collar was not riveted in order to allow expansion.

A portable telemetry receiver (Model TR-2, Telonics, Inc., 1300 West University, Mesa, Ariz.) and an antenna array (Model RA-NS-2) consisting of a 2-element, directional yagi antenna mounted on each end of a 2.0-m long aluminum crossboom, were used to receive radio signals. A 180° phase shifter (Model TAC-5, Telonics) was used in conjunction with the directional antennas to create a "null" direction-finding system. The crossboom was bolted to the top of a 2.6-m length of aluminum conduit that served as a mast. The antenna array was adapted for use from the back of a pickup truck by using a mast-holding pipe bolted into the truck bed. A compass rose, secured to the mast-holding pipe with a set screw, was used to determine bearings.

Telemetric monitoring was begun after restraining wing-brails were removed from five study cranes and they voluntarily left the release pen. We attempted to record locations of all radio-equipped cranes four days per week, at least once during three periods of the day: morning (0500-0959), midday (1000-1559), and evening (1600-2059). We recorded station, crane

number, time, and bearing. Fixes were determined by plotting two bearings with angles of intersection of at least 60° but not more than 120° onto a clear-film overlay of a 1:24,000 U. S. Geological Survey topographic map of the study area. The habitat type of each location was determined by overlaying the clear-film onto aerial photographs of the same scale.

Use of each habitat type by the released cranes was put on a relative basis by employing a use index (UI) (Hoffman 1976). The UI compares the percentage of locations recorded from a given habitat type to the availability of the habitat type:

$$\text{Use Index} = \frac{\%\text{ number of locations recorded from a given habitat type}}{\%\text{ availability of the habitat type}}.$$

Habitat availability was determined by calculating the area occupied by each habitat type as a percentage of total area considered available to the study cranes. For the purposes of this study, the area considered available to the cranes was based on the movements of the study cranes and the 1981-released cranes within the boundaries of the Gautier Unit of the Refuge. Representative areas of each habitat type were present within 0.5 km of the release pen. We assumed for the purposes of data analysis that all habitat types were available to the instrumented cranes at all times. A UI greater than 1 indicates that use of a particular habitat exceeded availability of the habitat. No assumption of habitat preference is purposely applied to the index in this study.

RESULTS

Wing-brails were removed from cranes 611 and 612 on 17 February 1982, and from cranes 610, 613, and 614 on 2 March 1982. Cranes 611 and 612 were first observed outside the release pen on 1 March and 3 March, respectively. Crane 613 did not leave the pen until 18 March, and cranes 610 and 614 were first observed outside the pen on 20 March.

A total of 176 telemetric locations was recorded over a 58-day period (3 March-29 April 1982): 51 locations of crane 610, 40 locations of 611, 46 locations of 612, 36 locations of 613, and 3 locations of 614. The transmitter on crane 614 began to malfunction on 4 March and was inoperable by 12 March. Only one crane (612) survived more than 2 months post-release. The other four cranes died in separate incidents occurring between 20-30 April.

Three of the five study birds (611, 612, and 613) dispersed from the release pen area between 9 and 11 April 1982. Cranes 611 and 612 were subsequently located together 3.5 km southeast of the release pen on 12 April. Crane 613 was located on 13 April in a fallow field 8.7 km northeast of the release pen.

More than 50% of the 176 locations were recorded in the savanna types, with 56 locations from the hydric savanna and 47 from the mesic savanna (Table 1, Fig. 1). However, hydric savanna comprised only 4% of all habitat available to the released cranes, and use of hydric savanna exceeded availability (Table 1). Hydric savanna had the greatest UI of any habitat type. The cranes used mesic savanna in proportion to availability (UI=1.0).

Although agricultural and fallow lands together comprised only 4% of available habitat, over 15% of locations were recorded from these two habitats (Fig. 1). Use indices of 3.3 and 4.0, respectively, show that use of agricultural and fallow lands exceeded availability (Table 1). Use of wooded drainage was proportional to availability. Low use indices for pine plantation (UI=0.3) and pine woodland (UI=0.1) indicate that availability exceeded use of these habitat types.

Twenty of 58 (34%) morning locations were recorded in hydric savanna, and 12 (21%) were recorded in mesic savanna (Fig. 1). No morning locations were recorded in pine woodland. Habitat-use during the morning period exceeded availability for hydric savanna, agricultural land, fallow land, and wooded drainage, with hydric savanna having the greatest UI of any habitat (Table 1). Mesic savanna and pine plantation received less use than the availabilities of these habitats would suggest.

Thirty-two of 90 (36%) midday locations were recorded in mesic savanna, and 26 (29%) locations were recorded in hydric savanna (Fig. 1). Use of hydric savanna, agricultural and fallow land, and mesic savanna exceeded availability during midday, with hydric savanna having the greatest UI of any habitat (Table 1). However, use of hydric savanna, agricultural land, fallow land, and wooded drainage decreased from morning to midday.

Table 1. Habitat availability and habitat use by pen-reared Mississippi sandhill cranes, Gautier Unit, Mississippi Sandhill Crane National Wildlife Refuge, Jackson County, Mississippi, 3 March-29 April 1982.

Habitat type	Area (ha)	Availability (%)	Number of locations	Percent of locations	Use Index (UI)[a]
Pine plantation	1113	36.3	22	12.5	0.3
Morning					0.3
Midday					0.4
Evening					0.3
Mesic savanna	801	26.1	47	26.7	1.0
Morning					0.8
Midday					1.4
Evening					0.4
Pine woodland	607	19.8	5	2.8	0.1
Morning					0.0
Midday					0.3
Evening					0.0
Wooded drainage	283	9.2	19	10.8	1.2
Morning					1.5
Midday					0.6
Evening					2.3
Hydric savanna	127	4.1	56	31.8	7.8
Morning					8.3
Midday					7.1
Evening					8.8
Agricultural land	80	2.6	15	8.5	3.3
Morning					5.0
Midday					2.7
Evening					1.5
Fallow land	53	1.7	12	6.8	4.0
Morning					3.0
Midday					2.3
Evening					10.6
Total	3064		176		

[a] Use Index = % number of locations divided by % habitat availability. UI of 1.0 indicates use proportional to availability.

Ten of 28 (36%) evening locations were recorded in hydric savanna (Fig. 1). Evening use of fallow land, agricultural land, hydric savanna, and wooded drainage exceeded availability (Table 1), and use of fallow land, hydric savanna, and wooded drainage increased from midday to evening. Fallow land had the greatest UI of any habitat type for the evening period. The relatively large increase of the fallow land UI from midday to evening is unexplained by other data or visual observations. However, only 16% of all locations were recorded from the evening period, and this paucity of data may disproportionately affect the indices within the time period.

DISCUSSION

General descriptions of habitat types and their use by wild Mississippi sandhill cranes have been presented in earlier studies (Valentine 1965, 1974, 1975). Valentine and Noble (1970) identified two plant communities, savannas and swamps, as being important to wild cranes and identified common plants found within each community. They stated that wild Mississippi

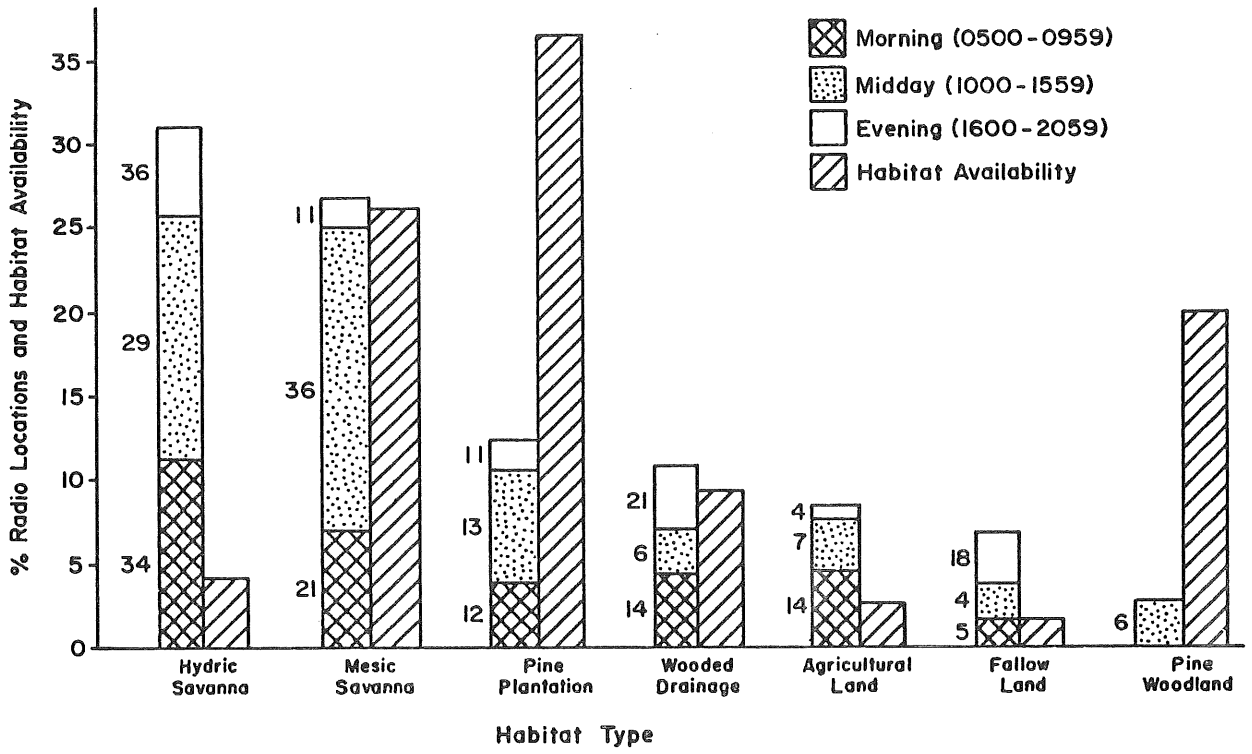

Fig. 1. Percent number of locations of released Mississippi sandhill cranes and percent habitat availability by time period and habitat type, Mississippi Sandhill Crane National Wildlife Refuge, 3 March - 29 April 1982.

sandhill cranes feed in pastures or in local cornfields during the winter, and utilize savannas, edges of swamps, and mature pine stands for summer feeding areas. They further stated that open meadow areas are essential to the existence of the Mississippi sandhill crane.

Numerous other investigators have also noted the predilection of sandhill cranes to open areas for nesting, feeding, loafing, and roosting activities (Walkinshaw 1949, Thompson 1970, Lewis 1974, Guthery 1975, Hoffman 1976, Valentine and Noble 1976, Riley 1982).

The use indices calculated for each habitat type show pen-reared cranes have the same affinity for open areas. Additionally, the absolute number of locations was always greatest in a savanna type. The relatively high use of the wooded drainage-type may reflect the close proximity of the release pen to the wooded drainage sample area. The margin and interior of the drain closest to the release pen was relatively open. Cranes may have used this area for foraging, loafing, or roosting activities. We observed wild and 1981-released cranes within this segment of the wooded drainage on several occasions.

Our field observations of the released cranes at the pen and in the surrounding area suggest a diurnal pattern of habitat-use not indicated by statistical analysis of the data. Before dispersal, the five study cranes centered their daily activities around the release site. The cranes usually fed at the release site during the mornings and evenings from self-feeders stocked with pelleted feed or from the agricultural and fallow plots established at the site. Wild and 1981-released cranes also fed frequently at the pen during the mornings and evenings.

The study cranes normally spent the midday hours in hydric savanna within the release pen, or in mesic savanna areas within 0.5 km of the release site. Hydric savanna inside the pen was used as midday loafing sites primarily within the first 10 to 14 days after release, and midday use of mesic savanna appeared to increase with time after release. We observed wild, 1981- and

1982- released cranes loafing together on several occasions in mesic savanna, and also observed numerous probe-holes at these sites. The observed increase in midday use of mesic savanna, and the concurrent decreased use of agricultural and fallow land, is supported by the use indices (Table 1).

We did not analyze habitat-use by individual cranes because of the small number of observations for any single crane. However, field observations after dispersal from the release-pen area suggest habitat-use patterns unique to cranes 612 and 613. Their habitat use patterns may have been atypical. Telemetric and visual locations indicated that crane 613 remained on, or in the immediate vicinity of, a 33-ha fallow soybean (Glycine max) field from time of dispersal (9 April) until death on 26 April. Vegetation in the field consisted of low (< 50 cm), herbaceous ground cover. Crane 613 was flushed several times from the open field and once from a patch of dewberry. Telemetric locations indicated that 613 roosted in a small (approximately 0.2-ha) marshy swale at the north end of the field, and also in or near a bayhead that extended out into the field.

The carcass of crane 613 was recovered on the margin of the swale and field. Examination of the esophagus contents revealed almost exlusively dewberry seeds. However, the carcass was in poor physical condition, and cause of death is believed to be starvation resulting from parasite lesions on the tongue and esophagus (pers. comm., Dr. Richard K. Stroud, USFWS National Wildlife Health Laboratory, Madison, Wis., 29 June 1982).

Cranes 611 and 612 left the release area between 9 and 11 April 1982, and were located together on 12 April in a series of agricultural and fallow, windrowed fields approximately 3.5 km south of the release pen. Crane 611 was killed on 20 April when struck by a vehicle on a nearby highway, but 612 remained in the area until late June and regularly utilized fallow fields during the day for feeding and loafing. We observed and flushed 612 several times from the windrowed fields. The affinity of crane 612 for the fallow fields may have been influenced by the abundance of fruiting dewberry present on the windrows, which may have provided this crane with a dependable food supply.

Relative use of different habitat types by released cranes during this study may have been affected to some degree by the brief period during which data were collected. The five cranes centered their daily activities around the release pen from time of release through 8 April, although study cranes were twice observed as far as 1.2 km from the pen. After cranes 611, 612, and 613 dispersed, cranes 610 and 614 moved from the pen to a mesic savanna 0.6 km to the southwest, but continued to feed daily at the release pen. Although all habitat types were available within 0.5 km, hydric savanna, agricultural land, and fallow land comprised the majority of the release site. The high use indices observed for these three habitats may be a reflection of the abundance of these habitats at the release site and the tendency of cranes to concentrate their early activities at the pen.

The dispersal of 611, 612, and 613, and the early deaths of 610 and 614, precluded a gradual range expansion from the release area and may have prevented full utilization of habitats available within 2-3 km of the release pen. Habitat-use patterns of the released cranes may have changed over time had the cranes been continually exposed to wild cranes and not dispersed from the release pen area soon after release.

Drewien et al. (1982) noted that six of seven surviving greater sandhill cranes released in Idaho remained within 1 km of the release site, associated with wild cranes, and quickly adopted daily activity patterns of the wild cranes. Mitchell and Zwank (1986) attributed the favorable survival of pen-reared Mississippi sandhill cranes released in 1981 to the tendency of the birds to remain in the vicinity of the release pen, which allowed the cranes to gradually expand their range and adjust to local conditions. In the present study, cranes 611, 612, and 613 moved from the release area into unfamiliar habitat over a period of 3 days. The restricted movements observed for cranes 611, 612, and 613 after dispersal may have been the result of unfamiliar or unsuitable habitat, and/or an apparent lack of association with wild cranes.

We observed many interactions between the study cranes and wild and 1981-released cranes from late January through mid-April. However, we did not observe 611, 612, or 613 in association with wild cranes after dispersal from the release site. By March, winter flocks of wild Mississippi sandhill cranes usually have disbanded, and mated pairs have become more territorial and aggressive toward other cranes. Increase in aggression may have limited associations between wild and released cranes as the study progressed. Cranes 611 and 612 appeared to have access to suitable crane habitat, but data indicate that they used fallow fields almost exclusively. Habitat-use patterns may have been different had 611 and 612

associated more with wild cranes. Crane 613 confined its activities to the fallow field between time of dispersal and death. This apparent restriction of movement may have been due in part to the unavailability of more suitable crane habitat. The fallow field was surrounded by upland, mixed pine-hardwood forest, and urban residential areas.

Habitat-use by Mississippi sandhill cranes in this study should be interpreted with caution because of the short sampling period and relatively few data, and should be supplemented with further studies of longer duration. Data gathered over an annual cycle would more adequately assess habitat-use of parent-reared Mississippi sandhill cranes released into the wild.

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A RESOURCE INVENTORY OF SANDHILL CRANE STAGING AREAS IN NEBRASKA

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Abstract: Sandhill crane (Grus canadensis) usage of the Platte and North Platte river valleys is well documented, but the actual land base supporting the population has not been well defined. In the present study, we delineated the lands occupied by sandhill cranes in 1979 and identified and quantified habitats and land use. Surveys conducted during March 1979 along 327 km of river valley indicated cranes occurred primarily in three areas totaling about 100,000 ha. Most cranes were located in the Kearney-Grand Island (Staging Area 1), Overton-Elm Creek (Staging Area 2), and Sutherland-North Platte (Staging Area 3) portions of the valley. Ninety-seven percent of the land area was privately owned and most non-channel lands were managed for agricultural production. Fifty-three, 38, and 28% of Staging Areas 1, 2, and 3, respectively, were under cultivation and planted mostly to irrigated corn. Native grasslands composed 23, 20, and 40% of staging areas 1, 2, and 3, respectively. Of the original river channel, about 79% was occupied by woody vegetation with the percentage ranging from 69 (Staging Area 1) to 90% (Staging Area 3). Reduced flows in the river because of upstream water developments have sharply reduced channel area, causing cranes to abandon about two-thirds of the roosting habitat formerly available. The abundance of waste corn has prevented food shortages as crowding has increased, but continuing loss of channel and meadow habitat necessitates major habitat management actions.

PROCEEDINGS 1985 CRANE WORKSHOP

Man in the past century has converted a major part of the grasslands and wetlands of the midcontinent region to cropland. Major changes in the distribution and abundance of the birds have resulted from habitat alteration. Impacts have been particularly pronounced on resident wildlife but migratory forms have also been affected. In the central plains region, habitat loss has left parts of the Platte and North platte river valleys as the only major spring staging areas for the midcontinent population of sandhill cranes. As a result, spectacular concentrations of cranes can be seen each spring along some portions of these rivers. The crowding of the crane population into a few segments of river channel and continuing habitat loss there and elsewhere has concerned crane biologists (Frith 1974, Lewis 1977). These concerns, spurred by various authorized, planned, and proposed water projects (Krapu et al. 1982), prompted the initiation in 1978 of extensive studies by the U. S. Fish and Wildlife Service. Among the investigations was a study to delineate and describe the land base occupied by the crane population during their stay in the Platte and North Platte river valleys. In this paper, we describe some of the findings.

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METHODS

Delineation of Staging Areas

Lands occupied by sandhill cranes along the Platte and North Platte rivers were delineated from crane survey data collected on 5, 12, 20, and 26 March 1979. These surveys encompassed about 327 km of the floodplain and some uplands from Kingsley Dam to Chapman, Nebraska. Surveys were conducted between 0900 and 1200 hours by 14-16 ground observers. Each observer was responsible for censusing a designated segment of the survey area. Crane distribution was recorded by legal quarter section (65 ha).

Habitat Assessment

Color aerial photographs (scale = 1:24000) were taken in August 1979 to document habitat types and land uses within the boundaries of the three major crane staging areas. Habitats were identified and delineated on the color photos and transferred onto USGS topographic maps of the same scale. Ground truth was obtained for most quarter sections. The principal habitat types were cultivated land, grassland, alfalfa hayland, woodland, and open channel. Other habitats included man-made pond, natural wetland, and irrigation canal. Land-use designations were agricultural, wildlife area, highway right-of-way, railroad right-of-way, park, sand and gravel development, business, and residence. The ownership of lands was determined from current plat books maintained by either the Register of Deeds Office or the County Clerk in the counties in which the lands were located. Land ownership categories were as follows: public recreational, public miscellaneous, private conservation, private residential, private commercial, or private agricultural. Public recreational lands consisted of parks, rest areas, and game management lands. The public miscellaneous category consisted primarily of highway and canal right-of-way and state school lands. Within each quarter section of land, the area of each land use and habitat were measured with a Numonics Model 1224[1] electronic digitizer and recorded along with ownership.

RESULTS

Historical Background

Explorers, trappers, soldiers, and others traveling the Oregon Trail between Oregon, California, Utah, and eastern locations and the builders of the first railroads provided a written record of pre-settlement conditions in the valleys of the Platte and North Platte rivers (McKinley 1935, Rollins 1935).

Explorers' reports from the early to mid-19th century indicate the riverbanks rarely had any trees and woods were restricted primarily to some islands in the channel. In the central Platte Valley near the city of Kearney, K. P. Woodbury in 1847 referred to a broad shallow river with many channels and islands flowing through a wide prairie bottomland with tall grasses, sloughs, and little or no timber except on a few river islands (William 1930:251-252). Trees, where and when found, were primarily cottonwood (*Populus deltoides*) and willow (*Salix* spp.); American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), hackberry (*Celtis occidentalis*), or red cedar (*Juniperus virginiana*) were mentioned infrequently. Kellogg (1905) described the Platte and Republican rivers as sandy streams with shifting bottoms so that timber was either wholly absent over long stretches or consisting only of scattered cottonwoods and willows.

Early explorers most often attributed the scarcity of timber to prairie fires. Grazing, browsing, trampling, and rubbing by bison and drought probably also influenced the growth and survival of trees. After the mid-19th century, the need for fuel and building materials by soldiers, settlers, and finally the railroad builders also caused the original scarce timber resource to become depleted.

The land surface of the Platte River Valley has been modified extensively since the 1870's when settlement of the area began. One of the most striking changes has been the expansion of woody vegetation. Native woodlands and planted woodlots have become characteristic of the

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[1] Reference to trade names does not imply government endorsement of commercial products.

valley. The increase of woody vegetation has been the result of numerous forces. A campaign by the government in the 1870's encouraged the planting of trees. In 1873, the Timber Culture Act was passed which permitted homesteaders who planted 4.1 ha of shelterbelt trees to obtain title to an additional 65 ha of land free of cost (Albertson and Weaver 1945). Settlement of the region also resulted in a gradual decline of prairie fires. The most significant woodland expansion in the Platte River Valley came in the 20th century, however, due to upstream diversion of water for irrigation and power generation. Dewatering of major parts of the river channel occurred as flows diminished; woody vegetation occupied the exposed surface. By 1969, the channel along a 365-km reach between Minatare and Overton, was only one- to two-tenths as wide as in 1865 due mainly to greater human use of the river water (Williams 1978). Woodland expansion in the Big Bend reach of the Platte Valley followed the closing of the gates of Kingsley Dam and The Tri-County Diversion Dam (Currier 1982).

A lack of detailed information on crane use of the Platte and North Platte rivers before the mid-twentieth century prevents an evaluation of changes in crane distribution over time. However, current knowledge of roosting habitat requirements (Krapu et al. 1984) and former habitat conditions (Williams 1978) suggests that before encroachment by woody vegetation, cranes used the entire 327-km section of river under study. Cranes made extensive former use of the river in the reach between the confluence of the North Platte and Platte rivers and Lexington (Walkinshaw 1956), where they no longer occur.

General Description of Staging Areas

Most sandhill cranes encountered during the surveys were in one of three areas along the Platte and North Platte Rivers (Fig. 1). Staging area 1 is situated mostly in the Platte River Valley between Kearney and Grand Island, a distance of about 73 km (Fig. 1). Staging area 2 is located in the Elm Creek-Overton section of the Platte River Valley and staging area 3 is located upstream from North Platte in the Hershey-Sutherland area (Fig. 1).

Sandhill cranes occurred within a land base of about 100,000 ha. Habitat composition of that area was as follow: cropland, 44%, grassland, 26%; alfalfa, 11%; river channel including area lost to woodland encroachment, 11%; and other uses, 8%. Ninety-seven percent of the land base, including lands underlying the channel, was privately owned and most was managed for agriculture. Corn was the principal crop grown with 41,094 ha in corn production during 1979.

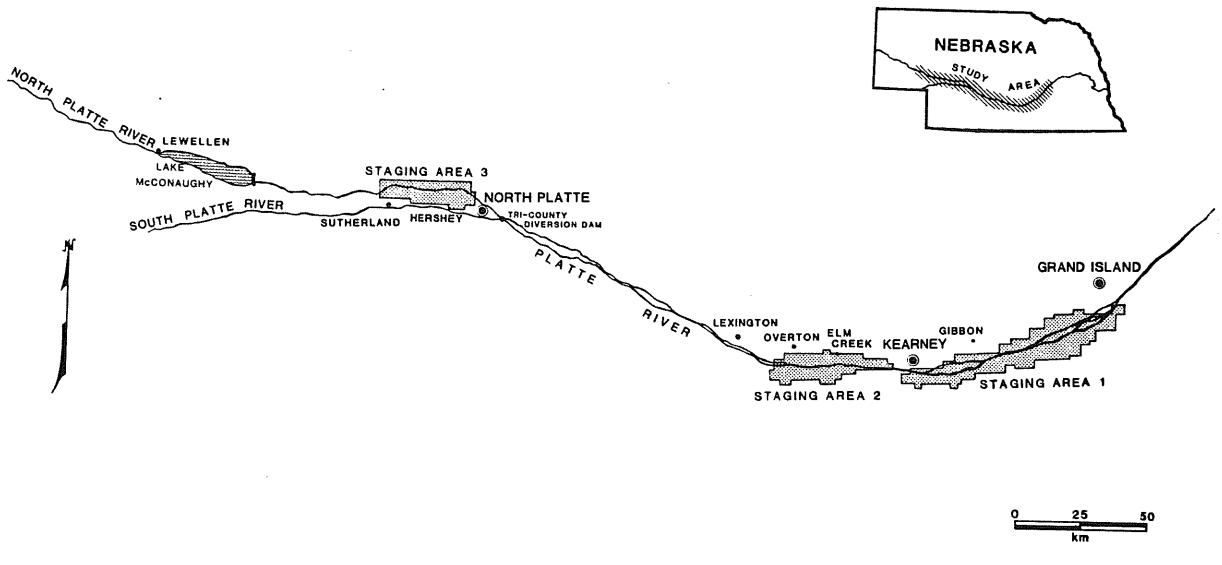

Fig. 1. Locations of staging areas of sandhill cranes in the Platte and North Platte river valleys of Nebraska.

Staging Area 1

Staging area 1 supports about three-fifths of the midcontinent sandhill crane population during their stay in the Platte and North Platte river valleys. About 95% of an estimated 57,820 ha were in private agricultural use including 30,409 ha (53%) of cultivated land, 13,607 ha (23%) of grassland, and 4,010 ha (7%) of alfalfa. Grassland occurred primarily in fenced pastures used as summer range for cattle. Most of the existing grassland was near the river channel (Fig. 2). These lands, because of their proximity to the channel, are often waterlogged during the growing season. Alfalfa is grown for livestock feed.

Woodlands occupied about 69% of the original river channel. A total of 3,971 ha were in various stages of woody plant succession and lost to crane use (Fig. 3). The present channel contained an estimated 1,828 ha. A detailed description of vegetation succession in channels following dewatering was presented by Currier (1982).

Public lands on Staging Area 1 provided little usable habitat for cranes. The 483 ha of land classified as public recreational were primarily state wildlife areas acquired in association with the construction of Interstate 80 and consisted of barrow ponds and woodlands. Among the other public lands were an estimated 511 ha of interstate right-of-way. Their proximity to Interstate 80 made them unsuitable for use by sandhill cranes. Sand and gravel development has occurred on about 562 ha or 1% of lands on Staging Area 1 (Fig. 2). The mined sites are avoided by cranes.

By 1979, only one tract, the 324-ha Lillian Annette Rowe Sanctuary of the National Audubon Society near Gibbon, had been acquired specifically for cranes and other migratory birds. This property, located in part on Fort Farm Island, is situated on a portion of river that receives high use by the cranes. More recently, the Platte River Trust (Platte River Whooping Crane Habitat Maintenance Trust) has acquired 1660 ha through fee title and easement at three sites on this staging area. These lands are managed for sandhill cranes and other migratory birds (P. J. Currier, pers. commun.).

Staging Area 2

Lands of this staging area extend from a few km west of Kearney to about Overton (Fig. 1). Ninety-six percent of the 25,700 ha were privately owned and devoted to agriculture at the time of the survey. Included in this land base were 9,691 ha of cropland, 5,081 ha of grassland, and 4,810 ha of hayland (Fig. 2). About 38, 20, and 18% of Staging Area 2 were cropland, grassland, and alfalfa respectively.

Channel roosting habitat in this portion of the Platte River was in an advanced state of deterioration by 1979. Under pristine conditions, about 4,233 ha of Staging Area 2 were channel. By 1979, however, all but about 672 ha had been lost to woody vegetation encroachment (Fig. 3). There were no private conservation areas on Staging Area 2 at the time of these surveys but the Platte River Trust has since acquired about 770 ha in fee title or easement at sites near Elm Creek and Overton. A total of 282 ha was devoted to private commercial activities with most (299 ha) in sand and gravel mining operations (Fig. 2).

Public lands composed about 2.5% of the land area with most in interstate right-of-ways and canals. The small area of public recreational lands on the staging area was not suitable for crane use.

Historically, Staging Area 2 has been used extensively by sandhill cranes and continues to support a significant number of birds. However, cranes have been prevented from occupying a substantial part of the river channel in recent years because of a shrinking channel width and associated woodland expansion (Fig. 2).

Staging Area 3

This area supports a high density of sandhill cranes. Approximately 18,400 ha lie within boundaries of this staging area of which 97% are private agricultural lands. Grassland, mostly occurring in uplands, was the dominant habitat type and occurred on 7,428 ha or 40% of the area. A total of 5,164 ha (28%) of cropland and 2,080 ha (11%) of alfalfa were present on the staging area. The distribution of cover types is shown in Fig. 2. Only about 302 ha, or 10% of an estimated original 3,049 ha of channel remained (Fig. 3) in 1979, reflecting impact of upstream water developments.

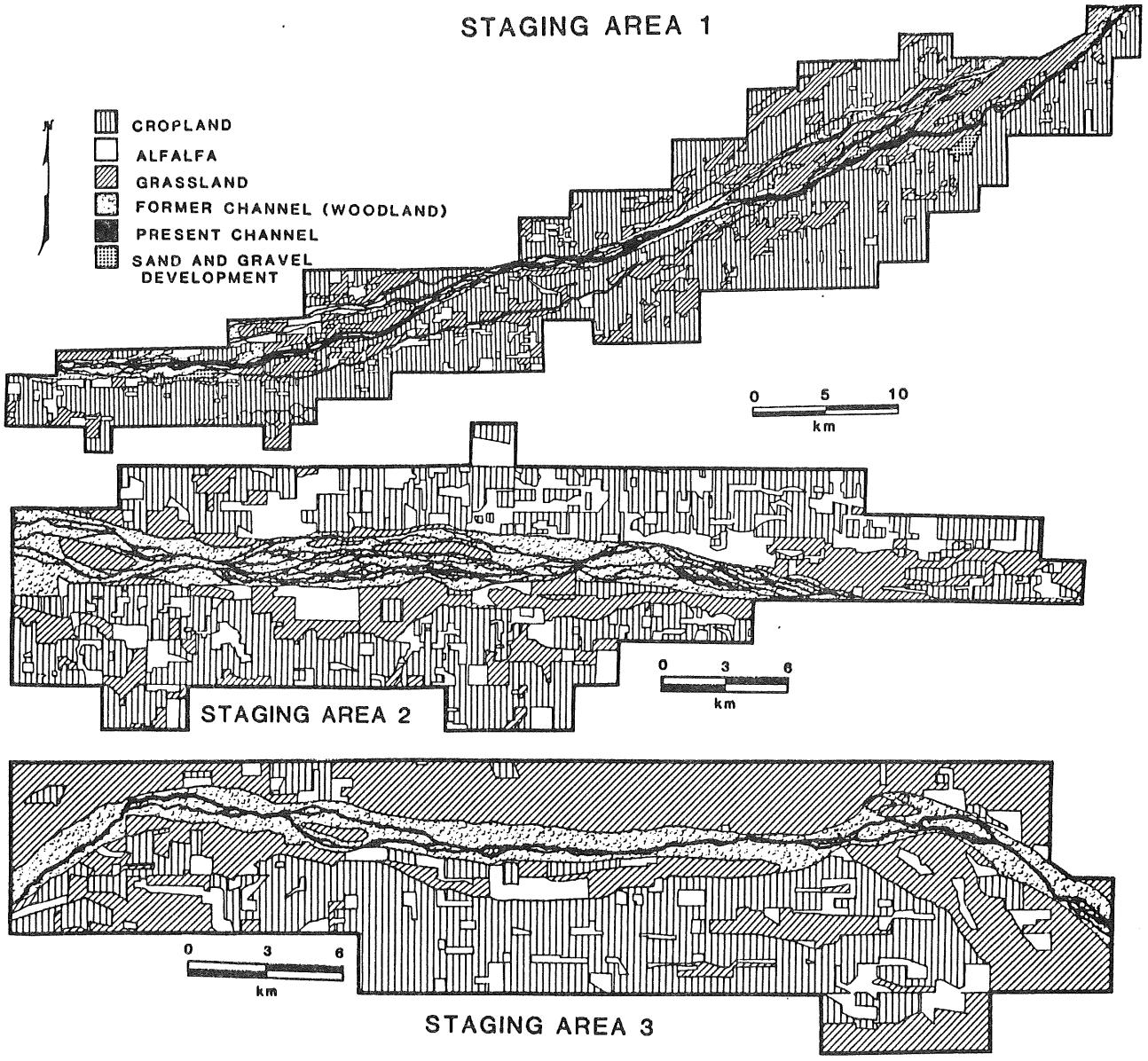

Fig. 2. Cover map of sandhill crane Staging Areas.

Public lands composed about 1% of this staging area, mostly irrigation canals. Of the 242 ha devoted to private commercial activities, about 153 ha were railroad right-of-ways. Sand and gravel mining occurred on 25 ha. The Nebraska Game and Parks Commission owns a 162-ha tract near Hershey that is used extensively by sandhill cranes.

DISCUSSION

Our study indicates massive changes in the vegetation of the Platte and North Platte river valleys during the past century. These changing habitat conditions have caused marked changes in the distribution of the cranes during their stay. The current distribution and densities of cranes are primarily a function of the location of remaining suitable roosting habitat and the abundance of waste corn. The plentiful supplies of waste corn have compensated for shrinkage of roosting habitat and allowed the birds to gather in high densities and to acquire substantial fat reserves (Krapu et al. 1985). However, crowding also causes the birds to be more susceptible to storms, disease, and other potential hazards (Krapu et al. 1982). Corn in excess of the cranes' needs was present during the study period (Reinecke and Krapu, in press) but with most of the cropland privately owned, and managed for agricultural production, it is potentially subject to alternative uses should economic conditions warrant the change.

The conversion of grassland and meadows of the Valley to cropland also raises concerns. The grassland habitat is used as foraging sites by cranes seeking protein and other nutrients deficient in corn (Reinecke and Krapu, in press). The native meadows have been largely replaced with cropland (Fig 2). Federal agricultural programs have contributed to grassland loss by offering monetary incentives for conversion of grassland to cropland. In order to qualify for inclusion in various federally sponsored set-aside programs, farm operators have been required first to develop a cropping history which thereby makes native grasslands ineligible for subsidy payments. Based on past trends and probable future actions, sufficient grassland habitat will be maintained only through directed efforts such as those now being undertaken by the Platte River Trust.

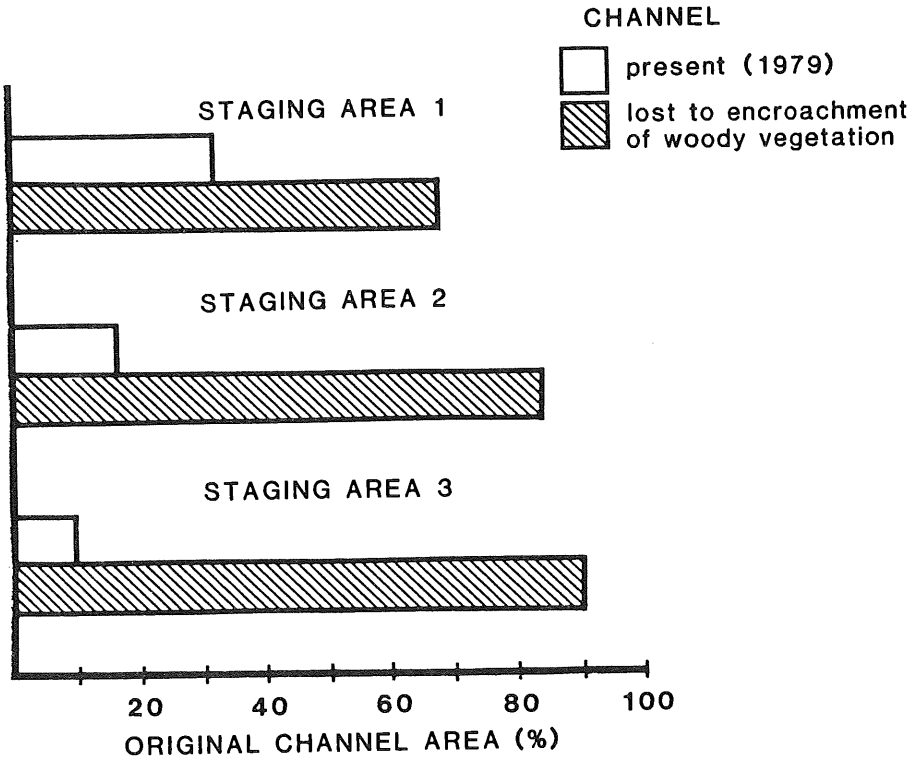

Fig. 3. Status of channel habitat on sandhill crane Staging Areas 1, 2, and 3.

The extent of woody vegetation on all staging areas reflects the pervasiveness of man's alteration of the Platte River ecosystem. Sandhill cranes are intolerant of high vegetation in close proximity to roost sites (Krapu et al. 1984) which underscores the need for cost-effective means to maintain an open channel in those reaches still used as roost sites by cranes, and to re-establish roosting habitat in portions where cranes no longer roost. Solving this problem is complicated by the numerous demands being made upon the remaining flows of the Platte River (Krapu et al. 1982, Krapu and Eldridge 1984). Innovative approaches to habitat reclamation, as are now being undertaken by the Platte River Trust and the National Audubon Society, offer hope that it will be possible to maintain and restore adequate habitat to meet the needs of the crane population during their annual spring stopover. Controlling woody vegetation and stabilizing channel conditions will likely involve a combination of mechanical, chemical, and hydrological techniques. The importance of this problem assures a challenge to resource managers for many years to come.

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FIVE-YEAR REPORT (1979-1984) OF THE CRANE CENTER AT OKA NATURE PRESERVE, USSR[1]

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Abstract: As part of the U. S.-USSR agreement on Environmental Protection, Project Siberian Crane began in 1977 with the goal of creating a captive group of Siberian cranes whose offspring would be released into the wild. In 1979 a Rare Crane Breeding Center was established at Oka Preserve to house the Siberian cranes and a collection of other rare cranes. Several abundant crane species are maintained there as surrogate research species and as foster parents. This paper describes pen facilities, nutrition, reproduction, chick rearing, and other aspects of rearing cranes at a high latitude location. The facility now contains 45 cranes of 9 species. Forty-one eggs have been acquired from the wild and 22 birds successfully raised.

PROCEEDINGS 1985 CRANE WORKSHOP

Cranes are one of the most vulnerable groups of birds. Although they are protected from hunting in the USSR, their numbers are being diminished almost everywhere by intensive development of wetlands, the burning of vegetation, and "disturbance" by man.

Seven species nest on Soviet territory: the Siberian (Grus leucogeranus), red-crowned (Grus japonesis), hooded (Grus monacha), white-naped (Grus vipio), common (Grus grus), sandhill (Grus canadensis), and demoiselle (Anthropoides virgo). The first four species are listed in the Red Data Book of the Moscow Naturalists' Society; they and the demoiselle are also registered in the USSR Red Data Book as endangered and needing urgent conservation measures.

At present the Siberian crane is the most threatened. It numbers about 300 birds (Byomye and Priklonskii 1976, Flint and Sorokin 1979, 1982). It nests only in the USSR in two discrete populations: in northeastern Yakutia and along the lower reaches of the Ob River. Nests of the Ob population were discovered only in 1981 (Sorokin and Kotlukov 1982). The Yakut population winters in China, the Ob population in India. Counts of the birds in India have indicated that only half as many birds winter there as 20 years ago. The number of Siberian cranes migrating through Northern Kazakhstan is also less (Elkin 1976). At this time the birds are in no real danger in their nesting areas; this is thinly settled territory and the birds are not disturbed. Hence the most important factor limiting the population of the Siberian crane is the low carrying capacity of the wintering grounds, and mortality from hunting and poaching in a number of countries during migration.

Traditional conservation methods (setting aside protected habitat) no longer are enough to protect the Siberian crane, and new, more effective ways are needed. One of these is raising rare species in captivity and then returning them to nature to replenish a vanishing population or to create a new population. Often the only way to save a species is to take some from the wild for captive breeding.

As part of the US-USSR Agreement on Environmental Protection, "Project Siberian Crane" began in 1977 with the goal of creating a captive group of Siberian cranes whose offspring would be released into the wild. Under this program in 1977 and 1978 the Soviet Union sent to the International Crane Foundation (ICF) 12 Siberian cranes eggs, taken from nests in Yakutia, from which 6 birds were raised. In 1980, two chicks and two eggs were sent to an ICF affiliate, the Walsrode Vogelpark (Bird Park, Federal Republic of Germany, FRG); three of these birds survived. For the future, the program envisions sending some eggs produced by these cranes back to the USSR to be put into nests of common cranes, and thereby, eventually to create a new population in central Russia near the Oka Nature Preserve.

To further this project on the Siberian crane, in spring 1979 a Rare Crane Breeding Center was established at Oka Preserve. The main goals of this Center are to create a captive breeding population of Siberian cranes whose eggs will be cross-fostered to common cranes, and to make a collection of other rare cranes (as an "emergency reserve") and of the more common species of cranes. The more common species will be used to develop captive maintenance and breeding techniques, and to incubate eggs of the rarer species.

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[1] Translated by Elizabeth C. Anderson, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria. Abstract added by the editor.

CONDITIONS FOR CRANES AT THE OKA CENTER

The Oka Nature Preserve is in the center of the European part of Russia, southeast of the Meshcher Lowlands. The climate in this region is temperate continental. The average temperature in January is - 10 to 11°C; in July it is +13°C. The annual precipitation is about 500 mm, about 20% of which comes in winter. Continuous snow cover averages 108 days (from 22 November to 9 March). The maximum snow depth is 89 cm, the lowest winter temperature is -44.7°C. There are frequent winter warm spells when the temperature may rise to 0°C.

Obviously, the Oka Crane Center is situated in a more rigorous climate than other centers abroad, thus, it is more difficult to successfully keep and breed cranes in captivity at this site.

The cranes' pens are placed on a raised part of the pine forest. Four complexes of pens have been built. Two are rectangular, with rectangular adjoining pens; two are hexaganol, with the pens in the shape of sectors. There are 36 pens in all, varying in area from 100 to 300 square meters. The soil is sandy with natural grass cover. There are trees in most of the pens (fir, birch), and bushes (willow, buckthorn, and raspberry) in a few.

The pens are enclosed by metal mesh fencing with 3-5 cm interstices, 2 m high. The exterior fences of the pens are embedded 20 cm into the ground as a precaution against terrestrial predators. Plastic netting with 10-cm openings covers the pens and permits us to leave the cranes full-winged.

All pens have shelters made of brick; the floors are concrete and covered with a layer of sawdust 5-7 cm deep. The area of one of these, meant to house a lone bird or a pair, is 7-9 square meters. During the winter the cranes spend most of their time in these shelters, where electric heaters keep the temperature between +3 and +5°C. On relatively mild days (when the temperature is no lower than -10°), the cranes are allowed into their outside yards. Snow is no hindrance to the birds; even tropical species readily go into the snow. Because there is only a slight change in temperature from inside their shelters to the out-of-doors, in 5 years no bird has caught a cold. At the same time, continuous winter outings help keep the birds' plumage clean and keep them in good physical shape.

Each pen has a plastic 15-20 l water trough. These are washed daily and the water is changed twice daily. Droppings are removed from the shelters daily, and twice a year (spring and fall) the floors are completely cleared of sawdust an the pen is disinfected. The floors are washed with a 3-5% solution of caustic soda mixed with formalin, and the walls, ceiling, and partitions are sprayed with a 10% solution of (monochloride iodine). At the entrance to each block of pens there is a "disinfection carpet" or foot bath-a box with sawdust, saturated with a 5% solution of caustic soda.

FORMATION OF A BREEDING STOCK OF CRANES IN THE CENTER

To create a breeding stock of cranes at Center, we have taken some eggs from nests in the wild toward the end of the incubation period, incubated and hatched them artificially, and raised the chicks. Since the Center was established, 41 eggs have been acquired; 33 hatched and 22 birds were raised (Table 1).

Table 1. Hatching success after incubation of crane eggs taken from the wild.

Crane species	Total eggs taken	No. of fertile eggs taken	No. of chicks hatched	Av. chick weight (g) (range in parentheses)	No. of birds raised
Siberian	29	26	25	126.9 (115.0-142.5)	15
Common	6	6	5	104.0 (102.0-144.0)	4
Sandhill	6	5	3	112.0 (110.0-113.0)	3
Total	41	37	33		22

Some birds are on loan from zoos in the USSR to form breeding pairs. Other cranes have been sent to us from the USA and the FRG as part of our collaboration. As of 1 November 1984, the Oka Reserve had 45 cranes of 9 species (Table 2).

CRANE NUTRITION

Our cranes eat mostly standard feed for broiler chickens--pellets 4.5 mm in diameter, with a protein content of 19.4-20.7%. At certain times of the year this is supplemented with whole grains (wheat, barley, corn). In 1984 at the time the adults were breeding and chicks were being raised, we prepared experimental batches of feed using a formula provided by ICF, and when we used the broiler feed we augmented it with a mix of vitamins.

The first common crane chicks raised at the Center were fed mostly natural foods: insects, aquatic invertebrates, fresh fish, frogs, boiled eggs, soft fresh cheese, leaves, and berries. On this high-calorie diet the chicks grew so fast that their legs began to be deformed. Simultaneously cutting back on their feed and increasing their exercise corrected this defect before it became permanent. In that year Siberian crane chicks were fed the same diet except that the proportion of river fish was increased. The fish were preserved frozen. By the age of 7-17 days, three of the four Siberian chicks showed signs of B-vitamin deficiency. They eventually died despite prolonged treatment with intramuscular injections of B_1, B_6, and B_{12}. The vitamin deficiency was caused by feeding them mostly frozen fish because in the fish enzymes had formed which destroy vitamins of the B group (Toubeau 1979).

The large group of Siberian crane chicks which we raised in 1980 ate feed sent by ICF, supplemented by insects, frogs, green leaves, and berries. No ailments were noted on this diet.

In 1983 we experimented feeding the Siberian chicks standard broiler feed. Some of the chicks developed vitamin D deficiencies, and four of them died.

In 1984 the crane chicks ate starter feed prepared by the ICF formula, plus various natural

Table 2. Origin of cranes at the Rare Crane Center, Oka Nature Preserve, as of 15 November 1984.

Crane species	Raised at the Center from eggs taken from the wild	Came to the Center as chicks (age 2-4 weeks)	Obtained from zoos in the USSR	Collected in the wild and given to the Center	Came from zoos abroad	Bred and reared at the Center	Total
Siberian	12	1		2			15[a]
Red-crowned		1	1				2
White-naped		1			2		3
Hooded			1		1	5	7
Common	4			1			5
Florida Sandhill (G. c. pratensis)					2		2
Greater Sandhill (G. c. tabida)					3[b]		3
Demoiselle		2	2				4
Stanley (Anthropoides paradisea)					2		2
Crowned (Balearica regulorum)			2				2
Total	16	5	6	3	10	5	45

[a] Thirteen cranes from the Yakut population and 2 from the Ob River population.
[b] Raised from eggs imported from the U. S. A.

foods and vitamin supplements. On this diet we successfully raised five hooded, one white-naped, and two demoiselle chicks (the latter three chicks came to the Center at the age of about one month).

CRANE REPRODUCTION

Most of the cranes at our Center are still immature, and some adults do not have partners. At present there are three breeding pairs: sandhill, hooded, and red-crowned. The adult sandhills were received in the summer of 1980 from the Washington Zoo. In April 1982 a hooded crane pair was formed by a 6-year-old male on loan from the Moscow Zoo and an adult female from the Walsrode Vogelpark. In spring 1984, a 3-year-old male red-crowned became sexually mature and was paired with a 9-year-old female on loan from the Novosibirsk Zoo. In 1984, the 4-year-old Siberian males began to produce good sperm, but the 4- and 5-year-old Siberian females had not yet begun to produce eggs.

To stimulate reproductive activity among the cranes at this high latitude, we artificially increased the length of day. Beginning at the end of February, day length was prolonged 1 hour daily, until it was 22-24 hours long. Under this regimen the sandhills began to lay eggs at the end of May, and the hoodeds in the beginning and middle of April. To increase the productivity of the breeding birds, the freshly-laid eggs were removed from their nests and placed in incubators or under brooders. The only sandhill hatched from an egg laid by birds kept at the Center was hatched in 1981 (Table 3). The best results came from the hooded cranes--a species which seems rather difficult to breed in captivity. It was first bred in captivity in 1976, at the International Crane Foundation (Archibald and Viess 1979). All five hooded chicks now at the Oka Preserve were reared in 1984. The high rates of fertile eggs and of chick survival were achieved due to the improved quality of their feed and the use of natural or mixed (natural and machine) incubation techniques (Table 4). The brooders used in 1984 were mostly sandhills. Only egg No. 6 was left to the hooded pair to incubate most of the period.

This Center presently does not have enough brooder cranes, consequently, it is very important to determine early in incubation whether an egg is fertile. The heavily pigmented shell of a hooded's egg makes it difficult to use an ovoscope, nevertheless we managed to see into the eggs well enough by the 5th day of incubation to detect the presence of an embryo. All of an unfertilized or unincubated egg glows, only the dark yolk being discernable. Half or two thirds of a fertile [fertilized] egg at the 5th day of incubation is not translucent, and by the 8th or 9th day in such an egg only the air chamber is translucent.

RAISING CHICKS

We raise our chicks basically by the methods used by ICF. The dried-off chick is removed from the incubator 15 to 20 hours after hatching and placed in a small (50 x 50 x 100 cm) collapsible pen made from wooden or metal frames over which small-celled plastic mesh has been stretched. The floor is covered with clean burlap bagging which is changed daily. The chicks

Table 3. Results of crane breeding at the Oka Preserve Center, 1981-1984.

Crane species	Number of eggs laid (in parentheses: fertilized)	Number of chicks hatched	Number of birds raised
Sandhill (1981-1984)	39(7)	4	1
Hooded (1982-1984)	13(6)[a]	5	5
Red-crowned (1983-1984)	6(1)[b]	1	

[a] Two eggs broken by the female.
[b] Four eggs were laid by the female in 1983 when the male was still immature.

are kept warm with 250-watt infrared lamps hung at such a height that the heat from them at floor level is 30-32°C. The chicks choose the most comfortable temperature regime by moving around within their "nurseries". Dishes of fresh water and fresh food are always available in the pens. During their first 7-10 days of life the chicks learn to eat with the aid of a colored stick or spoon; after that they eat independently. At the age of 2 or 3 weeks the chicks are transferred to more spacious pens, each 12 square meters. The chicks are taken for progressively longer daily walks, starting at the age of 2 days so that their legs develop properly. Their weight is checked daily until they are 2 months old. The infrared lamps are provided to warm them until they are about 2 months old.

LOSS OF CRANES AT THE CENTER; ACCIDENTS

The Oka Preserve has lost 18 cranes for various reasons (Table 5). Avitaminosis is the leading cause. Accidents are responsible for many deaths, too. The most hazardous is breaking legs, and also strained tendons in growing chicks. Two sandhill chicks hatched after artificial incubation from eggs laid by a female at the Center were very weak and died on the 1st and 3rd days of life; one chick was left with the sandhill parents to raise and died from emaciation when 6 days old. Besides broken legs which led to the death of birds, there were several situations where the birds damaged their beaks. The Siberian cranes suffered this most: three Siberians aged 4 months, 11 months, and 5 years broke their upper beaks in front of the nostrils (a length of 5-7 cm). One Siberian, beginning at the age of 9 months, broke halves of its bill 6-7 cm from the end three times. The first two times the beak regrew; the third time it had to be shortened by amputation at the site of the break. All birds with broken bills learned to eat from deep vessels.

Table 4. Method of incubation of crane eggs in 1984.

Crane species	Egg number	Amount of time spent[a] In an incubator	Under a brood crane	Duration of incubation (days)	Weight chicks (g)
Hooded	2	30(1-10; 12-31)	1 (11)	31	95.0
	3	5(1-3; 30-32)	27 (4-29)	32	90.0
	4	15 (9-19; 28-31)	16 (1-8; 20-27)	31	97.7
	5	8 (12-18; 30)	22 (1-11; 19-29)	30	103.0
	6	4 (28-31)	27 (1-27)	31	88.7
Red-crowned	2	3 (1-2; 32)	29 (3-31)	32	146.0

[a] In parentheses the days of incubation

Table 5. Causes of mortality of cranes at the Oka Preserve Crane Center, 1979-1984.

Crane species	Avitaminosis	Accident	Heat stress	Interspecific aggression	Disease (instead)	Other reasons	Total
Siberian	7	4	1				12
Common					1	1	2
Red-crowned				1			1
Sandhill						3	3
Totals	7	4	1	1	1	4	18

Beak damage in young Siberian cranes was caused mostly when the inquisitive birds tried to reach something in a neighbor's pen and broke their beaks in the netting. The adult Siberians who damaged their beaks were usually more aggressive individuals who tried to peck their neighbors or Center staff through their pen's nettings. To prevent such accidents some of the net partitions in the pen area were replaced with plywood shields, and pine branches were put up as an obstruction along the partitions in the outer walls or fences of the pens. Some minor beak damage occurred also in hooded, white-naped, and Stanley cranes.

So far, the Oka Crane Center has achieved the following: (1) We have laid the foundation for a gene bank of rare cranes; (2) We have mastered the methods of artificial incubation and hand-rearing of chicks; (3) We have established conditions for keeping cranes the year around, in good physical condition, and for breeding; and (4) We have basically solved the problem of providing proper feed for birds of various ages at various seasons.

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CAPTIVE PROPAGATION OF WHOOPING CRANES, 1982-1984

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Abstract: During the period 1982-1984, captive whooping cranes (Grus americana) at the Patuxent Wildlife Research Center (PWRC) produced 93 eggs. Fifty-eight eggs were retained at PWRC; 35 eggs were cross-fostered to wild pairs of greater sandhill cranes (G. canadensis tabida) at Grays Lake National Wildlife Refuge (GLNWR) in southeastern Idaho. Thirty-two chicks were successfully fledged, 18 at PWRC and 14 at GLNWR. To increase the size and genetic composition of the captive flock, 7 whooping crane eggs were collected in Wood Buffalo National Park (WBNP), Canada, and were transferred to PWRC between 1982 and 1984. Five of these eggs hatched and 4 chicks were raised. A single whooping crane chick was hatched and reared at the International Crane Foundation (ICF) in 1982. Although many problems have been encountered in propagating whooping cranes, the most significant historical factor limiting production has been the small size of the captive flock. The loss of 8 birds (2 males, 6 females) at PWRC in 1984 has unfortunately magnified this problem. In order to increase the size and productivity of the captive flock and rectify the currently male-skewed sex ratio, it is recommended that: (1) egg transfers from wild pairs in WBNP be continued indefinitely; and (2) egg transfers from PWRC to GLNWR be discontinued for the next several years.

PROCEEDINGS 1985 CRANE WORKSHOP

Whooping crane populations began to decline following European colonization of North America. Available evidence suggests that the most dramatic decline occurred during the late 1800's and early 1900's as the species' principal breeding areas were settled (Allen 1952). By 1937, only two small remnant breeding populations remained--a sedentary group of 11 birds in southwestern Louisiana, and a migratory group of 18 birds that wintered along the Texas coast on the newly-established Aransas National Wildlife Refuge (Erickson and Derrickson 1981). The Louisiana population continued to decline, and in 1948 the last individual was taken into captivity.

Although the migratory population survived, it had only increased to 21 birds by 1954. The slow growth of this population, coupled with the discovery that these birds were breeding in a remote, undisturbed area of Wood Buffalo National Park, NWT, Canada (Allen 1956), concerned many biologists, and suggested that conventional conservation measures (i.e., protective legislation, habitat preservation, and research) might not prevent extinction. Lynch (1956) subsequently proposed using captive propagation as a means to augment the growth of the wild population. Although this proposal generated considerable controversy initially, preliminary studies with sandhill cranes were eventually initiated.

In 1966 the Canadian Wildlife Service (CWS) and U. S. Fish and Wildlife Service (FWS) agreed to collect eggs from wild pairs in WBNP in order to establish a captive flock at the Patuxent Wildlife Research Center in Laurel, Maryland. Fifty eggs were collected and transferred to PWRC between 1967 and 1974, and whooping cranes hatched and hand-raised from these eggs formed the nucleus of the captive breeding flock. The egg collections and subsequent propagation efforts have been described previously (Erickson 1975, 1976, Kuyt 1976, Kepler 1976, 1978, Erickson and Derrickson 1981, Carpenter and Derrickson 1981).

Derrickson and Carpenter (1981) recently reviewed whooping crane production in captivity for the years 1967-1981. This paper updates this information for the period 1982-1984, discusses modifications in propagation methods undertaken during these years, and provides an overview of current problems and research directions.

RESULTS

Whooping Crane Production at the International Crane Foundation

In 1975, a female whooping crane (Tex) was transferred from PWRC to the International Crane Foundation (ICF) in Baraboo, Wisconsin, for breeding purposes. This bird had been hatched at

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the San Antonio Zoo (SAZ) in 1967, and had been sent to PWRC subsequently for pairing. Unfortunately, because she had been hand-reared and was highly imprinted on humans, all pairing attempts at PWRC failed. Dr. George Archibald (Director, ICF) intended to bring Tex into laying condition by acting as her surrogate mate, and then to fertilize her via artificial insemination (AI). Although this technique succeeded, and Tex laid a single egg in 1977, 1978, and 1979, no chicks were successfully hatched. Despite considerable efforts on the part of ICF staff members, Tex did not lay in 1980 or 1981 (G. Archibald, pers. comm.).

Before the 1982 breeding season, ICF and PWRC staff decided to make a concentrated effort to obtain offspring from Tex. Again acting as Tex's surrogate mate, Dr. Archibald lived with her throughout the prebreeding period. Whooping crane semen collected from a male donor at PWRC was routinely shipped to ICF two to three times per week for AI. Although initial inseminations were accomplished using cryogenically-preserved semen samples, fresh semen samples were shipped and inseminated as Tex approached laying condition. On 3 May 1982, Tex laid a fertile, thin-shelled egg which was placed under a nesting pair of captive sandhill cranes for incubation. After 18 days of "natural" incubation, weight loss of the egg was determined to be excessive due to its thin shell. Thereafter, the egg was machine incubated and periodically dipped in controlled temperature water baths to halt the excessive water loss and minimize the potential for embryo mortality. The male chick ("Gee-Whiz") hatched on 1 June and was successfully hand-raised. This bird is the only whooping crane currently at ICF; Tex was unfortunately killed by a raccoon (Procyon lotor) on 22 June 1982.

Whooping Crane Production at the San Antonio Zoo

Following the death of the San Antonio Zoo (SAZ) male ("Crip") in March 1979, his former mate and a 1979-hatched chick were transferred to PWRC. In return, SAZ received an adult pair of whooping cranes on breeding loan from PWRC. This pair produced eggs for the first time in 1982 at SAZ. Two eggs--laid on 21 and 26 March, respectively--were soft-shelled. It appeared the soft shell problem might be diet related, consequently, a supply of breeder ration and crushed oystershell was immediately shipped from PWRC to SAZ. Although a hard-shelled egg was laid on 5 April, it was infertile.

Like most other captive pairs of whooping cranes, this pair of birds did not exhibit normal copulatory behavior. Consequently, before the 1983 breeding season, SAZ Aviculturist Jeff Perry visited PWRC for training in AI procedures. Unfortunately, attempts by SAZ personnel to inseminate their pair failed. Semen samples adequate for AI could not be obtained from the male even though he was cooperative. The SAZ pair laid eggs on 14 and 19 March 1983. The first egg was found broken, and the second proved to be infertile.

Mr. Perry again visited PWRC for insemination training in early 1984, and it was decided at that time that fresh semen samples from a donor male at PWRC would be transferred to SAZ several times weekly for AI during the breeding season. The SAZ pair laid hard-shelled eggs on 10, 12, and 29 March, 1984. The first two eggs were infertile, and the third, although fertile, failed to hatch (J. Perry, pers. comm.).

Following the loss of seven whooping cranes at PWRC to eastern equine encephalitis (EEE) in the fall of 1984, CWS, FWS, and SAZ officials agreed to return the breeding pair at SAZ to PWRC in order to augment the captive flock. In return, SAZ would receive an unpaired, subadult male for display purposes. These transfers were completed in early 1985.

Whooping Crane Production at PWRC

When compared with the years 1977-1979, whooping crane egg production was poor at PWRC in 1980 and 1981. Only 2 females laid eggs in each of these years, and production totaled only 6 and 11 eggs. Reduced production in both years stemmed from the unfortunate loss of several breeding females, and the absence of laying in several other females apparently in response to disturbance and stress during the prebreeding period (Derrickson and Carpenter in press). As a result, the entire breeding program was reviewed before the 1982 breeding season, and various aspects of husbandry, behavioral management, and AI procedures were modified. In order to reduce stress and minimize the impact of necessary disturbances, all activities involving contact with breeding pairs (i. e., feeding, AI, egg checking) were subsequently handled only by the four-man AI team, and were completed on a regular schedule.

At the onset of the 1982 breeding season, the PWRC flock included five females that were considered potential breeders. Although three of these birds (UL, UR, and GI) had laid at PWRC

previously, two had not: a 5-year old female (HI) that had recently been paired with a 1974-hatched male, and the female ("Ektu") that had been transferred to PWRC and re-paired to a 1977-hatched male following the death of Crip at SAZ. All five of these females produced eggs in 1982, 1983, and 1984. Laying chronology and egg production per female were similar to that recorded at PWRC in previous years (Table 1).

Each year, whooping crane eggs were collected within 1-2 hours of oviposition and were placed in the nests of captive pairs of sandhill cranes for "natural" incubation. Flotation examinations (cf. Westerkov 1950) were conducted after 20-23 days of incubation to determine whether or not eggs contained live embryos. Eggs that did not show embryo movements during two consecutive flotations on separate days were subsequently opened and their contents examined.

Captive females at PWRC produced a total of 93 eggs over the 3-years (28 in 1982, 34 in 1983, and 31 in 1984, Table 2). One egg (UL#3) was broken by a female immediately after oviposition in 1984. Excluding this egg, 57 eggs were retained at PWRC either because they were infertile or contained dead embryos, or because they were laid too early in the season to be cross-fostered to wild sandhill cranes at GLNWR in southeastern Idaho. Forty-six (81%) of the 57 eggs were fertile, 35 (76%) hatched, and 18 (51%) chicks were successfully raised. Fourteen of these chicks were hand-raised, and four chicks were foster-parent reared by captive sandhill cranes.

The remaining 35 eggs produced by the captive flock were cross-fostered to wild pairs of sandhill cranes at GLNWR as part of the ongoing effort to establish a second, migratory population of whooping cranes in North America (Drewien and Bizeau 1978, U. S. Fish and Wildlife Service 1980). Egg transfers from PWRC were accomplished annually between late May and early June, the exact timing being determined by the prevailing weather conditions and sandhill crane nesting chronology at GLNWR. All 35 eggs were fertile, 28 (80%) hatched, and 14 (50%) whooping crane chicks were successfully raised to fledging by their sandhill crane foster-parents (Table 3, R. C. Drewien, pers. comm.).

As previously mentioned, whooping crane eggs were collected from nests in WBNP and transferred to PWRC between 1967 and 1974 to establish the captive population. Although eggs were routinely collected each year during the period 1975-1981, all of the eggs were transferred to GLNWR in support of the cross-fostering project rather than to PWRC to augment the captive flock. Derrickson and Carpenter (1981) subsequently suggested that egg transfers to PWRC be resumed on a limited basis in order to increase the size and enhance the behavioral, demographic, and genetic management of the captive population. This proposal was officially submitted to the CWS-FWS Program Review Committee in May 1982. After thorough discussion, it was agreed that: (1) PWRC would receive 2-3 wild-origin eggs each year beginning in 1982; and (2) all eggs would be derived from those breeding pairs whose offspring were either unrepresented or under-represented in captivity. As a result of this decision, seven whooping crane eggs were transferred from WBNP to PWRC between 1982 and 1984. Five (71%) of these eggs were fertile and hatched, and four (80%) chicks were successfully raised to fledging. Three chicks were hand-reared using conventional procedures, and one chick was foster-parent raised by a pair of captive sandhill cranes.

Table 1. Whooping crane laying chronology and egg production per female at PWRC.

Year(s)	Date of egg laying		Eggs per female	
	First	Last	Mean	Range
1975-1981	18 March[a]	11 June[b]	4.6[c]	1-11
1982	3 April	21 May	5.6	4-7
1983	25 March	30 May	6.8	4-9
1984	28 March	27 May	6.2	2-10

[a] Earliest laying date recorded for period.
[b] Latest laying date recorded for period.
[c] Weighted average for period.

Table 2. Summary of whooping crane production at PWRC, 1982-1984.

Year	No. of laying females	Total no. of eggs	Eggs retained at PWRC				Eggs transferred to GLNWR			
			No.	Fertile[a]	Hatched	Fledged[b]	No.	Fertile[c]	Hatched	Fledged
1982[d]	5	28	15	12	9	6(0)	13	13[e]	11	4
1983	5	34[f]	22	18	14	8(1)	12	12[e]	11	8
1984	5	31[f]	20	16	12	4(3)	10	10[e]	6	2
Totals	-	93	57	46	35	18(4)	35	35	28	14

[a] Fertility determined for unhatched eggs by examination of egg contents. Eggs containing no detectable embryo were considered infertile, therefore, the number of eggs listed as fertile is considered a conservative estimate.
[b] Numbers in parentheses indicate number of chicks that were foster-parent reared by captive pairs of sandhill cranes.
[c] Fertility determined by presence of embryo movements during flotation examinations conducted before and after transfer to GLNWR.
[d] In all years, eggs retained at PWRC were incubated under sandhill cranes, and chicks were either hand-reared or foster-parent raised by pairs of sandhill cranes. All eggs transferred to GLNWR were incubated under sandhill cranes at PWRC until transfer.
[e] One egg lost to a predator before hatching.
[f] One egg broken by parents after oviposition.

Table 3. Whooping crane eggs transferred from WBNP to PWRC, 1982-1984.

Year	Eggs			Chicks fledged
	Total	Fertile	Hatched	
1982	2	2	2	1
1983	2[a]	2	2	2[b]
1984	3[a]	1	1	1[b]
Totals	7	5	5	4

[a] One egg was infertile and another probably infertile because no embryo could be detected upon examination. Contents of both eggs were saved for pesticide/contaminant analyses.
[b] Chick was foster-parent reared by a captive pair of sandhill cranes.

Adult and Subadult Mortalities

During the period 1982-1984, there were 11 adult and subadult mortalities in the captive population (Table 4). Seven of these deaths occurred at PWRC between 17 September and 4 November 1984 as a result of an outbreak of eastern equine encephalitis--a disease caused by a virus (eastern equine virus, EEV), and spread among birds by a mosquito (Culiseta melanura). In all seven birds, the symptoms appeared suddenly and death occurred soon thereafter. Following diagnosis of the disease, PWRC personnel initiated programs to: (1) monitor and control C. melanura populations; (2) monitor whooping crane exposure to the virus; (3) innoculate whooping cranes with existing EEV vaccines; and (4) develop and test new and potentially more effectiveEEV vaccines. Resuits of these efforts have been positive thus far, and it is now believed that propagation activities at PWRC can be resumed without further incident.

Table 4. Adult and subadult whooping crane mortalities in captivity, 1982-1984.

Year	Location	Sex	Year hatched	Status (origin)[a]	Cause of death
1982	ICF	F	1967	Adult (C)	predation
	PWRC	F	1978	Subadult (C)	unknown[b]
	PWRC	F	1979	Subadult (C)	anesthesia[c]
1984	PWRC	F	1967	Adult (W)	injury[d]
	PWRC	F	1981	Subadult (C)	EEE[e]
	PWRC	M	1983	Subadult (W)	EEE
	PWRC	F	1979	Adult (C)	EEE
	PWRC	F	1968	Adult (W)	EEE
	PWRC	F	1982	Subadult (C)	EEE
	PWRC	M	1978	Adult (C)	EEE
	PWRC	F	1982	Subadult (C)	EEE

[a] W = hatched from wild-origin egg; C = hatched from captive produced egg.
[b] Bird was released at GLNWR as part of a reintroduction experiment in the summers of 1981 and 1982. In both years she was captured and returned to PWRC because she had not paired with a wild male. Necropsy results suggested that death may have resulted from a nutritional problem.
[c] Bird died while undergoing surgery to repair torn ligaments and tendons in the right tibio-tarsal joint.
[d] Bird died of complications resulting from an injury to the right tibio-tarsal joint.
[e] EEE = eastern equine encephalitis.

Nine of the 11 adult and subadult whooping cranes lost in captivity between 1982 and 1984 were females, including 3 breeding birds and several subadults that would have initiated laying over the next several years. The captive population has increased from 19 to 35 birds since early 1982, however, the present sex ratio is skewed toward males and the age distribution is skewed toward the younger age classes. Female mortalities, in particular, have placed rather severe constraints on the potential growth and productivity of the captive population for the immediate future.

DISCUSSION

The whooping crane propagation program was established to minimize the probability of extinction, foster basic research, develop propagation and husbandry techniques, and produce offspring for release into the wild (Erickson 1975, Erickson and Derrickson 1981). The importance of the first goal has diminished considerably as the wild population has increased. The remaining goals - research, captive breeding, and reintroduction - remain essential components of the recovery plan for this species.

Over the past decade, considerable progress has been achieved in breeding whooping cranes in captivity. Research on captive whooping cranes and sandhill cranes has resulted in the continuous refinement of propagation and husbandry procedures, and the development of potential reintroduction techniques. Although these advances have demonstrated that sustained captive production is feasible, and that captive-produced birds can be returned to the wild, a number of significant problems still remain and need to be resolved. These problems and research activities aimed at their solution are addressed briefly below.

Artificial Insemination

Since whooping crane eggs were first produced at PWRC in 1975, the captive breeding program has had to rely exclusively on AI to obtain fertile eggs. During 1975-1981, many of the eggs produced each year (20-45%) were infertile despite AI, and egg infertility remained perhaps the major obstacle in the captive propagation (Derrickson and Carpenter 1981). As a result, AI

procedures were extensively modified beginning in 1982 in an effort to improve egg fertility and egg production. Procedural modification included: (1) all propagation activities involving contact with breeding pairs - including AI - were conducted by the same personnel throughout the entire breeding season; (2) handling procedures were modified to accommodate the behavioral idiosyncracies and preferences of individual birds; (3) nervous pairs and/or females were not handled or inseminated until after laying commenced; (4) semen was consistently deposited in the oviduct rather than in the cloaca; (5) laying was observed closely, and females were inseminated within 1-2 hours after each oviposition as well as three times weekly; (6) females were worked to climax following semen deposition; and (7) females were reinseminated whenever evaluation of semen samples revealed either low sperm concentration or low motility.

Although all whooping crane eggs were removed as laid, selected pairs were allowed to incubate a sandhill crane egg or dummy egg until each clutch was completed. This procedure was used on three pairs that routinely began incubation with the first egg, and was accomplished in order to minimize stress, foster normal reproductive activities, and promote a more normal laying cycle.

During the 1982 breeding season, captive females laid a total of 28 eggs of which 26 were covered via AI. Twenty-four of the 26 eggs (96%) were fertile-the highest fertility rate achieved with captive whooping cranes thus far. The aforementioned procedural modifications were duplicated during the 1983 and 1984 breeding seasons with both whooping cranes and Mississippi sandhill cranes (*G. c. pulla*), and similar results were obtained. Whooping crane egg fertility was 91% (30 of 33 covered eggs) in 1983 and 90% (26 of 29 covered eggs) in 1984. These levels of egg fertility are similar to those observed in wild whooping cranes, and obviously represent a major advance for the captive propagation program.

AI was originally incorporated into the whooping crane breeding program to solve the immediate problem of egg infertility. Although this technique has proven successful and will find continued use within the program, additional attention now needs to be focused on the causative factors underlying adult copulatory problems. A more complete understanding of these problems will hopefully lead to the development of routine propagation procedures which promote normal adult copulatory behavior.

Rearing Procedures

Chick rearing procedures at PWRC were modified in 1978 to exclude artificial incubation and hand-rearing. All eggs were collected as laid, and were placed in the nests of breeding sandhill cranes for foster-parent incubation and rearing. This program was initiated after experiments with sandhill cranes revealed that chicks raised by parents were more robust and vigorous than hand-raised chicks, and did not develop the leg and toe problems frequently encountered during conventional hand-rearing. Parent-raised chicks are properly socialized to conspecifics rather than to human caretakers, consequently, it was believed that these birds would be more likely to show normal social and sexual behavior when reaching adulthood.

Although chick mortality was reduced each year as parent-rearing techniques were refined, a substantial number of chicks were still being lost during or within 5 days of hatching. Initial efforts to closely monitor hatching events and the physical condition of young chicks proved largely counterproductive, and did not reduce early mortality. Consequently, in 1982 and 1983, whooping crane eggs were removed just before hatching, and the chicks were adopted back to their sandhill foster parents after 5-10 days of conventional hand-rearing. Even though this procedure had worked well in experiments with sandhill cranes, its application to whooping cranes failed due to problems associated with hatching chronology, unpredictable weather conditions, and inappropriate chick-adult behavior. The majority of whooping crane chicks hatched in both years were therefore hand-raised. Fortunately, the incidence and severity of leg disorders were minimized by restricting food intake and increasing exercise levels to control chick growth rates (Derrickson and Carpenter *in press*).

The failure of the adoption technique stimulated a thorough review of parent-rearing procedures before the 1984 breeding season, and resulted in a number of major modifications in antibiotic and anthelminthic medications and treatment schedules. These changes--particularly the injection of gentamicin for the first 3 days after hatching--substantially reduced chick mortality in both whooping cranes and sandhill cranes. It is now expected that these modifications will greatly increase the future production of parent-reared birds which will be suitable for either captive breeding or release into the wild. To enhance future whooping

crane rearing capabilities, PWRC has been expanding its propagation facilities, increasing its captive flock of sandhill cranes, and hiring additional qualified personnel.

Delayed Reproduction

Available information on marked individuals suggests that wild females normally begin laying at 4-5 years of age (E. Kuyt, pers. comm.). Although some captive females have laid eggs when 5 years old, the majority have not initiated laying until considerably older--a situation which has greatly reduced overall productivity. Fortunately, because the principal factors responsible for delaying reproduction have now been identified (Kepler 1976, 1978, Derrickson and Carpenter 1981, In press), it is usually possible to diagnose these problems, and then modify either the environment or key breeding procedures to secure early and/or consistent breeding. For example, 2 females (a 5-year-old laying for the first time, and a 15-year-old laying for the first time after being re-paired) were successfully brought into laying condition in 1982 by minimizing all handling before laying commenced. Similarly, a 2-year-old, parent-reared female and a 5-year-old, parent-reared male were successfully paired in the fall of 1983, and breeding activities the following spring progressed up to the point of nest building. It seems highly probable that this compatibly-paired female would have initiated laying the following year at 4 years of age; unfortunately, she was lost to EEV in the fall of 1984.

The early pairing of sexually compatible individuals clearly remains crucial to securing early reproduction. To this end, researchers at PWRC are now applying cytological techniques (Biederman and Lin 1982, Biederman et al. 1982) to sex immature whooping cranes. Cytological sexing can be accomplished at an earlier age, and is much more reliable than either behavioral or surgical sexing procedures. This technique, along with improved behavioral management, should ensure the early pairing and early reproduction of captive whooping cranes in the future.

Captive Population Size and Management

The wild whooping crane population underwent a severe reduction in recent times and has recovered only slowly. This relatively prolonged bottleneck has undoubtedly eroded genetic variation as a result of random drift and increased inbreeding. Although the extent of this reduction remains unknown, it is imperative that extant levels of genetic variation be maintained in both the wild and captive populations. Captive propagation can only be effective in this process if programs are scientifically managed to maximize the size of the effective breeding population, and minimize the adverse effects of inbreeding (Frankel and Soule 1981). These rather difficult tasks require intensive husbandry programs which incorporate behavioral management (Kleiman 1980, Derrickson and Carpenter In press), demographic management (Foose 1977, Goodman 1980), and reproductive/genetic monitoring and veterinary support (Carpenter 1977, Flesness 1977, Bernischke et al. 1980, Senner 1980).

Although applied research has resulted in considerable progress in the behavioral, demographic, and veterinary aspects of managing the captive whooping crane population, relatively little attention has been directed toward elucidating methods and procedures necessary for proper genetic management. To date, the captive breeding program has operated on the assumption that individuals derived from different wild territories are genetically unrelated, and hence can be paired for breeding purposes. However, because all of the captives were obtained from a small population with a high degree of relatedness, this assumption is probably invalid, and the present breeding regime could ultimately result in unacceptable levels of inbreeding. Low rates of inbreeding can adversely affect reproductive performance (i. e., fertility, fecundity, age of maturity), as well as other physical and behavioral traits (cf. Flesness 1977, Ralls et al. 1979, 1980, Senner 1980, Greenwell et al. 1982). Thus, it is imperative that cytological and biochemical investigations be completed to determine existing levels of genetic variation, and establish breeding objectives that will minimize inbreeding. Although this research has been repeatedly proposed, investigations have not been initiated.

Due to the substantial mortality of young birds, and the delayed reproduction of adults, the captive whooping crane population has never been very large. The small size of the captive flock has adversely affected the ability to form sexually and socially compatible pairs, and has placed rather severe limitations on flock productivity (Derrickson and Carpenter 1981). The size of the captive population must obviously be increased to enhance long-term captive

management capabilities and increase the production of offspring available for reintroduction purposes. Current levels of pair productivity suggest that a captive breeding unit of 15-20 pairs could achieve both of these goals, therefore, every effort should be made to supplement the current growth rate of the captive population in the immediate future. For this reason, it is suggested that (1) the annual transfer of two to three wild-origin eggs from WBNP to PWRC be continued indefinitely, and (2) the transfer of captive-produced eggs form PWRC to GLNWR be discontinued for at least 2-3 years. These actions would not interfere with ongoing recovery programs, and would result in a much needed expansion of the captive flock.

Release Experimentation

One of the continuing objectives of the captive breeding program is to provide offspring to establish or augment wild whooping crane populations. Within the past decade, considerable progress has been made in developing reliable reintroduction methods for captive-produced stock. As previously mentioned, whooping crane eggs from PWRC have been routinely cross-fostered to wild pairs of sandhill cranes at GLNWR since 1976. Although original efforts to cross-foster captive-produced eggs were unsuccessful, initial problems were eventually solved by using natural rather than artificial incubation, and by transferring only those eggs containing viable embryos (Derrickson and Carpenter 1981). Since these modifications were undertaken in 1979, hatchability and survivorship has equalled that observed in wild-origin eggs and chicks derived from WBNP. Future expansion of the captive breeding flock should substantially increase the number of eggs available for cross-fostering.

Increasing attention is now being given to the possibility of directly releasing captive, subadult whooping cranes into the wild. This technique, if feasible, could eventually be used to either supplement or replace cross-fostering in the establishment of additional wild populations. Although recent experimental releases of captive, parent-reared sandhill cranes have shown encouraging results (Nesbitt 1979, Drewien et al. 1981, Zwank and Derrickson 1981, Derrickson and Carpenter In press), existing methods and procedures will have to be further refined before direct releases of whooping cranes will become generally practicable. This research must be continued and expanded in the future if captive propagation and planned reintroductions are to play a substantial role in whooping crane conservation and management.

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THE HATCHING PROCESS IN CRANES WITH RECOMMENDATIONS FOR ASSISTING ABNORMAL CHICKS

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Abstract: This paper examines the hatching process in cranes. The hatching process is separated into three phases: Scratching and Peeping, Pipping, and Emergence. Data for six species of crane chicks that hatched without assistance at the International Crane Foundation (ICF) were reviewed to determine the amount of time required for each phase. This information serves as a reference for recognizing weak and malpositioned embryos. Guidelines are presented for assisting abnormal embryos with the hatching process.

PROCEEDINGS 1985 CRANE WORKSHOP

Cranes are currently being bred in captivity to maximize reproduction, increase genetic diversity, and restock wild populations. Although hatchability at many captive propagation centers is good, there is an unnecessary loss of healthy, unhatched crane chicks simply because aviculturists are unfamiliar with the normal sequence and duration of events that comprise the hatching process. Chicks that fail to hatch are not necessarily unfit for survival or genetically undesirable. Some are weak due to imperfect incubation conditions, others may be developmentally normal but incapable of pipping due to slight malpositioning in the egg. By using behavioral and temporal hatching data of chicks that hatch without assistance, aviculturists may be able to recognize atypical eggs and to assist these embryos whenever necessary.

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METHODS

Cranes hatched at the International Crane Foundation from 1981-1984 included sarus (Grus antigone), sandhill (G. canadensis), Stanley (Anthropoides paradisea), Siberian (G. leucogeranus), red-crowned (G. japonensis), and white-naped (G. vipio). Eggs were collected from the wild, incubated naturally under captive sandhill cranes, or incubated artificially in Petersime Forced-air Model 1 incubators. Eggs were artificially incubated at 37.6°C, with a wet bulb reading of 27.8°C for white-naped Cranes and 30.0°C for all other species.

Detailed records were maintained on all eggs (Fig. 1). Artificially incubated eggs were weighed every second day and the weights were graphed to determine percent weight loss. An initial weight was taken on naturally incubated eggs of captive cranes. After these eggs were removed from the adults, and placed in the incubator, they were weighed every second day. Thirteen and 17% weight losses were calculated from the initial weights of each egg and graphed to serve as a guideline for the actual weight loss. Fig. 2 depicts abnormal weight loss for a whooping crane (G. americana) egg. Observations were also made on embryonic movement in eggs at rest on a flat surface or immersed in water (Fig. 3a).

Eggs were removed from the incubator tray after 27 days for Siberian Cranes, 28 days for Stanley and sandhill cranes, 29 days for white-naped cranes, and 30 days for red-crowned and sarus cranes. At this time the air cell was traced in pencil and the egg placed horizontally on a piece of hollow foam at the bottom of the incubator with the large portion of the air cell on top (hatch position). When scratching and peeping sounds were heard, or the chick had pipped the shell, the eggs were removed from the incubator and placed in a Petersime Hatcher at 37.2°C, with a wet bulb reading of 33.9°C. The egg was then checked four times daily (0800, 1200, 1700, and 2200 hours) and data recorded on an Information Form (Fig. 4).

INTERNATIONAL CRANE FOUNDATION

EGG DATA SHEET Succession No. 20

Incubator No._____ F X I_____ Date 29 April 83

Egg No. 7-32-3 Dam Terry Sire J.C.

Egg length 108.60mm Egg width 60.55 mm Egg weight (initial) 205.18 g

Egg weight (end) _____ % weight loss_____

Day	Weight	Day	Weight
1	205.18	19	186.64
2		20	
3	203.38	21	184.60
4		22	
5	201.29	23	182.67
6		24	
7	199.14	25	180.32 (moves on table)
8		26	
9	197.14 (looks F)	27	178.09
10		28	
11	194.95	29	175.74
12		30	
13	192.78	31	174.05 (moved to hatch position)
14		32	
15	190.85	33	
16		34	
17	188.75	35	
18		36	

Remarks: Collected - laid between 10 A.M. and 10:45 A.M.

Fig. 1. Egg data sheet used at International Crane Foundation to record egg weight changes and other information.

We recorded the behavior of all hatching chicks and measured the amount of time required for each phase of the hatching process. We developed a table of these times for each species by using the data from all chicks that hatched without assistance. Aviculturists may use this table as a guideline for hatching crane eggs and for learning when to expect certain behavioral patterns. Suggestions are given for assisting chicks that fail to exhibit normal behavior in the hatching process.

RESULTS

The hatching process has been divided into three phases (Archibald and Viess 1979):

1. Scratching and Peeping Phase. The chick cuts the inner membrane and begins breathing oxygen with its lungs. Scratching and peeping sounds may be heard when the egg is held near the aviculturist's ear (Fig. 3b). This Phase begins when the first sounds can be heard and continues until the chick pips the shell.
2. Pipping Phase. The chick makes a small hole in the shell in the middle of the upper edge of the air cell (Fig. 3c). Pipping Phase is the time interval from pipping of the shell until the chick rotates counterclockwise and begins to break away the shell over the air cell.
3. Emergence. The chick rotates counterclockwise and breaks away pieces of shell along the outline of the air cell (Fig. 3d). The Emergence Phase is the time interval from the beginning of rotation until the chick has completely freed itself from the shell.

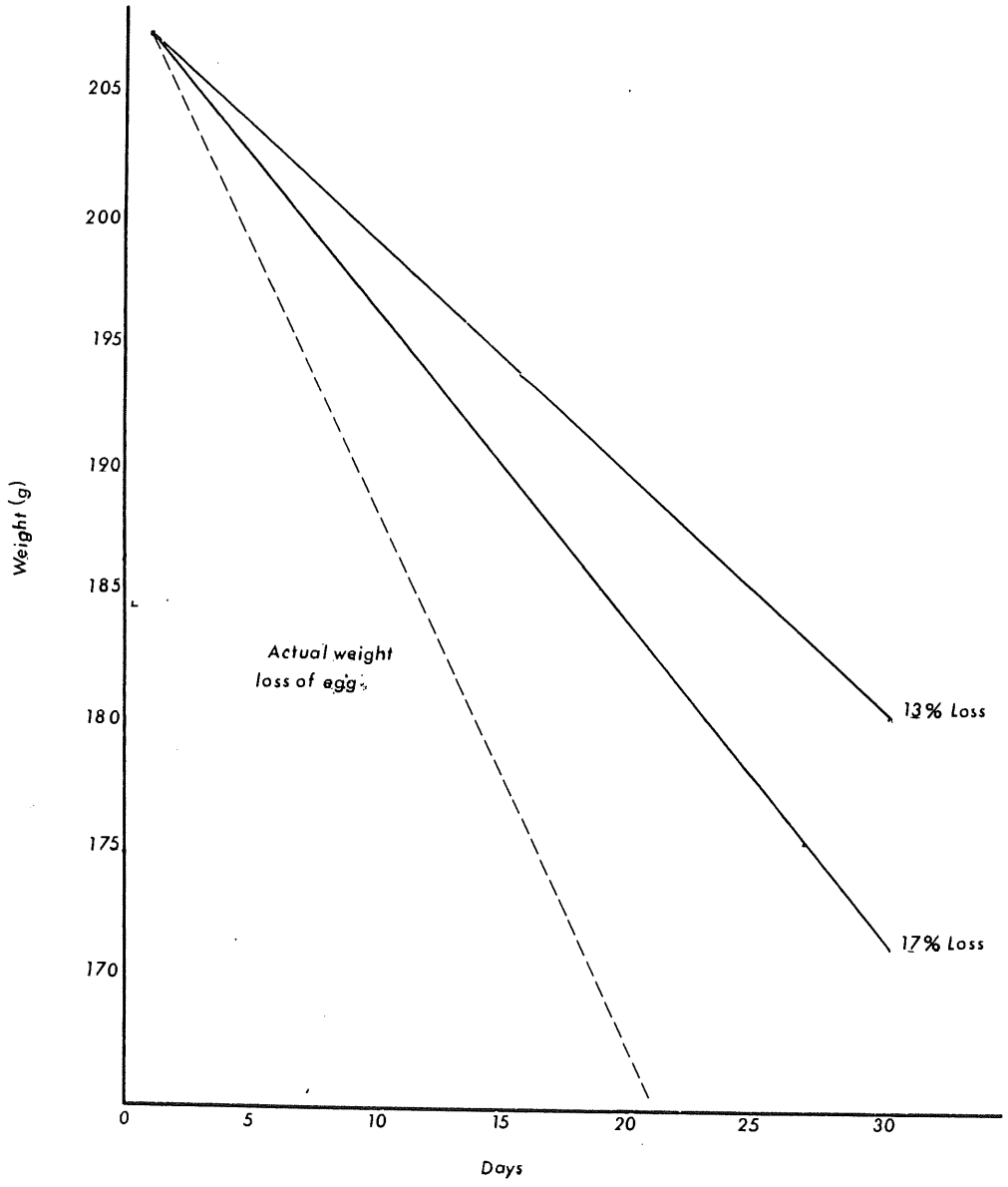

Fig. 2. Abnormal weight loss in a whooping crane egg as incubation progresses.

The duration of the Phases in the hatching sequence, including means, standard deviations, and ranges, are outlined in Table 1. Table 2 lists the days of the incubation period in which each Phase begins.

The incubation period including the hatching sequence, ranged from 30.3 days in the Siberian Crane to 33.5 days in the red-crowned crane. Lengths of the hatching sequence are remarkably similar among these species. By substracting the length of the hatching sequence from the length of the total incubation period, one can calculate the time when a normal chick should start to hatch.

We reviewed the hatching records of 132 crane eggs that hatched at ICF from 1981-1984. Of these eggs, 51 (38.6%) were given assistance and 81 (61.4%) hatched without help. Table 3 shows the hatching phase at which help was first given and the percentage of chicks that survived.

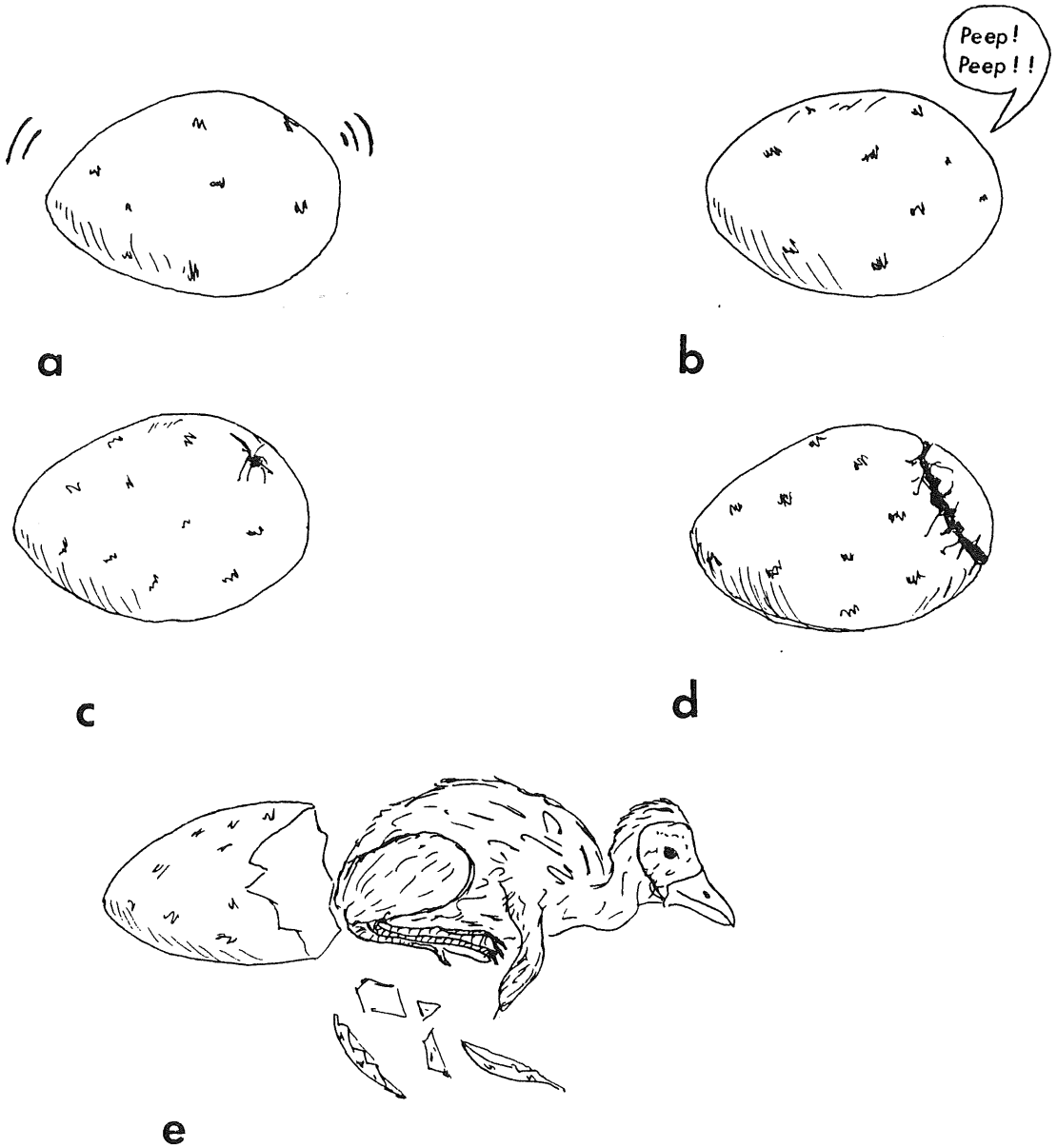

Fig. 3. Normal Hatching sequence of cranes: (a) movement, (b) scratching and peeping, (c) pipping, (d) rotation, and (e) emergence.

Assistance involved correcting malpositioned chicks, making an air hole in the shell of chicks that failed to pip on schedule, moistening the inner membrane when it restricted chicks during emergence, and suturing unretracted yolk sacs. The amount of assistance given a chick was based on its behavior and general vigor, and sometimes it was difficult to determine a chick's fate had assistance not been given, but in most situations the chick would not have survived. Necropsies seldom determined primary cause of death, but judging from the reports, assisted chicks failed to thrive for reasons other than avicultural intervention. ICF concentrates on raising endangered cranes, and aviculturists have not had large enough samples to experimentally determine the minimum amount of assistance a hatching chick may require. But the high percentage of chicks that hatched with assistance and survived indicates that helping them is beneficial.

PIPPING AND HATCHING INFORMATION

Egg No. 07-32-04 Species: Grus canadensis pratensis Chick No. Thal

Date moved to hatcher 29 May 83 Days of incubation 27 days

08:00		17:00	Peeping & scratching, moved to hatcher
12:00		22:00	Peeping & scratching
Date 30 May			
08:00	Still peeping & scratching	17:00	Sounds strong
12:00	Peeping & scratching, sounds strong	22:00	Pipped!
Date 31 May			
08:00	2" cicumpipped	17:00	Few more chips pecked from air cell. Going strong.
12:00		22:00	Hatched out!! Shell wt: 32.27 g Chick wt: 122.61 g Umbilicus not completely dried, applied iodine
Date 1 June			
08:00	Moved to Brooder	17:00	
12:00		22:00	

Onset of scratching and peeping: 27 days, 7 hours Scratching time 29 hrs.

Pipped Shell: 28 days, 12 hours Pipping time 10 hrs.

Onset of hatching: 28 days, 22 hours Emergence time 14 hrs.

TOTAL HATCHING TIME: 53 hrs.

Scratching and peeping: Date 29 May 83 Days of incubation 27 days

Pipped: Date 30 May 83 Days of incubation 28 days

Hatching: Date 31 May 83 Days of incubation 29 days

Fig. 4. ICF record sheet for pipping and hatching information.

RECOMMENDATIONS FOR ASSISTING CHICKS WITH HATCHING

Assisting chicks with the hatching process is a skill the requires extreme patience and the ability to distinguish between normal and abnormal hatching behavior. It is important to be able to recognize the atypical embryos. More harm than good may be done if normal, but relatively slow chicks, hatch too soon because of intervention. Successful hatching is often dependent on the aviculturists ability to evaluate the chick's vigor. A chick may enter one phase of the hatching sequence prematurely and compensate for it by prolonged activity in the next phase, or vice versa. Note that the duration of each phase is highly variable; this variability should be carefully considered when making a decision to assist a chick. The mean times for each species only provide a general guideline. Eggs must be treated as individuals, however, and their behavior evaluated several times a day.

The most common problem ICF crane chicks had with hatching was weakness at some stage in the process. Occasionally, chicks were malpositioned within the egg (Fig. 5a) and had to be placed in the proper hatching position (Fig. 5b). Some chicks emerged before the yolk sac was fully absorbed. These problems are addressed in the following paragraphs, with suggestions on how to recognize and correct them. Sterility of instruments and good hygiene are extremely important because chicks are very susceptible to infection.

Table 1. Duration of intervals (hrs) between the major events in the hatching process of six species of cranes.

	Moving to scratching	Scratching to peeping	Peeping to pipping	Pipping to rotating	Rotating to emergence	Pipping to emergence
G. vipio						
Mean	50.3	5.8	19.0	19.6	16.4	31.1
Range	9-125	0-28	4-33	14-24	3-58	19-48
s	33.2	7.49	8.02	3.97	15.4	7.68
N	17	25	23	14	11	16
G. japonensis						
Mean	74.3	12.1	19.5	11.7	14.7	25.3
Range	28-194	0-37	2-34	5-17	4-24	9-34
s	40.2	11.39	9.25	4.24	6.65	8.75
N	14	16	15	10	10	12
G. leucogeranus						
Mean	18.3	9.7	18.6	20	7.3	26.2
Range	9-24	4-15	3-35	10-25	3-14	9-50
s	8.14	5.51	10.77	8.66	5.86	14.06
N	3	3	7	3	3	6
G. canadensis						
Mean	101	5.57	23.2	19.2	7.4	26.5
Range	72-154	0-43	14-39	4-26	4-15	14-48
s	36.68	12.21	7.01	11.37	4.09	10.35
N	4	14	15	9	10	18
G. antigone						
Mean	---	12.5	25.5	22.3	7.25	18.5
Range	---	10-15	24-29	14-29	2-14	5-43
s	---	3.54	2.11	7.64	5.74	10.13
N	---	2	11	3	4	11
A. paradisea						
Mean	---	9.0	26.0	9.5	7.5	17.0
Range	---	9	15-39	9-10	5-10	14-20
s	---	0	12.12	0.71	3.56	4.24
N	---	2	3	2	2	2

Table 2. Days of incubation elapsed at the onset of each hatching phase in six species of cranes.

	Movement	Scratching and peeping	Pipping	Emergence
G. vipio				
Mean	28.1	29.6	30.3	31.5
Range	26-30	29-31	29-32	30-33
sd	1.26	0.81	0.81	1.04
N	16	16	19	18
G. japonensis				
Mean	28.4	31.6	32.4	33.5
Range	26-30	31-32	32-33	32-34
sd	1.88	0.51	0.51	0.66
N	12	12	12	13
G. leucogeranus				
Mean	26.7	28.6	29.0	30.3
Range	25-28	28-29	28-30	30-31
sd	1.06	0.52	0.63	0.58
N	10	10	6	3
G. canadensis				
Mean	25.1	29.9	30.3	31.4
Range	21-29	28-31	26-34	27-35
sd	2.23	1.33	1.73	1.80
N	17	15	19	19
G. antigone				
Mean	28.8	30.5	31.5	32.4
Range	26-30	30-31	31-32	32-33
sd	1.64	0.58	0.58	0.55
N	5	4	4	5
A. paradisea				
Mean	27.5	29.0	30.5	31
Range	27-28	29	30-31	31
sd	0.71	0.0	0.71	0.0
N	2	2	2	2

Table 3. Hatching phase at which assistance first occurred.

Phase	No. of eggs	No. hatched/survived	%hatched/survived
Scratching & Pipping	8	3	37.5
Pipping	21	19	90.5
Emergence	20	20	100.0
Premature Emergence	2	0	0.0
Total	51	42	82.4
Eggs hatched w/o assistance	81	73	90.1

Movement Before the Scratching and Peeping Phase

Although embryonic movement is not described as a phase of the hatching sequence, the vigor of the chick may be determined by the extent to which movement occurs. Movement begins at 23-27 days of incubation.

If the embryo causes the egg to move when it is laid on a flat surface, but scratching is not heard after the normal time for the onset of scratching, the vigor of the embryo should be monitored every 4 hours to determine if it is losing strength. Weakness is indicated by a reduction in movement of the egg. Scratching will eventually be heard if the embryo retains its strength. If the embryo weakens, it may die unless immediate action is taken.

If the embryo has weakened, break the shell carefully above the air cell and remove the shell (Fig. 5c). Extreme care must be taken not to tear the membrane covering the embryo. The chick's neck normally lies along the lower edge of the air cell in a clockwise direction, with the beak in the middle of the air cell's upper edge. The beak is obvious as a pointed structure under the membrane and movement can often be seen. If the beak is not obvious, it can sometimes be located by gently touching the membrane that covers the embryo. If the beak is neither obvious nor readily located, the chick may be malpositioned in the egg and surgery is necessary to reposition it.

First moisten the membrane with warm, dilute glycerol solution (Fig. 5d) (B. C. Wentworth, pers. comm.). The membrane will change from opaque white to transparent and the blood vessels will become visible. There are usually fewer blood vessels in the central area where the beak is normally located. At this central location lift the membrane gently with a forceps and make a 1-2 cm slit with a sharp scissors (Fig. 5e). Be very careful to avoid cutting a blood vessel. The blood vessels lie in a translucent gel between the membrane and the embryo. By using a blunt probe, this gel and the blood vessels can be pushed back from the region of the incision along the membrane to the borders of the air cell to expose the embryo (Fig. 5f). Gently probe the embryo to locate the shoulder and neck. The neck can then be followed to the head. Using the thumb and forefinger pull the neck and head gently and slowly toward the air cell and fold it in the proper position for hatching (Fig. 5g). The beak should be opened and fluid withdrawn from the mouth cavity using a needleless syringe. At this point, the embryo should start to breathe on its own.

Next, transparent plastic should be placed over the open end of the egg and taped to the shell (Fig. 5h) to prevent premature emergence, dehydration, and heat loss. Make a hole through the plastic over the beak so the chick may breathe. The chick should be maintained in this condition until the calculated time of emergence. Check the membranes for blood flow. The chick should not be removed from the shell until blood flow through this membrane has ceased (see Pipping Phase to Emergence Phase section).

Scratching and Peeping Phase

As soon as the chick starts scratching, evaluate the chick's strength for future comparisons. Scratching sounds become more vigorous until peeping is heard, or the two sounds may be heard simultaneously. If scratching becomes weaker or peeping is not heard after approximately 24 hours, open the shell over the air cell to determine if the embryo is malpositioned or if it is simply weak. If it is malpositioned use the procedure described in the "Movement Prior to Scratching and Peeping Phase" section, to place the chick in the correct hatching position. If it is weak, wet the membrane and make a slit above the beak to permit the chick to breathe. Liquids which might drown the chick should be removed from the mouth cavity using a needleless syringe. A plastic sheath should be placed over the open end of the egg with a hole cut through for the chick's beak.

Peeping to Pipping Phase

After the embryo begins to peep, evaluate its vigor for future comparison. If the peeping sound is weak, listen closely and judge where the beak is situated. Make a small air hole through the air cell as near as possible to this point. Air passing through the hole and over the membrane will sometimes cause the membranes to dry and adhere to the embryo, if the hole is not directly over the beak. This drying may cause the embryo to become trapped in the shell. The embryo often regains its strength and continues to hatch normally after the air hole is made. But if the chick has not started to rotate within the normal time interval, remove the

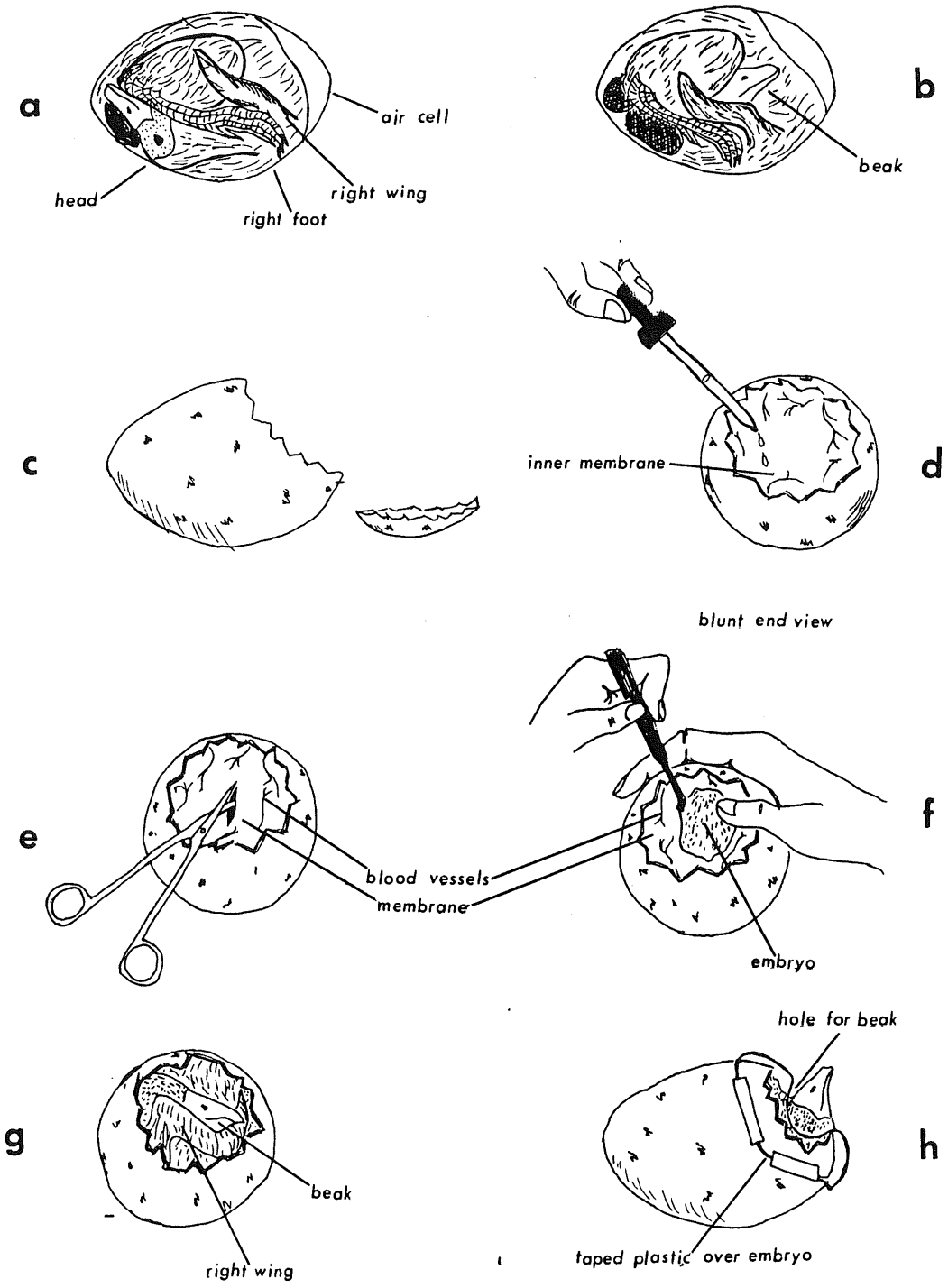

Fig. 5. Steps for correcting crane chick malpositioned in the egg: (a) abnormal hatch position, (b) normal hatch position, (c) shell removal over air cell (large portion of air cell on top), (d) moistening inner membrane (shell over air cell removed), (e) slit inner membrane to expose chick, (f) use blunt probe to remove membrane from air cell area, (g) pull head into normal hatch position (right wing below head), and (h) tape clear plastic over open part of egg, with hole for chick's beak.

shell over the air cell and wet the membrane with dilute glycerol solution. Examine the vessels for blood flow. If the blood flow has stopped some vessels will be difficult to see due to lack of blood, and clots will be visible in others. The membrane over the chick should not be removed until the blood flow has ceased, an indication that the yolk sac has been absorbed and the umbilicus closed. Helping the embryo emerge before the blood has ceased flowing through the membrane can result in lethal hemorrhage and/or emergence of the chick before the entire yolk has been absorbed.

Pipping Phase to Emergence Phase

A normal chick rests after pipping the shell and then begins to rotate counterclockwise in the egg breaking away bits of shell around the outline of the air cell. The chick's yolk sac has been absorbed into the abdomen and the umbilicus has closed by the time it has completely freed itself from the shell.

If the chick has pipped, and more than 30 hours pass before it starts to rotate, remove the shell over the air cell and wet the membrane with dilute glycerol solution to examine the blood vessels. If the blood flow has stopped and the membrane is stuck to the chick, release the membrane by sliding a blunt probe between it and the chick. The membrane can then be removed from the exposed side of the chick. A strong chick will usually rotate and emerge after the membrane is removed.

If the chick does not emerge, unfold its head and neck from the hatching position and gently lift the chick from the egg just to the point where the umbilicus can be examined. Be very careful not to pull too hard, because the umbilical region is extremely prone to hemorrhage, and if ruptured, the chick may bleed to death. If the umbilicus has closed, slide the chick back into the egg in natural hatching position and allow it to emerge on its own. If there is still yolk sac protruding through the umbilicus, place the chick back in the egg, cover the large end of the egg with a plastic sheath and make a hole for the head and neck. The chick should be resting on its ventral surface. Use warm, sterile saline solution to moisten the yolk sac and umbilicus, and to facilitate absorption of the yolk sac. After the umbilicus has closed, allow the embryo to emerge from the egg by removing the plastic.

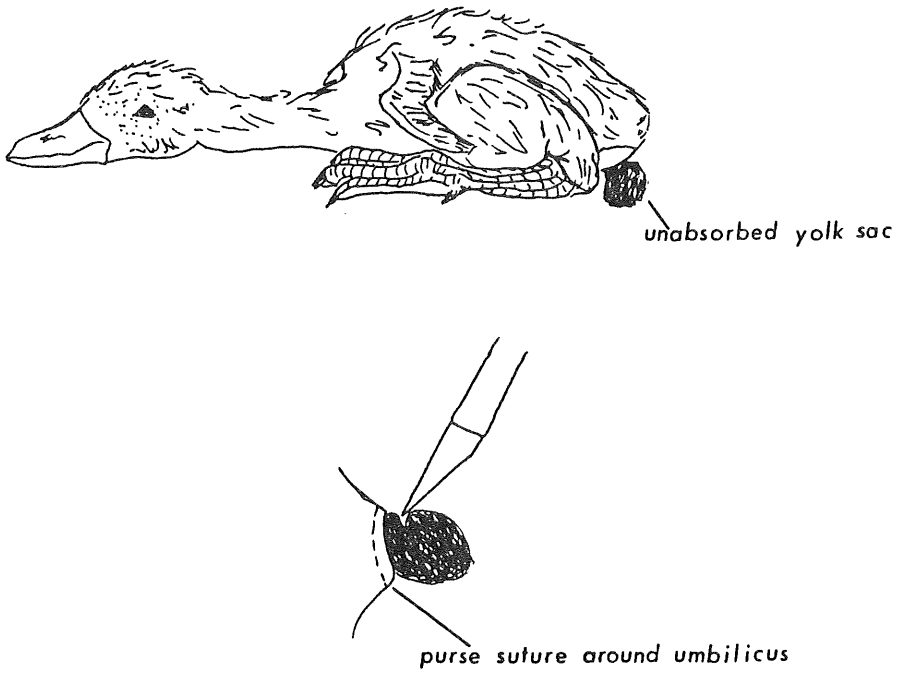

Fig. 6. Premature emergence of crane chick: (a) chick emerged before absorption of yolk sac, and (b) umbilical region showing purse suture and removal of yolk sac.

Sometimes the umbilicus will only partially close, with a portion of the yolk sac pinched off outside (Fig. 6a). Further absorption of the yolk into the abdomen is unlikely in this situation. Remove the chick from the shell and place it on a soft dry cloth on a heating pad or hot water bottle. Make a purse suture using 3.0 chromic gut on the skin surrounding the umbilicus (P. Howard pers. comm.) and tie off the extra yolk. Remove the yolk sac (Fig. 6b) and apply antibiotic and blood stop powders to the umbilical region.

Emergence Phase to Walking

A few minutes after emerging, a healthy chick will sit up on its hocks and lift its head and neck up off the surface for several seconds. The chick is standing and walking within 1 or 2 days. The first 2 days after hatching are critical for the development of motor skills. If the chick is weak and/or has been disoriented in the shell, it may have problems with muscular coordination. If one leg is stronger that the other, the chick will roll over on its side and back. This condition may be fatal if the chick is left in such a position. Restrict it to a sitting position by placing it on a soft, flat surface with supports on either side and behind. The chick may be taped into this position, released every few hours, and assisted in its efforts to stand and walk. Orientation problems may be corrected with such therapy.

CONCLUSION

Artificial incubation and hatching of cranes at ICF has allowed aviculturists to make step-by step observations on both normal and abnormal chicks. We have been able to determine the duration of each phase of the hatching process by keeping thorough records on all eggs and by making close observations of the hatching chick's behavior. It is important to consider both the time factors and the behavior of chicks when evaluating their condition during the hatching process. Some chicks which appear on schedule may exhibit behavioral abnormalities that can be corrected with assistance.

Hatching conditions vary between crane propagation centers and so will the problems encountered by the chicks. The methods presented here were successful in assisting weak and malpositioned cranes during hatching at ICF. Although the issue of assisting chicks with hatching is controversial, chicks that would not have hatched without our assistance now appear to be strong, healthy cranes.

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TIMING INSEMINATIONS TO MAXIMIZE FERTILITY IN CRANES

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Abstract: Maximum production is the key to a successful breeding season in a captive propagation center. In this paper, frequency of artificial insemination (AI) of cranes will be discussed. Information regarding the duration of sperm retention in a female, and optimal times for fertilization, will be assessed and used to maximize fertility of eggs produced in captivity.

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Maximum production and survival is the key to a successful breeding season in a captive propagation center. There are many aspects to attaining maximum production in such a program. For cranes these include proper nutrition, appropriate pen facilities, good pair bonding, successful breeding - naturally or by artificial methods, and sufficient nesting materials. The frequency of artificial insemination (AI) of cranes in a breeding program will be discussed in this paper. Common cranes (Grus grus) were studied to determine the duration of sperm retention in a female. Parts of the reproductive tract in a female crane were also examined in a search for a possible site for sperm storage. This information, in combination, with knowledge of the birds' behavior, physiological changes, and past AI data, will help determine the appropriate frequency and optimum times of insemination. Such knowledge should improve the efficiency of captive breeding programs, while maximizing the fertility of eggs produced by AI.

I would like to thank ICF's staff and researchers - G. Archibald, R. Besser, L. Hartman, M. Putman and S. Swengel - for their help and cooperation with this paper. A very special thanks to A. Lapp and B. Wentworth; without their help the lab work would not have been completed. Finally, thanks to Joyce Gavin for her help with this manuscript.

SPERM STORAGE IN FEMALE BIRDS - "FERTILE PERIOD"

Among domestic fowl, sperm survive for time intervals in the oviduct following AI and natural copulation. Thus, one insemination may fertilize a number of eggs over a period of 2 to 3 weeks (Lake 1975). The eggs during this period may be ovulated in repeated short or long sequences of days, this time period being the "fertile period" (Gilbert and Wood-Gush 1971). As long ago as 1737 anatomist William Harvey noted that a hen laid a fertile egg 20 days after isolation from the rooster (Pearl and Surface 1909).

The fertile period and factors affecting its duration have been studied in depth in domestic species of birds such as the fowl, chicken, turkey, duck, goose, and guinea fowl, where achieving maximum fertility in commercial breeding flocks is important (Lake 1962, 1974).

The fertile period phenomenon has also been described in several species of wild birds, e.g. the mallard duck (Anas platyrhynchos) (Elder and Weller 1954), pheasant (Schick 1947), quail (Sittman and Abplanalp 1965), and dove (Riddle and Behre 1921).

Artificial insemination has become a recognized method of breeding domesticated birds and in some species obligatory (turkeys) in order to obtain adequate fertility (Lake 1975). A consistently high level of fertility must be maintained throughout an extended breeding season. The female must be inseminated with sufficient numbers of spermatozoa, and at the proper frequency, depending on the length of the fertile period in order to achieve high fertility (Lake 1975).

SIGNIFICANCE OF THE FERTILE PERIOD

The complete significance of the fertile period phenomenon is not known, however, it would be an advantage to wild species where the hen lays a large clutch of eggs and where there may only be one mating during the entire season. An example of this is in a lek system: a female sage grouse enters a male's territory, mates, then retreats to lay a clutch of 6 to 8 eggs (Wiley 1973). Chances of mating more than once or twice during the breeding season are low.

In flockmating, it is an advantage that spermatozoa remain viable in the oviduct for an extended period, because it helps to maximize fertility. A male can mate daily with many females - but the chances of this sperm covering (assuring fertilization) any one hen daily

with a successful ejaculation is small. Therefore, the fertile period phenomenon would ensure a carry-over of viable spermatozoa in each hen until the male remates (Lake 1975). This phenomenon also helps to alleviate labor problems of handling many hundreds of hens daily in a commercial breeding program (Lake 1975).

SPERM HOST GLANDS

Simple tubular epithelial sperm-host glands are located in the fowl on the vaginal side of the uterus (Lake 1975). Here, spermatozoa can be found within a few minutes after intravaginal insemination. The sperm resides for a period of days or weeks afterwards (Fuji and Tamura 1963, Bekhtina and Diagulleva 1964, Bohr et al. 1964). The sperm host glands, where spermatozoa are stored during the fertile period, are believed to be located in the utero-vaginal junction (Lake 1975). Temporary sperm storage occurs in the infundibulun of the oviduct. These storage sites were first described by Van Drimmelen (1946, 1949).

Hormone levels also play a role in sperm viability. Lamoreux (1940) showed that the most productive hens laid relatively fewer infertile eggs and had consistently longer duration of fertility than poor layers. He postulated that estrogen levels in circulation in the productive hens might play a role in producing a more favorable environment for support of spermatozoa in the oviduct. Lake (1975) states that the maximum time span over which fertile eggs have been produced after a single natural or artificial insemination is 42 days in a domestic turkey (Meleagris gallopavo). He compiled a list of mean duration of fertile periods (Table 1) for several species of birds. There are species differences and differences between domesticated species and wild species. Mean duration may be longer in the domestic birds because they have been selected for improved reproductive efficiency and possibly for an increase in length of the fertile period.

TIMING INSEMINATIONS

The timing of the beginning of the fertile period is just as important as its duration. The spermatozoa must be present in the female's reproductive tract at the time of ovulation or shortly thereafter (Gee and Temple 1978). For example, in prairie falcons (Falco mexicanus) an insemination 50 hours before oviposition did not fertilize an egg, but inseminations 60 hours before oviposition did produce fertile eggs (Boyd et al. 1977). As a result, it is beneficial to determine the length of time needed for egg formation, information which would allow producers and researchers to inseminate at the proper time - before shell formation occurs.

CONCENTRATIONS OF SPERMATOZOA

Along with the frequency and timing of inseminations, the number of spermatoza inseminated is also important in maximizing fertility in birds. The number of spermatozoa required varies between birds. In the domestic fowl the average maximum duration of fertility is achieved when 60 to 120 million spermatozoa are inseminated (Taneja and Gowe 1961, 1962). If this required number for fertility is not inseminated some hens may remain completely infertile and lay several infertile eggs in the sequence following insemination (Lake 1975). In these conditions, the plausability of sperm storage in the oviduct may be questioned. Therefore, it is important to consider the various elements involved in fertilization.

SPERM STORAGE IN CRANES

The International Crane Foundation (ICF) in Baraboo, Wisconsin, is dedicated to the preservation and propagation of endangered species of cranes. AI (occurring March-August) plays an active role in ICF's captive propagation program. Reasons for the use of AI are similar to those for domestic poultry management, such as: incompatible cranes may be kept separated because of behavioral problems; there may be a shortage of unrelated, sexually mature, breeding males; males may have physical disabilities preventing them from copulating naturally; cranes may be imprinted on humans and not pair bond with other cranes; or new bloodlines are needed to provide genetic variability in the flock (LaRue 1981, Russman 1980. Artificial insemination in cranes, Unpubl. rept.).

As in a commercial domestic flock, the frequency of insemination is critical to achieve maximum fertility. Timing of the insemination is also just as important as frequency.

Table 1. Mean duration of the fertile period in various species of wild and domesticated birds (adapted from Lake 1975).

Species	Days	Reference
Domestic goose (Anser anser)	6	Johnson 1954 Oliver 1971
Mallard duck	7	Ash 1962 Elder and Weller 1954
Domestic turkey	28	Parker 1949 Hale 1955
Ring-necked pheasant (Phaisianus colchicus torquatus)	18	Schick 1947
Domestic fowl (Gallus domesticus)	12	Dodge 1951
Guinea fowl (Numida meliagris)	7	Petitjean 1966
Japanese quail (Coturnix coternix japonica)	6	Sittman and Abplanalp 1965
Ringdove (Zenaidura macroura)	8	Riddle and Behre 1921

Previously, inseminations were performed every other day and just following oviposition (in order to ensure fertilization of the next egg). This was found to be both stressful and disruptive for the birds. The routine was therefore altered to three weekly inseminations with the additional post-oviposition insemination. This was also the procedure employed by Patuxent Wildlife Research Centger (PWRC) in Laurel, Maryland for whooping cranes (G. americana) and sandhill cranes (G. canadansis) and proved to be optimal (LaRue 1980).

Recently another facet "cryogenic semen preservation" has been added to the captive breeding program at ICF. Semen is collected from male cranes three times weekly and, when samples are not needed for female inseminations, the samples are frozen and stored until they are needed. Although most of the collected samples are used immediately, there are times when samples can be stored and not used for immediate insemination. One example is the Siberian Crane (G. leucogeranus). At ICF the males begin producing semen in early March, however, the females do not begin egg-laying until late March to late April. If these early samples were inseminated (one month before egg-laying) they would not fertilize any eggs and would therefore be wasted. Thus, the early samples can be frozen and stored. The male Siberian cranes complete their semen production in May, while the females continue to lay eggs into June (Putnam, in prep). In May-June the frozen semen can be inseminated to ensure fertility of late-produced eggs.

FERTILE PERIOD IN CRANES

As discussed previously, there is a "fertile period" in several species of domestic and wild birds. We attempted to identify the fertile period in cranes in order to improve the breeding program at ICF. If we could identify this period, then inseminations could be timed properly and care, labor, and semen could be used more efficiently. Two pairs of common cranes were used for the experiment. These two pairs of birds copulated naturally. In 1982, each pair was kept together in the same pen until two clutches of eggs were laid and then each male was moved to an adjacent pen. The birds were separated physically but visual and audible contact were maintained. The pair was then reunited after the female had laid two additional clutches. The fertile period was calculated as 6 days because a fertile egg was laid up to 6 days after separation of the pair. In 1983, the pairs were separated immediately after the first clutch of eggs was laid, and they were kept apart until the laying period was completed. This proved to be a more valid test. After separation, one pair laid only one clutch of eggs and it was infertile (this pair began laying very late in the season - one month later than the other pair). The other pair laid four more clutches of eggs - the first one was fertile and the second egg of that clutch was laid 10 days after the birds were separated. So, for this pair the fertile period was presumed to be 10 days (Table 2).

Table 2. Fertility experiment using common cranes in 1983.

Pairs		Egg #	Date eggs laid	Fertility
Pair #1	Together	1	12 May 1983	F
		2	23 May	F
	Separated (23 May)	3	6 June	I
		4	9 June	I
Pair #2	Together	1	26 April	F
		2	28 April	F
	Separated (28 April)	3	6 May	F
		4	8 May	F
		5	17 May	I
		6	20 May	I
		7	30 May	I
		8	31 May	I
		9	6 June	I
		10	9 June	I

[a] F = Fertile, I = Infertile.

A female sandhill crane at PWRC laid a fertile egg 20+ days after the insemination (Gee, pers. comm). This bird was housed with a male, but the pair had never copulated and the female had not produced fertile eggs without AI.

Another method of determining that there is some sperm storage in cranes is by reviewing past AI records. The data demonstrates that the maximum amount of time from an insemination to the laying of a fertile egg was 9 days. This does not mean that the fertile period was only 8 days because females were never left alone (as with the common crane experiment) to determine this, however, it showed that it was possible to fertilize an egg when the last insemination occurred 9 days before oviposition.

Among the five species of cranes examined, most of the fertile eggs and most of the infertile eggs occurred following inseminations 2, 3, and 4 days before oviposition, with the greatest percentage at 3 days (Fig. 1). However, most of the inseminations normally occur during this time period. Inseminations made less than 2 days before oviposition were not included because it takes approximately 48 hours for egg formation (Putnam, pers. comm.). The proportion of infertile to fertile eggs does not increase as the period after the last insemination increases at least through 9 days (Fig. 1).

The period just after an egg is laid is the best time to inseminate a female in order to maximize fertility. The newly ovulated egg or one that is about to be ovulated then encounters spermatozoa and becomes fertilized before shell formation.

Unfortunately, my sample size is very small. Each of the five species is represented by only one bird for the AI part of this experiment. Despite the small sample number, some individual differences were observed (Figs. 2 & 3). The sandhill crane had the highest fertility when the last insemination was 4 days; for the white-naped crane (G. vipio), it was 3 days; the red-crowned crane (G. japonensis), 2 days; and the Siberian crane was 2 and 6 days (Fig. 2). Looking at when the greatest percentage of infertile eggs were laid the sandhill crane was greater than 10 days; white-naped crane, 2 days; Eastern sarus crane, 3 days; red-crowned crane, 3 days; and the Siberian crane, 4 days. Also, in at least two seasons, the female red-crowned crane's first egg was infertile and in at least four seasons her last two eggs were infertile, regardless of the frequency of inseminations. One reason for this phenomenon may be the lack of synchrony of breeding seasons for the male and female. As mentioned previously, the males begin producing semen as much as one month before the females lay eggs. However, many times these early season samples have a high percentage of abnormal sperm (Russman 1982) that may be incapable of fertilization. Similarly, toward the end of the breeding season, the spermatozoa may not be as viable. If spermatozoa are stored inside the female, they may become stale and not be as viable (Lake 1975).

It is difficult to interpret the data because experiments were not designed specifically for fertility trials as was true for the common cranes. Such an experiment would have been valuable but difficult to do in a captive breeding program. It would also be very beneficial to perform additional controlled experiments in which various females are inseminated at varying times, and the resultant fertility rates documented.

CONCENTRATION OF SPERMATOZOA IN CRANE INSEMINATIONS

As is true among domestic fowl, the concentration of spermatozoa involved in the inseminations is important to fertility rates. Gee and Temple (1978) found that good crane semen has 200-300 million spermatozoa/ml. Consequently, another reason for infertility may be that the concentration of spermatozoa is insufficient to fertilize the eggs. Semen samples from captive cranes are very small - less than 0.01 ml. It is difficult with such volumes to obtain enough spermatozoa to fertilize an egg.

SPERM HOST GLANDS IN CRANES?

The experiment with the common cranes suggested that sperm storage occurs in cranes, so we looked for sperm host glands. A blind female white-naped crane laid one egg. Immediately upon oviposition, the bird was inseminated with a good quality (B/90, B = good, 90 means 90% of the sperm were motile at the time of collection) semen sample (Putnam 1982). The bird was then euthanized and necropsied. The entire oviduct, ampula of the infundilulum, and utero-vaginal junction were fixed and sectioned. Slides were prepared and stained with a variation of the H and E staining procedure (Clayden 1971). Sperm host glands were not found. Several hypotheses were made to explain this finding: (1) the female had only laid one egg in 3 years and her reproductive tract may not have been sufficiently active to house these glands or to merit semen storage, (2) it may have been beneficial to inseminate the female several times before the experiment, so that more spermatozoa would have been in the reproductive tract at the time of sectioning, or (3) these glands may have a different morphology or be located in different areas of the reproductive tract than in other birds.

DISCUSSION

Maximum production in a captive propagation program is achieved in many ways. One of these ways is through careful management of the breeding season. In a program such as ICF's, which incorporates AI in the breeding program, several aspects are entailed. As described in this paper, sperm storage in the female crane does exist for at least 9 days. There is seasonality in sperm and egg production, but these two are not always synchronized in captive crane pairs. As a result - the timing of inseminations is critical to maximize fertility. The best times to

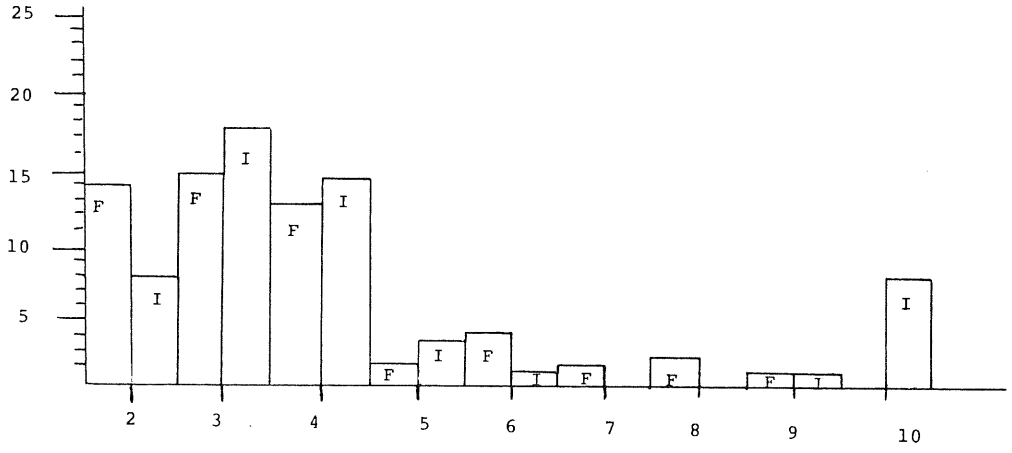

Fig. 1. Percentage of fertile and infertile eggs after insemination at various interval before oviposition among five species of cranes.

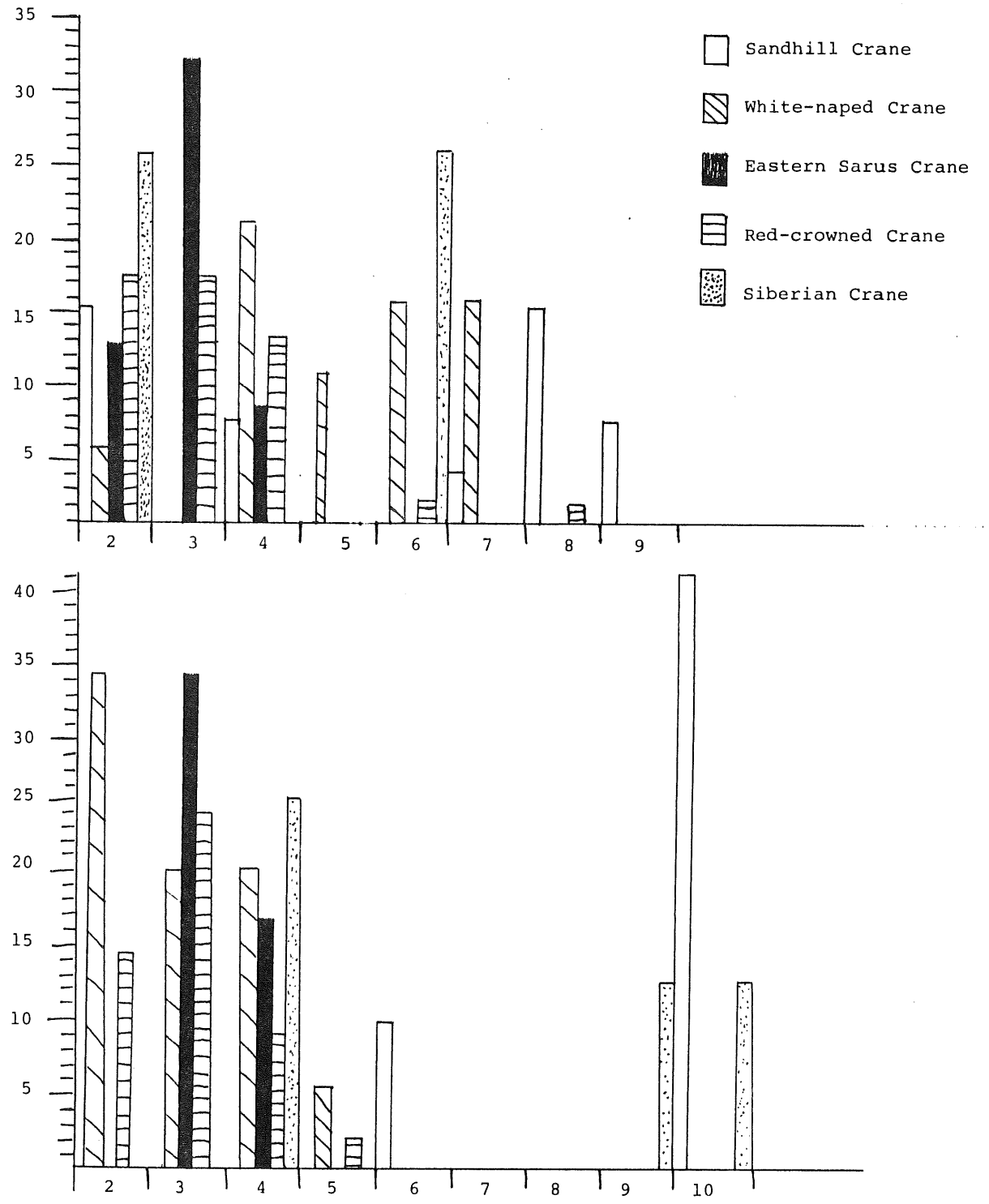

Fig. 2. Percentage of fertile eggs (above) and infertile eggs (below) following insemination of five species of cranes.

inseminate appear to be 2 to 4 days before egg laying and just after oviposition. Female cranes also must be watched carefully because each has her own pattern of egg laying. The female's schedule of inseminations should correspond to her laying pattern. This scheduling requires maintenance and study of detailed insemination and egg laying data for each female. Concentration of spematozoa in these samples is important as well as looking at quality of individual sperm. A sample may appear to be of good quality but still lack sufficient spermatozoa to fertilize an egg. Insufficient spermatozoa necessitates additional inseminations. There may be some type of sperm storage receptacle in the female crane, but it has not been located. Additional studies of crane oviducts will be performed in the summer of 1985.

There are no clear cut answers about when to inseminate. Gee and Temple (1978) and LaRue (1980) have given a good schedule of 3 days per week. However, it is just as important to be flexible and alter this schedule when needed to fulfill the needs of each crane. In this way, production can be maximized, thus preserving endangered cranes.

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IMPORTANCE OF PEN SIZE IN RAISING CRANE CHICKS

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Abstract: Twenty-five eastern sarus (Grus antigone sharpii) and brolga (G. rubicundus) chicks hatched within a 2 week period in late February 1984 at the International Crane Foundation (ICF). The cold weather and the short hatching interval required implementing a new rearing method - one that was different from past ICF methods. There are advantages and disadvantages to each method. ICF averages no more than five new chicks at a time during the regular breeding season. The method we used in 1984 required less rearing space and enabled us to raise 25 chicks simultaneously. The main disadvantage to this new method is that the chicks were much more aggressive because they were not placed together right after hatching.

Proceedings 1985 Crane Workshop

Dr. George Archibald, Director of the International Crane Foundation, visited 60 nests of the eastern sarus and brolga cranes in Queensland, Australia, from mid-January through mid-February 1984. His goal was to bring 24 eastern sarus and 12 brolga crane eggs back to Baraboo. The purpose of collecting the crane eggs was two-fold - ICF needed new blood for their own breeding stock and they wanted to reintroduce the eastern sarus crane in Thailand (Archibald 1984).

Special care was taken to transport the eggs from Australia to Baraboo. The eggs were placed in two plywood portable incubators to traverse the continent. Collection of the eggs took place during the last phase of incubation and all were close to hatching. During the 72-hour trip, 5 chicks hatched (Archibald 1984).

The Australian eggs presented a unique situation to ICF aviculturists. ICF normally rears no more than 5 newly hatched chicks at a time. Now they suddenly had more than 25 chicks hatch within 13 days (Table 1). These chicks were the first to use the hatchery and chick rearing buildings constructed in 1983-84. However, the buildings were not completed by the time the chicks hatched into a world that was vastly different from the locale that they came from in Australia.

Wisconsin was in the last stage of winter with some snow still on the ground. The chicks would be over 63 days old before it would be warm enough for them to go outside. Since the weather kept the chicks indoors, they were unable to exercise and had no opportunity to socialize with each other. The exercise yard was not completed until mid-June 1984 and by this time the chicks had fledged and were being prepared to move to other locations. With so many chicks, the rearing space had to be cut in half in order to accommodate them.

Table 1. Hatching and fledging success of eastern sarus and brolga cranes at ICF, 1984.

Results	Eastern sarus	Brolga
Number of eggs	24	12
Infertile	4	1
% infertile	17	8
Failed to hatch[a]	1	0
Post-hatch mortality[b]	1	4
Fledged	17	5
% fledged	90	45

[a] Pipped and died.
[b] Eastern sarus died from unknown causes; 2 brolgas died from unknown causes and 2 from blindness/neurological disorder.

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[1] Present address: Miami Metrozoo, Bird Department, 12400 SW 152 Street, Miami, FL 33177

This paper describes the advantages and disadvantages of two different methods of rearing crane chicks. The method used in all years preceding 1984 included adequate space and exercise for the chicks. The 1984 method involved using less rearing space and no exercise during the first few weeks.

PREVIOUS ICF REARING PROCEDURES

ICF's first crane chicks usually hatch sometime in May. Chicks are moved from the hatcher to a brooder box within 24 hours. To prevent imprinting, we affix a mirror to the side of the brooder box so the chick can see itself. Crane chicks are too aggressive to be raised together. So they are separated from each other by a screened partition. The screen allows the chicks to see and imprint on one another without the danger of injuring one another. At times, the chicks will constantly fight with their neighbors through the screen. We then have to replace the screened partition with a solid wall so that the chicks will not harm themselves.

The staff encourages the chicks to eat and drink several times a day. ICF uses red spoons to stimulate the chicks to eat and drink. Most parent cranes have red somewhere on their head and this color acts as a stimulus. Chicks start pecking at the red spoon and inadvertently find the food that is being offered. They will soon eat readily from the spoon and after several days they will be eating from the bowl by themselves. We add marbles to the water dish to enable the chicks to learn how to drink on their own. The chicks peck at the brightly colored marbles and will get a drink of water.

Feeding is continued until the chick appears to be eating well and gaining weight properly. Chicks are initially fed a starter diet at 2 weeks of age. We supplement the diet by adding vitamins and electrolytes to their drinking water until they fledge.

In their first weeks of life, it is important to regulate the chicks' growth. Excessively rapid growth can lead to the development of leg and wing problems. Some chicks have inwardly or outwardly bowed legs. Others are unable to hold their wings up properly when the primaries begin to grow (angel wing). A healthy chick will be moved at age 2 to 3 weeks to a bigger pen with an outdoor enclosure. Chicks hatch in early May, thus they can be taken outside almost every day for exercise (walking and swimming). The chicks are allowed to go outside within 5 days after hatching (weather permitting). Volunteers spend the day outside with the chicks in an exercise yard which contains two wading pools. The volunteers prevent aggression between the chicks and may feed the younger ones. At fledging, primaries are clipped on one wing; by this age they have reached a minimum level of aggression and can safely be left unattended in the exercise yard.

SPRING 1984 REARING METHODS

The Australian chicks were the first to reside in the new hatchery complex. The brooder boxes used in previous years quickly filled up and additional ones had to be constructed. Due to a critical lack of space, there were two chicks in each brooder box, with a screened partition between them. All of these chicks were reared in one-half the space of previous years' chicks. The average floor area of our regular full size brooder boxes is 0.9 m^2, but our brooder boxes that were divided in half measured only 0.5 m^2 (Table 2).

These 25 chicks (plus 4 other chicks who lived less than a week) received constant care and observation (more so than in the past). They were even fed at 1000 hours-something which had not been done before at ICF. Although all chicks received the same amount of care, we discovered differences between the species.

With our constant care, the eastern sarus chicks did quite well following the first few critical days. However, the brolga chicks did not fare as well because it took longer for them to begin eating on their own. When eastern sarus were eating on their own, brolgas at the same age were still being hand fed. The brolgas grew at a slower rate than the eastern sarus (Fig. 1). This difference between the two growth curves is statistically significant at the 0.05 level. The slow growth of the brolgas required them to remain in the brooder room for a longer time than the eastern sarus (Table 3).

Due to several factors, chicks of both species stayed in the brooder room longer than any previous chicks (Table 3). They spent most of this time in the one-half brooder boxes. These accommodations became less than adequate after the chicks grew bigger. They were moved to pens in the chick house as soon as it was possible. The cool weather was partly responsible for the

Table 2. Dimensions of brooder boxes and chick pens contrasted between 1984 and previous years.

Style	Length (m)	Width (m)	Area (m^2)
Brooder box type I-whole	1.1	0.8	0.8
Brooder box type I 1984	1.1	0.4	0.4
Brooder box type II-whole	1.0	0.7	0.7
Brooder box type II 1984	1.0	0.4	0.4
Brooder box type III-whole	0.9	1.2	1.1
Brooder box type III 1984	0.9	0.6	0.6
Brooder box type IV-whole	0.9	1.1	1.0
Brooder box type IV 1984	0.9	0.6	0.5
Brooder box type V-whole	0.8	1.2	1.0
Brooder box type V 1984	0.8	0.6	0.5
Indoor chick pen-whole	3.1	1.8	5.6
Indoor chick pen 1984	1.6	1.8	2.9
Outdoor chick pen	5.9	1.8	10.9

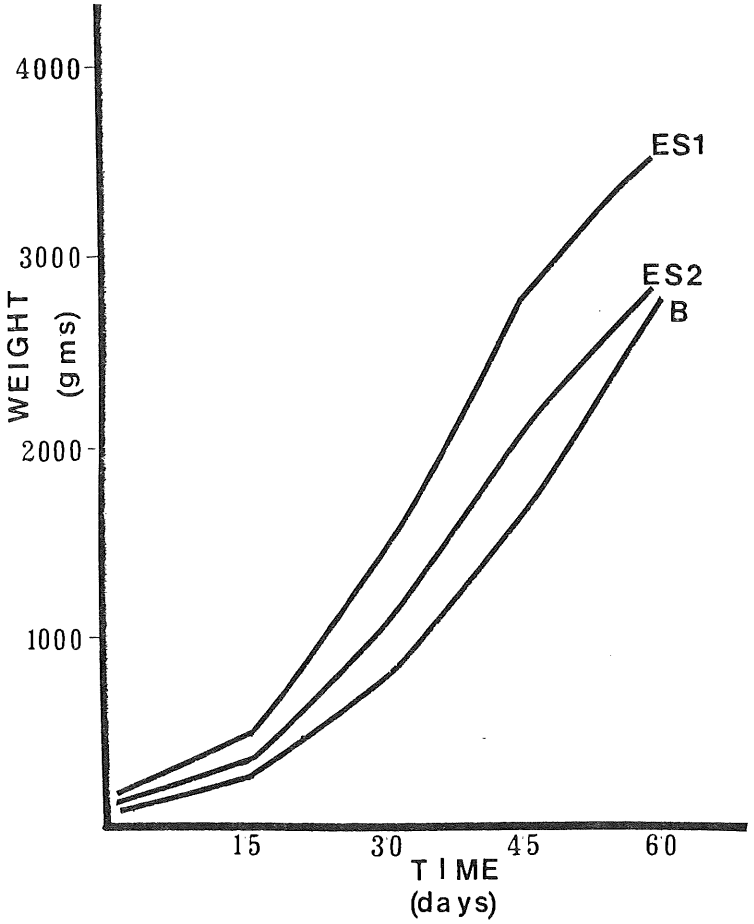

Fig. 1. Growth curves for 1984 eastern sarus (ES1), previous eastern sarus (ES2), and 1984 brolga (B).

Table 3. Time eastern sarus and brolga chicks spent in brooder boxes and chick pens.

Group	Sample size	Days spent in		Age (days) when moved to full-sized chick pen
		Brooder boxes	One half chick pen	
1984 e. sarus	18	33	16	49
5 previous e. sarus	5	23		32
1984 brolga	7	45	9	54

delay in moving the chicks out to the chick pens. The pens had to be acclimated to the appropriate conditions for the chicks. The sand had to be thoroughly dry and the temperature had to be brought within a range of 70° F by using heaters and heat lamps. Space was limited at first in the chick house. Consequently, the chicks were only allotted one-half of the indoor pens - an area of 2.9 m^2 (Table 2). However, by 49-53 days each chick had its own pen and at 63 days they had access to their outdoor runs.

With 25 chicks in the brooder room, there was potential for problems. The heat lamps kept the temperature of the brooder room between 80-90° F and at a very high humidity level. Disease could have spread rapidly in the high temperature and high humidity. In spite of these conditions, the chicks suffered no further mortality in the brooder room after they survived the first week.

GROWTH RATES

Under the same conditions (diet, temperature, humidity), the eastern sarus grew more rapidly than the brolgas. I also examined the growth rates of previous eastern sarus chicks raised at ICF (Fig. 1). It appears that the 1984 eastern sarus, even though they were raised in minimal space, initially grew at a faster rate than previous eastern sarus chicks (Fig. 1). This growth difference is also statistically significant at the 0.05 level. We cannot make significant comparisons using previous brolgas because ICF had only raised one brolga in the past.

LEG PROBLEMS

Although using limited space for rearing crane chicks allowed us to raise a greater number, the limited space, lack of exercise, and constant feeding resulted in several chicks having bowed legs. Table 4 shows the number of chicks with leg problems (past and present) plus the first day each group of chicks started to experience leg problems. To treat the bowed legs we limited the chicks access to food. Chicks normally are given access to food ad lib but under these circumstances food was provided for three 1-hour periods daily (morning, noon, and night). After they were moved into the chick pens they had more room to move about and were given access to their outdoor runs after 24 April (when they were 63 days old). In time, with exercise and by limiting food the chick's legs straighted.

AGGRESSION

Chicks normally are outside with each other within 5 days of hatching. The spring 1984 chicks never spent time with each other. Interchick aggression normally decreases to a safe level by 40 days. At 100 days, the spring 1984 chicks still exhibited a high level of aggression because they had no previous contact with one other. By mid-June 1984, all of the chick pens were occupied and new ICF chicks would soon be ready for pens of their own. The 3-month-old Australian chicks had to be placed in one pen to free pens for other chicks. The intense aggression the chicks were still exhibiting complicated the process of finding compatible penmates. I tried 30 random (sex unknown at this time) combinations of chicks, but I was only able to get compatible combinations with one brolga pair and three eastern sarus

pairs. Many of the chicks would fight with each other whenever they were placed in the same pen. Potential penmates were first observed to see if the two chicks were compatible. Supervision was gradually decreased until it was safe to leave the chicks unattended during the day. After spending several days together without problems, penmates were left together for the night. In this way, we were able to empty pens for other chicks to occupy.

Preliminary sexing was done on the Australian chicks by comparing their weights and the measurements of their culmen and tarsus. The actual sex was determined at 9 months by surgical sexing (Table 5). Preliminary sexing was required because the chicks were to be put in bachelor flocks at the site where the adult cranes were housed. At the new site, the chicks would have more space and it would be a healthier environment for them. Before being moved each group of chicks was first penned together. This was due to the intense aggression that

Table 4. Eastern sarus and brolga cranes experiencing leg problems in 1984 in contrast with previous years.

Total chicks raised	Sample size	Chicks with bowed legs Number	Chicks with bowed legs % of total	Day condition first noticed
1984 e. sarus	18	15	83	7
Previous e. sarus	10	2	20	21
1984 brolga	7	3	43	55
Previous brolga	1	0	0	0

Table 5. Weights and measurements of 1984 eastern sarus and brolga chicks at 100 days.

Chick number[a]	Weight (g)	Culmen (mm)	Tarsus (mm)	Predicted sex	Actual sex
S26A	3713	116	254	F	Unknown
S12A	3800	122	262	F	F
S30B	4027	122	236	F	F
S11A	4167	121	267	F	F
S12B	4195	130	252	F	F
S33B	4280	126	272	F	F
S9A	4337	127	254	F	Unknown
S29A	4653	133	292	M	Unknown
S11B	4682	137	267	M	M
S33A	4696	137	257	M	M
S46	4710	144	275	M	M
S21	4852	138	267	M	M
S53B	4880	127	264	M	F
S53A	4937	135	272	M	M
S30A	5008	127	273	M	M
S9B	5051	135	264	M	M
S27A	5476	130	274	M	M
B55A	2950	109	241	F	F
B47A	4082	---	---	F	Unknown
B14	4082	116	286	F	Unknown
B24A	4337	122	279	M	Unknown
B39	4568	122	292	M	Unknown

[a] B = brolga, S = sarus, siblings designated by A & B of same #.

many of the chicks were still exhibiting. We watched each group until their aggression had subsided to an acceptable level, and then each group was moved to the new location. After being moved, we made further observations until we ascertained they were still accepting each other along with the new site.

FOOD CONSUMPTION

We measured the daily food intake for three brolga and three eastern sarus chicks from the 7th through the 11th week. However, the data were inconclusive. The percentage of body weight consumed did not vary greatly between the two species. However, a chick consumes about twice as much food per body weight as an adult crane (Table 6).

CONCLUSION

It is significant that such big birds can be reared in such limited space. The successful fledging of 90% of the eastern sarus and 45% of the brolgas is good when one considers the circumstances in which these chicks were reared. Since we have been successful in rearing cranes in limited space, this may encourage other institutions with limited rearing facilities to raise cranes in the space that is available to them. However, ideally chicks should be reared with adequate space such as the entire brooder boxes and chick pens (Table 2).

If others choose to rear cranes in limited space, there are a few things that they should keep in mind. Rearing a large number of chicks in limited space creates a potential disease hazard (which under these conditions could spread rapidly). Adequate exercise is critical to proper development, particularly to reduce the incidence of leg problems. During the time the chicks are housed in limited space, they should exercise together daily under close supervision for at least several hours and all day if possible. Arrangements should be made for inside facilities where the chicks can exercise if the weather is too inclement for them to be outside. A few days spent inside in a small brooder box could cause serious leg problems in a growing chick. Along with getting vital exercise, the chicks also benefit from social contact with one another. With social contact at an early age, aggression will decrease much sooner. Interaction with peers at a young age also reduces the likelihood that a young crane will become imprinted on humans.

Table 6. Average daily feed consumption.

Species and age (months)	% of body weight	Body weight (g)
Eastern sarus-1.5 months	9.5	2689
Brolga-1.5 months	9.7	1582
Eastern sarus-1.75 months	6.0	3236
Brolga-1.75 months	10.3	2390
Eastern sarus-2 months	5.4	3477
Brolga-2 months	9.9	2649
Eastern sarus-2.33 months	8.6	4047
Brolga-2.33 months	7.9	3118
Eastern sarus-2.75 months	8.3	4199
Brolga-2.75 months	7.4	3325
Adult[a]	4.8	9759

[a] Average from five species of cranes: Grus japonensis, Grus antigone antigone, Grus vipio, Grus leucogernaus, Bugeranus carunculatus (Hallbey T. A., 1979. Feed and feeding: habits of captive cranes. ICF Unpubl. Rept.).

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WORKSHOP RESOLUTIONS SUBMITTED TO PERSONS OR AGENCIES

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1. PRESIDENT AND CONGRESS OF THE UNITED STATES

The U. S. Congress is presently holding hearings on reauthorization of the Endangered Species Act. Participants at the 1985 Crane Workshop support reauthorization of the Act in its entirety. We believe the Act has had major beneficial effects in slowing extinction rates and in promoting the recovery of some species such as the whooping crane and the Mississippi sandhill crane. The Act has helped to maintain the United States as a world leader in the conservation movement.

Participants at the Workshop request that Congress and the President reauthorize the Act with full funding support.

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2. U. S. FISH & WILDLIFE SERVICE

Participants of the 1985 Crane Workshop congratulate the U. S. Fish & Wildlife Service for their continued support of efforts to establish a second wild population of whooping cranes. The second flock, begun in 1973, now contains approximately 30 individuals. This innovative recovery effort, using a foster parent species, should be funded at least through 1989 when the project is scheduled for evaluation.

Participants of the 1985 Crane Workshop congratulate the U. S. Fish & Wildlife Service on the progress made in enhancement of the endangered Mississippi sandhill crane flock by gentle release of captive-reared cranes. The recent success in these efforts is encouraging and substantially increases the chance for this subspecies to survive.

Participants of the 1985 Crane Workshop congratulate the U. S. Fish & Wildlife Service on their funding of studies to evaluate areas in Florida, Georgia, and Michigan as potential sites to establish a future whooping crane population. These three-year research projects will provide the background information needed to move toward achieving the Whooping Crane Recovery Plan's recommendation that a third wild population be established.

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3. U. S. FISH & WILDLIFE SERVICE and NORTH AMERICAN FLYWAY STATES AND COUNCIL

Participants of the 1985 Crane Workshop request the U. S. Fish & Wildlife Service and all North American Flyway States and Councils to initiate a nationwide conversion to nontoxic shot for the hunting of waterfowl and sandhill cranes by 1989.

Ample evidence now demonstrates that an increasing number of areas have high levels of lead shot deposition, with subsequent lead poisoning to many species of water birds. An increasing number of wildlife species are exhibiting lethal and sublethal effects of lead ingestion.

Participants of the 1985 Crane Workshop are particularly concerned about the whooping crane. We believe it imperative that managers employ measures to minimize all forms of mortality for this endangered species and for other bird species vulnerable to poisoning by lead shot ingestion. Both the whooping crane and sandhill crane are susceptible to lead ingestion on areas incurring annual use by waterfowl hunters.

A suitable nontoxic shot substitute is available for waterfowl hunting. A planned, carefully orchestrated nationwide conversion would allow hunters and the arms and ammunition industry sufficient time to increase the supply of nontoxic shot and to step-up development of other possible nontoxic shot substitutes. We urge American hunters to support the ban on this environmental hazard.

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4. STATES OF NEBRASKA, COLORADO, and WYOMING, and AGENCIES OF THE U. S. GOVERNMENT

Whereas: the Platte River and associated wet meadows in central Nebraska and along the North Platte in western Nebraska comprise one of the most important habitats for cranes in the world, are utilized as a spring staging area by approximately 500,000 sandhill cranes--virtually all of the mid-continental population and 80 percent of the North American population--and are recognized as critical migratory habitat for whooping cranes; and

Whereas: the Platte River is also important for other nationally and internationally important wildlife resources, including several million ducks and geese that follow the Central Flyway, and for bald eagles during migratory and wintering periods, and for least terns and piping plovers for nesting; and

Whereas: the Platte River has many values of public interest that are dependent upon instream flows, including public and private recreational uses, recharge of underground water supplies used for irrigation and municipal purposes, preservation of water quality and maintenance of channel flood flow capacity, along with other ecological, educational, and historical values; and

Whereas: 70 percent or more of the natural flow in the Platte River in central Nebraska downstream from the diversion for the Tri-County Project near North Platte to the confluence with the Loop near Columbus is normally diverted, resulting in a drastic reduction in the quality and quantity of riverine and wetland habitat available for cranes, waterfowl, least terns, and piping plovers, and the degradation of many other values of public interest associated with instream flows;

Therefore be it resolved that the participants of the 1985 Crane Workshop strongly urge the states of Nebraska, Colorado, and Wyoming and agencies of the federal government withhold funding for construction of additional water diversion projects in the Platte River Basin until interstate agreements and state water plans are approved that adequately sustain the remaining flows needed to safeguard wildlife resources of national and international significance, and to protect and enhance recreational, agricultural, municipal, water quality, flow capacity, fisheries, economic, and cultural values of public interest dependent upon instream flows.

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5. CALIFORNIA DEPARTMENT OF FISH AND GAME and U. S. FISH & WILDLIFE SERVICE

In the San Joaquin-Sacramento River Delta of California, approximately sixty percent of the Central Valley Population of greater sandhill cranes and forty percent of the Pacific Flyway Population of lesser sandhill cranes roost on ponds that are drained after mid January when the waterfowl hunting season terminates. Participants of the 1985 Crane Workshop recommend that Region 1 of the U. S. Fish & Wildlife Service and the California Department of Fish and Game pursue active management of lands in this area to ensure provision of roosting sites for the sandhill cranes after waterfowl hunting ends until the cranes migrate in spring. In addition to providing and maintaining roosting areas on public lands, we recommend that both state and federal agencies secure easements on private lands to allow management for the cranes.

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6. U. S. FISH & WILDLIFE SERVICE

Participants of the 1985 Crane Workshop express concern at the 8th Circuit Court Appeals Judgement filed 9 January, 1985 in United States v. Dion. The decision has severe effects in terms of species conservation and enforcement of wildlife laws and regulations by the U. S. Fish & Wildlife Service. The Dion judgement implies that any taking of wildlife by an Indian on a reservation is a legitimate exercise of treaty right, exempt from prosecution under the Eagle Act or the Endangered Species Act. Both wild flocks of whooping cranes utilize Indian lands during the migration, winter, or nesting periods. The Circuit Court ruling, by effectively legalizing the killing of cranes on Indian lands, poses a risk of directly bringing about the extinction of these populations. Workshop participants support the U. S. Fish & Wildlife Service in their efforts to obtain a review of this decision by the U. S. Supreme Court.

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7. CANADIAN WILDLIFE SERVICE

Participants at the 1985 Crane Workshop congratulate the Canadian Wildlife Service of Environment Canada for their continued support of management and research on the endangered whooping crane. We also applaud the Canada-United States agreement that is about to be signed. This agreement commits the two nations to continued cooperative efforts to recover the endangered whooping crane through ongoing studies at Grays Lake, Idaho and at some future site in eastern North America.

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8. U. S. FISH & WILDLIFE SERVICE, STATE WILDLIFE AGENCIES and FLYWAY COUNCILS

Whereas: whooping cranes are endangered and sometimes occur within areas open to sandhill crane hunting, in close association with flocks of sandhill cranes; and
Whereas: it is sometimes difficult to distinguish between the two crane species, especially between immature whooping cranes and sandhill cranes, in dim and variable light and weather conditions, or where cranes are encountered as flying silhouettes; and
Whereas: great blue herons and other protected birds are sometimes mistaken by hunters for sandhill cranes; and
Whereas: sandhill cranes require specialized roosting sites that are limited in number and distribution within the migratory and wintering range of the species; and
Whereas: sandhill cranes are most vulnerable at their roosting sites, and excessive disturbance could result in abandonment of use of these wetlands and surrounding feeding areas; and
Whereas: at present sandhill crane hunting hours are allowed to open one half hour before sunrise; and
Whereas: in some states such as North Dakota sandhill crane hunting is closed in the early afternoon, while in other states hunting continues until sundown;
Therefore be it resolved by participants of the 1985 Crane Workshop that:

1. The U. S. Fish & Wildlife Service, state wildlife agencies, and the flyway councils are urged to adopt regulations that delay daily opening and that advance afternoon closing of hunting to diminish the risk of sandhill crane hunting resulting in the accidental or careless shooting of whooping cranes or other protected birds, to minimize disturbance of sandhill crane roosting areas, and to advance the observance of hunting practices that are consistent with good sportsmanship.
2. The U. S. Fish & Wildlife Service, state wildlife agencies, and the flyway councils are urged to continue to define and implement other hunting regulations that will minimize the potential adverse impact of sandhill crane hunting on whooping cranes and other protected species, and on specific sandhill crane populations that may be disproportionately affected by hunting harvests.

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9. U. S. FISH & WILDLIFE SERVICE, CENTRAL FLYWAY COUNCIL, and WILDLIFE DEPARTMENTS OF NORTH DAKOTA, SOUTH DAKOTA, and OKLAHOMA

Current sport hunting seasons for sandhill cranes in North Dakota, South Dakota, and Oklahoma overlap the primary migration period for whooping cranes through these states. Because the whooping crane is an endangered species protected by the Endangered Species Act, the participants of the 1985 Crane Workshop urge the U. S. Fish & Wildlife Service, the Central Flyway Council, and the wildlife departments of North Dakota, South Dakota, and Oklahoma to closely examine any potential risk the extended hunting season in these states poses to migrant whooping cranes. We urge that increased hunter education be conducted to minimize risks to whooping cranes. We recommend that careful consideration be given to limiting sandhill crane hunting seasons to precede whooping crane migration in North Dakota (prior to September 17) and South Dakota (prior to October 1) and to following whooping crane migration in Oklahoma (after December 1). This practice was used in previous years and provided adequate protection for whooping cranes while providing quality recreation for hunters.

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10. U. S. FISH & WILDLIFE SERVICE and U. S. ARMY CORPS OF ENGINEERS

Participants of the 1985 Crane Workshop are concerned about threats to whooping cranes and their wintering habitat associated with the Gulf Intracoastal Waterway in and near the Aransas National Wildlife Refuge, Texas. These threats include erosion from boat wakes, degradation of habitat from discharge of dredged material, disturbance from boat traffic, and danger of chemical spills.

The participants of the 1985 Crane Workshop commend the U. S. Fish & Wildlife Service and the U. S. Army Corps of Engineers on the initiation of a study to address the reduction or elimination of these threats. We urge these agencies to give serious consideration to relocation of the Gulf Intracoastal Waterway to a less sensitive route.

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11. ORGANIZERS AND SPONSORS OF THE 1985 CRANE WORKSHOP

The participants of the 1985 Crane Workshop have thoroughly enjoyed "staging" on the Platte River the last few days. We wish to express our appreciation to the workshop co-chairman, James C. Lewis and John VanDerwalker, to the local committee, and to the workshop sponsors, the Platte River Whooping Crane Habitat Maintenance Trust, the National Audubon Society, and the U. S. Fish & Wildlife Service. Their efforts have resulted in many fine papers, excellent field trips, and the opportunity for crane biologists from throughout the continent to meet and exchange information. Thanks!
