FOOD AND FEEDING HABITS OF RELEASED FLORIDA SANDHILL CRANES

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Abstract: Food habits of 4 pairs of free-ranging Florida sandhill cranes (Grus canadensis pratensis) on St. Catherine’s Island, Georgia, were studied from May to October 1990. Food items were identified and quantified at close range (<10 m). The 4 pairs varied in how they used plant and animal resources (P < 0.0001). Animal material in the diets averaged 19.1% and ranged from 13.4 to 36.7%. Plant material averaged 80.9% in the pairs’ diets. Major foods included subsurface bulbs, roots, and tubers of yellow star grass (Hypoxis macrantha), catbrier (Smilax glauca), and false garlic (Allium bivalve), longleaf pine seeds (Pinus palustris), and insects. Food habits shifted seasonally for all pairs (P < 0.0001). In July and August the percent occurrences of yellow star grass and false garlic in the diets were >50%. During September and October pine seed occurrence was >75% in the diets of 2 pairs. Amphibians, crustaceans, and small mammals were used opportunistically. Use of visual and tactile senses in foraging behavior are suggested mechanisms influencing food choice.

Key Words: Florida sandhill cranes, food habits, Georgia, Grus canadensis pratensis, tactile sense, visual cues

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An estimated 4,000–6,000 Florida sandhill cranes inhabit peninsular Florida and the Okefenokee Swamp in southeast Georgia (Nesbitt 1982). Between 1985 and 1988, 26 Florida sandhill cranes were released on St. Catherine’s Island, Georgia, by The New York Zoological Society, Wildlife Survival Center (Winn 1990). A remaining population of 4 pairs present in 1991 represents the first introduction of sandhill cranes into a barrier island ecosystem. Successful assimilation of the species has been measured by the establishment of daily routines, defense of territories, and breeding.


The objective of this study was to identify and quantify food items in diets of the released cranes on St. Catherine’s Island. Numbers of individual food items consumed suggest how resources may be utilized (Thomas and Taylor 1990). Empirical data on food utilization by released cranes can contribute to understanding feeding ecology and behavior of wild cranes and adaptability of reintroduced cranes. Knowledge of food habits of Florida sandhill cranes might establish crane habitat requirements and land use policies to protect crane habitats in Florida and Georgia.

I thank the New York Zoological Society for supporting the research, especially J. Iaderosa and B. Winn of The Wildlife Survival Center staff. Also, I thank F. Larkin, R. Hayes, M. Harris, S. Holly, and T. Fannin of The St. Catherine’s Island Foundation. Special thanks are due M. C. Coulter for design advice; S. A. Nesbitt for information on sandhill cranes; W. M. Brown, R. C. Drewien, G. F. Gee, P. Klien, and J. Small for reviewing the manuscript; and J. Hatfield for statistical review.

STUDY AREA

St. Catherine’s Island is an 8,903-ha barrier island southeast of Savannah, Georgia. The barrier islands are recent geological formations. St. Catherine’s Island has a Pleistocene core, its maximum elevation is 66 m, and it is surrounded by Holocene sand dunes and marshes. Two forest types dominate the 2,833-ha core: a mixed overstory of live oak (Quercus virginiana) and hickory (Carya tomentosa), with an understory of red bay (Persea borbonia), and a mixed live oak and longleaf pine overstory. The understory of both forests types is dominated by thick saw palmetto (Serenoa repens).

A longleaf pine savannah dominates the north end of the island. Bahia grass (Paspalum notatum) and broom-straw (Andropogon virginicus) are the most abundant grasses. Grazing pastures are mainly bahia grass with low wet areas dominated by pickercrcl weed (Pontederia hexipomon), pennywort (Oblaria virginica), and false garlic. Bahia grass with broom-straw and dog-fennel (Eupatorium capillifolium) dominates an open pasture zone on the southern portion of the island.

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Table 1. Numbers of food items identified in the diets of 4 pairs of Florida sandhill cranes on St. Catherine's Island, Georgia, May – October 1990.

<table>
<thead>
<tr>
<th>Food item</th>
<th>May/Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep/Oct</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant foods</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow star (<em>Hypoxis micrantha</em>)</td>
<td>790</td>
<td>474</td>
<td>505</td>
<td>193</td>
<td>1,962</td>
</tr>
<tr>
<td>False garlic (<em>Allium bivalva</em>)</td>
<td>113</td>
<td>82</td>
<td>74</td>
<td>19</td>
<td>288</td>
</tr>
<tr>
<td>Catbrier (<em>Smilax glauca</em>)</td>
<td>4</td>
<td>3</td>
<td>48</td>
<td>86</td>
<td>141</td>
</tr>
<tr>
<td>Pine seeds (<em>Pinus palustris</em>)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5,155</td>
<td>5,155</td>
</tr>
<tr>
<td>Holly (<em>Ilex opaca</em>)</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Acorns (<em>Quercus virginiana</em>)</td>
<td>0</td>
<td>0</td>
<td>76</td>
<td>252</td>
<td>328</td>
</tr>
<tr>
<td>Muscadine (<em>Vitis rotundifolia</em>)</td>
<td>0</td>
<td>0</td>
<td>37</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>Sable palm (<em>Sabal palmetto</em>)</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Hydrocotyl (<em>Hydrocotyl umbellata</em>)</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>907</td>
<td>559</td>
<td>750</td>
<td>5,705</td>
<td>7,921</td>
</tr>
<tr>
<td><strong>Animal foods</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insects*</td>
<td>603</td>
<td>120</td>
<td>156</td>
<td>902</td>
<td>1,781</td>
</tr>
<tr>
<td>Japanese beetle grub (<em>Popillia japonica</em>)</td>
<td>16</td>
<td>7</td>
<td>10</td>
<td>20</td>
<td>53</td>
</tr>
<tr>
<td>Spadefoot toad (<em>Scaphiopus holbrooki</em>)</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Fiddler crab (<em>Uca pugnax</em>)</td>
<td>0</td>
<td>13</td>
<td>11</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Eastern mole (<em>Scalopus aquaticus</em>)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>620</td>
<td>141</td>
<td>184</td>
<td>923</td>
<td>1,868</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,527</td>
<td>700</td>
<td>934</td>
<td>6,626</td>
<td>9,789</td>
</tr>
</tbody>
</table>

*Excluding Japanese beetle larvae.

METHODS

Rearing techniques produced sandhill cranes that were unafraid of humans but able to survive on St. Catherine's. Pairs were also accustomed to vehicles. All 4 pairs were approachable on foot to within 6 m. At this distance birds foraged towards and away from the observer in equal proportions, indicating that foraging behavior was not affected by human presence. Three of the pairs were individually marked by colored leg bands.

Diet was determined by focal observations of foraging crane pairs. I used 8 × 25 binoculars to identify and quantify individual food items. Numbers of individual food items consumed by each pair (frequency of occurrence) were enumerated (Thomas and Taylor 1990). All items were identified to species except insects. Small mammals, amphibians, and crustaceans were identified as they were consumed. Subsurface food items were identified by pinpointing probing locations with the nearest obvious landmark (i.e., a bright flower or piece of bark); then I dug to locate similar food items. Once I became familiar with these food items, digging was no longer necessary. Foraging remains, such as inedible plant blades, could be collected, identified and counted. As understanding of feeding habits increased, some food items could be identified by bird foraging posture.

Each pair was observed for 1 day each week on a random schedule. A 12-hour (0700–1900) day was subdivided into 8 90-minute periods. Observations were alternated between the male and female. Each 90-minute period was divided into 10-minute focal periods alternating with 10-minute “off” periods. During focal periods, food items were identified and counted. Thus 50 minutes of each 90-minute observation period for 1 bird were used to quantify food data. In the 10-minute “off” period only "foraging" or "not foraging" was recorded. Breaks from
feeding (>1 min) throughout the 90 minutes were noted as "not foraging."

The chi-square test of homogeneity was used to assess differences in food habits between pairs. Six food categories were chosen based on frequency of occurrence in the diets. Pairs were tested for differences in diets and whether diets changed from May through October. The chi-square test analyzed whether pairs used different plants and animals and whether pairs used different combinations of plant and animal foods. Four independent chi-square statistics, 1 per pair tested for independence of month and food, were summed to get the overall test of independence by month and food. Total degrees of freedom were the sum of the independent tests.

RESULTS

Food Habits

A total of 207 90-minute focal observation periods provided information about the numbers and types of food items consumed and the percent occurrence of items in each sandhill crane pair's diet. Fourteen food items were identified in the diets of sandhill cranes (Table 1). Five frequently occurring foods, yellow star grass, false garlic, smilax, insects, and pine seeds, were used as categories for chi-square analysis.

Food habits varied significantly ($\chi^2 = 3.554; df = 15; P < 0.0001$) among crane pairs (Table 2). Pairs foraged on 4 separate territories; some overlap occurred, but encounters usually resulted in displacement of 1 pair. False garlic bulbs were eaten most frequently by Pair 3 and accounted for ≥58.5% of items eaten during May–August (Table 3).

<table>
<thead>
<tr>
<th>Pair</th>
<th>May/Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep/Oct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yellow star (73.7)</td>
<td>Yellow star (78.4)</td>
<td>Yellow star (36.5)</td>
<td>Insects (90.4)</td>
</tr>
<tr>
<td>2</td>
<td>Insects (56.4)</td>
<td>Yellow star (70.1)</td>
<td>Yellow star (48.8)</td>
<td>Pine seeds (75.8)</td>
</tr>
<tr>
<td>3</td>
<td>False garlic (58.5)</td>
<td>False garlic (75.4)</td>
<td>False garlic (86.7)</td>
<td>Insects (69.4)</td>
</tr>
<tr>
<td>4</td>
<td>Yellow star (79.6)</td>
<td>Yellow star (81.1)</td>
<td>Yellow star (71.1)</td>
<td>Pine seeds (96.0)</td>
</tr>
</tbody>
</table>

*Diets varied seasonally for all pairs ($\chi^2 = 6.582.4; df = 45; P < 0.0001$).

Tubers of yellow star grass and insects were staples in the diets of 3 pairs.

Food habits varied seasonally ($\chi^2 = 6.582.4; df = 45; P < 0.0001$). Insects did not appear in the diet of Pair 1 until September/October (Table 3). Some birds responded to the availability of pine seeds. Pairs 2 and 4 occupied territories where pine seeds were available and shifted their food habits from subsurface bulbs and tubers in May/June through August to pine seeds in September/October (Table 3). Although an availability study was not conducted, an abundance of pine seeds was noted in late September.

The combined diet of the 4 pairs consisted of more plant ($\chi^2 = 225; df = 3, P < 0.0001$) than animal matter (Table 4). An expected 50% occurrence per food type was used to calculate the chi-square statistic. Plants averaged 80.9% occurrence, whereas animals (small mammals, amphibians, crustaceans, and insects) averaged 19.1% of the diets. The animal portion of the diet ranged from 13.4% (Pair 4) to 36.7% (Pair 3) among the 4 pairs. Individual pairs used animal and plant resources differently ($\chi^2 = 1,941; df = 3; P < 0.0001$).

Feeding Strategies

My observations of foraging cranes suggest that they rely on vision and tactile senses to identify food items. Tacha (1987) described a stereotypic food-searching and gleaning posture for sandhill cranes; I observed this

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Table 2. Frequently occurring food items (no. counted) consumed by 4 Florida sandhill crane pairs on St. Catherine's Island, Georgia, May–October 1990.*

<table>
<thead>
<tr>
<th>Pair</th>
<th>Yellow star Cattail</th>
<th>Pine seeds</th>
<th>False garlic</th>
<th>Insects</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>387</td>
<td>20</td>
<td>0</td>
<td>48</td>
<td>138</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>714</td>
<td>8</td>
<td>2,129</td>
<td>25</td>
<td>944</td>
<td>329</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>215</td>
<td>123</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>861</td>
<td>113</td>
<td>3,026</td>
<td>0</td>
<td>576</td>
<td>73</td>
</tr>
<tr>
<td>Total</td>
<td>1,962</td>
<td>141</td>
<td>5,155</td>
<td>288</td>
<td>1,781</td>
<td>462</td>
</tr>
</tbody>
</table>

* Food habits varied significantly between crane pairs ($\chi^2 = 3.554; df = 15; P < 0.0001$).
Table 4. Number counted and percent occurrence of plant and animal food items consumed by 4 pairs of Florida sandhill cranes on St. Catherine's Island, Georgia, May – October 1990.

<table>
<thead>
<tr>
<th>Pair</th>
<th>Plants No.</th>
<th>Plants %</th>
<th>Animals No.</th>
<th>Animals %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>493</td>
<td>76.1</td>
<td>155</td>
<td>23.9</td>
</tr>
<tr>
<td>2</td>
<td>3183</td>
<td>76.7</td>
<td>966</td>
<td>23.3</td>
</tr>
<tr>
<td>3</td>
<td>217</td>
<td>63.3</td>
<td>126</td>
<td>36.7</td>
</tr>
<tr>
<td>4</td>
<td>4,028</td>
<td>86.6</td>
<td>621</td>
<td>13.4</td>
</tr>
<tr>
<td>k</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>80.9</td>
<td></td>
<td></td>
<td>19.1</td>
</tr>
</tbody>
</table>

* Significant difference among pairs for plants and animals in the diets ($\chi^2 = 225$, df = 3, $P < 0.0001$). Significantly different usage of plants and animals ($\chi^2 = 1,941$; df = 3; $P < 0.0001$).

**DISCUSSION**

The frequency of occurrence for subsurface bulbs and tubers and pine seeds as major diet items (Table 3) shows the dependence of St. Catherine's cranes on plant material. Small mammals, crustaceans, and amphibians were consumed opportunistically as cranes searched for other major diet items.

Pairs consumed plant and animal foods differently because of differences in food availability within their territories. Pair 1 foraged the pine savannah on the north end of the island and ate mostly yellow star. Pair 3 foraged primarily in a large, moist area where false garlic was abundant but pine seeds were unavailable. Pair 2 used a large open pasture dominated by live oaks and scattered pines, while the territory of Pair 4 was dominated by a mixed live oak and red bay forest and open grass pastures. These latter 2 pairs had more variable diets (Table 4).

Cranes shifted foods seasonally in response to their availability. Cranes expended energy searching for (visually or by probing) and digging subsurface plant items. Pine seeds, once present in late September, were readily available at the surface, and cranes did not waste energy in fruitless searching.

Repeated posture sequences where cranes used visual and tactile cues helped me identify specific food items during this study. I found that posture cues can serve to distinguish between subsurface and surface plant items, insects, and small mammals, crustaceans, or amphibians.

More study is needed to confirm the dependence of sandhill cranes on their visual and tactile senses to locate foods. This study involved cranes introduced into a previously unoccupied habitat. Availability of food items in this new habitat needs to be known to quantify selection and preference for specific foods.

Sandhill cranes showed seasonal selectivity for major food items. Biomass conversions were not made but could alter the rankings of foods in the 6-month-long spring-to-fall study period. Biomass values would probably not affect seasonal selectivity, since pairs tended to concentrate on particular food items during each season. Further studies are needed to evaluate the nutritional significance of preferred foods to cranes.

**LITERATURE CITED**


CHARACTERISTICS OF WHOOPING CRANE ROOST SITES IN THE PLATTE RIVER

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Abstract: The Big Bend of the Platte River in central Nebraska provides important migration habitat for whooping cranes (Grus americana). River profiles were obtained at 23 confirmed nocturnal roost sites occupied by whooping cranes during 1983–90. Whooping cranes selected roost sites that had shallower water depths than at unused sites. All but 4 roosts were located in channels wider than 150 m; roost sites were an average of 27.8% of the channel width from the nearer shore. Nearly 90% of the roost sites had a trench of deeper water on both sides. Proper management of the Platte River is necessary to provide whooping crane stopover habitat.

Key Words: Grus americana, physical characteristics, river, roosts, whooping crane

The Platte River, Nebraska, is a strategically located migration stop for whooping cranes in the Wood Buffalo-Aransas population (U.S. Fish and Wildlife Service 1981, 1986; Shenk and Armbruster 1986; Faanes and Bowman, in press). Recognizing the importance of the Platte River to whooping cranes, the U.S. Department of the Interior in 1976 designated an 83-km reach of the "Big Bend" of the river as critical habitat (Federal Register 43:20938-20942).

Despite the critical habitat designation, habitat conditions for whooping cranes and other avian species have become degraded in recent years. Currier et al. (1985) and Sidle et al. (1989) described losses of riverine channel and wet meadows resulting from water development projects in the Platte River system. The continued existence of suitable whooping crane roosting habitat is now dependent on the maintenance of adequate instream flows and active management and removal of wooded vegetation from the riverine channels.

Certain attributes of whooping crane roost sites have been described. Johnson and Temple (1980) and Johnson (1982) listed criteria as follows:
(1) channel width: ≥55 m, most >155 m;
(2) flow: slow, <6 km/hour at roost, with possibly faster waters elsewhere in channel;
(3) water depth: <20 cm (Johnson and Temple 1980) or <30 cm (Johnson 1982), optimally 5–15 cm;
(4) vegetation: absent, i.e., no submergent, floating, or emergent vegetation at roost;
(5) substrate: fine, usually sand;
(6) horizontal visibility: unobstructed view from bank to bank and several hundred meters upstream and downstream;
(7) overhead visibility: open, i.e., no tall trees, tall and dense shrubbery, or high banks near roost;
(8) feeding sites: relatively close, usually <1.6 km;
(9) isolation: usually >0.4 km from human developments and isolated from them by tall trees or high banks; and
(10) sandbars: nearby presence of gently sloping sandbars with sparse vegetation.

Lingle et al. (1984, 1986) described 2 roost sites on the Platte River (these are also included in our evaluation), which generally met the above criteria. Ward and Anderson (1987) described 5 roost sites used by 2 subadults in 1983 during fall migration from Saskatchewan to Texas. Their sites were in lacustrine or palustrine, as opposed to riverine, habitats, so their conclusions may not be directly applicable here. They noted, however, that whooping cranes used sites with muddy bottoms. Four of the roosting wetlands they described were shallow, so it was impossible to determine any preference by the birds for water depth. The remaining wetland ranged in depth from 0 to 52 cm; depth at the roost site was 18 cm.

Howe (1989) presented information on 86 stopover sites, mostly palustrine, used either by 15 whooping cranes that were radio-marked or by others in company with marked birds. Water depths averaged 14.1 cm (SD = 9.0 cm). He found no indication that whooping cranes selected sites based on substrate texture. Birds did not appear restricted to sites with unlimited visibility; 64% had maximum visibility <2 km. Feeding sites were usually nearby; 56% were within 1 km.

Armbruster (1990), summarizing a workshop involving authorities on whooping crane migration, developed a set of assumptions about whooping crane habitat selection, which can serve as testable hypotheses for future research. Migrational habitat was characterized as having (1) horizontal visibility, (2) water depth ≤30 cm, (3) little human disturbance, and (4) feeding areas nearby.
One deficiency noted by other investigators (Ward and Anderson 1987, Howe 1989, Armbruster 1990) was the lack of information on habitats available to the birds, in addition to information about sites actually used, so that preference for particular features could be ascertained. Our study is an attempt to remedy this situation. We have information not only for riverine roost sites used, but also on alternative sites available at the same reach of the river.

Field data were gathered by a number of employees of the Grand Island, Nebraska, office of the U.S. Fish and Wildlife Service, and by the Platte River Whooping Crane Trust, Nebraska Game and Parks Commission, and National Audubon Society; we are grateful to all. O. Bray, R. Khan-Malek, G. L. Krupu, D. L. Larson, and R. McCue provided helpful comments on earlier drafts of the manuscript.

FIELD METHODS

We recorded habitat characteristics at 23 nocturnal roost sites occupied by whooping cranes during 1983–90. All 23 roosts are used in the analyses of channel width; data from 19 transects are included in the analyses of channel topography and water depth. All sightings were on different days; of the 19 roosts, 15 were in spring and 4 were in fall. Transects were generally surveyed within 5 hours after whooping cranes departed. Three or 4 observers conducted bank-to-bank transects positioned over the roost site and perpendicular to the river current. Measurements in 1983 were taken at 1-m intervals; measurements in subsequent years were at 3-m intervals across the channel. The set of measurements along the transect represented a profile of the river at the roost site. All but 3 profiles included measurements taken at roost sites. For 3 profiles, the roost site was between 2 measured sites, and we interpolated values of depth linearly.

We measured total channel width and at each interval on each transect we recorded water depth and distance from shore. In addition to channel width, we considered several variables including (1) water depth, (2) distance to nearer shore, (3) distance to nearer shore as a percentage of total channel width, and (4) an indicator variable (0 or 1) for whether or not the site was surrounded by a trench of deeper water (≥ 15 cm deeper).

We compared 1,400 sites along the 19 transects across the river, all of which were inundated (i.e., shore and sandbar measurements were excluded). Nineteen sites represented roost sites of whooping cranes, and 1,381 were considered unused sites. Channel widths at 23 roost sites were compared with values given in U.S. Fish and Wildlife Service (1981: Appendix I).

ANALYTIC METHODS

We examined variables one at a time to compare their distributions at roost sites versus unused sites. We compared not only means of the variables but also the entire distributions, to determine whether or not there was a certain range of values favorable to roosting. Continuous variables (water depth and distances) were compared between roost and unused sites with t-tests (either assuming equal variances or not, depending on the outcome of F-tests of equal variances). Tests of entire distributions were based on Kolomogorov-Smirnov statistics. Percentages of observations above versus below certain values were compared with a G-test for 2 × 2 contingency tables, as

![Fig. 1. Profiles of whooping crane roost sites (a) near the Minden, Nebraska, bridge on 10 April 1987 and (b) near the Gibbon, Nebraska, bridge on 6 April 1988. Elevations are in cm above water surface (indicated by dashed line) and distances from shore are in m. Dots denote roost sites.](image-url)
Table 1. Summary statistics for variables at whooping crane migrational roost sites and unused sites along Big Bend of the Platte River, Nebraska, 1983–90.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Roost sites</th>
<th>Unused sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \bar{x} )</td>
<td>SD</td>
</tr>
<tr>
<td>Channel width (m)</td>
<td>217</td>
<td>79</td>
</tr>
<tr>
<td>Water depth (cm)</td>
<td>20.2</td>
<td>9.4</td>
</tr>
<tr>
<td>Distance to nearer shore (m)</td>
<td>66.2</td>
<td>44.1</td>
</tr>
<tr>
<td>Relative distance to nearer shore (%)</td>
<td>28</td>
<td>11</td>
</tr>
</tbody>
</table>

were indicators of whether or not sites were surrounded by deeper water. All analyses used procedures FREQ, NPAR1WAY, TTEST, and UNIVARIATE of the Statistical Analysis System (SAS Institute 1987, 1988).

RESULTS

Water Depth

Examples of typical bank-to-bank transects are shown in Fig. 1. Roost sites were shallower on average than unused sites (20.2 cm versus 31.1 cm; \( t = 4.85, P < 0.001 \); Table 1). Moreover, the range of water depths at roost sites was more restricted than at unused sites: the interquartile range (the values between which half of the observations lie) was only 10.1 cm for roost sites, as opposed to 21.4 cm for unused sites. The distributions differed according to the Kolomogorov-Smirnov test (\( P = 0.0038 \)). Clearly, depths at roost sites were more concentrated than at unused sites (Fig. 2).

Channel Width

Whooping cranes roosting in the Platte River have been noted to select sites with broad channels free of woody vegetation and with adequate horizontal and overhead visibility (U.S. Fish and Wildlife Service 1981). We found that inundated channel widths at roost sites ranged from 52 to 366 m (Table 1). Roost sites were at wider stretches of the river than average (\( t = 2.00, P = 0.047 \)). Of 23 roost sites evaluated, 19 were in channels \( \geq 150 \) m wide. More than 80% of the channel was inundated in all but 2 transects.

Distance to Nearer Shore

Roost sites and unused sites had similar average distances to the near shore (66.2 m and 65.5 m, respective-
shore, as opposed to 316 (23%) unused sites (Fig. 4). The exception was a roost site that was 9.2% of the channel width from the nearer shore; because the channel was so wide, however, this percentage still represented a distance of 23 m.

**Surrounded by Deeper Trench**

Of 19 roost sites, 17 (89.5%) had a trench of deeper water on both sides; only 70% of the unused sites were so surrounded ($G = 4.10$, df = 1, $P = 0.043$). Roost sites without deep water on both sides had a shallow trench on 1 side and a deep trench on the other.

**DISCUSSION**

Whooping cranes generally select nocturnal roost sites in the Platte River based on the security offered by the site and proximity to feeding areas. Ample foods were available close to the river throughout our study area, so food probably did not strongly influence the selection of roost sites.

Cranes favored shallow water for roost sites. Water depths there were tightly clustered about the mean of 20.1 cm, a depth somewhat greater than those reported by Ward and Anderson (1987) and Howe (1989). Only 1 of 19 sites, at 49 cm, was deeper than 30.5 cm. Other than that exception, our results are in accord with the findings of Johnson (1982) and the model described by Armbruster (1990), characterizing water depth as not exceeding 30 cm.

We found whooping crane roost sites in channels ranging in width from 52 to 366 m. Johnson and Temple (1980) proposed a minimum width of 55 m. The narrowest roost site in our sample was 52 m, consistent with their recommendation; most were $>150$ m, similar to those reported by Johnson (1982). Lingle et al. (1986) suggested that whooping cranes might choose widest available sites.

Channels of the Platte River that normally carry water (active channels) are bounded by woody perennial vegetation. The banks and vegetation form visual obstructions for whooping cranes standing in the river and enhance their security, as long as the banks and vegetation are not close to the cranes. Use of channels wider than 150 m is substantiated by observations at other riverine roost sites not necessarily on the Platte River (R. Lock, pers. commun.). Similarly, an expanse of water at the roost apparently provides whooping cranes with a sense of isolation and security (Shenk and Armbruster 1986, U.S. Fish and Wildlife Service 1987). All but 2 of the measured channels in this study were $>80$% wet, which suggests that whooping cranes may select channels with sufficient water to afford them security. Also, greater width indicates higher flows, which facilitate the development of trenches of deeper water surrounding roost sites.

Our analysis indicated that whooping cranes generally roost some distance from shore. Only 5.3% of the roost sites were within 23 m, as opposed to 22% of the unused sites. Johnson and Temple (1980) thought that whooping cranes needed to be at least 6.1–9.1 m away from shore or emergent vegetation. Some findings of Johnson and Temple (1980) should be viewed with caution because their analysis was based on only 2 measurements taken at the roost sites, and some of their roost sites were examined 16 years after occupancy. Armbruster (1990) suggested a 20-m overwater distance to visual obstructions as the approximate tolerance limit for whooping cranes at nontraditional sites, which is consistent with our findings.

We found that deeper water surrounding a roost site may be an important selection factor (17 of 19 roosts were so surrounded). No other studies have examined this habitat feature in detail. The presence or absence of trenches of deeper water is dependent on the current flow rate and channel morphology. Changes in the bed of alluvial streams that result in short-term changes in
hydrologic variables are often related to the preceding flow regime (Milhous et al. 1984).

During aerial surveys, we have observed that deeper trenches of water surrounding a sandbar may draw attention to a potentially suitable roost site. Once cranes are on the sandbar, deeper trenches may serve as barriers to potential mammalian predators (Biology Workgroup 1990), providing additional security.

Water flows during our surveys ranged from 16 to 108 m³/second ($\bar{x} = 59$ m³/sec) or 576 to 3,800 cubic feet per second ($\bar{x} = 2,080$ cfs). We suggest that flows in the 59 m³/second (2,000 cfs) range are necessary in the Platte River during spring and fall migration periods to provide an adequate distribution of deeper water trenches to aid whooping cranes in selecting nocturnal roost sites. U.S. Fish and Wildlife Service (1987) and Faanes and Bowman (in press) made similar recommendations based on other data sets. Flows of 227 m³/second (8,000 cfs) at intervals have been recommended to scour vegetation from the channel (U.S. Fish and Wildlife Service 1987).

To provide more meaningful analyses, future riverine roost transects should involve profiles at a variety of unused sites for comparison on a larger scale. We recommend that future profiles be made not only through a roost site but also, at a minimum, 100 m upstream and 100 m downstream of the site. With additional data we could develop a multivariate analysis incorporating the relevant variables in combination. We believe this approach would significantly increase the validity of various habitat models developed for whooping crane habitat in the Platte River system. The resulting models, of course, should be tested against fresh data sets.

LITERATURE CITED


UNUSUAL MOVEMENTS AND BEHAVIORS OF COLOR-BANDED WHOOPING CRANES DURING WINTER

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Abstract: Color-banding of whooping cranes (Grus americana) has allowed individual recognition of >45% of the population between 1985 and 1990 and has provided the opportunity to monitor individual movements and behaviors. Unusual occurrences have included: 5 whooping crane juveniles that separated from their parents prior to reaching the wintering grounds, a sandhill crane (G. canadensis) juvenile wintering with a whooping crane pair, whooping cranes that oversummered at Aransas, a widowed crane that paired with a new mate within 48 hours, 2 cranes that did not reach the wintering grounds until 3 years of age, a known nesting pair that spent much of the winter apart but nested together again the following summer, 2 juveniles that were abandoned at the beginning of or during spring migration, and a whooping crane that left the wintering area in January but returned in March.

Key Words: behaviors, color band, Grus americana, individual recognition, movements

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Prior to the color-banding of whooping cranes, knowledge about specific whooping cranes was limited. Banding on the breeding grounds (Kuyt and Goossen 1987) during 1977–88 resulted in >45% of the population being color-marked between 1985 and 1990, with a peak of 59.4% of the wintering population marked during 1988–89. Individual marking showed that adult whooping cranes returned annually to the same winter territories, which were more easily delineated with banded birds present. The role of the parental territory in subsequent movement patterns and territory establishment was also described (Stehn and Johnson, 1987). Bishop (1984) documented subadult behavior and movement patterns and Stehn (in press) reported re-pairings of widowed adults on the wintering grounds. Resightings of color-banded cranes on the breeding grounds provided data on age structure, age of first breeding, and mortality (Kuyt and Goossen 1987).

Color-banding has also increased census accuracy on the wintering grounds by making it possible to differentiate adults from subadults. Banding has shown when specific birds have failed to arrive at Aransas National Wildlife Refuge (NWR), Texas, and surrounding areas in the fall, and has helped to assess mortality on the wintering grounds. Although normal patterns of distribution and behaviors of whooping cranes on the wintering grounds are now well documented (Bishop 1984, Stehn and Johnson 1987), unexpected events occur annually. This paper describes a series of behavioral and movement anomalies that have been discovered primarily through identification of color-marked or radio-tagged whooping cranes.

J. C. Lewis encouraged me to summarize these observations. Reviews by C. A. Faanes, J. C. Lewis, and D. W. Stahlecker improved the final manuscript. J. L. Sanchez graciously drew the figures.

STUDY AREA AND METHODS

The whooping crane population winters in approximately 8,175 ha of saltmarsh and bay habitat spread over 53 km of the central Texas coast. Although some limited range expansion has occurred over the past 20 years, a higher density of whooping cranes is found in the traditional use areas (Stehn and Johnson 1987). Whooping cranes winter on the Blackjack and Lamar peninsulas, San Jose and Matagorda islands, and Welder Point (Fig. 1).

Bands of differing color combinations were placed on whooping crane juveniles prior to fledging in Wood Buffalo National Park as part of a cooperative Canadian Wildlife Service and U.S. Fish and Wildlife Service program (Kuyt 1979). Color-band notation is derived from Kuyt and Goossen (1987). Bands are read left leg to right leg, and from top to bottom on each leg; letters indicate common colors and letter size indicates band size. The hatch year of the banded crane follows in parenthesis. Bands were identified on the wintering grounds from airplanes by making 1 or more passes at approximately 15–20 m altitude. Spotting scopes were used during ground observations. All locations for color-marked whooping cranes were recorded on maps and behaviors were documented in fieldnotes as they occurred.

RESULTS AND DISCUSSION

Juveniles Wintering Away From Aransas

Whooping crane juveniles sometimes become separated from their parents before reaching Aransas, thereby wintering instead in unusual locations (Stehn and Johnson...
1987). There are 5 known instances of juvenile-parent separation occurring during fall migration. This represents 1.4% of all observations of the 368 juveniles in the wintering population during 1938–90. Color bands on some of these wandering juveniles allowed them to be identified. Case histories are as follows:

1. A juvenile (1958) was present at the Mingo National Wildlife Refuge, Missouri, 1–17 December 1958, 725 km east of the whooping crane migration corridor. This bird was not resighted in that area nor, because it was unmarked, is it known if it reached Aransas during subsequent winters.

2. Juvenile nil-R (1977) was sighted near Meade, Kansas, 3–9 April 1978 with 3 sandhill cranes (U.S. Fish and Wildlife Service 1978). This bird had not been seen at Aransas during the 1977–78 winter but was seen there the following winter.

3. Juvenile B-W (1984) wintered with sandhill cranes south of El Campo, Texas, 104 km northeast of Aransas (Thompson 1986) (Fig. 2). His parents wintered at Aransas. B-W returned to Wood Buffalo National Park after his first winter, where he was sighted 5 km from his parents' nest site (E. Kuyt, Canadian Wildlife Service, pers. commun.). He was in a group of 7 whooping cranes in South Dakota in the fall of 1985; that group included subadult female BWsp-BWsp (1984) (U.S. Fish and Wildlife Service 1986). The male B-W spent his second winter south of Brazoria, Texas, with BWsp-BWsp (Lange 1986). Since males are usually dominant, B-W probably influenced BWsp-BWsp to winter away from Aransas. BWsp-BWsp stayed at Aransas the following winter. After B-W once more returned to Wood Buffalo in 1986 (Kuyt 1986), he was next sighted with a smaller unbanded crane at Goose Lake on the Aransas National Wildlife Refuge.
on 29 November 1986, 11 km northwest of the traditional whooping crane marshes. On 20 January 1987, crane B-W was located for the first time in a traditional whooping crane use area on the refuge. It is probable that the unbanded crane was his mate, and that she had brought B-W to Aransas. B-W nested with an unbanded crane in 1987 (Kuyt 1987), and he and his mate occupied a winter territory from 1987–88 through 1990–91.

4. In January 1987, chick WbW-o (1986) was seen near Hydro, Oklahoma. On 10 February, WbW-o was observed near the Quivira National Wildlife Refuge in south-central Kansas, 274–290 km north of Hydro. The bird returned to the Hydro area where it was sighted 21 February through 11 March (Butts 1988). It spent at least 34 days on the Platte River in spring 1987 with sandhill cranes (Faanes and Lingle 1988) and was sighted in Wood Buffalo National Park in May (Kuyt 1987). WbW-o spent its second winter near Edna, Texas, 72 km from Aransas (U.S. Fish and Wildlife Service 1988a)(Fig. 2). On 14 March 1988, it was back near Hydro, 6 km from where it had been the previous year (U.S. Fish and Wildlife Service 1988b). As a 3-year-old, this bird arrived at Aransas in November 1989 but did not remain throughout the winter. In February 1990, it was located near Telfern, Texas, 58 km northeast of the refuge (U.S. Fish and Wildlife Service 1990). WbW-o was not sighted during the 1990 summer (E. Kuyt, Canadian Wildlife Service, pers. commun.) or during the 1990–91 winter and is presumed dead.


Subadults Wintering Away From Aransas

In mid-January 1987, subadult GwG-GwG (1985) left Matagorda Island and spent 2 months with sandhill cranes near LaWard, Texas, 72 km northeast of the wintering area (Fig. 2). This was the first documented instance of a whooping crane leaving Aransas during the winter period. It was sighted back on Matagorda Island on 18 March. During fall 1987, GwG-GwG was sighted at Aransas Refuge 4 times between 28 October and 4 November, but then apparently spent the remainder of winter 1987–88 outside the traditional wintering area. It was sighted 17–18 April, 1988 near Optima National Wildlife Refuge, Oklahoma, with 2 other whooping cranes in the same general area where it had been sighted in the spring of 1987 (U.S. Fish and Wildlife Service 1988b).

During the 1988–89 winter, subadults W-YbY (1987) and YbY-GwG (1987), located in November near their juvenile territories, were not sighted between December 1988 and March 1989 and presumably wintered outside the census area (Fig. 1). They reappeared in April 1989 at Aransas. In another instance, subadult YbY-GwG (1987) was last seen on Matagorda Island at the beginning of January 1990 and was presumed dead. However, it returned to Matagorda Island in November 1990 after wintering elsewhere for part of the previous winter.

Although they occur infrequently, movements such as these make the whooping crane census more difficult. When subadult birds are not located on several consecutive census flights, it is possible that they have left the traditional wintering area rather than died.

Unusual Movements Of Territorial Wintering Cranes

Territorial cranes usually remain within their own defended areas throughout the winter. However, they occasionally will cross into a neighbor's area if the adjacent pair is at the far side of their territory or if the neighboring cranes remain in migration. For example, in fall 1987, the Ayres Island and South Redfish Slough pairs,
adjacent to the territory of the North Sundown Bay pair who had not yet arrived, spent 50% and 67% of observation time, respectively, in the vacant territory. Upon arrival, the North Sundown Bay pair reclaimed their former territory from the interlopers.

Territorial cranes occasionally make unexpected movements to other areas. In the 1980–81 winter, the unbanded West Welder Point family group moved between Welder Point and Egg Point near the south end of Aransas, a distance of 40 km, and stayed 10–20 days before returning to Welder Point. The unbanded Cottonwood Bayou family group moved 21 km from Matagorda Island to the refuge the same winter, staying approximately 30 days before returning to their territory. The identities of the unbanded family groups were known because only 2 of the 6 juveniles occurring that winter were unbanded and all juveniles were normally located in their known territories on weekly census flights.

In February 1984, the unbanded Egg Point adults with their radioed juvenile Y-y/r left their territory and moved 16 km to the southern edge of Matagorda Island, where they remained through March and early April. On 5 April, this family group apparently started migration, flew northeast 35 km, then reversed course and returned to their territory on Egg Point, which they had not occupied for 2 months, a net displacement of 14 km. The following day, the family started their northbound migration.

On the 21 March 1985 census flight, 2 cranes initially sighted on San Jose Island were observed flying 8 km towards the south end of the Aransas National Wildlife Refuge. After the cranes landed, they were identified as the unbanded Blackjack Point pair returning to their territory.

The Cedar Bayou territorial pair with juvenile GwG-W (1988) on San Jose Island during the 1988–89 winter crossed Carlos Bay to the refuge, a distance of 10 km, before returning to their territory. They spent a combined total of 31 days on the refuge during 2 separate time periods, 3–30 January and 22–27 February.

As spring approaches, whooping cranes increase their forays outside of their territories. Near the end of March 1986, the North Dunham Bay pair, containing crane B-R (1977), wandered as far as 6 km from their territory. On 4 March 1986, the South Redfish Slough pair, containing male r/w-BwB (1979), moved 3 km south of their territory and interacted with 2 other territorial pairs for 15 minutes before returning to their defended area.

**Unusual Subadult Movements On the Wintering Grounds**

Subadults occasionally move long distances to widely different parts of the wintering grounds. During an aerial census flight on 8 February 1985, subadults Y-b/b (1983), r/r-B (1982), and r-Y (1983) were being chased by a territorial pair near Bludworth Island. Thirty minutes later, the same trio was sighted on San Jose Island, 6 km away. They would have been counted twice if not for the presence of color bands indicating that the trio had moved. Subadult BWsp-R (1983) was sighted on the refuge in November 1985, on Welder Point 34 km away on 9 December, and back on the refuge 3 days later. During the 1985–86 winter, 2 radioed cranes, W-R (1982) and r-Y (1983), normally on the southern end of Matagorda Island, were located 16 km away on San Jose Island on 23 December and an additional 4 km farther on the Aransas Refuge on 26 December before being found back on Matagorda Island on 30 December. During 1 census the following winter, these same 2 cranes were sighted initially on Matagorda Island and 3.5 hours later 14 km away on the southern end of the refuge.

During the 1987–88 winter, the 2 subadults b/b-Y (1983) and BWsp-BWsp (1984), possibly paired at the time, moved between northern parts of the crane use area on Matagorda Island and the southernmost use area on San Jose Island, a distance of 40 km.

**Use of Agricultural Fields During Winter**

Although whooping cranes feed extensively on grain during migration (Howe 1989), they rarely are found during the winter in grain fields. Agricultural lands are located adjacent to the northern boundary of the Aransas NWR (Fig. 1). The unbanded Mustang Lake family group, whose territory is only 15 km from farm fields, fed on newly planted seed corn there in late February 1985. They also were located on 9 occasions in grain fields in November 1987. Even though this family made many 7-km flights to a salt marsh 8 km from grain fields and occasionally used pastureland within 2 km of farm fields, these birds rarely used grain fields. Whooping cranes apparently prefer salt marsh areas during winter.

In the fall, a few birds are sometimes sighted in the agricultural fields north of the refuge. This usually occurs at the end of their migration. Also, shortly after arriving at Aransas, a few whooping cranes may return to the farm fields and associate with sandhill cranes. In November 1987, 2 subadults (W-R [1985] and an unbanded bird) moved 23 km from the southern end of the refuge to the farm fields north of the refuge where they remained for at least 9 days. In November 1988, 3 subadults (o/w-BWsp [1986], RwR-YbY [1987], and an unbanded bird) that had initially been sighted on the refuge moved to Burgentine Lake and the adjacent farm fields, a distance of 13 km.
They remained for approximately 2 weeks before returning to coastal marshes. Three subadults (o/o-Y-B [1986], YbY-Y [1987], and an unbanded bird) left the refuge in late November 1988, moved to rice fields 40 km north of Welder Point, and then returned to the refuge by 21 December.

**Pair Formation And Mortality**

Observations of color-banded birds have proven helpful in determining when pair formation occurs. Bishop (1984) observed that banded subadults formed pair bonds after associations that lasted from 1 to 3 years. Pair formation can occur quickly in spring, and subadults who were solitary throughout the winter may nest as pairs in summer (Stehn, in press).

Mortality on the wintering grounds has also been documented through observations of color-marked cranes. In January 1990, the unbanded North Dunham Bay territorial male lost its unbanded mate. Within 48 hours, after the widowed male and juvenile mixed with subadults, the male paired with female R-Y (1986). This is the most rapid pair formation ever documented. If the new mate had not been color-banded, the loss of his mate probably would have been overlooked.

In spring 1988, adult male B-W was sighted in Saskatchewan with a banded subadult, but not with its unbanded mate (Johns 1988). B-W nested during 1988 with an unbanded mate (Kuyt 1988a). Did B-W and his mate migrate separately, or had the mate died and been replaced by another unbanded female?

**Establishment Of Territories**

Pairs that include color-marked whooping cranes have established winter territories prior to their first nesting attempt (Bishop 1984). In at least 1 case, a pair used the same area for 4 years before they aggressively defended a territory. During the 1983-84, 1984-85, and 1985-86 winters, the banded Pipeline Flats pair, R-W-O (1978) and B-W-r/w (1979), stayed in the vicinity of the Pipeline Marsh on the wintering grounds, sometimes associating with subadults, and were sometimes chased by adjacent territorial pairs. During the 1986-87 winter, the pair never associated with subadults, and the following winter this pair aggressively defended a territory.

After apparent pair formation in 1985, the pair, r-Y (1983) and W-R (1982), with a territory on South Matagorda Island, repeatedly appeared in an area next to the territory of the male's parents on Ayres Island but were chased back to Matagorda. They were located near Ayres Island 10 of 26 times in the 1985-86 winter, 14 of 23 times during 1986-87, 7 of 25 times in 1987-88, 1 of 19 times in 1988-89, 0 of 7 times in 1989-90, and 0 of 17 times during 1990-91; they stayed exclusively on their territory during the latter 2 years. This demonstrates how territory use can develop over a period of years.

Pairs without defended winter territories are often tolerant of subadults. After pairing in December 1987, the Boat Ramp pair, Y-BWsp (1984) and WbW-WbW (1985), spent 3 winters on the same area. During the 1989-90 winter they would no longer tolerate subadults as they had during the previous 2 years. Each year, especially in late winter, they were seen a few times on Matagorda Island, where both whooping cranes had been raised as juveniles. Finally, in 1990-91 they spent the entire winter on Matagorda, suggesting some pairs become more dominant with time so that they may eventually acquire a territory in a desired location near the male's parental territory.

**Trial Separation Of A Mated Pair**

Nesbitt and Wenner (1987) documented the ephemeral nature of pair bonds in sandhill cranes. In whooping cranes, the first "trial separation" of a mated whooping crane pair was documented during the 1988-89 winter. Male whooping crane Y-G (1985) and female W-B (1984) first nested in 1988, but both eggs were destroyed (Kuyt 1988b). The pair had never associated during the previous winter and were sighted separately during migration in April 1988 (U.S. Fish and Wildlife Service 1988b). From 15 November to 13 December 1988, they apparently wintered together. On 3 January 1989, the 2 birds were 45 km apart. This split continued throughout the winter and they apparently did not migrate together. However, they nested again in 1989 (Kuyt 1989a) and remained together the following winter until the loss of W-B in January 1990.

**Whooping Crane Pair With A Sandhill Crane Chick**

During 1990-91, the Middle Matagorda Island family group included 2 adult whooping cranes and a sandhill crane juvenile. In 1988, 2 whooping crane eggs and a sandhill crane egg were found in a whooping crane nest in Wood Buffalo National Park (Kuyt 1989b). This suggests that the 1990-91 mixed species family group was a reverse cross-fostering by a sandhill crane pair.

**Natural Abandonment of Juveniles**

Most whooping crane pairs are initially sighted on the breeding grounds without their young of the previous year (Kuyt 1979). Bard (1956) observed 2 whooping crane adults to depart from Saskatchewan during spring migra-
tion and leave their 2 young behind on the ground. Further cases of young abandonment have not been described.

On 17 April 1989, I observed a family group start migration at Aransas. After 10 minutes of spiral flight, the juvenile only briefly in close formation with the adults, the juvenile split off from its parents and returned to the refuge. No aggressive interactions were noted prior to the separation.

The separation of a radiocollared juvenile from its parents near Alticane, Saskatchewan, also apparently occurred in flight on 26 April 1984. I observed a family group and an unbanded whooping crane start a high, spiraling flight at 1222 hours. Radio signals for the next 75 minutes indicated that the juvenile continued flight nearby. The aircrew located the solitary juvenile at 1425 hours. The other 3 cranes were not sighted. No ground observations, i.e., aggressive interactions between the parents and juvenile earlier that morning, had indicated that a separation from the juvenile would occur.

Oversummering Cranes At Aransas

Prior to 1988, Lewis et. al. (in press) reported that 24 cranes (1.1% of wintering cranes) had oversummered between 1938 and 1987. Some of the oversummering birds were cripples that could not fly. Two subadult whooping cranes, o-R (1986) and B-WbW (1986), spent the 1988 summer at Aransas with a frequency of association of 38.6%. In April 1989, subadult o-R (1986) was captured and diagnosed with avian tuberculosis. This was the first definite case of the disease in the Aransas/Wood Buffalo whooping crane flock, although a radiocollared juvenile killed by a coyote at Aransas in 1983 had avian tuberculosis or a similar disease. Subadult B-WbW disappeared in August 1989 and was presumed dead; avian tuberculosis was suspected. The onset of the disease possibly kept both of these subadults from migrating in 1988 and 1989.

CONCLUSIONS

Color-banding of whooping cranes has allowed the study of movement and behavior patterns of individual birds. Color bands greatly enhance the accuracy of population censuses and aid in differentiation of adult and subadult cranes and documentation of mortality. Howe (1989) and Kuyt and Goossen (1987) analyzed the relationship between banding and mortality. Banding does stress the birds during capture and requires a substantial commitment of labor and funding. On the wintering grounds, the identification of color bands leads to increased disturbance both on the ground and in the air because of the need for closer approaches by observers. However, resumption of the banding program may be required to continue close monitoring of the flock. Increased observation of the flock may be needed to determine the causes of recent increases in mortality.

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Job 1. 46pp.


BEHAVIOR OF WHOOPING CRANES DURING INITIATION OF MIGRATION

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Abstract: Whooping cranes (Grus americana) observed immediately before the initiation of migratory flights exhibited increased alertness, wing ruffling, and head tilting. Seven observations at Aransas National Wildlife Refuge (NWR), Texas, indicate that the departure of 1 group of whooping cranes may influence other nearby cranes to start migration, even though later departing groups may fly separately.

Key Words: behavior, flight initiation, Grus americana, migration

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Only limited information on crane behavior prior to and during migratory flights has been published. A flock of sandhill cranes (G. canadensis) initiating migration was joined by smaller groups and single individuals from nearby areas (Williams 1970); Nesbitt (1975) noted that the sight and sound of migrating sandhill cranes seemed to stimulate migration in sandhill cranes on the ground. Both reports came from Paynes Prairie, Florida. Shields and Benham (1968) witnessed the departure of 20 whooping cranes, all members of a group at a supplemental feeding area, from Aransas NWR. Fourteen minutes later, they noted 3 additional whooping cranes initiating migration 2 km north of the feeding area. They postulated that the calls of the 20 departing cranes were audible to the other 3 whooping cranes and precipitated their migration.

The radio-tracking of whooping cranes during migration from 1981 to 1984 (Howe 1989) enabled biologists to regularly observe their behavior prior to the start of migratory flights. In some cases, crane pre-flight behavior enabled observers to predict that the birds would migrate (Stehn 1983, 1984). I recorded additional information on premigratory behavior of whooping cranes on their wintering grounds at Aransas NWR, Texas, between 1985 and 1990. I describe premigratory behavior and report 7 additional cases when migrating whooping cranes apparently influenced others to begin migration.

Most data presented here were gathered incidentally while I was involved in management activities at Aransas NWR. H. E. Hunt and D. H. Ellis graciously provided additional observations. Reviews by C. A. Faanes and D. W. Stahlecker improved the final manuscript.

METHODS

As a ground crew member that tracked migrating whooping cranes radio-marked between 1981 and 1983 (Howe 1989), I had ample opportunity to observe their premigratory behavior. During spring migrations of 1983 and 1984, we followed the same adult pair of whooping cranes, with different radio-tagged young each year, northward from Texas to Saskatchewan, Canada. The family group was at times accompanied by 1–4 other whooping cranes. Observation time of these cranes during 35 days in 1983–84 totalled 158 hours (Stehn 1983, 1984). Between 1985 and 1990, observations were made on crane groups at Aransas NWR on 11 days when those cranes initiated a migratory flight. Because observation periods at Aransas varied from 1 to 120 minutes, only the radio-tracking observations were used to quantify premigratory behavior. Qualitative entries in field notes were summarized for this report.

RESULTS AND DISCUSSION

Pre-flight Behavior

A key behavior predictive of migration was increased alertness among the entire group of birds. For several minutes before flight, 1 or more cranes, including the adult male, would show extended alert behavior. In contrast, members of whooping crane groups on the wintering grounds are rarely all alert unless reacting to a specific disturbance, predator, or other cranes. Prior to short wintering grounds flights, cranes will stop feeding, then fly within seconds with no predictive behavior except flight intention noted.

Another behavior that predicted migratory flight of a family group was head tilting by the adult male. He would tilt his head sideways with the bill slightly above the horizontal, presumably to look up at the sky. Head tilting was noted 84 times on 16 different days and was observed from 1 to 12 times preceding all 7 migratory flights. However, on 9 occasions, occurrences of head tilting were not followed by migration. On 19 days, no head tilting was observed and no migratory flights were initiated (Table 1). Based on 7 observations of premigration behavior, head tilting first occurred an average of 32 minutes (range = 7–83 min) prior to initiation of migration. Head tilting
Table 1. Number of observation days and the relationship of head tilting behavior to initiation of migration in whooping cranes at Aransas National Wildlife Refuge, 1983–84.

<table>
<thead>
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<th>Followed by migration</th>
<th>Not followed by migration</th>
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</thead>
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<tr>
<td>Head tilting observed</td>
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<tr>
<td>Head tilting not observed</td>
<td>0</td>
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</table>

might always precede migratory flight but is not always indicative that migration will occur.

D. H. Ellis (U.S. Fish and Wildlife Service, pers. commun.) noticed a similar behavior that he termed monocular gazing. This behavior occurs in the captive flock at the Patuxent Wildlife Research Center when the whooping cranes look skyward at birds flying overhead. The function of this head tilting behavior prior to migration is unknown, but it could be used by whooping cranes to assess weather conditions. On the wintering grounds, head tilting is rarely observed if the birds are just making a flight to another nearby location. It has been observed at Aransas primarily when raptors fly near the cranes. Head tilting has been observed in sandhill cranes when other sandhill cranes fly overhead (W. M. Brown, University of Idaho, pers. commun.).

Whooping cranes typically fed intensively for several hours before initiating migratory flights (n = 7). On only 1 occasion did cranes act differently. On 17 April 1983, 4 whooping cranes at the Quivira NWR in Kansas were feeding at 0615 hours when first observed but then loafed for 2.3 hours in an open water marsh before migrating. No food items were found where the cranes had been when the site was visited immediately after their departure (Stehn 1983).

Alertness increased and feeding decreased to occasional pokes at the ground shortly before (x̄ = 18 min, n = 5, SE = 5) whooping cranes began migration. Head tilting was occasionally observed, along with an increase in comfort movements (preening, wing stretching, flapping, or ruffling). Drinking was observed on 3 of 7 occasions at an average of 15 minutes before migration. Preening and/or resting were observed immediately before initiation of flight in 1 instance, and increased alert behavior was noted only within the final 10 minutes before migration.

In a family group, the male was usually the first to show increased amounts of alert behavior, followed by the female, and lastly the chick. Most all cranes were alert during the minute prior to flight. Immediately before liftoff, all of the birds were at full alert and grouped into a tightly spaced formation facing into the wind with the adult male in the lead. The male leaned forward (flight intention) and took a few steps as he became airborne along with the other cranes. On 2 occasions, juveniles initially showed flight intention while the family became airborne almost simultaneously.

Heat waves that began to impair vision through a spotting scope usually occurred an average of 14 minutes (n = 4, SE = 4) before the onset of migration. Thermal currents are an integral part of crane spiral migration flight (Melvin and Temple 1982), and the heat waves were an indication that whooping cranes waited until heated air was rising before departing.

Influence Of Migrating Cranes On Other Cranes

Eleven observations of whooping cranes at Aransas indicate that a group of cranes starting migration often influence initiation of migration by other cranes. On 3 April 1985, I observed a widowed male and a widowed female crane, each with their respective juveniles, that had wintered together on the male's territory. The group of 4 cranes was first observed standing alert in a line at 0910 hours. At 0915 the 4 cranes took flight and flew approximately 2 km. After the 4 cranes had passed by, a territorial pair about 1 km away also took flight and joined them. All 6 birds circled for approximately 5 minutes but never gained altitude. The cranes then returned to their respective territories, the pair landing approximately 250 m from the group of 4. Little feeding or movement was subsequently observed except for a limited amount by the 2 juveniles. At 0940 hours, the 4 cranes were once more alert and in line. The neighboring pair was also alert. In the group of 4, the lead crane looked around at full alert. The other adult preened and ruffled its wings. One juvenile, the second in line, went into an exaggerated lean for about 10 seconds. All 4 took flight into the wind, then quickly turned to head north-northwest (335°). This time the neighboring pair took flight immediately and joined the 4. The cranes flew 100-150 m above the ground until they were out of sight. Two different whooping cranes, located approximately 6 km to the northeast, also took off about the same time, circled, and then landed. Ten minutes later, the 2 birds began migration (H. Hunt, Louisiana Tech University, pers. commun.). It is unknown if these 2 cranes had been aware of or influenced by the departure of the other cranes.

On 6 April 1984, 2 whooping cranes departed from the refuge at 0928 hours. The pair vocalized and flew in a large spiral pattern. A radiated family group located approximately 2 km to the southeast took flight at 0930 hours.
hours and migrated with the other 2 cranes (H. Hunt, Louisiana Tech University, pers. commun.).

On 8 April 1986, I observed a family group at Aransas starting migration. Three subadult cranes nearby then flew. One returned to the ground while the other 2 birds continued climbing until they were near, but not in formation with, the family in spiral, migratory flight. All 5 cranes headed north-northwest. A neighboring territorial pair remained on the ground. Similarly, on 14 April 1986, 2 family groups from nearby territories on Matagorda Island started migration about 3 minutes apart, spiralling high into the sky.

On 7 April 1988, a family group of cranes started migration from Rattlesnake Island on Aransas. They were observed walking and standing, feeding little, for about 25 minutes near a freshwater source. They initiated migration at 1035 hours, flying close to a family group and a pair on the edge of Sundown Bay. At 1100 hours, the Sundown Bay pair started migration. The family on Sundown Bay unison-called shortly after the pair left but remained on the ground. Fifty minutes later, a single crane was observed initiating migration about 4 km away from the Sundown Bay family group.

On 13 April 1988, 1 family group and 7 subadult whooping cranes were observed along South Sundown Bay at Aransas. For 42 minutes, the cranes stood and/or preened, with only the juvenile walking and feeding. The simultaneous lack of activity by 3 different crane groups was unusual and suggested migration was impending. At 0957 hours, the family group initiated migration. One minute later, 1 of 3 subadults that had been closest to the family followed and joined the family. One minute later the group of 4 subadults also flew and began to spiral under the other 4. The single subadult dropped back and joined the other 4 subadults. Eight minutes later, the 5 subadults returned to South Sunday Bay while the family apparently continued migration. Two of the group of 5 started migration within the next 30 minutes.

At 0830 hours on 14 April 1988, a family group (3 birds) and a group of 5 subadult whooping cranes were closely associated at Mustang Lake. At 0915 hours, the family ceased feeding and loafed and preened, although occasional wing flapping was observed. The subadult group continued to feed until 0947 hours. All cranes were alert much of the next 15 minutes. At 1002 hours, the family group started migration, flying over the subadults. Two of the 5 subadults followed and joined the family. One of the 3 subadults that stayed behind, female B-o-y (1986), had a 100% frequency of association during the 1987–88 winter with male W-RwR (1985), who migrated. These 2 birds have subsequently mated with others.

At 0936 hours on 12 April 1990, 4 of 7 cranes (presumably subadults) on the edge of Sundown Bay, took flight apparently because my boat had drifted too close. The 4 cranes headed north-northwest, and while in spiral flight, were joined by a fifth whooper that had not been sighted previously. By 1002 hours, the 5 migrating cranes were out of sight. The 3 remaining cranes stayed on the edge of Sundown Bay until 0946 hours and then flew 2 km and landed. At 1013 hours, a family group that had been 2 km from the original group of 7, approached and landed 100 m from the 3 subadults. After 5 minutes during which all 6 cranes were alert, the family took flight at 1018 hours and were followed 30 seconds later by the 3 subadults. The family group spiralled high while the 3 subadults stayed lower. At 1025 hours, 1 subadult apparently returned to the refuge while the other 2 continued spiraling and were lost from sight at 1028 hours.

On 17 April 1990, a family group (Y-BWsp [1984] and WbW-WbW [1985]) started migration from the Boat Ramp Marsh. No other cranes were in the vicinity on that day. During the final 48 minutes before flight, the birds stood and preened. Wing ruffling and flapping were observed. Both adults drank 24 minutes before flight, and the male head tilted once 20 minutes before migration. After takeoff, the cranes flew in straight flapping flight for 4 minutes, then spiraled until lost from sight. At 0820 hours on 18 April the family was back near the Boat Ramp. A similar "false start" was documented by radiotelemetry in April 1984 when the Egg Point family group flew north-northwest 35 km and then returned to the refuge (Stehn 1992). On the second morning the Boat Ramp family group alternated feeding and loafing/preening until 1005 hours. The group stopped feeding and alternated between alert, loaﬁng, or preening behaviors for 19 minutes. Head tilting was observed 6 times 5–9 minutes before migration. The group departed at 1026 hours. After 2 minutes of straight flight, the cranes spiraled until out of sight.

CONCLUSIONS

Behaviors used to predict an impending migratory flight include increased amounts of alert behavior, wing comfort movements, and head tilting. On the wintering grounds, the departure of a group of cranes may influence other nearby cranes to start migration. However, these groups may fly separately. Whooping cranes in migration are almost never found in large groups (U.S. Fish and Wildlife Service 1986).

LITERATURE CITED

HOWE, M. A. 1989. Migration of radio-marked whooping cranes


TEMPORAL PATTERNS OF SANDHILL CRANE ROOST SITE USE IN THE PLATTE RIVER

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Abstract: Temporal patterns of daily arrival and departure of sandhill cranes (Grus canadensis) at roost sites were examined along the Platte River in Nebraska during spring 1990. Departure times were earliest and arrival times were latest during the beginning of the staging season (9–21 March). Date within the staging season was the primary variable associated with time of initial departure and arrival, but arrival and departure times were also influenced by climatic factors. Departure times correlated positively with fog and precipitation ($P < 0.05$) and negatively with air temperature ($P < 0.05$), whereas arrival times correlated positively with both cloud cover and air temperature ($P < 0.05$).

Key Words: flock, Grus canadensis, migration, Nebraska, roost site, sandhill cranes

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Nearly 90% of the mid-continent population of sandhill cranes stop along the Platte and North Platte rivers in Nebraska from March to mid-April (Lewis 1977; Iverson et al. 1985, 1987). During this time, they deposit stores of fat (Krapu et al. 1985, Tacha et al. 1987) in preparation for migration to their breeding grounds in Canada, Alaska, and eastern Siberia (Krapu et al. 1982, 1984). The timing of roosting activities has been described (Frith 1974; Lewis 1974, 1979; Iverson et al. 1987); however, information on the temporal patterns of arrival and departure of sandhill cranes throughout the spring staging season is lacking. These data are needed to effectively manage the cranes when they utilize the river roost sites. Our objectives were to describe the temporal patterns of arrival and departure of sandhill cranes from roosts during the morning and evening and assess the effect of abiotic factors on arrival and departure patterns.

Special thanks go to J. Luebs, K. Strom, and the Platte River Whooping Crane Maintenance Trust for access to their properties. We also thank T. Parrish and B. Baker for critical review of the manuscript. Funding was provided by the U.S. Bureau of Reclamation and the U.S. Fish and Wildlife Service.

STUDY AREA AND METHODS

The study area was in south-central Nebraska along the Platte River between Grand Island and Kearney (see Lingle 1992). Spring precipitation in Nebraska contributes to the Platte River Basin flow, but most of the flow is from snowmelt in the Rocky Mountains (Eschner et al. 1981). The mean monthly temperatures range from −4.9°C in January to 25.7°C in July. Total annual precipitation ranges from 47.5 to 60 cm (Stevens 1978). The river is braided and interspersed with many sandbars. Land use around the river is predominantly agriculture and was 60% cropland, 20% native grassland, 15% riparian woodland, and 5% tame pasture (Reinecke and Krapu 1979). The riparian woodland was comprised of open canopy cottonwood (Populus deltoides) with red cedar (Juniperus virginiana) and rough-leaf dogwood (Cornus drummondii) (Currier 1982).

Observations were made from 3 sites. Site 1 was 1.8 km upstream from the Highway 281 bridge on the south channel and had a mean channel width of 246 m and shallow water with many exposed sandbars. Site 2 was 3 km upstream from the Wood River bridge on the south channel and had an average channel width of 357 m and several large, vegetated islands. Site 3 was 2.2 km downstream from the Highway 10 bridge and had an average channel width of 406 m and many small vegetated islands. All 3 sites were used extensively by sandhill cranes during staging in previous years.

The 3 sites were viewed from blinds on the river bank with 10 × 50 binoculars or a 2X Noctron IV night vision scope. Observations of sandhill cranes were conducted from each blind every third day between 9 March and 15 April. Counts of all birds arriving at or departing from the roosts and the times of arrival or departure were recorded at 5-minute intervals. Evening counts were started 90 minutes prior to sunset and continued until all birds had
arrived at the roost. The following morning, counts were made of the same roost, beginning 1 hour prior to sunrise and continuing until all sandhill cranes had left the roost or until 90 minutes after sunrise. In this paper, we define "flock" as all birds at 1 roost site during a single night.

Influences of environmental variables on flock formation and dispersal were assessed. Data were recorded at 5-minute intervals during evening and morning counts; variables included cloud cover, fog or precipitation, wind speed, wind direction, air temperature, and fractional illumination of the moon. Cloud cover was described as 1 of 5 classes: 0, 1–25, 26–50, 51–75, or >75% (overcast). Fog or precipitation was described as either absent or present. Wind speed was categorized into 1 of 5 classes: 0, 1–16, 17–32, 33–48, or >48 km/hour. Wind direction was categorized into 1 of the 8 cardinal directions or as calm. Fractional illumination of the moon was expressed as a value between 0 and 1 (Nautical Almanac Office, United States Naval Observatory and Her Majesty's Nautical Almanac Office, Royal Greenwich Observatory 1990).

Statistical tests were executed with SOLO (BMDP Statistical Software, Inc. 1988). Differences in departure and arrival times, flock size, and percentage of the flock leaving and arriving at the roost were examined with 1-way analysis of variance (ANOVA). If the ANOVA indicated a difference, Duncan's multiple-range test was used to separate means. Stepwise forward multiple regression (Kleinbaum et al. 1988) was used to compare date and climatological variables to time of initial arrival and departure time when 11–20, 41–50, and 91–100% of the flock had departed or arrived. These flock sizes were selected to allow us best estimates of site usage. Eight independent variables were included in the analysis of departure and arrival times (Table 1). Initial departure time (IDT) and initial arrival time (IAT) also were used as independent variables in the regression analysis to estimate time at which 11–20, 41–50, and 91–100% of the flock had departed or arrived. Prior to analysis, each angle of the variable WINDDIR was converted to its sine and cosine equivalent (Table 1). Second order polynomial models were developed for arrival times of roosting flocks. Because preliminary analysis indicated collinearity between predictor variables DATE and DATE², a mean deviate transformation (\(x_i - \bar{x}_i\)) was applied to the predictors to reduce collinearity (Kleinbaum et al. 1988, Neter et al. 1989).

**RESULTS**

Estimated size of crane flocks differed among sites. The mean flock size at Site 1 was 1,647 ± 381 (SE) sandhill cranes (range = 355–4,695), whereas the mean

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE²</td>
<td>Day of the year, squared.</td>
</tr>
<tr>
<td>DATE</td>
<td>Day of the year, numbered in sequence with 1 January = 1.</td>
</tr>
<tr>
<td>FOG/PREC</td>
<td>Presence or absence of fog or precipitation.</td>
</tr>
<tr>
<td>CLOUDCOV</td>
<td>Percentage of sky covered by clouds.</td>
</tr>
<tr>
<td>TEMP</td>
<td>Air temperature in degrees C.</td>
</tr>
<tr>
<td>FLOCKSZE</td>
<td>Number of sandhill cranes present at a roost on a given date.</td>
</tr>
<tr>
<td>WINDSPEED</td>
<td>Relative velocity of wind in km/hr.</td>
</tr>
<tr>
<td>WINDIR</td>
<td>Direction of wind expressed at 1 of 8 cardinal directions.</td>
</tr>
<tr>
<td>SINE WD</td>
<td>Sine of wind direction.</td>
</tr>
<tr>
<td>COSIN WD</td>
<td>Cosine of wind direction.</td>
</tr>
<tr>
<td>MOON²</td>
<td>Fractional illumination of the moon expressed as a value between 0 and 1.</td>
</tr>
<tr>
<td>IDT</td>
<td>Initial departure time in minutes before and after sunrise.</td>
</tr>
<tr>
<td>IAT</td>
<td>Initial arrival time in minutes before and after sunset.</td>
</tr>
</tbody>
</table>

Table 1. Independent variables in regression analysis of the influence of abiotic factors on departure and arrival times of sandhill cranes roosting along the Platte River, Nebraska, spring 1990.

flock size at Sites 2 and 3 was significantly larger (\(P < 0.05\)) at 4,383 ± 936 (range = 404–9,805) and 4,577 ± 878 birds (range = 1,492–13,190), respectively.

**Flock Departure**

While the initial departure time did not differ among sites, the time when different proportions of the birds left varied at sites. Sandhill cranes departed an average of 20 and 25 minutes later at Site 2 than at Sites 1 and 3 (\(P < 0.01\)). At Site 2, 41–50% of the flock departed an average of 35 minutes later than at Site 3 (\(P < 0.02\)). Likewise, time at which 91–100% flock departed differed among sites (\(P < 0.009\)). Cranes departed an average of 38 and 60 minutes later at Site 2 than Sites 1 and 3.

Initial departure time varied temporally (\(P < 0.0005\)). Sandhill cranes left the roosts earlier and for a shorter period during 9–21 March than during 22 March–15 April (Fig. 1). The initial departure time averaged 15 and 23 minutes earlier from 9 to 21 March than during the
periods of 22 March – 3 April and 4 – 15 April. The length of departure at Sites 1 and 3 was short from 9 to 25 March, but increased substantially thereafter, whereas the length of departure at Site 2 remained constant throughout the entire staging season (Fig. 1). During the period from 9 to 21 March, 25 and 33% of the flocks took 60 to 90 minutes each day. However, between 22 March and 15 April the proportion of flocks with a departure length greater than 90 minutes increased to 83%. The time at which 11 – 20% of the flock departed also varied temporally (P < 0.0003) and averaged 19 and 33 minutes earlier from 9 to 21 March than in periods 22 March – 3 April and 4 – 15 April.

Similarly, the proportion of the flock leaving the roost before sunrise varied temporally (P < 0.0001). The percentage of departing sandhill cranes was significantly higher from 9 to 21 March than 22 March – 15 April (Fig. 2). The percentage of the flock departing before sunrise was greatest during the first 9 – 12 days of the staging season and then declined, leveling off toward the end of the staging season. This trend was observed among all 3 sites.

**Abiotic Factors.**—Time of initial departure correlated with various independent variables. Variability in initial time of departure was best accounted for by DATE and FOG/PREC (Table 2). The inclusion of TEMP as an independent variable in the multiple regression did not improve the model.

Time when 11 – 20% of the flock departed highly correlated with IDT (r = 0.92). The variable IDT accounted for more variability in time at which 11 – 20% of the flock departed than DATE and FOG/PREC, which had substantially lower correlations.

The time when 41 – 50% of the flock had left the roost was best accounted for by a multiple regression including

![Fig. 2. The influence of the time of the staging season (date) on the proportion of sandhill cranes departing from the roost prior to sunrise at different sites during spring stopover along the Platte River, Nebraska, 1990.](image-url)
Table 2. Regression equations accounting for variability in departure time (Y) for IDT, T20, T50, and T100 of sandhill cranes from the roost during spring staging along the Platte River, Nebraska, 1990. Departure time is described as time of initial departure (IDT), a time when 11-20 (T20), 41-50 (T50), and 91-100% (T100) of the flock had departed. Independent variables are Day of the Year (DATE), Presence or Absence of Fog or Precipitation (FOG/PREC), b Air Temperature (TEMP), c and Initial Departure Time (IDT).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>$R^2$</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(IDT)</td>
<td>0.71</td>
<td>$Y = -85.98 + 0.78$ (DATE) + 23.03 (FOG/PREC) - 0.72 (TEMP)</td>
</tr>
<tr>
<td></td>
<td>0.67</td>
<td>$Y = -85.98 + 0.78$ (DATE) + 23.03 (FOG/PREC)</td>
</tr>
<tr>
<td>(T20)</td>
<td>0.84</td>
<td>$Y = 14.18 + 1.39$ (IDT)</td>
</tr>
<tr>
<td></td>
<td>0.47</td>
<td>$Y = -118.14 + 1.26$ (DATE) + 17.10 (FOG/PREC)</td>
</tr>
<tr>
<td>(T50)</td>
<td>0.57</td>
<td>$Y = -110.64 + 1.39$ (DATE) + 33.03 (FOG/PREC) - 2.11 (TEMP)</td>
</tr>
<tr>
<td>(T100)</td>
<td>0.45</td>
<td>$Y = 79.76 + 2.15$ (IDT)</td>
</tr>
<tr>
<td></td>
<td>0.26</td>
<td>$Y = -148.15 + 2.24$ (DATE)</td>
</tr>
</tbody>
</table>

* Time in minutes before and after sunrise.
b Coded for 0 = no fog or precipitation, 1 = presence of fog or precipitation.
c In degrees C.

DATE, FOG/PREC, and TEMP as independent variables (Table 2). Departure time correlated positively with DATE and FOG/PREC and negatively with TEMP. The variable IDT singly or in combination with other independent variables was not a determinant of the time at which 41-50% of the flock left the roost.

The time when 91-100% of the flock departed was best explained by IDT. DATE was significant in accounting for the time when 91-100% of the flock left the roost but had a lower correlation than IDT. The other independent variables, FOG/PREC and TEMP, did not correlate with the time of 91-100% flock departure.

**Flock Formation**

Arrival times did not differ among sites, however, initial arrival time varied temporally ($P < 0.0001$). Sandhill cranes arrived at the roosts earlier from 4 to 14 April than from 9 March to 3 April (Fig. 3). Initial arrival times averaged 60 and 50 minutes earlier from 4 to 14 April than during the periods of 9-21 March and 22 March -3 April.

Similarly, the proportion of the flock arriving at the roost before sunset varied temporally ($P < 0.0001$). The percentage of the flock arriving before sunset averaged 7% from 9 March to 3 April but increased to 57% from 4 to 14 April toward the end of the staging season (Fig. 4).

Sandhill cranes arrived at the roost at a far greater rate during the formation of the first half of the flock than the later half (Fig. 5). This trend was apparent during the entire staging season. Differences between the rate of arrival from the time when the flock was initially formed to half formed were significant ($P < 0.0004$), as was the difference between arrival rates from the time the flock was half formed to fully formed ($P < 0.0001$). The rate of arrival during 9 March -3 April was higher than during 4-14 April ($P < 0.05$) (Fig. 5). Between 9-21 March and 22 March -3 April, the first half of the flock formed at a rate that averaged 13 and 8 minutes greater than in the period of 4-14 April. During the later half of flock formation, differences were even greater. The rate of formation of the remaining half of the flock averaged 16 and 19 minutes less from 4 to 14 April than in the time period of 9-21 March and 22 March -3 April. Likewise, the total length of time from initial to final flock formation was characterized by a significant increase from the period of 4-14 April ($P < 0.05$). The total length of flock formation averaged 40 and 37 minutes longer from 4 to 14 April than 9-21 March and 22 March -15 April.

**Abiotic Factors.**—Time of initial arrival highly correlated with date and various climatic variables. Variability in time of initial arrival was best accounted for by DATE, DATE $^3$, CLOUDCOV, and TEMP (Table 3).

Time when 11-20% of the flock had formed highly correlated with IAT ($r = 0.97$). The variables DATE,
DATE$^2$, CLOUDCOV, and TEMP in combination also accounted for substantial variability in time at which 11–20% of the flock arrived at the roost and positively related to arrival time (Table 3).

The time when 41–50% of the flock had formed was best accounted for by IAT singly. The polynomial regression of DATE, DATE$^2$, and CLOUDCOV was also an important determinant of the time when 41–50% of the flock arrived at the roost. The inclusion of TEMP as an independent variable in the regression did not improve the model.

Variability in time when 91–100% of the flock was formed was best explained by IAT. The variable DATE was significant in accounting for the time when 91–100% of the flock arrived at the roost, but did not correlate as closely with arrival time as IAT. The other independent variables DATE$^2$, CLOUDCOV, and TEMP did not correlate with the time of 91–100% flock formation.

**DISCUSSION**

This study demonstrated a trend in the timing of roosting activities during the staging season. Departure times were earliest, arrival times latest, and the rate of departure and arrival were greatest at the beginning of the staging season and less during the middle and late portions of the staging season. Also, as departure times became later, arrival times were earlier, and departure and arrival rates were considerably lower.

**Flock Departure**

Daily departure rates differed among the 3 sites. Why sandhill cranes remained on 1 roost (Site 2) longer than on either of the other 2 sites is unknown, but cranes arrived at Site 2 a full week later than at the other 2 sites. Initial departure times varied temporally. Sandhill
cranes were leaving the roost earlier at the beginning of the staging season, as early as 45 minutes before sunrise. Frith (1974) observed sandhill cranes leaving roosts along the Platte River as early as 2 hours before sunrise. The time of initial departure during the end of the staging season averaged 23 minutes later than at the beginning. Iverson et al. (1987) and Lewis (1974) reported similar initial departure times for sandhill cranes along the North Platte River in Nebraska and in Kansas and Oklahoma. Stephen (1967) found that in Saskatchewan, sandhill cranes began to leave the roost about 23 minutes before sunrise.

The proportion of the flock leaving the roost before sunrise varied temporally. The percentage of sandhill cranes departing from the roost averaged 74% during the beginning of the staging season, then declined sharply to 17% later. Similarly, Lewis (1974) reported that an estimated 18% of the sandhill cranes had departed the roosts by sunrise in Kansas and Oklahoma. Stephen (1967) and Lewis (1979) stated that an average of 25% of the sandhill cranes left their roosts by sunrise in Saskatchewan and Nebraska, respectively.

**Flock Formation**

Daily arrival times at the roosts did not differ among sites but varied temporally with sandhill cranes arriving at roosts earlier at the end of the staging season. The mean time of initial arrival at the end of the staging season was 40 minutes before sunset. In describing roosting behavior of sandhill cranes in Kansas and Oklahoma, Lewis (1974) noted that birds occasionally arrived at the roost as early as 2–3 hours before sunset but more commonly arrived at the roost more than 100 minutes before sunset. Other evidence of early arrival times included observations made by Frith (1974) of sandhill cranes along the Platte River in Nebraska. He maintained that most of the birds arrived at the roosts between 1 hour before sunset and 0.5 hour after sunset. In a recent study, Iverson et al. (1987) reported a later arrival time, which averaged 6.5 minutes after sunset for radio-equipped birds on river roosts along the North Platte River in Nebraska.

The proportion of the flock arriving at the roost before sunset also varied during the staging season with an increase (from 7 to 57%) through the staging season. Similarly, Lewis (1974) observed that in Kansas and Oklahoma, 56% of the sandhill cranes had arrived at the roost prior to sunset. In a study of roosting behavior of sandhill cranes along the Platte River in Nebraska, Lewis (1979) reported that 64% of the birds had arrived at the roost by sunset.

On several occasions, large numbers of sandhill cranes were observed at Site 2 throughout the day. During this time, they were loafing, preening, drinking, and flying back...
Table 3. Regression equations accounting for variability in arrival time (Y) for IAT, T20, T50, and T100 of sandhill cranes to the roost during spring staging along the Platte River, Nebraska, 1990. Arrival time is described as Time of Initial Arrival (IAT), a time when 11 - 20 (T20), 41 - 50 (T50), and 91 - 100% (T100) of the flock had formed. Independent variables are Day of the Year (DATE), Day of the Year Squared (DATE²), Percent Cloud Cover (CLOUDCOV), Air Temperature (TEMP), a and initial Arrival Time (IAT).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>R²</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAT</td>
<td>0.86</td>
<td>[Y = -37.44 + 2.54(\text{DATE}) + 0.10(\text{DATE}^2) + 4.26(\text{CLOUDCOV}) + 1.55(\text{TEMP})]</td>
</tr>
<tr>
<td>T20</td>
<td>0.94</td>
<td>[Y = -4.16 + 0.84(\text{IAT})]</td>
</tr>
<tr>
<td>T50</td>
<td>0.79</td>
<td>[Y = -36.78 + 2.09(\text{DATE}) + 0.08(\text{DATE}^2) + 4.18(\text{CLOUDCOV}) + 1.31(\text{TEMP})]</td>
</tr>
<tr>
<td>T100</td>
<td>0.87</td>
<td>[Y = -12.36 + 0.69(\text{IAT})]</td>
</tr>
<tr>
<td></td>
<td>0.73</td>
<td>[Y = -40.70 + 1.68(\text{DATE}) + 0.72(\text{DATE}^2) + 3.80(\text{CLOUDCOV}) + 1.05(\text{TEMP})]</td>
</tr>
<tr>
<td></td>
<td>0.69</td>
<td>[Y = -33.53 + 1.58(\text{DATE}) + 0.93(\text{DATE}^2) + 3.54(\text{CLOUDCOV})]</td>
</tr>
</tbody>
</table>

\(^a\) Time in minutes before and after sunset.
\(^b\) Coded for 1 = clear, 2 = 1 - 25%, 3 = 26 - 50%, 4 = 51 - 75%, 5 = > 75% (overcast).
\(^c\) In degrees C.

and forth from the river to feeding areas. Similar patterns of diurnal activity were reported by Lewis (1976) for sandhill cranes in Kansas and Oklahoma. Diurnal roost activity may be attributable to the characteristically mild weather conditions during such activity (Lewis 1976).

**Abiotic Factors**

Fog or precipitation also influenced initial departure time. Sandhill cranes remained on roosts longer during mornings with fog and precipitation, probably because fog and precipitation limit visibility and make flight more hazardous. Lewis (1978) observed that rain or fog and cloud cover and strong winds (>48 km/hour) delayed departure. In contrast, Frith (1974) reported that high wind velocities (>32 km/hour) promoted earlier departures. Our study did not indicate wind speed or cloud cover to be determinants of initial departure time. However, cloud cover influenced initial arrival time. Sandhill cranes arrived earlier at the roost during periods of increased cloud cover, perhaps because cloud cover decreased light level.

Air temperature also explained some variability in initial departure and arrival times. During periods of cold weather, birds left and returned to roosts later. This implies a thermodynamic advantage to feeding later during the morning and during dusk when temperatures are warmer. A similar relation has been described for black ducks (*Anas platyrhynchos*) by Albright et al. (1983). They observed that during cold temperatures it was more advantageous for black ducks to conserve energy resting than to expend energy foraging.

**LITERATURE CITED**


SANDHILL CRANE ROOST USE • Norling et al. 113


SOCIAL PREFERENCE OF FOUR CROSS-FOSTER REARED SANDHILL CRANES

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Abstract: Four greater sandhill cranes (Grus canadensis tabida) were hatched and reared individually by 4 non-sandhill crane pairs: 2 by white-naped crane (G. vipio) pairs, 1 by a Siberian crane (G. leucogeranus) pair, and 1 by a red-crowned crane (G. japonensis) pair. After 1 year the sandhill cranes (2 male and 2 female) were placed in enclosed pens adjacent to an opposite-sexed, same-age bird of the foster species on 1 side and an opposite-sexed, same-age conspecific on the other side. Data were collected throughout 1 year and included proximity between test and choice birds and behaviors displayed. Each test bird socialized with the foster species more than with a conspecific. This preference was much more apparent for females than for males.

Key Words: conspecific, crane, cross-foster, Grus, social preference

PROC. NORTH AM. CRANE WORKSHOP 6:114-119

The technique of cross-fostering has had a long and varied history from the pre-automatic incubator practice of allowing hens to raise all manner of fowl to the modern egg switches between endangered and non-endangered birds (Drewien and Bizeau 1978). In captivity, managers usually limit potential mates for a chick raised in this manner to conspecifics. In the wild, however, potential mate choices are not limited, and any aberrant behavior can potentially mean psychological castration. It is vitally important, therefore, that any rearing technique reliably produce young attracted only to conspecifics.

The influences of the foster parents (imprinting) on the chick’s adult responses and preferences are a major concern. Schutz (1965, 1970) examined the effects of cross-fostering on various species of ducks and found that foster-reared male ducks frequently mated with the foster species. Extensive research of altricial zebra finches (Poephila guttata) cross-fostered to Bengalese finches (Lonchura striata domestica) (Inmelmann 1972; Sonneman and Sjolander 1977; ten Cate 1982, 1984; ten Cate et. al. 1984) have shown that sexual preference for the foster species was more apparent in male than in female zebra finches.

The model for precocial sexual imprinting is the coturnix quail (Coturnix coturnix japonica) for which Gallagher has investigated social experience (1976), persistence and stimulus quality (1978a), and variability in mate preference (1978b). He found that the timing and duration of the exposure to a foster subject was crucial to imprinting. Harris (1969) conducted an extensive cross-fostering study between herring gulls (Larus argentatus) and lesser black-backed gulls (L. fuscus). He found abnormal migration patterns and a large amount of hybridization. The foster parents had an extremely influential effect on the behavior and mating of the adult.

Artificial cross-fostering in cranes in the wild at Grays Lake National Wildlife Refuge, Idaho (U.S. Fish and Wildlife Service 1986) began in 1975. Sixteen years later in 1991, 12 whooping cranes (G. americana) are the result of 288 eggs transplanted into greater sandhill crane nests. The 4 females in this flock, all presumed sexually mature, disperse widely. The failure of these birds to pair and reproduce has been attributed to the scarcity of females on the wintering grounds and summering grounds where pair associations have an opportunity to develop” according to the Whooping Crane Recovery Plan (U.S. Fish and Wildlife Service 1986:41). Pairing has also not occurred between whooping cranes and greater sandhill cranes.

Cross-fostering has been used extensively in captivity with many species to let experienced parents care for abandoned young or to give inexperienced parents a chance to learn to raise less valuable young. Cranes are no exception; Ueno Zoo in Japan, St. Catherine’s Island in Georgia, and the International Crane Foundation (ICF) in Wisconsin, among others, have included cross-foster methods in their chick rearing programs (Voss 1974). At Ueno Zoo, a red-crowned crane was raised by a white-naped crane pair. Upon maturing, it was not interested in other red-crowned cranes and, instead, courted white-naped cranes. The male was forced paired with a female red-crowned crane by eliminating all contact with white-naped cranes. The male accepted the female and remained paired from 1978 to 1983. In 1984 the female was hospitalized and the male again showed interest in white-naped cranes. When the female red-crowned crane was returned, the male rejected and killed her. Thereafter, the male only courted white-naped cranes (Nakayama 1970).

Further literature review suggests that sexual imprinting due to cross-foster rearing is species specific. Powell (1991) found that killdeer (Charadrius vociferus) cross-fostered by spotted sandpipers (Actitis macularia) showed no preference, as adults, for the foster species.
In 1987 the International Crane Foundation (ICF) began an investigation into social preferences among several crane species. The previous year, several pairs of endangered cranes had raised young greater sandhill cranes as a means of gaining parenting skills. Mate choice in greater sandhill cranes typically begins with associations in non-breeder flocks late in the second year (Walkinshaw 1973). Florida sandhill cranes averaged 5 associations before a permanent pair bond was established (Nesbitt and Wenner 1987). Based on those studies, Lewis (1986) speculated that greater sandhill cranes have 3–6 associations before a final mate is chosen. Our investigation was designed to start before these initial associations and to document preferences of the cross-fostered birds.

We wish to thank G. W. Archibald, J. T. Harris, C. M. Mirande, and S. R. Swengel of ICF and C. A. Faanes of the U.S. Fish and Wildlife Service for their helpful review comments. A large amount of appreciation goes to J. N. Adams, N. K. Laughlin, and S. R. Swengel for statistical assistance. We would especially like to thank F. C. Arengo and M. S. Merkle for their hours of data collection.

METHODS

Eight 1-year-old cranes were observed. All were raised at ICF, but under varying conditions. Four sandhill cranes were cross-fostered; their social and mate preferences were examined. One male (SH-M₁) was fostered by red-crowned cranes, a female (SH-F₁) was fostered by Siberian cranes, and a female (SH-F₂) and a male (SH-M₂) were fostered by separate pairs of white-naped cranes. The 4 birds representing foster parents were a female red-crowned crane (RC-F) raised by puppets and humans in costume, i.e., "isolation-reared" (Horwich 1989), a male Siberian crane (SM-M), a male white-naped crane (WN-M), and a female white-naped crane (WN-F) that were all hand-reared by ICF staff with other crane chicks. All 8 birds hatched between 20 May and 17 June 1986.

Two adjacent pen units were used for our study, with 4 birds in each (Figs. 1 and 2). The units were visually isolated from each other by tennis netting. Each unit was divided into 4 pens. The interior of each pen was divided by 4 stakes into 3 rows and 9 cells (Fig. 3). The birds were then arranged so that each sandhill crane had a choice of associating with an opposite-sexed conspecific and an opposite-sexed foster species individual. The left unit held RC-F, SH-M₁, SH-F₁, and WN-M (Test Group 1). The right unit held S-M, SH-F₂, SH-M₂, and WN-F (Test Group 2).

Elevated blinds on 2 nearby buildings allowed easy viewing of all study cranes. Data were recorded for 30-minute periods per unit per day of observation. For each 30-minute period, scan samples of behaviors were recorded as well as the location of each bird at 30-second intervals. At the beginning of each interval, a code for each bird's behavior and location was recorded.

There were 98 observation days from 9 September 1987 to 5 August 1988, excluding February and March 1988. Five days of observation per month were randomly chosen from 10 months for the analysis. Only 3 days in December 1987 and 1 day in August 1988 were available because there were fewer observation days in these months. Therefore, the random sample was 44 of the 98 available days.

<table>
<thead>
<tr>
<th>RED-CROWNED</th>
<th>SIBERIAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female (RC-F)</td>
<td>Male (S-M)</td>
</tr>
<tr>
<td>SANDHILL</td>
<td>SANDHILL</td>
</tr>
<tr>
<td>Male (SH-M₁)</td>
<td>Female (SH-F₂)</td>
</tr>
<tr>
<td>SANDHILL</td>
<td>SANDHILL</td>
</tr>
<tr>
<td>Female (SH-F₁)</td>
<td>Male (SH-M₂)</td>
</tr>
<tr>
<td>WHITE-NAPE</td>
<td>WHITE-NAPE</td>
</tr>
<tr>
<td>Male (WN-M)</td>
<td>Female (WN-F)</td>
</tr>
</tbody>
</table>

Fig. 1. Arrangement of cranes within pens prior to 1 November 1987. Double line indicates a visual barrier.

<table>
<thead>
<tr>
<th>WHITE-NAPE</th>
<th>SIBERIAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (WN-M)</td>
<td>Male (S-M)</td>
</tr>
<tr>
<td>SANDHILL</td>
<td>SANDHILL</td>
</tr>
<tr>
<td>Female (SH-F₁)</td>
<td>Female (SH-F₂)</td>
</tr>
<tr>
<td>SANDHILL</td>
<td>SANDHILL</td>
</tr>
<tr>
<td>Male (SH-M₁)</td>
<td>Male (SH-M₂)</td>
</tr>
<tr>
<td>RED-CROWNED</td>
<td>WHITE-NAPE</td>
</tr>
<tr>
<td>Female (RC-F)</td>
<td>Female (WN-F)</td>
</tr>
</tbody>
</table>

Fig. 2. Arrangement of cranes within pens after 1 November 1987. Double line indicates a visual barrier.
Because human (aviicultural) activities at the lower edge of the pens might cause birds to spend more time at the far end of their pens, and thus bias the experiment, 1 row of 4 birds (Test Group 1; RC-F, SH-M1, SH-F1, and WN-M) was reversed on 1 November 1988, midway through the study (Figs. 1 and 2). Two separate analyses were performed for these cranes, 1 for pre-switch and 1 for post-switch data.

Only behaviors that indicated a social preference (Mirande and Archibald 1990) were analyzed. These included (a) foraging, (b) walking, (c) following, (d) approaching, and (e) maintenance behaviors (resting and preening) performed within 1 cell of an adjacent bird, and (f) run-flapping with or (g) guard calls performed closest to an adjacent bird.

RESULTS

Proximity

Before the rearrangement of Test Group 1 (Fig. 4), SH-M, was in the row closest to RC-F 72% of the time and in the row closest to SH-F 4% of the time. SH-F, was in the row closest to SH-M, 2% of the time, but in the row closest to WN-M 49% of the time. After the switch (Fig. 5), SH-M, spent 18% of his time in the row next to RC-F and 62% of his time in the row closest to SH-F1. SH-F, was in the row closest to SH-M, 7% of the time, while she spent 91% of her time in the row closest to WN-M.

In Test Group 2, SH-F2 used the row closest to SH-M2 4% of the time and the row closest to S-M 82% of the time (Fig. 6). SH-M2 was in the row closest to SH-F2 36% of the time and in the row closest to WN-F 27% of the time.

Behavior

The cross-fostered cranes performed some social behaviors much more frequently than other behaviors (Table 1). A $\chi^2$ goodness-of-fit test (df = 1, $\chi^2 = 2250.53$, $P < 0.001$) showed that cross-fostered birds performed social behaviors near foster species more than near the conspecifics. For this analysis all 4 sandhill cranes were grouped together. Types of behaviors performed adjacent to a conspecific were tested (df = 6, $\chi^2 = 146.07$, $P < 0.001$) and those behaviors performed adjacent to the
foster species were tested (df = 1, $\chi^2 = 5.378.75$, $P < 0.001$).

DISCUSSION

Our results indicate that cross-fostering has a major influence on later social choice in sandhill cranes. The 2 female sandhill cranes preferred to be near their respective foster species. This trend persisted after we switched the 1 row of birds. Nesbitt and Wenner (1987) contend that, in natural situations, the female crane is generally the more active individual when pairing occurs, choosing her mate from a large group of prospective bachelors.

The preference of the males is more difficult to ascertain (Figs. 1 and 2). Neither exhibited a tendency to be close to either the foster species or the conspecific. The amount of time SH-M$_1$ spent near RC-F decreased after his row was switched. Thus his association with RC-F is probably an artifact or result of his fear of humans.

The results of the behavior analysis are clearer. Although no strong indicators of pair formation were observed during data collection (e.g., dancing [only performed once by SH-M$_1$] and unison calling), other behaviors indicating preference were apparent. Foraging and maintenance behaviors, activities that all birds engage in
Table 1. Number of observations of behaviors that indicate social preference performed by 4 cross-fostered sandhill cranes from 9 September 1987 to 5 August 1988.

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Near conspecific</th>
<th>Near foster bird</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage*</td>
<td>53</td>
<td>1,404</td>
</tr>
<tr>
<td>Maintenance*a,b</td>
<td>13</td>
<td>928</td>
</tr>
<tr>
<td>Run-flap*c</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Walk*</td>
<td>0</td>
<td>57</td>
</tr>
<tr>
<td>Guard call*</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Approach*</td>
<td>9</td>
<td>61</td>
</tr>
<tr>
<td>Follow*</td>
<td>1</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>94</td>
<td>2,519</td>
</tr>
</tbody>
</table>

\[ \chi^2 = 146.07, \quad \chi^2 = 5,378.75, \quad P < 0.001, \quad P < 0.001 \]

*Within 1 cell.
*a Rest, preen.
b With another.
c Closest to.

throughout their lives, were performed by the greater sandhills within 1 cell of the foster species much more often than they were performed the same distance from the conspecific. A preference for the foster species was further shown when a bird chose to approach, follow, or walk with the adjacent bird.

Preferences may be related to choice of individuals as well as species. One might ask, for example, if SH-F2 chose S-M because she did not like SH-M2 and there were no other male sandhills available. If so, our small sample size (n = 4) would have skewed our data. However, the results more likely are the consequence of the cross-foster rearing method. If further studies are conducted, they should include a larger number of test cranes and/or choices.

Even if individual preferences were more significant than species preferences, the cross-foster technique would not be suitable for reintroduction. In a cross-fostering release program, a large number of the foster species would be present compared to a small number of conspecifics, especially in a new population. The cross-fostered young would have to prefer a conspecific over an individual of its foster species in order to obtain a conspecific mate. Even if either species would be accepted, an unsuitable mate choice would be probable. Also, because of its unusual upbringing, the cross-fostered young might be unable to attract a mate of either species.

The study birds remained in their pens after formal observations were completed. On several occasions unison calling was heard from SH-F2 and S-M (>5 occurrences and initiated by either bird), WN-M and SH-F2 (initiated by SH-F2), and RC-F and SH-Mj. Unison calling between sandhill cranes was never heard. Sample sizes were too small to allow for statistical analysis.

Based on the availability of other suitable rearing methods for release programs and the potential for negative impacts on future reproduction, even in captivity, we do not believe it is advisable to rear cranes by the cross-foster method. In the future, ICF will limit cross-fostering to situations where we allow endangered cranes to gain initial rearing experience with a more common crane species, before the parents rear chicks of their own species.

LITERATURE CITED


DEVELOPMENT OF AN ISOLATION-REARING/GENTLE RELEASE PROCEDURE FOR REINTRODUCING MIGRATORY CRANES

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Abstract: During 1988-90, in an effort to develop a reintroduction technique for the whooping crane (Grus americana), we reared 38 greater sandhill crane chicks (G. canadensis tabida) in isolation from humans and gentle-released them on Seney National Wildlife Refuge (NWR) in the Upper Peninsula of Michigan. Chicks were reared in the field with a puppet/costume technique. After chicks completed acclimation to wild conditions in a release pen, we induced them to migrate by breaking their flock into small groups, relocating some groups, and using guide birds. Solutions to migration initiation problems encountered in 1988-89 were developed and then successfully tested on an additional cohort in 1990. For 38 chicks released in 1988-90, minimum survival, 1 year after release, was 84%, minimum return rate to Upper Michigan was 74%, and estimated return rate was 97%. Return rates were similar for males and females.

Key Words: Grus canadensis, isolation-rearing, migration, reintroduction, release, sandhill crane

PROC. NORTH AM. CRANE WORKSHOP 6:120-130

The Wood Buffalo/Aransas flock is currently the only self-sustaining population of whooping cranes in the wild. The recovery of this species will require establishment of additional populations (U.S. Fish and Wildlife Service 1986). Cross-fostering, a reintroduction technique whereby whooping crane eggs are placed in the nests of wild sandhill crane foster parents that then rear the chicks as their own, was not successful in establishing a breeding population at Grays Lake NWR, Idaho (Drewien et al. 1989). Therefore, alternative reintroduction techniques must be developed. Releases of captive, parent-reared sandhill cranes to augment the existing non-migratory, wild population on Mississippi Sandhill Crane NWR have achieved some success (Zwank and Wilson 1987, Ellis et al. 1992), but releases of parent-reared sandhill cranes in a migratory situation at Grays Lake NWR were unsuccessful (Drewien et al. 1982, Bizeau et al. 1987). Unlike the cranes released in Mississippi, the birds released at Grays Lake had received little or no conditioning to the wild before release.

Parent-rearing is also a very expensive method of rearing chicks. A flock of potential parents, minimally 4-5 years old, must be maintained. Only some of these adults will prove to be suitable parents, and only 1 chick can normally be reared by each suitable pair per year. Because of possible imprinting problems (Mahan and Simmers 1992), sandhill cranes should not be used to rear whooping cranes that are to be released into the wild. Because numbers of suitable, captive, whooping crane parents capable of rearing young are limited, the practical use of parent-rearing in a whooping crane reintroduction is also limited.

Use of hand-reared birds in reintroduction attempts provides the most practical alternative. The controlled environment maintained for hand-reared birds can eliminate much of the preflighting mortality that may accompany parent-rearing, and large numbers of chicks can be reared with few adult rile models. Although cranes hand-reared in captivity by conventional techniques, i.e., excessive exposure to human features and activity, have generally proven unsuitable for release into the wild (Nesbitt 1979), hand-reared birds that have been reared in isolation from humans survive well after release (Horwich 1989; Horwich et al., in press; Ellis et al. 1992).

Some of the first successful releases involving sandhill cranes reared by hand but with minimal exposure to human activity were made by Hyde (1968:165-168) in Oregon and M. Isham (pers. commun. 1987) near the Bernard W. Baker Sanctuary in Lower Michigan. In Wisconsin, Archibald and Archibald (in press) introduced use of the puppet in rearing cranes for release, and Horwich (1989) expanded isolation-rearing to its definitive form by including use of visual and auditory imprinting models and wearing of a costume by all human caretakers. This report describes isolation-rearing by the puppet/costume technique in the field and the methods used to induce migration of 38 sandhill cranes reared and released.

1Present address: U.S. Fish and Wildlife Service, Seney National Wildlife Refuge, Seney, MI 49883
on Seney NWR in 1988–90.

We thank the current and former Seney NWR staff, especially M. G. Tansy, D. N. Frickie, and J. W. Kurth, and many volunteers and assistants, particularly D. May, M. Eberts, E. S. Stoetzer, T. J. Reuther, J. M. Reuther, D. W. Bauer, and R. P. McKee. We thank staffs of the Hiawatha National Forest; Jasper-Pulaski Fish and Wildlife Area (Indiana DNR [Department of Natural Resources]), especially J. E. Bergens; the Florida Game and Fresh Water Fish Commission, particularly S. A. Nesbitt, K. S. Williams, S. T. Schwikert, J. R. Brady, and T. H. Logan; and the International Crane Foundation (ICF), especially G. W. Archibald, C. M. Mirande, S. R. Swengel, M. Nagendra, and T. A. Mahan. We are grateful to C. M. Lakes and J. C. Clem (Ohio DNR) for helicopter support and to the Wisconsin DNR, Tennessee Wildlife Resources Agency, Georgia DNR, and Okfuskee NWR for their cooperation. We thank J. C. Lewis, J. M. Valentine, R. L. Refsnyder, R. H. Horwich, and L. H. Walkinshaw for advice or assistance. Funding was provided by the U.S. Fish and Wildlife Service, U.S. Forest Service, Michigan DNR Nongame Wildlife Program, and the U.S. Institute of Museum Services through the ICF. S. R. Swengel and N. F. R. Snyder made helpful comments on
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STUDY AREA AND FACILITIES

Seney NWR consists of 38,631 ha in Schoolcraft County in the east-central Upper Peninsula of Michigan (Fig. 1). Approximately 65% of Seney NWR is wetland. Additional wetland habitat is contained on the adjacent Lake Superior State Forest (421,020 ha) and Hiawatha National Forest (356,127 ha). The eastern portion of Seney NWR supports a sandhill crane density of about 0.43 breeding pair/km² (Urbanek and Bookhout, in press). The chick-rearing/release area is located in the east-central portion of the refuge and includes a 31-ha and an 11-ha upland meadow, known as Subheadquarters and Smith Farms, respectively; the 47-ha Lower Goose Pen Pool and marsh; and A-Pool, an 89-ha drawn down pool containing the release pen.

The Chick Rearing Facility

The facility consisted of a chick building and runs and an imprinting model pen. The senior author lived nearby in a trailer to ensure that chicks were not left unattended. The building consisted of a main structure and an adjacent room serving as a hatchery and laboratory. The main structure was divided into 16 individual 1.36- × 0.91-m compartments, 8 on either side of a central hallway. A vertically sliding door, which could be operated from the hallway, connected each compartment to an outside 0.91- × 2.42-m run. Each compartment door opened into the hallway and contained a 17.8-cm-diameter covered hole, through which a puppet could be inserted, under a 27.9- × 27.9-cm window of 1-way glass. The floor in each compartment was covered with a removable section of outdoor grass carpet that was changed daily. Outdoor runs had a floor of sand sloping 15% downward from the building. Dividers between runs were of 1.2-m-high plastic mesh. Heat was provided by 1 250-W red-lens infrared heat lamp in each compartment. In addition to ventilation provided by doors to the runs and 4 windows, an exhaust fan drew air from the chick compartments and through the loft of the building. Heat lamps and exhaust fan were thermostat-controlled.

A 16.4- × 10.9-m imprinting model pen was 1.82 m high on the sides, 3.33 m high in the center, and topped with 2.54-cm-mesh game farm netting. It was located 0.6 m from the 8 east runs in full view of all chicks in those runs. Chicks housed in the west side of the building also had limited visual access to the models during exercise sessions. Except for the side adjacent to the runs, the interior perimeter of the pen was lined with a visual barrier of 1.2-m-high black landscaping fabric.

A swimming pool, approximately 7.5 m in diameter and 1.2 m deep, was excavated in the facility yard in 1990. The pool replaced a small tank and wading pool that had previously been used in the chick exercise regimen.

The Release Area

The 1.85-ha release pen was on A-Pool, the 89-ha release site located 1 km west of the chick-rearing facility. Water levels on the pool were regulated to provide an attractive staging area for wild cranes. The pen was built on an area of mudflat and shallow marsh and contained 1 small upland island. The pen was an irregular, open-topped, 8-sided polygon of fence 2.42 m in height. Predators were deterred with an additional 0.30 m of fence buried below ground and 2 electrified wires positioned 0.3 and 0.6 m below the top of the fence. A concealed observation tower was constructed on a wooded dike overlooking the pen.

METHODS

Egg Collection

Sandhill crane eggs in late incubation were collected during 19–29 May from known nesting territories on Seney NWR, the Lake Superior State Forest, and the Hiawatha National Forest. Eggs were collected by helicopter in 1988–89 and on foot in 1990.

Chick Rearing

Isolation-rearing procedures were similar to those previously used by Horwich (1989). General care was based on the protocol used at the ICF, Baraboo, Wisconsin, and modified to accommodate isolation requirements. Each chick was assigned an individual compartment, except for 2 chicks of the 1988 cohort, who were compatible and shared the same compartment from hatching until release. Each compartment contained a taxidermic brood mount, food, and water. Sex of chicks was determined by chromosomal analysis of developing feathers (Van Tuinen and Valentine 1987). Humans were always in costume when in sight of the chicks, and any human conversation was limited to whispering so that the chicks would not hear human voices.
Frequent weighing of chicks was necessary to monitor their growth rates and adjust food intake and exercise levels accordingly. Because several injuries, one of which was fatal, resulted from weighing chicks with a spring scale in 1988–89, a digital walk-on scale was used in 1990 to weigh chicks greater than 2 weeks of age. Chicks could then be weighed without being handled by enticing them onto the scale with the puppet.

Chicks were exercised 1–2 hours each day by walking after a costumed parent (refer to illustration in Urbanek 1990a) and occasionally by swimming. Chicks were divided into 4 socialization groups of 3–5 individuals in 1988–89 and 3 groups of 3 in 1990. Chicks were usually isolated from members of other socialization groups until mid-summer in 1988–89 and through most of the rearing period in 1990.

To reinforce their fear of humans, we intentionally frightened chicks by chasing them with vehicles and as screaming, uncostumed humans. Most of these sessions were conducted after fledging to avoid the problem of chicks running away and hiding where they could not be readily found and protected.

Imprinting Models

Two to 3 wild sandhill cranes were confined in the imprinting model pen adjacent to the east side of the chick building in each year. In addition, Cranes #9 and #13 (1988 cohort) spent summers 1989 and 1990, respectively, at the facility and served as free-ranging imprinting models.

Release of the Chicks

Chicks were led to the pen by the costumed parent and released from 24 August to 7 September. When 87–105 days of age, each chick was individually color-banded and equipped with a 164–166 MHz solar/NiCad radiotransmitter (Telemetry Systems, Inc., Mequon, WI). Color bands and transmitters were leg-mounted above the tibio-tarsal joints. In 1989–90 chicks were banded immediately before release. In 1988, because of a delay in obtaining transmitters, chicks were first released into the pen and banded about 1 week later.

The release pen was baited with ear and shelled corn to attract wild cranes and provide food for the released chicks. A costumed dummy was erected in the pen so that the chicks would remain there until they were flying in and out with wild birds. The dummy consisted of a crane costume, the same as that worn by the costumed parent, stuffed with polyethylene sheeting and mounted on a metal stake (refer to illustration in Urbanek 1990a). The dummy was removed approximately 2 weeks after chicks were placed in the pen.

After completion of their acclimation to wild conditions, some chicks were retrieved with the puppet/costume and translocated to encourage proper migration or to correct migration problems. Because the chicks were attracted to the costume and accustomed to following costumed parents, capture with the costume was straightforward. A costumed parent appeared, playing the brood call on a tape recorder, where the chicks could see or hear him. The chicks walked or flew to the parent and then followed the parent to a waiting box to which the desired chick was guided and then pushed in for transport. This method of capture and transport involved minimal handling and avoided potentially injurious restraint of legs or wings.

Visual observation and radiotracking were performed from a ground vehicle and aircraft according to standard procedures (Urbanek 1988) along the Great Lakes-to-Florida migration route. Transmitting ranges of properly functioning transmitters, although variable, were approximately 5 km ground to ground, 20 km ground to air, and 150 km air to air. Reception was by a 7-element, truck-mounted yagi antenna from the ground and by 2 2-element, strut-mounted antennae from fixed-wing aircraft.

RESULTS

From 44 eggs and 1 small wild chick collected in 1988–90, 38 chicks (18 males and 20 females) were reared to fledging (84.4%). Chicks fledged at ages of 64–81 days. The 7 deaths that occurred during the rearing period occurred during 1988–89. At least 6 of these chicks died as a result of inadequate attention or accidents. By 1990 these problems were corrected by installing an adequate staff of 3–4 people to care for chicks in the critical period from hatching until chicks were feeding without assistance, avoiding handling chicks unless absolutely necessary, using a walk-on scale to weigh chicks during the period when legs were rapidly growing (15 days after hatching to fledging), and scaling gaps or slots where chicks could become entrapped or catch their heads. All 9 of the chicks hatched in 1990 were reared to fledging.

Gentle Release and Initiation of the First Migration from Seney

The wild Seney sandhill crane population follows a migration route to staging areas in northeastern and east-central Wisconsin, a major stopover at Jasper-Pulaski Fish and Wildlife Area (J-P) in northwestern Indiana, and wintering areas from southern Georgia southward to near
Lake Okeechobee, Florida. Our goal was to have the isolation-reared cranes follow the same route.

The 1988 Release. — More than 80 wild cranes, including 41 that had been individually color-marked during 1984–88, were noted on A-Pool. Although the chicks roosted and fed with the wild flock, they were closely associated only with each other. Groups of chicks often separated from the wild flock and returned to the rearing facility or Subheadquarters Farm, where there were few or no wild birds.

By 28 September, 8 of the 16 chicks had migrated with wild cranes to Wisconsin on their own volition and without manipulation. Seven of these birds later appeared at J-P (Fig. 1), and the eighth bird probably passed through J-P as well, although he was not observed again until he was found with a failing transmitter on his wintering site in Florida.

The other 8 chicks had exhibited cohort loyalty, formed a self-guiding flock, and remained at Seney NWR after all wild cranes had departed. On 23 October these chicks were retrieved, transported 370 km, and released at the Sucker Creek and Chaffee Creek areas (Fig. 1) among the central Wisconsin staging areas already occupied by the other chicks. Six of these birds later migrated appropriately to J-P. Another was reported alone on 7 December in east-central Illinois; he was not seen again until the following October when he was found with a malfunctioning transmitter near his migration release site in Wisconsin. The remaining bird (Crane #7) became separated from the last wild flock that departed from Wisconsin on 20 November. He then spent 3 days flying south, then north, and then south again across east-central Wisconsin before he was recaptured, transported to J-P, and released.

The 1989 Release. — Baiting was discontinued on 17 September, earlier than in 1988. Up to 100 wild cranes appeared in the pen with the chicks while baiting was maintained. After baiting was discontinued, however, the wild flock dissipated. A tight flock consisting of the 13 chicks, #9 and #7 of the 1988 cohort, and a non-banded wild female remained.

On 23 September, Crane #9 and many wild birds in the area departed from Seney toward Wisconsin without the chicks. The next day the 13 chicks, exhibiting cohort loyalty and independent flock identity, began using a newly planted wheat field, 11 km east-southeast of the release area. Because they were usually not with wild birds, we attempted to break up their flock and distribute smaller groups of chicks among the remaining flocks of wild birds.

On the evening of 25 September, 4 chicks were captured with the costume at the wheat field and transported to west E-Pool, 4 km north-northwest of A-Pool, where 12 wild cranes were present. On the morning of 26 September, these chicks departed with the wild birds and were later found on staging areas in Wisconsin. On 28 September another successful translocation was performed when 3 chicks were transported to the Marblehead area (Fig. 1), 30 km south-southwest of the rearing/release area, and released into a flock of 8 wild cranes. These 3 chicks migrated with 4 remaining wild birds on 8 October and were later found at Navarino Wildlife Area (Fig. 1), a major staging area in Wisconsin. In 8 other translocations, however, in which birds were moved 8–27 km and including 5 attempts in which chicks were released in areas occupied by only a pair or no wild birds, the chicks quickly returned to the rearing area or to their favorite feeding area. Translocations thus appeared most effective when the chicks were moved on the evening before a good migration day, e.g., on 25 September, or when the chicks were moved 30 km or more away. Some chicks became temporarily less wary of humans as a result of repeated recapture and their association with the wheat field, which was near human activity. One chick that repeatedly returned to the wheat field, even after being retrieved 5 times and released up to 27 km away, was finally transported to Pickford (Fig. 1), 110 km east of the wheat field. She migrated to a farm near Pentwater in the Lower Peninsula (Fig. 1), where she was found without other cranes and without fear of humans. We retrieved her again and then released her into the flock at J-P. She demonstrated completely normal wild behavior after that release, including appropriate migration through Wisconsin in both subsequent springs.

The remaining 5 chicks apparently migrated successfully from the Upper Peninsula on 16 October with yearling Crane #7 as leader, but their route and destination were unknown. The group was not seen again until the following April at French Creek Wildlife Area, Wisconsin (Fig. 1). Crane #7 had displayed aberrant migration behavior during the previous autumn and spring migrations (Urbanek 1990b), and he was therefore not the best candidate for flock leader. In summary, all members of the 1989 cohort were induced to initiate autumn migration from Seney on their own power as a result of these manipulations, but only 7 of the 13 chicks migrated to the target staging areas in Wisconsin.

The 1990 Release. — Eleven 1- and 2-year-old, isolation-reared cranes and approximately 60 wild cranes staged at the A-Pool release area in 1990. To avoid the problem of chicks disassociating from the older birds and leaving the area, we continued bating of A-Pool or Subheadquarters Farm until all 9 of the chicks had migrated.

Results of the 1988 and 1989 releases clearly indicated that the greatest problem in initiating the first migration of isolation-reared chicks was the potential for too many
chicks to group together and form a self-guiding flock that did not follow wild birds. To minimize familiarity among members within each release group, we placed 1 member from each original socialization group in each release group in 1990.

On 22 September we released 3 chicks on the McMillan staging area (Fig. 1), 25 km northeast of A-Pool; this area contained about 100 birds, including 3 isolation-reared cranes from the 1988–89 cohorts. Three chicks were released on the Engadine staging area, 31 km east-southeast of A-Pool; this site was the second largest staging area in the Upper Peninsula and contained about 800 birds, including 2 members of the 1989 cohort. Three chicks were allowed to remain on A-Pool.

Forecasted conditions suitable for migration did not appear on 23 September. Of the 3 chicks released at McMillan, 1 quickly returned to A-Pool; the other 2 flew 18 km to Engadine where they found and regrouped with the chicks that had been released there. On 26 September 1 of these 2 chicks returned to A-Pool and rejoined the 4 chicks located at the primary release site.

On 27 September some cranes departed from Seney, and on 28 September, an excellent migration day, most remaining wild cranes left the area. While 3 of the chicks were associating with a resident family at Lower Goose Pen marsh, the other 2 departed from A-Pool with wild cranes and 3 members of the 1989 cohort.

These latter 3 cranes migrated together to Sucker Creek/White River Marsh (Fig. 1), a major Wisconsin staging area. This was an improvement, because these were 3 of the cranes that had followed #7 of the 1988 cohort during the previous autumn and migrated to an unknown area.

The 2 chicks that left A-Pool with the 3 cranes of the 1989 cohort flew only to the Garden Peninsula (Fig. 1) before landing. Meanwhile, the 4 chicks from Engadine passed over the Stonington Peninsula, just west of the Garden Peninsula, in a flock of 20 cranes, and they were later found near Navarino Wildlife Area (Fig. 1). On 30 September the 2 chicks on the Garden Peninsula departed with 9 wild cranes. One chick joined a large staging flock at Hanson Lake Bog near the Wisconsin border (Fig. 1), and the other found and rejoined the chicks at Navarino.

After 28 September the 3 chicks remaining at Seney NWR joined a flock composed of Cranes #7 and #13 of the 1988 cohort, 2 cranes of the 1989 cohort, and 4 wild cranes. One of the 1989 cranes had followed #7 during the previous autumn migration. On 19 October, we attempted to induce migration of the 11 birds by frightening them with cracker shells but succeeded only in driving away #13 and 1 wild crane.

Good conditions for migration were present on 24 October, and the flock of 9 cranes departed without prompt, but they flew southward over the length of the Garden Peninsula instead of following the more westerly, appropriate route over the mainland (Fig. 1). They flew out over the open water of Lake Michigan/Green Bay twice but would not cross, and after 2 hours of disoriented flight over the southern tip of the peninsula, they landed.

On 25 October, migration conditions were excellent throughout the day with a 13–16 km/hour north wind and clear skies to the south. The flock departed at 0950 hours and flew westward across Green Bay to intercept the correct migration route on the mainland. At approximately 1500–1600 hours, they passed just east of the Borth and White River Marsh staging areas in Wisconsin (Fig. 1) without stopping. They continued flying southbound until dark when, at 1930 hours, they landed near Huntley in McHenry County, Illinois (Fig. 1). The next morning they departed with 5 additional wild cranes who had joined them. Despite a 13–30 km/hour south wind, the flock of 14 birds arrived just north of J-P, where the 5 additional wild cranes landed, 5.5 hours later. The 9 cranes from Seney continued southbound for an additional 0.5 hour and landed in the Goose Pasture on J-P.

DISCUSSION

Rearing at the Field Site

Rearing of sandhill crane chicks at the Seney facility has been successful; we achieved a 3-year average of 84% of hatchlings fledged and a 100% fledging rate in the final rearing year. The 3 problems that contributed to the death of 7 of the 36 chicks in the rearing program in 1988–89 were (1) inadequate attention to teach the newly hatched chicks to feed on the artificial diet, (2) handling injuries, and (3) structural hazards at the rearing facility. As a result of the experiences of 1988–89, these problems were eliminated and all 9 of the chicks hatched in 1990 were reared to fledging and release with no notable injuries or significant leg problems.

Because they were reared in the field at the release site, these cranes were well adapted for life in the wild. Rearing and release at the same site also provided an unambiguous natal area, which may be important to subsequent homing by cranes released into a migratory situation.

Gentle Release Procedures for a Migratory Flock

Isolation-rearing on site provided the ultimate gentle release. To some extent, because they were taken out daily
for exercise, chicks were "gentle released" since hatching. All survival adaptations, including foraging, predator defense, social interaction, and migration have an innate basis. Isolation-rearing of crane chicks in groups of their own species on site provided the proper stimuli to elicit appropriate instinctive behaviors and enhance them through addition of learned skills. Upon transfer to the release pen, the chicks already possessed most of the requirements necessary for survival in the wild. The major lessons still to be learned from the wild birds were greater fear of humans and mammalian predators and the specifics of the traditional migration route.

The procedure to complete acclimation of isolation-reared cranes to wild conditions was more efficient than could be accomplished with parent-reared birds. Chicks were led to the release pen by a costumed parent, thus eliminating unnecessary handling. A costumed dummy in the pen served as an effective parent to keep the chicks within the protection of the pen until they were flying out to feed and roost with wild birds. Wing brailing, a restraint method that would have required additional handling and could have damaged the flying ability critical to these migratory cranes, was therefore not necessary. Most activities within the wild flock are contagious, and chicks readily imitated and followed the wild birds, including flushing when an uncostumed human was spotted. When translocation or transmitter replacement was necessary, isolation-reared chicks and even some older birds, unlike parent-reared cranes, could be quickly and easily retrieved as a result of their attraction to the costume. The rapid capture of groups of released chicks or errant birds so that they could be translocated to ensure proper migration would not have been possible with parent-reared birds.

Although isolation-reared chicks readily associated with older cranes, they also possessed strong cohort loyalty. This cohort loyalty was generally adaptive because it facilitated increased foraging efficiency, detection and avoidance of predators, and proper social development within the species. The cohort loyalty and independent flock formation most evident between release and first migration did not negatively affect survival. In other studies cranes have incurred greatest mortality in the period immediately following release (Nesbitt 1979, Bizeau et al. 1987). On Seney NWR, in 3 years of releases involving 38 different chicks, survival was 100% in the 18- to 60-day period between release and departure on their first migration. The survival record during this "vulnerable" period could have been no better. These birds, reared on site, clearly possessed the foraging and predator avoidance skills necessary for their survival after release.

Cohort loyalty did, however, present 1 significant problem: it interfered with initiation of the first migration. Chicks preferentially associated with other members of their release cohort rather than with other birds. When too many chicks were together at the same location, they tended to form their own self-guiding flock. In 1988–89, solutions to this problem were identified and developed. Methods to induce isolation-reared cranes to migrate with other birds were then tested and confirmed to be successful in the 1990 release.

For the chicks to migrate, close association with specific wild birds was not necessary. However, the chicks had to be with wild birds when the wild birds departed. A casual co-occurrence in the same flock was sufficient for the chicks to be swept up in the contagious excitement that initiates migration. The methods to induce proper migration, which depended on keeping chick group size small and chicks being in the wild flock when the wild birds migrated, are detailed below.

**Baiting.**—Distribution of both chicks and wild birds can be controlled by baiting. At Seney, baiting with corn worked well because this preferred food item was unavailable elsewhere in this area. Shared, easily obtainable food was the most important element keeping the chicks with the wild flock. Baiting should be continued at the primary release site until all chicks have migrated. In 1988, bait was still present in the pen within 24 hours of the first major departure of wild birds. As a result, most of the wild birds stayed at the release area with the chicks, and 8 of 16 chicks departed from Seney with wild birds and without additional manipulation. In 1989, however, baiting was discontinued 6 days before the first major departure of wild birds. Most wild birds left the release pen, the chicks lingered, and the first migrating wild birds subsequently departed without them. In almost every instance when bait was unavailable in the release area, chicks eventually moved into grain fields off the refuge. Chicks quickly developed a strong bond to these sites even though some, e.g., a wheat field used in 1989, contained few or no wild birds and were too near human activity. This situation promoted reduced fear of humans and failure to migrate properly because of lack of experienced guides. Such bonding to unacceptable sites must not be allowed to happen. The primary feeding site must be under the selective control of the researcher, and at Seney NWR this was readily accomplished by baiting.

**Flock Break-up and Translocation.**—The release cohort should be divided into groups of 2–5 chicks before significant numbers of wild birds have left the area. Ideally, 2 or more release pens with no more than 5 chicks at a single release site should be used. At Seney NWR, to save time, expense, and logistical problems associated with construction of more pens, all of the chicks completed their acclimation to wild conditions in a single pen, and...
then small groups were removed for transfer to other sites.

Successful departure is expedited if chicks that are to be translocated are captured and moved on the afternoon preceding a good migration day. If they are moved sooner, they are more likely to leave the wild birds at the new release site and return to the rearing area or search for their cohorts. Translocation becomes less effective the more times it is practiced. Ideally, the birds should be moved once. Exposure of chicks to humans, costumed or not, should be minimized during the release period. Excessive capture and transport should be avoided. The more a chick is exposed to wild birds and the less a chick is handled, the more it will behave like a wild crane.

Guide Birds.—Chicks not only followed wild cranes but also readily followed older isolation-reared birds. Up to 5 chicks will follow 1 adult guide bird. Crane #7 of the 1988 cohort led groups of chicks just before and during migration in both 1989 and 1990, although he did not migrate correctly until 1990, his third autumn migration. If a single isolation-reared crane that has demonstrated previous, unusual migratory behavior becomes a flight leader, sufficient monitoring effort to ensure that the birds are tracked continuously from departure to their destination must be allotted. In 1990, the last crane flock to leave Seney NWR was composed mostly of isolation-reared birds, and all 3 cohorts were represented in that flock. The affinity of previous isolation-reared cranes for the release area and their readiness to associate with newly isolation-reared chicks could engender effective use of guide birds and formation of a cohesive core population in the reintroduction of an endangered crane species.

Performance of Isolation-reared Cranes after Release into the Wild

For 38 chicks released in 1988–90, minimum survival, 1 year after release, was 84%; minimum return rate to Upper Michigan was 74% and was similar for males and females (Table 1). An account of migration movements, wintering areas, summering activities, and social behavior of the isolation-reared cranes after integration into the wild (Urbanek 1990b; Urbanek and Bookhout, in prep.) is beyond the scope of this paper. However, a brief summary of the performance of sandhill cranes that were isolation-reared and gentle released in this migratory situation is presented here.

Survival.—Overall, cranes isolation-reared and released in the Great Lakes region have demonstrated high survival in comparison to cranes reared with other techniques and released in other areas (Table 2). Migration through the corn belt provides abundant, high quality food with few predators. These factors, which contribute to high survival of wild cranes on this migration route (Urbanek 1990b), also contribute to high survival of isolation-reared birds, even though these latter birds do not have the advantage of instructive and protective parents. Mortality of only 2 released juveniles was confirmed. Chick #17 (1989 cohort), initially reared by her own wild parents and then isolation-reared from age 3 weeks to fledging, died on a roost site during her summer stopover at Navarino Wildlife Area. Cause of death could not be determined, but predation was suspected. Chick #4 (1990 cohort) was found dead along with a wild bird at a wintering site on Kanapaha Prairie, Florida. Death appeared due to aflatox-
### Table 2. A comparison of survival of captive-reared sandhill cranes 8–12 months after release into the wild.

<table>
<thead>
<tr>
<th>Release location</th>
<th>Rearing location</th>
<th>Rearing method</th>
<th>Number released</th>
<th>Number surviving</th>
<th>Minimum survival (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Columbia</td>
<td>On site</td>
<td>Partial isolation</td>
<td>17</td>
<td>7-9</td>
<td>41</td>
<td>Leach (1987)</td>
</tr>
<tr>
<td>Oregon</td>
<td>On site</td>
<td>Isolation</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>Hyde (1968:165-168)</td>
</tr>
<tr>
<td>Idaho</td>
<td>Patuxent</td>
<td>Parents</td>
<td>12e</td>
<td>1</td>
<td>8</td>
<td>Drewien et al. (1982)</td>
</tr>
<tr>
<td>Idaho</td>
<td>Patuxent</td>
<td>Parents</td>
<td>21f</td>
<td>4</td>
<td>19</td>
<td>Bizeau et al. (1987)</td>
</tr>
<tr>
<td>Florida</td>
<td>Patuxent</td>
<td>Hand, no isolation</td>
<td>17e</td>
<td>0</td>
<td>0</td>
<td>Nesbitt (1979)</td>
</tr>
<tr>
<td>Florida</td>
<td>Patuxent</td>
<td>Parents</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>Nesbitt (1979)</td>
</tr>
<tr>
<td>Florida</td>
<td>Patuxent</td>
<td>Parents</td>
<td>27f</td>
<td>15</td>
<td>56</td>
<td>Nesbitt (1988)</td>
</tr>
<tr>
<td>Mississippi</td>
<td>Patuxent</td>
<td>Parents</td>
<td>42f</td>
<td>24</td>
<td>57</td>
<td>Ellis et al. (1992)</td>
</tr>
<tr>
<td>Mississippi</td>
<td>Patuxent</td>
<td>Parents</td>
<td>61f</td>
<td>45</td>
<td>74</td>
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<tr>
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<td>Patuxent</td>
<td>Isolation</td>
<td>28f</td>
<td>26</td>
<td>93</td>
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<td>Texas</td>
<td>On site</td>
<td>Isolation</td>
<td>7</td>
<td>2</td>
<td>29</td>
<td>Nagendorf (1992)</td>
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<tr>
<td>Lower Michigan</td>
<td>On site</td>
<td>Partial isolation</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>Isham (pers. commun. 1987)</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>ICF</td>
<td>Partial isolation</td>
<td>2</td>
<td>1</td>
<td>50</td>
<td>Archibald and Archibald (in press)</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>ICF</td>
<td>Isolation</td>
<td>5</td>
<td>4</td>
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<td>Horwich (1989)</td>
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<td>Upper Michigan</td>
<td>On site</td>
<td>Isolation</td>
<td>16</td>
<td>15</td>
<td>94</td>
<td>THIS STUDY—1988 COHORT</td>
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<td>89</td>
<td>THIS STUDY—1990 COHORT</td>
</tr>
</tbody>
</table>

* In addition to THIS STUDY, only Horwich (1989), Nagendorf (1992), and the third Mississippi reference cited above used the isolation-rearing technique described in this study. Archibald and Archibald (in press) used a puppet. Other studies using rearing methods identified as "isolation" or "partial isolation" involved minimal exposure to humans and/or rearing in a secluded area but did not involve use of a costume.

b 1 yearling released directly into the wild in August 1976, 5 yearlings, 2 2-year-olds, and 4 3-year-olds released directly into the wild on 18 June 1980.

c 19 yearlings and 2 2-year-olds held on site in small, roofed pen for 4–6 days before release, 19 June–3 July 1984.

d 14 juveniles released directly into the wild in September 1971, and 3 6-month to 4-year-olds released (some returned to captivity and released again) after being held in small pen on site, 1974–77.

e 11 juveniles and 4 yearlings released 4 April 1985 and 12 juveniles released 2 January 1987 after being banded and held for 4–6 weeks in large, open release pen.

f All Mississippi cranes were banded and held in a large, open release pen for 4–6 weeks before release. The first entry includes releases from winters 1980–81 to 1985–86. The second entry includes releases from winters 1986–87 to 1990–91. The third entry consists of the isolation-reared cranes from among the total of 65 cranes released in winters 1989–90 and 1990–91. Except for 1 yearling released in winter 1980–81, all cranes released in Mississippi were juveniles.

b 12 chicks were reared according to standard isolation protocol from hatching in 1989. Another was a wild, parent-reared foundling donated to the project and added to the experiment at the approximate age of 3 weeks; this chick was later found dead in a marsh in Wisconsin.

icosis resulting from consumption of moldy peanuts; mortality from this source has been a chronic problem affecting a small number of birds at this site (S. A. Nesbitt, pers. commun.). Neither of these chick deaths appeared related to the isolation-rearing technique.

**Summer Dispersal.**—Recorded rate of return of isolation-reared cranes to Upper Michigan was high (Table 1) despite significant transmitter failure and difficulties in observing birds in their summer habitats. Unlike female whooping cranes in the Grays Lake experiment (Drewien et al. 1989), female sandhill cranes reared on Seney NWR returned to their natal area. No cranes that migrated from Seney on their own power are known to have summered in Wisconsin. The only bird that could be monitored, i.e., had a fully functional transmitter, and that may have summered in Wisconsin was released there the previous autumn. Despite being released 370 km away in Wisconsin in autumn 1988, 3 males returned to Seney NWR the following spring.

Of 28 isolation-reared sandhill cranes whose return to
the Upper Peninsula has so far been documented, 24 returned as yearlings to or within 35 km of Seney NWR (2 of these birds later summered up to 66 km away), 3 summered in the Soo core area (extreme eastern Upper Peninsula or adjacent Ontario, 80–155 km east of Seney), and 1 spent parts of the summer in both areas. Of the 3 birds that spent the summer of 1989 in the Soo area, 2 summered as a male-female pair and both males later returned to Seney NWR as 2- or 3-year-olds.

Males and females returned in approximately equal numbers to the general refuge area. However, once arrived, males exhibited strong affinity for the specific area on which they were reared and originally released, whereas female distribution, at the local level, appeared to be dependent on the other wild or isolation-reared cranes with whom the females associated. Males moved either alone or with other birds, and several returned to the rearing building itself. Females, on the other hand, were always in the company of, and usually following the lead of, other birds when observed on the ground. Excluding the 3 birds in the Soo area and the male that possibly summered in Wisconsin, mean distance of primary yearling summering areas from the original rearing/release area (1 observation per bird, 6 used if bird had 2 summering areas) was 3.5 km for males (range 1–14 km, n = 11) and 26.6 km for females (range 0–66 km, n = 14). In a release of whooping cranes properly imprinted during the isolation-rearing procedure, only other isolation-reared birds would be available as conspecific associates; therefore, we expect that summer dispersal of female whooping cranes would be less than dispersal of female sandhill cranes and more closely approximate the virtual lack of dispersal shown by males.

Wintering Areas. — Wintering of isolation-reared cranes on major areas used by wild cranes in southern Georgia and peninsular Florida appeared related to the outcome of the initial migration from Seney to Wisconsin and to the age of the bird. In 1988, 5 of 8 chicks that migrated unassisted from Seney to central Wisconsin were found on the major wintering areas used by most wild cranes, but only 1 of 8 birds transported to Wisconsin and released was found on these wintering areas. In 1989, 3 of 6 surviving chicks that performed the initial leg of migration correctly were found in these wintering areas, but none of 6 others were found. In 1990, all chicks began migration correctly, and 5 of 8 chicks with functioning transmitters were subsequently found on the major wintering areas. Two others were found in a large migrating flock on a major spring stopover in southeastern Tennessee; their presence at that location indicated that they wintered at least that far south along the correct migration route.

During their first migration, therefore, some juveniles, particularly those that did not begin migration from the natal area correctly, tended to deviate or shortstop rather than proceed farther south to the major wintering grounds. Such chicks, unlike wild chicks that follow parents, do not have as much incentive to remain in a wild flock flying the long, 4-day route from J-P to Florida, especially when adequate feeding and roosting sites are available en route. However, wintering on major areas increased in subsequent winters. Of the 15 birds of the 1988 cohort known to be alive after their first year in the wild, 9 were located on the major sandhill crane wintering areas in southern Georgia and peninsular Florida in winter 1989–90. These 9 birds included all 7 of the birds that had flown from Seney to central Wisconsin correctly during their first migration and still had functional transmitters. Thus 100% of the cranes that initiated their first migration correctly from their natal area in 1988 and could be monitored wintered on the appropriate wintering areas during their second winter. This result suggests that if chicks can be induced to depart from Seney correctly on their first migration, by the second winter they will be using the same wintering areas used by most wild members of the population. Data from 1990–91 also supported this contention, although transmitter malfunction greatly reduced sample size during that winter.

Further Research Needs

The major objective of the current sandhill crane research, to confirm that cranes isolation-reared in the field can exhibit high survival and return to the natal area in a migratory situation, has been achieved, and continued monitoring of the experimental sandhill cranes to document breeding behavior is planned. Additional work, however, is necessary before this reintroduction technique can be used to establish self-sustaining populations of the whooping crane. Whether a new species, the whooping crane, can successfully establish itself in an area where it currently does not occur cannot be determined by use of the sandhill crane as a surrogate.

Will isolation-reared whooping cranes survive as well as sandhills on the same route? Can whooping cranes learn a migration route from sandhill cranes or otherwise migrate in a manner to ensure their survival? Whooping cranes will not have large numbers of their own species with which to associate over a large summering area; will they therefore show an even more restricted summer distribution around the Seney NWR rearing/release site than that already demonstrated by returning, yearling sandhills? Will homing to this site increase as the birds reach breeding age? Will whooping crane females seek out and associate with other members of their own species on
the summering area or will they disperse among the sandhills? Will isolation-reared whooping cranes pair with their cohorts and reproduce? Are breeding pairs in which both parents were isolation-reared capable of rearing chicks in the wild? These are questions that must be answered before a reintroduction technique is completed. These questions cannot be answered by use of the sandhill crane as an experimental surrogate. Ideally, resolution of these questions requires use of whooping cranes. Because eggs of this species are unavailable, the red-crowned crane (*Grus japonensis*), a white, eastern Asian species that is most similar to the whooping crane, is being used as an experimental surrogate in 1991. Individuals of this species are being isolation-reared on Seney NWR for release into the sandhill flocks so that progress in development of the isolation-rearing/gentle release procedure for reintroducing migratory cranes will continue.

**LITERATURE CITED**


