**Abstract:** Managers of migratory game birds require accurate information about bird movements to delineate populations, protect important habitats, and regulate harvest. Data describing movements of sandhill cranes (*Grus canadensis*) belonging to the Pacific Flyway Population (PFP) are lacking. We used satellite telemetry to monitor movements of PFP lesser sandhill cranes (*Grus canadensis*) captured in the upper Cook Inlet and Bristol Bay regions of Alaska. Satellite transmitters were deployed on 19 flightless young (colts) and 3 adults over 3-years (2000-2002). Chronology, routes, and stopover or staging areas were identified for fall and spring migration periods. On average, cranes (n = 11) took 27 days (range = 13-44 days) to travel from summer areas in Alaska to winter areas in the Central Valley of California (CVC). Winter locations were concentrated in the Sacramento – San Joaquin River Delta and the East Grasslands (Merced County) regions. In spring, cranes (n = 10) took an average of 58 days (range = 45-65 days) to return to Alaska. In spring, most marked cranes (70%) staged at the Potholes Reservoir region in central Washington. PFP cranes that summer in Cook Inlet and Bristol Bay used identical migration routes and winter areas. Only 3 of 9 colts returning to Alaska, as juveniles, revisited their natal site. We found no evidence that PFP cranes monitored with satellite transmitters mixed with cranes from the Mid-Continent Population (MCP) or with “western segment” PFP cranes.

**Key words:** Alaska, Bristol Bay, Central Valley of California, colts, Cook Inlet, distribution, *Grus canadensis*, migration, Pacific Flyway Population, route, sandhill crane, satellite telemetry, staging areas.
much of the current information delineating the range of PFP lesser sandhill cranes has been speculative. As a result, current hypotheses describing affinities among breeding, staging and wintering areas have gone untested.

Managers of migratory game birds require accurate information about bird movements to delineate populations, protect important habitats, and regulate harvest. This is especially true for PFP cranes because they exhibit isolated distributions during certain periods of the year. Whether gene flow exists among separate breeding areas in Alaska is unknown.

We used satellite telemetry as a tool to identify migration routes, stopover and staging areas, and lengths of stay for PFP sandhill cranes captured in Alaska. We also describe the geographic distribution of PFP cranes during winter and summer months. Delineating affinities among winter, migration, and summer areas is necessary to manage PFP cranes through reliable inventories and appropriate harvest regimes. The need for this information is particularly important for habitat protection as current proposals for development projects throughout the PFP range could have deleterious impacts on habitat quality and quantity. Potential impact on cranes from local developments has generated public concern and the demand for addi-
tional information regarding their breeding origin, population estimates and harvest rates.

METHODS AND STUDY AREA

We captured sandhill cranes in the upper Cook Inlet and Bristol Bay regions of Alaska (Fig. 1). Twelve satellite transmitters were deployed on flightless young (colts) at 4 locations in upper Cook Inlet (Palmer Hay Flats, Anchorage Coastal Wildlife Refuge, Susitna Flats, Point McKenzie) in 2000 and 2001, and 7 satellite transmitters were deployed on colts in Bristol Bay (Nushagak Peninsula) in 2002. Colts were captured with the aid of a Robinson 22 helicopter. When a family group was observed from the air, the pilot hovered the aircraft over a colt at approximately 1m above ground level allowing a person to exit the aircraft, capture, and restrain the bird. One colt per family group was captured. At the capture site, we sampled blood for sexing and future genetic analysis. Whole genomic DNA was isolated from blood samples using a salting-out procedure (Medrano et al. 1990). Sex of all individuals was determined using the chromo-helicase-DNA-binding (CHD) avian sex determination primers P2 and P8 (Griffiths et al. 1998).

We attached a satellite transmitter with a leg-band attachment above the tibio-tarsal joint with the stainless steel antenna pointing down (Melvin et al. 1983, Ellis et al. 2001). To the other leg we applied a USFWS metal leg band and a yellow leg band (5cm tall) with a unique alphanumeric code for identification in the field. After release, the colt immediately reunited with adults waiting nearby for all but 2 captures.

Three satellite transmitters were deployed on adult cranes at a spring staging area in upper Cook Inlet (Matanuska Valley) on 27 April 2002. Adult cranes were captured with the use of a rocket net over bait (Urbanek et al. 1991). Marking and processing protocols for adults and colts were otherwise identical.

Each satellite transmitter weighed approximately 55g (with band attachment) and was programmable with up to 5 duty cycles (Microwave Telemetry, Inc.; Table 1). Transmitters contained a battery voltage sensor that was useful in determining the life expectancy of the transmitter. Transmitter signals were received by 4 National Oceanic and Atmospheric Association polar-orbiting satellites. Data were transmitted approximately every 60 seconds during the on-cycle in frames of four, 8-bit messages. Signals were analyzed using Argos Data Collection and Location Systems. Locations were calculated from a Doppler shift in signal frequency (Fancy et al. 1988). We used Argos “standard” and “auxiliary” location data processing services. The accuracy of “standard locations” (class codes 1, 2, and 3) is generally < 1000m and requires that the satellite receives at least 4 messages during a pass over the transmitter (Argos 1996). Location accuracy for “standard locations” with class code 0 is generally > 1000m with no maximum limit (Argos 1996). The accuracy of “auxiliary locations” (class codes A and B) cannot be calculated because the normal system specifications are relaxed to provide locations calculated from 2 or 3 messages. The lack of an estimate for accuracy, however, does not necessarily mean “auxiliary locations” are inaccurate. To distinguish inaccurate locations, we used a program developed by David C. Douglas (USFWS) based on comparing distance, rate, and angle of consecutive locations. Additionally, all usable locations were checked manually for accuracy. Argos locations with class code Z were rejected.

Because satellite transmitters did not transmit continuously

<table>
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<th>Date deployed</th>
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<th>2</th>
<th>3</th>
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<td>34</td>
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<td>August 02, 2002</td>
<td>8</td>
<td>26</td>
<td>42</td>
<td>6</td>
<td>106</td>
</tr>
</tbody>
</table>

* Indicates duty cycle during fall migration.

b Indicates duty cycle during spring migration.
we can only report locations acquired during the transmission cycle. To provide a comprehensive description of the migration route used by PFP cranes while maximizing battery life, we programmed our satellite transmitters to transmit more frequently during migration than other times of the year (Table 1). Nevertheless, stopover sites used by cranes for brief periods (< 2 days) may have gone undetected. Further, the exact route taken during migration may be imprecise for cranes that traveled long distances between transmission cycles. Finally, the number of days reported for cranes while in route and spent at stopover or staging areas was approximated; accuracy being dependent on the number of hours during the off-cycle (Table 1).

To reliably illustrate crane distribution on winter and summer range we used the most accurate location per transmission cycle. Accuracy was based on class code, and in the event of a tie, the number of messages received per satellite pass. All acceptable locations per transmission cycle, however, were used to illustrate migration routes because locations were frequently obtained while birds were flying.

Locations for individual cranes were mapped using a Geographic Information System (ArcView) and posted at http://www.wildlife.alaska.gov/index.cfm?adfg=waterfowl.crane. To illustrate migration routes because locations were frequently obtained while birds were flying.

RESULTS

We deployed 22 satellite transmitters on PFP cranes (Table 2). Sex ratios were ca. 50:50 (11 males, 10 females and 1 unknown; Table 2). We received little information from 5 transmitters because the birds were depredated and the transmitters were recovered soon after capture (n = 3), shot during the hunting season (n = 1), or the transmitter failed for unknown reasons soon after release (n = 1). Seventeen satellite transmitters provided ample location data (Table 2). Of these, however, 3 went off-line prior to the expected life of the transmitter, and 5 were deployed on cranes that either shed the transmitter or died before returning to Alaska.

Fall Migration

Coastal route. - PFP cranes began their southerly migration in early September (mean = 11 September; Table 3). Cranes captured in Bristol Bay during 2002 began fall migration approximately 8 days later than cranes captured in upper Cook Inlet (Table 3). Since cranes were not captured at Cook Inlet and Bristol Bay during the same year, ascribing a biological meaning to the difference in departure dates between the two nesting areas was not possible.

PFP cranes departed Bristol Bay and traveled east directly to the Kenai Peninsula where they potentially mix with Cook Inlet cranes (Fig. 2). We suspect Bristol Bay cranes entered Cook Inlet through passes in the Aleutian Range south of Illiamna Lake. Bristol Bay cranes continued east and accessed the Gulf Coast of Alaska by flying directly over the Kenai Peninsula and through Prince William Sound. PFP cranes captured in upper Cook Inlet accessed the Gulf Coast by traveling southeast over the Chugach Range. We believe Portage Pass and the Knik Glacier are two primary access corridors to Prince William Sound. Once reaching the Gulf coast in south central Alaska, upper Cook Inlet and Bristol Bay cranes flew southeast along the coast. At Pt. Spencer, PFP cranes left the outer coast and continued migration through the islands and straits of the Alaska panhandle. In contrast to the low-lying areas used by cranes along the outer coast, cranes commonly stopped at higher elevations while traveling through the panhandle. We suspect berry production in perched muskegs and alpine meadows provided foraging habitat at these locations.

Five stopover sites were frequently used by cranes during fall migration in Alaska (Table 4). Twelve of 15 cranes (80%) stopped near the Yakutat Forelands, 40% in the vicinity of the Bering Glacier lowlands and on the Stikine River Delta, and 27% stopped on the Copper River Delta and near Gustavus (Fig. 2). Cranes remained at Gustavus for the longest duration followed by the Yakutat Forelands (Table 4).

On average, PFP cranes left Alaska and entered British Columbia 12 days after beginning fall migration (range = 5–19 days; Table 3). Cranes captured in Bristol Bay spent less time traveling through Alaska (mean = 8 days) than did cranes captured in upper Cook Inlet (mean = 14 days) even though Bristol Bay birds traveled a longer distance. Again, because birds of different nesting areas were marked in different years, inferring biological meaning to this difference is not possible.

Interior route. - Near the Stikine River Delta, PFP cranes migrated inland and entered central British Columbia near Stewart (Fig. 2). They continued south through the Fraser River and Okanagan Valleys. PFP cranes traveled through British Columbia quickly (mean = 5 days, range = 1–18 days; Table 2). With such rapid movement through the province, only a few stopover sites could be reliably identified in British Columbia (Table 4). Locations near Smithers, and Kamloops were used most frequently (Fig. 2), although one crane spent 14 days near Prince George (Table 4).

PFP cranes continued south staying west of the Selkirk Mountains and entered north central Washington near Oroville (Fig. 2). The primary stopover site was in central Washington in the vicinity of the Potholes Reservoir (Fig. 4) where 71% of marked cranes spent, on average, 5.5 days (range = 1–13; Table 4). Two cranes, however, stopped for a brief period east of Monse, Washington (Okanogan County) north of the Columbia River (Fig. 2). Though five stopping areas were identified (Table 4) PFP cranes moved south through central Oregon quickly before entering California, making it difficult to obtain many locations (Table 2). A portion of the population appeared to enter California by crossing the northwest corner of Nevada (Fig. 2). Once in California, cranes traveled directly to winter areas (Table 3). On average, it took 27 days (range = 13–44 days) for PFP cranes to complete the ca. 3,600-km migration from summer range in Alaska to winter range in California (Table 3).
Table 2. Satellite transmitter identification, date and location deployed, age, sex and fate of bird, number of days active, and number and quality of locations received for satellite transmitters deployed on Pacific Flyway Population lesser sandhill cranes captured in Alaska in 2000, 2001 and 2002.

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<th>Capture location</th>
<th>Age</th>
<th>Sex</th>
<th>Days active&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Fate&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Number of locations/class code&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Total&lt;sup&gt;d&lt;/sup&gt; locations</th>
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<td>Palmer Hay Flats</td>
<td>Colt</td>
<td>F</td>
<td>417</td>
<td>off-line</td>
<td>15 27 71 163 57 77</td>
<td>418</td>
</tr>
<tr>
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<td>Palmer Hay Flats</td>
<td>Colt</td>
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<td>77</td>
<td>unknown</td>
<td>3 6 13 28 29 24</td>
<td>104</td>
</tr>
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<td>Anchorage Coastal Refuge</td>
<td>Colt</td>
<td>F</td>
<td>46</td>
<td>shot</td>
<td>2 0 2 16 4 10</td>
<td>47</td>
</tr>
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<td>Colt</td>
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<td>137</td>
</tr>
<tr>
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<td>Anchorage Coastal Refuge</td>
<td>Colt</td>
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<td>Matanuska Valley</td>
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<td>unknown</td>
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<td>Colt</td>
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<td>unknown</td>
<td>1 12 54 141 67 87</td>
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</table>

<sup>a</sup> Number of days from transmitter deployment to date when fate determined.
<sup>b</sup> Sandhill cranes with unknown fates either carried a defective transmitter, shed the transmitter, or died. Cranes carrying satellite transmitters that went off-line did so at the anticipated end of battery life. Depredated cranes were recovered.
<sup>c</sup> See methods for description of class codes.
<sup>d</sup> Class code Z locations included in total.

Fig. 2. Locations acquired with satellite telemetry for Pacific Flyway Population lesser sandhill cranes during Fall migration and while on wintering areas in Bering.
Table 3. Migration chronology for Pacific Flyway Population lesser sandhill cranes captured in upper Cook Inlet (2000 and 2001) and Bristol Bay (2002) regions of Alaska. X indicates where the satellite transmitter either failed; the bird died; or shed the transmitter.

<table>
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<tr>
<th>Year/ID(^a)</th>
<th>Begin</th>
<th>Alas.</th>
<th>B. C.</th>
<th>Wash.</th>
<th>Oreg.</th>
<th>Calif. range</th>
<th>Approximate no. days in:</th>
<th>Total trip</th>
<th>Arrive</th>
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</tbody>
</table>

\(^a\) All cranes were marked as flightless colts except 33092 which was an adult.  
\(^b\) Oregon-Idaho border.
The average arrival date on wintering grounds in the CVC for PFP cranes was 7 October (range = 19 Sep.-20 Oct.). We obtained location data for 11 cranes in the CVC; 10 cranes were monitored throughout the winter and 1 crane went off-line in late October. In winter, location data were obtained for 438 of 455 possible transmission cycles (n = 11 cranes). The best locations for each duty cycle were mostly class codes 1-3 (74%), 24% were class code 0, and 1% were class code A.
Fig. 3. Locations acquired with satellite telemetry for Pacific Flyway Population lesser sandhill cranes during spring migration in 2000, 2001 and 2002, and for adult cranes while in Alaska during the spring and summer in 2000 and 2001. For migration locations, circles depict cranes captured in upper Cook Inlet and squares depict cranes captured in Bristol Bay.
Winter crane locations concentrated in 2 primary areas (Fig. 2): the Sacramento – San Joaquin River Delta (Delta) where 56% of all locations (n = 8 marked cranes) occurred and in Merced County (130 km to the south) where 35% of all locations (n = 6 marked cranes) occurred (Table 5). Within the Delta, 63% of the locations were concentrated on Staten Island, Tyler Island, Canal Ranch, Brack Tract, Terminous Tract, and New Hope Tract. Ninety-four percent of locations in the Delta region were within ca. 425 km². In Merced County 94% of the crane locations were within 1473 km² and included Sandy Mush Country; Kesterson, San Luis and Merced National Wildlife Refuges (NWRs); and the Los Banos and Volta State Wildlife Areas. Only 9% (n = 4 marked cranes) of all locations occurred outside the Delta and Merced County (Table 5). Two cranes were located in these peripheral areas for only a few days (i.e. 1 duty cycle). Crane 33092 stayed near Vernalis for approximately 30 days and crane 13385b stayed north of Delano at the Pixley NWR (Fig. 2) for 83 days.

Though the overall winter range in the Delta and in Merced County for all cranes was relatively large, locations obtained for individual PFP cranes were generally localized. Home ranges of individual cranes averaged 168 km² (SD = 132 km²) in the Delta (range = 7-371 km²) and 1,021 km² (SD = 942 km²) in Merced County (range = 67-2,332 km²; Table 5).

**Spring Migration**

We obtained location data for 10 cranes during spring migration (Fig. 3). PFP cranes began their spring migration 9 March (range: Feb 28 to Mar 24; Table 3). The travel route north in spring was similar to fall (Fig. 2) but took approximately twice as long to complete (mean = 58 days; Table 3). Unlike fall migration, PFP cranes stopped for an average of 42 days at staging areas in the Pacific Northwest before continuing north. The Harney Valley in Oregon, and the Potholes Reservoir and Banks Lake regions in Washington were the most frequently used staging areas in those states (Table 6). Two cranes traveled further east than the fall migration route and spent ≥ 35 days in the vicinity of Fruitland and Wilder, Idaho before entering Washington (Fig 3). Spring and fall stopover sites in British Columbia and Alaska were similar but relatively less time was spent traveling through Alaska in the spring (Table 3).
PFP cranes arrived on their summer range during the first week of May (mean = 6 May).

Summer Range

Adults. - Three adult cranes captured during late April at a spring staging area in the Matanuska Valley, AK remained near the capture site for approximately 10 days before dispersing to summer areas in the Susitna and Kahltna river drainages (Fig. 3). Summer locations were generally localized in this boreal forest, muskeg habitat suggesting that breeding territories were established. Greater than 82% of summer locations for each adult crane were within a 16 km² area in 2001. Transmitters on 2 adults subsequently failed just prior to anticipated fall migration. In addition to migration data, 33092 visited the capture location (staging area) the following spring and then returned to summer in the same general location (Susitna River Valley) as the previous year (Fig. 3). The core area, however, used by

Table 5. Number of duty cycles present and approximate area (km²) of home range for individual Pacific Flyway lesser sandhill cranes at specific locations in the Central Valley of California during the winter in 2000, 2001 and 2002.

<table>
<thead>
<tr>
<th>Crane ID</th>
<th>Delta region near Vernalis</th>
<th>near Merced</th>
<th>near Delano</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Home range</td>
<td>No. of cycles</td>
<td>Home range</td>
</tr>
<tr>
<td>13381</td>
<td>124</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>13382</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13385b</td>
<td>7</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>13386</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13387</td>
<td>119</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>29302</td>
<td>239</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>29501b</td>
<td>329</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>29502b</td>
<td>46</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>29503</td>
<td>371</td>
<td>44</td>
<td>0</td>
</tr>
<tr>
<td>33092</td>
<td>106</td>
<td>29</td>
<td>45</td>
</tr>
</tbody>
</table>

* Satellite transmitters cycled on for 6-8 hrs every 96-106 hrs during the winter.

Table 6. Approximate number of days spent at spring stopover and staging areas in the Pacific Northwest by Pacific Flyway Population lesser sandhill cranes in 2000, 2001 and 2002 estimated with satellite telemetry.

<table>
<thead>
<tr>
<th>Staging area</th>
<th>Crane identification number</th>
<th>Total days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29302</td>
<td>29503</td>
</tr>
<tr>
<td>Warner Valley, Oreg.</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Harney Valley, Oreg.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yonna Valley, Oreg.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>near Wilder, Id.</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>Potholes Reservoir region, Wash.</td>
<td>42</td>
<td>34</td>
</tr>
</tbody>
</table>

Banks Lake, Wash.             | 1     | 1     | 8     | 0     | 20     | 7     | 0     | 0     | 0      | 0      | 37     |
33092 during the summer in 2002 was larger (67 km² vs. 14 km²). Relatively less accurate location data during the summer in 2002 may have been responsible for the larger area making it difficult to predict breeding status of 33092 that year.

Colts. - Between fledging and fall migration PFP cranes captured as flightless young in upper Cook Inlet remained within 27 km (mean = 10.3 km, SD = 9.8 km) of their natal site. After arriving in upper Cook Inlet the following spring (late April-early May), juvenile cranes did not return to the vicinity of the natal site. Only one crane (female 29302) revisited the natal site, but in late May, and 2 cranes (female 29501b and male 11386) came within 25 km of their natal site (Fig. 4). Two juvenile cranes (female 13387 and male 29503) returned to upper Cook Inlet but not within 110 km of their natal location (Fig. 4). Brief visits to natal sites may have gone undetected because our transmitters were programmed to transmit for 8 hours every 2 days during this period (Table 1).

Two juvenile cranes returned to Alaska but not Cook Inlet. Female 13381 spent the summer on the Gulf Coast of Alaska between Cape Suckling and the Yakutat Forelands, over 360 km east of Cook Inlet (Fig. 4). The last location for a male 29052b was obtained on the Alaska Peninsula (May 19) indicating the bird had traveled through Cook Inlet and was possibly heading to Bristol Bay (Fig. 4).

Of the 5 juveniles returning to upper Cook Inlet, 2 summered on the Kenai Flats, two near the Palmer Hay Flats, and one on Chickaloon Flats (Fig. 4). One juvenile, who summered on the Kenai Flats, made a brief foray to the upper Kasiltna drainage (a breeding area). Colts captured in Bristol Bay staged ca. 80 km east of the capture site soon after fledging and prior to fall migration (Fig. 2). Both juveniles (males) that returned the following year visited the immediate vicinity of the natal site in early spring then dispersed to outlying areas (Fig. 4). The extensive movements of some juveniles during the summer, the lack of accurate location data from mid-late summer for others, and the 5-day duty cycle for Bristol Bay cranes precluded meaningful calculation of summer range (km²) for juvenile cranes.

DISCUSSION

Using satellite telemetry we were able to describe the movements of individual PFP lesser sandhill cranes on summer range in Alaska, winter range in California, and through fall and spring migration. The majority of our satellite transmitters were deployed on colts and may not accurately reflect movements and distribution of other age and social classes in the population. Colts, however, remain with their parents at least through their first migration and winter (Tacha 1988) and likely reflect movements of breeding adults during those periods. We believe non-breeding adults were not represented in this study. Though our sample size was small to fully compare migratory pathways of birds nesting in Cook Inlet and Bristol Bay, all cranes captured in both locations followed the same migratory path and wintered in small, well defined areas of the CVC (Fig. 2).

We do not know the degree of fidelity to breeding sites for adult PFP cranes. The only adult monitored through two consecutive summers returned to the same area (Fig. 3). Most juveniles, however, did not return to their natal sites the first year following hatch (Fig. 4). If fidelity to breeding areas by adults is strong, then it appears that juveniles did not accompany their parents, at least during the later stages of spring migration. Tacha (1988) reported that juvenile cranes remain with their parents until April, approximately 10 months after hatch. The average date of arrival on summer areas for our birds was May 6. Some cranes arrive in upper Cook Inlet up to a week earlier than our marked birds (unpubl. data). Consequently, migration chronology and path exhibited by our radioed juveniles in the spring is more difficult to extrapolate to other segments (age and social status) of the population. Nevertheless, we saw little variation in spring movements through the Pacific Northwest and British Columbia among 9 juveniles and 1 adult monitored during the study.

Stopover, Staging and Winter Areas

Though our satellite transmitters were programmed to transmit more frequently during migration (8 hours on and 26-48 hours off; Table 1) we could not identify stopover sites used for short durations (≤ 2 days). Locations used for longer durations, however, were easily identified. Additionally, lengths of stay at stopover and staging areas should be regarded in relative terms, as we could not precisely quantify their duration.

PFP lesser sandhill cranes completed migration from summer range in Alaska to winter range in the CVC in 13 to 40 days (Table 3). Both the minimum and maximum transit times were from individuals monitored during the fall in 2001 indicating that either cranes exhibit different migration strategies, or experienced different weather conditions.

The migration route for PFP cranes in Alaska is narrow and restricted to the coast by a series of glaciated mountain ranges (Chugach, St. Elias, Wrangell and Coastal Mountains). During fall migration, more time was spent in Alaska than in other states or provinces (Table 3), partly because Alaska makes up the largest proportion of the travel route. Stopover sites in Alaska were used for relatively short durations, especially in the spring, with longer stopovers occurring during the fall at Gustavus and the Yakutat Forelands (Table 4). That 80% of radioed cranes stopped at the Yakutat Forelands during fall migration indicates that the area provides a desirable resource. The relatively high use of the Bering Glacier lowlands, Stikine and Copper River Deltas, and Gustavus indicates their importance to migrating cranes. Only Gustavus and the Copper River Delta have been previously described as stopover sites for PFP cranes. Streverler and Matkin (1983) reported a minimum of 12,899 cranes passed through Gustavus during the fall in 1981,
6,870 of which landed on the Dude Creek State Critical Habitat Area. Herter (1982) indicated similar numbers of cranes migrating through and stopping briefly on the Copper RiverDelta.

British Columbia also comprises a large proportion of the total migration route but most cranes spent relatively little time (≤ 5 days) in this province during fall and spring migration (62% and 100% of marked cranes, respectively; Table 3), making stopping areas difficult to determine. As was the case in Oregon, a large proportion of locations obtained during the fall were of flying cranes. Most cranes migrated through these regions during the short duration of the transmitters off-cycle, and were located a considerable distance along the migration route during the next transmission period.

The Pothole Reservoir region (Grant County), including Columbia River NWR in central Washington, received more use by radioed cranes than other locations along the migration corridor. This was more apparent in the spring when 70% of radioed birds used the area for 10–42 days (Table 6). Cranes also frequently used the Banks Lake area (north of the Potholes Reservoir region, in the spring) but cranes were not detected there in the fall. These staging areas in Washington, plus locations used for long periods in Oregon and Idaho (Table 6), are important to cranes because they undoubtedly provide a large proportion of the nutritional resources used for the energetic demands of migration (Krapu 1987). Infrequent stops by cranes in British Columbia and Alaska during the spring suggest that foraging opportunities may be limited along this portion of the migration route.

The geographic extent of PFP lesser sandhill cranes monitored during the winter was restricted to 2 primary locations within the CVC with little interchange between areas (Fig 2). With exception of the federal wildlife refuges and state wildlife areas in Merced County, most of the winter locations appear to be on private lands. This is especially true for cranes using lands in the Delta region. Future development of these wintering areas should be monitored closely because traditionally important roost and foraging areas may be limited (Pogson 1990).

Affinities Among Breeding and Wintering Areas

The western boundaries separating the breeding ranges of the PFP and the MCP are in close proximity (Fig. 1) yet we, as did others (Pogson et al. 1988, Krapu and Brandt in prep), found no evidence of overlap between the two populations anywhere during their annual cycle.

Our data suggest that, though geographically distant, the upper Cook Inlet and Bristol Bay breeding populations are genetically linked. PFP cranes breeding in these areas utilize the same migration routes, staging and wintering areas. During the summer, however, juvenile cranes captured in upper Cook Inlet as colts exhibited a broader geographic distribution the subsequent summer than expected based on the close proximity of their natal sites. While 5/7 juveniles returned to the upper Cook Inlet region only one returned to its natal site (Fig. 4). The large dispersal distances of these juvenile cranes can provide gene flow between the two breeding areas.

Littlefield and Thompson (1982) previously described the geographic range of PFP lesser sandhill cranes. They separated the population into two segments based on differences in migration corridor and winter distribution. The migration route for the “western segment” included the Willamette Valley, Oregon, the Washington coast through Puget Sound, and the coast of British Columbia and Alaska. Cranes following this migration route staged at Sauvie Island, Oregon and Ridgefield NWR, Washington during the spring and fall (Littlefield and Thompson 1982, Cooper 1996, Littlefield and Ivey 2002) and wintered near Red Bluff, California. Red Bluff is north of wintering areas used by cranes monitored during this study. Some cranes remain on Sauvie Island over winter (Littlefield and Ivey 2002, Ivey et al. 2005). In recent years, however, sandhill cranes have not used the Red Bluff area during winter, and their current wintering location is unknown (Ivey pers. comm.). The migration route and winter areas described by Littlefield and Thompson (1982) for the “eastern segment” of PFP lesser sandhill cranes was nearly identical to that used by cranes during this study. We found no evidence that PFP lesser sandhill cranes breeding in Cook Inlet and Bristol Bay use an all-coastal route along British Columbia and Washington during migration. During the fall, all marked cranes left the coast near the Stikine River Delta in Alaska and used an interior route through central British Columbia, Washington and Oregon to wintering areas in the CVC. A reverse route was taken in the spring.

Cranes of the PFP nesting on islands in southeast Alaska and along the coast of northern British Columbia are believed to be Canadian subspecies (Littlefield and Ivey 2002, Ivey et al. 2005). Preliminary evidence suggests that they follow a migration route, stage, and winter in areas similar to that described for the “western segment” of the PFP lesser sandhill cranes. It is likely that this coastal, component of the Canadian subspecies explains the geographical differences in range described by Littlefield and Thompson (1982) for the “western” segment of the PFP. No overlap appears to exist in the breeding range of PFP cranes captured in Bristol Bay and Cook Inlet (this study) with cranes breeding to the south along the Pacific Coast (Ivey et al. 2005), suggesting that the coastal group is not part of the PFP lesser sandhill cranes. The possibility of gene flow between these populations, however, warrants further study.

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_______, in prep. Geographic distribution and relative abundance of subspecies and subpopulations of midcontinental sandhill cranes, fidelity to breeding sites, and exposure to hunting.


THE STATUS OF THE COMMON CRANE (GRUS GRUS) IN EUROPE - BREEDING, RESTING, MIGRATION, WINTERING, AND PROTECTION

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Abstract: At present, about 160,000 and 100,000 cranes are migrating on the West-European and on the Baltic-Hungarian routes, respectively, from the northern, middle, and northeastern parts of Europe. On both routes, the resting maxima, simultaneously determined since the 1980’s, has increased three-fold. This increase in migratory cranes is the result of shorter migration routes with higher return rates, a growing passage from the northernmost part of Russia beginning in the 1990’s, and a protected status in the European Union at breeding as well as at many resting and wintering sites. Hence, the cranes learn to find and use new breeding and resting locations. Further changes in the migratory behaviour are a 2 to 4 weeks earlier return of the brood-birds in spring and a likewise delayed departure of the last crane groups in autumn. Wintering locations in Western Europe have been shifted to the north: in 1980/81 some 100 cranes wintered in France, whereas in 2000/2001 there were about 68,000 birds doing so.

In several European countries there are working groups for the protection of cranes. Every year, the German group organizes an internal meeting to co-ordinate activities. Its mostly honorary members supervise the protection of the breeding and resting places over the whole country. About 50 autumn resting places with 200 up to 50,000 cranes at maximum, are systematically watched by the experts. The state co-ordinator enters the data obtained into an annual synopsis. A survey of crane resting in Germany over 25 years is available. The European Crane Working Group co-ordinates the protective strategies, data acquisition, and ringing of birds. It supports public relations, the exchange of information, scientific research, and European Crane Workshops. The positive development of the crane population in Europe is the result of the cooperation of all parties concerned. It convincingly shows that intense cultivation of the land can be consistent with successful execution of essential protective measures.

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Key words: breeding, Common Crane, European/German Crane Working Group, Grus grus, migration, protection, resting, wintering

THE EUROPEAN CRANE WORKING GROUP (ECWG)

Crane working groups have been formed in many European countries (Prange 2003a). The ECWG is promoting the exchange of crane information in Europe, enabling scientists and nature conservators from the countries to meet at conferences, coordinate the European ringing program, and continuously summarize the state-of-the-art knowledge in proceedings. Five European meetings have been held: in Hungary (1985, 15 countries), Estonia (1989, 23), Germany (1996, 20), France (2000, 15), Sweden (2003, 22), and a smaller one in Spain (1994, 13). For two decades the group has been working together within the European framework in an increasingly unified way. However, the economic disparity between eastern and western Europe still prevents many crane researchers from eastern countries from attending meetings.

An international data base for ringed and radio-tracked birds is being developed for the European crane ringers in the ECWG (Miikulainen 1995, Alonso and Alonso 1999, 2003, ECWG 2002, Rinne 2003). Future efforts of the European Group are to:

- organize the European Crane Workshops,
- develop strategies to protect breeding, resting, and wintering sites,
- coordinate the ringing and recording programs,
- combine EC extension programs with a re-moistening of resting regions,
- promote scientific investigations within international cooperation,
- create programs for young people contributing to the natural wildlife and preservation,
- and to exchange topical data via the Internet.

THE GERMAN CRANE WORKING GROUP

In Germany, cranes have been monitored in their breeding areas and in up to 50 resting sites for about 25 years (Mewes 1996a, b, 1999, 2003, Prange 1989, 1995a, b, 2002, 2003, Mewes et al. 2003). Further tasks of the German Crane Working Group are to:

- ensure the conservation of the crane habitats,
- guide nature tourists to observation points near the resting sites,
- carry out scientific work and promote international cooperation,
- organize a national meeting each year,
- and to run a Crane Information Centre within the biggest resting region at the Baltic sea coast (Ruegen-Bock-area).

The ringing of about 600 cranes, partly with radio transmitters, is coordinated by this centre in Groß Mohrdorf near the city of Stralsund.

Development of the Breeding Crane Populations

Germany is the northwestern boundary of the distribution of breeding cranes with the highest breeding density in its northeastern states (Mecklenburg-Western Pomerania: ≥ 1,500 pairs, Brandenburg: ≥ 1,200 p., Mewes 1996a, b, 1999, 2003, Prange et al. 1999b).

In Central Europe, the population shows remarkable growth (Fig. 1). It should be noted that the total number of breeding pairs in Germany (2003: about 3,800) has increased 6-fold over 3 decades. A real increase and improved methods of observation and record keeping have contributed to this result (Prange 1989, Mewes 1996a, 1999, 2003, Nowald et al. 1999, Prange et al. 1999a, b). This increase has been observed since the beginning of the 1970’s. Prior, the crane population was in decline for two centuries, reaching its lowest level in the 1950’s.

This sustained growth is due to an increase in the traditional breeding regions and re-colonization of areas in the South, West and North resulting in a 150 km shift in the western distribution boundary. The reasons for this increase are improved protected status of the birds and their habitats on their whole western flyway, shorter migration courses, and an earlier onset of breeding. Within the traditionally populated areas, small moist-damp regions - even in the open surroundings and close to settlements - are increasingly occupied as breeding grounds.

An increase of breeding populations is reported from Scandinavia, Poland, the Baltic countries, Finland, and regions of the Ukraine and Russia, too. New breeding of a few pairs is known in France, England, the Netherlands, and the Czech Republic (Swanberg and Bylin 1993, Gavris 1999, Lundgren 1999, Lundin et al. 1999, Nowald et al. 1999, Prange 1999, Prange et al. 1999a, b, Tofft 1999, Treuenfels 2000, Lundin 2001, 2003, Bobek et al. 2003, Budrys 2003, Hake 2003, Markin 2003, Mewes et al. 2003, Salvi 2003a). The reproduction results of different European regions are shown in Table 1.

Table 1. Common Crane reproduction in different parts of Europe.

<table>
<thead>
<tr>
<th>Reproduction Type</th>
<th>Central Europe</th>
<th>Scandinavia</th>
<th>Northeastern Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeding pairs with Juv</td>
<td>65 %</td>
<td>55 %</td>
<td>?</td>
</tr>
<tr>
<td>Juv/pairs with breeding attempt</td>
<td>0.90</td>
<td>0.75</td>
<td>0.70</td>
</tr>
<tr>
<td>Juv/successful pairs</td>
<td>1.40</td>
<td>1.20</td>
<td>?</td>
</tr>
<tr>
<td>Juv at the peak of resting</td>
<td>13–15 %</td>
<td>11–13 %</td>
<td>11–12 %</td>
</tr>
<tr>
<td>Direction of population size change</td>
<td>↑↑↑↑</td>
<td>↑↑</td>
<td>↑</td>
</tr>
</tbody>
</table>

Migration Routes in Central and Western Europe

At present, about 160,000 and 100,000 cranes are migrat- ing on the West-European and on the Baltic-Hungarian route (Fig. 2), respectively. On both routes, the resting maxima simultaneously determined between 1980 and 2003 has increased three-fold (Prange 1989, 1995a, 1996, Fintha 1999a,b, Prange et al. 1999a, b, Salvi 2003a,b, Végvári 2003, Végvári and Tar 2003) (Fig. 3).

The Baltic-Hungarian route is used mainly by cranes from north-eastern Europe as the Finnish ringed cranes show. Less than 5 % of the Scandinavian birds use this route. In comparison with it, the West-European route is used mainly by North- and Central-European birds with a high percentage coming from the North-east (Table 2).

On both routes there are now 250,000 cranes migrating. Not as much is known about the number of cranes using the East-European and Asian migration routes (Fig. 4) (Litvinenko and Neufeldt 1988, Markin and Sotnikova 1995, Prange 1995a, b, 1999, 2002, 2003, Meine and Archibald 1996, Urban 1996, Ashtiani 1999, Gavris 1999, Grinchenko et al. 1999, Rahmani 1999). World-wide the total population of the Common Crane amounts to more than 400,000 birds.
Fig. 2. Main migratory routes in Europe.

Fig. 3. Increase of the crane migration on the West-European and the Baltic-Hungarian route over three decades.
Resting Sites on the Migratory Routes

In middle and northern Europe, the spring migration is less significant than the autumn one, which at traditional resting sites is interrupted for weeks and months. The cranes depart to their winter quarters in batches, resting on their way.

After rearing their juveniles, the indigenous cranes gather at “assembly sites”. The larger ones turn into “resting sites” of indigenous and passing populations during the months of September and October. Sites used by *Grus grus* usually are of three kinds:

- **Sleeping sites** are in shallow waters of ponds, lakes, rivers, swamps, and backwaters of the Baltic Sea. The cranes will go there in the evening and leave in the morning.
- **Pre-assembly “stop-overs”** are used at sleeping sites with small bodies of water. The short distance to the banks requires “stop-overs” at surrounding fields and meadows with short vegetation. From there, the water is approached at dusk.
- Food is collected daily, mainly from large-scale agricultural fields, up to a distance of 25 km from the sleeping sites.

At assembly and resting sites, supervised by the older cranes, the juveniles learn group-related behavior such as looking for and taking up food, the daily rhythm of resting, ease, and activity, and the social behaviour within the group. During this period, nourishing food, from stubble-fields and fresh seeds is taken up to store fat for the migration to come.

Agriculture, hunting and tourism should cooperate in developing suitable “crane management” at large resting sites, considering interests of all the parties concerned and attaining reasonable compromises to protect the cranes as well as agricultural fields. This project could also include “diversion
Autumn Resting on the Western-European Migratory Route

This migratory route includes larger resting regions in Sweden, northern Poland, northern Germany, north-eastern and south-western France, and north-western Spain. The stopover sites can be classified in 4 categories:
- Assembly sites of indigenous cranes, occupied between July and September.
- Assembly and resting sites of indigenous and passing cranes (“long-term rest”) between August and November.
- Stopover sites for passing cranes on migration (“short-term rest”) between October and November.
- Resting and wintering sites in south-western Europe with changing stops between November and March.

At present, the largest numbers of cranes rest at sites in Eastern Hungary (Hortobágy: up to 70,000), in the Northwest of France (Lac du Der: up to 60,000), and in the Northeast of Spain (Laguna de Gallocanta), in the Southwest of France (Aquitaine), and in the Northeast of Germany (Ruegen-Bock region at the Baltic Sea coast, Linum-Nauen northwest of Berlin) with each up to 50,000 cranes at the peak of the resting season (Fintha 1999a, b, Le Roy 2002, Mewes et al. 2003, Salvi 2003b, Végvári and Tar 2003, and see Prange 1995a, b, Prange et al. 1999a, b, Lundin 2003, Salvi 2003a).

In north-eastern Germany there are about 50 resting sites known. In autumn there are from 200 to 50,000 cranes resting. They reached a peak of 130,000 cranes simultaneously at the resting climax in the second half of October 2001 and 2002 (Fig. 5). At the Baltic coast (Ruegen-Bock region) Scandinavian birds are resting, whereas in inland Germany mainly the resident and north-east European populations are found (Fig. 6).

Changes in the Crane Migration over three Decades

Due to growth in population and an immense immigration from the Northeast, the number of migrating cranes in central Europe has increased from less than 50,000 at the beginning of the 1970’s to more than 160,000 birds in the year 2004. A similar increase has also occurred in the passage on the Baltic-Hungarian route (Prange 1989, 2002, 2003b, 2004, Mewes et al. 2003). There are many reasons for the increase in the number of migratory cranes (Tables 3 and 4). Three key factors are: a) shorter migration routes with higher return rates, particularly in Western Europe, b) a growing passage from the north-western part of Russia from the beginning of the 1990’s, maybe as a result of food shortage in agriculture (Anzigitova et al. 2003, Salvi 2003a, and c) protected status in most of the European countries in the areas of breeding as well as of resting and wintering. Hence, the cranes learn to find and open new breeding and resting locations.

In addition to these changes, brood birds are returning 2 to 4 weeks earlier in the spring. Likewise, the last crane groups are departing later in the fall. Thus, wintering sites in western Europe have been shifted to the North: in 1980/81 some 100 cranes wintered in France, whereas in 2000/01/02 there were about 70,000 birds (Fig. 7) doing so (Salvi et al. 1995, 1996, Salvi 1999, 2003a, Le Roy 2002, Prange 2002, Alonso et al. 2003). The positive development of the crane population is also the result of the readiness of all parties concerned to co-operate. Besides, the data convincingly shows that intense cultivation of the land can be consistent with the successful execution of protective measures necessary.

New Results and Developments

A large number of ringed and radio-marked cranes provided new information about individual histories, onset and interruption of breeding, behaviour at breeding, resting, and wintering.
The cranes wintering sometimes in Germany belong to the indigenous population. Radio-tracked cranes from western Siberia were wintering in Israel: “Carolina” needed 70 days for flying about 6,500 km, resting 41 times whereas “Dora” needed 40 days for 6,000 km, resting at 10 sites (Alon et al. 2003). Wessling (2002) developed a new method of computer-analyzing crane calls, which allows one to differentiate between individuals in pairs and at breeding places.

Table 3. Reasons for different population developments.

<table>
<thead>
<tr>
<th>Central Europe</th>
<th>Scandinavia</th>
<th>North-eastern Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migration distance /km</td>
<td>500-2,500</td>
<td>1,200-4,000</td>
</tr>
<tr>
<td>Arrival at breeding places</td>
<td>February</td>
<td>March/April</td>
</tr>
<tr>
<td>Beginning with breeding</td>
<td>March</td>
<td>April</td>
</tr>
<tr>
<td>Success of a second clutch</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 4. Changes of the Central European crane population over two decades (1980 → 2000).

1. • Increase of breeding pairs • six times
   • More breeding pairs out of woodlands
   • Extension of the breeding area • 150 km to the West
   • 50 km to the North
   • 160 km to the South
   • Increase of breeding pair density • double the density

2. • Increase of migrating/resting cranes 50,000 → 160,000
   • Changes in the origin of migrating cranes • from North: from East%/70:30 → 40:60

3. • More wintering further north • esp. France

4. • 3 weeks earlier return of breeding pairs • March → February

The cranes wintering sometimes in Germany belong to the indigenous population. Radio-tracked cranes from western Siberia were wintering in Israel: “Carolina” needed 70 days for flying about 6,500 km, resting 41 times whereas “Dora” needed 40 days for 6,000 km, resting at 10 sites (Alon et al. 2003). Wessling (2002) developed a new method of computer-analyzing crane calls, which allows one to differentiate between individuals in pairs and at breeding places.

Protective Measures

In Germany the crane is considered the leading bird of the
moist-damp areas. As a result, about 80% of the resting sites are officially protected. Protected status allows a vital crane population to thrive near human activity. In spite of the progress, problems remain. While not a significant factor in the European Union, hunting disturbs crane populations in other countries. Everywhere flights are being actively expelled from agricultural fields. In Germany as a rule, farmers do not get any compensation for evident damage. However, for some years now, within large resting sites “diversion feeding” has been adopted (always some acres, away from paths, using waste corn), which in combination with an appropriate crane management (leaving the corn fields as stubble-fields, early new sowing) has been incorporated in large-scale agriculture and financed sometimes by the local state government. The local crane working groups try to present conclusions considering the different interests and positions. Other efforts are necessary to lead nature tourists to observation points, away from the suitable sleeping sites at the resting places. A new big problem arises from rapidly growing wind power stations which should not be built on traditional resting places. A new big problem arises from rapidly growing wind power stations which should not be built on traditional resting places that are within a few kilometres of sleeping sites. The specific requirements for the protection of the Common Crane are summarized in Table 5. With the needs of the Common Cranes given consideration there is no reason to believe that we will not have this magnificent bird among us in abundance for generations to come.

LITERATURE CITED


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Table 5. Specific requirements for the protection of the Common Crane in Europe.

<table>
<thead>
<tr>
<th>Section</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Protection and supervision of resting and wintering sites</td>
</tr>
<tr>
<td></td>
<td>– protection status</td>
</tr>
<tr>
<td></td>
<td>– disturbances as small as possible</td>
</tr>
<tr>
<td></td>
<td>– availability of enough water</td>
</tr>
<tr>
<td></td>
<td>– restricted hunting</td>
</tr>
<tr>
<td>2.</td>
<td>Ensuring food</td>
</tr>
<tr>
<td></td>
<td>– agricultural crane management</td>
</tr>
<tr>
<td></td>
<td>– artificial feedings for diversion</td>
</tr>
<tr>
<td>3.</td>
<td>Protection of breeding sites</td>
</tr>
<tr>
<td></td>
<td>– protection status as far as possible</td>
</tr>
<tr>
<td></td>
<td>– restricted hunting and visiting</td>
</tr>
<tr>
<td></td>
<td>– reduction of predators, esp. wild boars</td>
</tr>
<tr>
<td>4.</td>
<td>Guiding tourists</td>
</tr>
<tr>
<td></td>
<td>– offering information</td>
</tr>
<tr>
<td></td>
<td>– observation points</td>
</tr>
</tbody>
</table>

Common crane (Grus grus) in Europe. Prange 75
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PATTERNS OF HABITAT USE BY WHOOPING CRANES DURING MIGRATION: SUMMARY FROM 1977–1999 SITE EVALUATION DATA

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AMY L. RICHERT2, State Museum, University of Nebraska-Lincoln, 424 Morrill Hall, Lincoln, NE 68588

Abstract: We used site evaluation data collected during 1977–1999 to examine patterns of habitat use by whooping cranes (Grus americana) during migration through the United States portion of the Wood Buffalo–Aransas flyway. We examined characteristics of 3 types of stopover habitats: 1) roost sites (n = 141 records), 2) feeding sites (n = 306), and 3) dual-use sites (i.e., where observer recorded cranes as using a site for both roosting and feeding (n = 248). Results in spring were influenced by the large number of records from Nebraska (> 67% of spring records) and in fall by frequent observations on Salt Plains and Quivira National Wildlife Refuges and Cheyenne Bottoms State Wildlife Area. Palustrine wetlands were the most commonly recorded wetland system (68.8%) used by whooping cranes; riverine wetlands accounted for 21.6% and lacustrine wetlands 9.6% of site evaluation records. Riverine sites were common only in Nebraska, where they accounted for 59.0% of roost sites. All social groupings of whooping cranes used palustrine wetlands for both roosting and feeding, whereas most of the whooping cranes found on riverine roosts were single cranes or nonfamily groups. Most wetlands used by cranes were seasonally or semipermanently flooded. Observers found whooping cranes on a wide range of wetland sizes. River widths ranged from 36 to 457 m and averaged 227 ± 88 (SD) m. Maximum depths of wetlands on which observers saw cranes ranged from 3 to 305 cm and averaged 51 ± 41 cm. Specific sites within wetlands where observers recorded cranes feeding or roosting averaged 18 ± 11 cm (range 3-61 cm). Observers described most wetlands as having soft substrates, low shoreline slope (< 5%), and clear or turbid water. Riverine roost sites and dual-use sites were consistent in their lack of vegetation, but palustrine sites varied in types of emergent vegetation and their distribution. Feeding sites were largely upland crops, with lower occurrence of seasonal or permanent wetlands, or upland perennial cover. At dual-use sites, cranes were most often found in palustrine permanent or seasonally flooded wetlands. In spring, observers recorded cranes most frequently feeding on row-crop stubble, with lesser use of small grain stubble and green crops. In fall, observers found cranes frequently on green crops, small-grain stubble, and row-crop stubble. Woodland habitat occurred adjacent to > 70% of riverine roost sites but adjacent to < 8% of palustrine roost sites. All riverine roosts and about half of palustrine roost sites also had adjacent upland cover; upland cropland was common for both. The most common habitats adjacent to feeding and dual-use sites were cropland and upland perennial cover. About two-thirds of feeding sites were < 0.8 km from palustrine roost sites, whereas over half of riverine roost sites were > 1.2 km from feeding sites. More than two-thirds of sites where observers found cranes were <0.8 km from human developments; 58% of observations were > 0.8 km from utility (power or phone) lines. Visibility varied by site use and wetland system. Private ownership accounted for > 80% of feeding sites used by whooping cranes; federal ownership accounted for most ownership of roost sites. More than 90% of roost sites that were under federal or state ownership were considered secure, whereas security of roosts on private lands was evenly split between secure and threatened. These observational data provide further insights into habitats used by migrant whooping cranes, but further investigations into habitat use patterns are needed.

Key words: Grus americana, habitat use, migration, whooping crane

Witnesses have observed whooping cranes (Grus americana) on various roosting and feeding areas throughout their migration path, which extends through North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas. The central Platte River in Nebraska is the best known spring stopover area for migrating whooping cranes, and characteristics of roost habitat have been examined in detail for the Platte River in Nebraska (Johnson 1982, Lingle et al. 1984, Faanes 1992, Faanes and Bowman 1992, Faanes et al. 1992). However, whooping cranes also use many other areas during spring and fall migration. Because these areas play a key role in crane migration, the recovery plan for the whooping crane identified the collection of data on the use of these habitats as an important task in the conservation of the species (U.S. Fish and Wildlife Service 1994).

The Cooperative Whooping Crane Tracking Project began in the United States and Canada in fall 1975. In 1977, the National Audubon Society organized a whooping crane reporting network to boost the effort to monitor sightings of whooping cranes. Data from earlier years, dating back to 1943, were compiled into the data sets, which have been coordinated and maintained by the U.S. Fish and Wildlife Service (USFWS). Also in 1977, the Whooping Crane Recovery Team initiated a pro-
gram to collect habitat data at sites where observers had seen whooping cranes. These site evaluations greatly expanded the scope and detail of data collected on whooping cranes during migration to include information such as wetland type and size, water quality, substrate, water depths, visibility, vegetation, and land cover. More than 25 parameters were recorded for each site that observers evaluated (U.S. Fish and Wildlife Service 1980).

Data from the confirmed sightings and site evaluation databases have been used in a number of studies. Johnson (1982) used observational data to investigate the use and significance of habitat in the Platte River valley for whooping cranes. Lingle et al. (1984) used observational and site evaluation data to characterize whooping crane use in the Platte River valley. Carlson et al. (1990) and Ziewietz (1992) used roost and feeding site data to develop a habitat suitability model for the Platte River. Stahlecker (1997) used roost site data to correlate stopover habitat availability with wetlands identified on National Wetland Inventory (NWI) maps. This paper provides the first comprehensive summarization of the USFWS databases to characterize roosting and feeding site use throughout the flyway.

METHODS

We used observation and site evaluation data collected during 1977−1999. All sightings were confirmed by a state or federal biologist or other reputable bird expert, and only confirmed sightings were included in the data sets. Observation data included information on date, location (description, county, and legal system [township, range, section]), and numbers of adults and juveniles. Observers collected site evaluation data for a subset of confirmed sightings during 1977−1999. The effort to collect this additional data varied among states and years; observers collected the most extensive and consistent data in Nebraska. Observers defined site use as feeding, roosting, or dual use (both feeding and roosting or where site use was unknown). We summarized some data for all site uses combined but conducted most data summarizations separately for each site use.

Howe (1987) reported on the habitat use, survival, and behavior of 27 whooping cranes (9 radio-marked and others associated with them) that were tracked between Wood Buffalo National Park and Aransas National Wildlife Refuge (NWR) during 1981−1984. However, we used only the sightings of these marked cranes that were reported by citizens (and other chance observations) in the site evaluation data sets; therefore, results reported here are independent of those in Howe (1987) (W. Jobman, USFWS, Grand Island, NE, personal communication).

In a number of cases, multiple observations (2−12 records) existed for the same bird(s) observed in an area. We believed that these multiple observations (referred to here as sub-observations) were similar to repeated measures and thus could bias some measures of habitats used. Therefore, we limited our analyses to only 1 record for each main observation. In most cases, the multiple records were due to recording a number of different feeding habitats, different locations (e.g., different quarter-sections), or different roost sites. Because we conducted most analyses separately for each site use, we excluded multiple sub-observations within each site-use data set, selecting only the first record for each main observation for that site use.

We did not conduct any statistical tests on the data because the observational data would violate several key statistical assumptions. First, we cannot verify that data are independent—it is impossible to know whether observations are from the same birds, or whether some cranes are more likely to be included in a series of observations. Second, statistical tests require that the probability of observation is the same among groups. With observational data, there is no way to determine if there is an increased likelihood of an observation in one habitat type over another. Therefore, we don’t know if the data are representative of the target population. Our presentation of the data, therefore, is entirely descriptive. Most results are reported as frequencies. Because some variables had multiple codes, sum of frequencies may be >100%. See Austin and Richert (2001) for detailed explanations of data processing.

Crane Groups

We classified the social group for each record using the number of adults and number of juveniles in the observations data. We classified cranes into 6 groups: 1) single adult, 2) single juvenile, 3) pair, consisting of 2 adults only, 4) single family group, consisting of 1−2 adults and 1−2 juveniles, 5) mixed group, consisting of a group with 1 adult and 1 juvenile, and 6) adult group, consisting of >2 adults and 0 juveniles. The number of juveniles often was missing (no data recorded), and sometimes the number of adults also was missing; we assumed that these were 0. We pooled records into 3 groups for some summaries: family groups (adults with at least 1 juvenile), nonfamily groups (adults with no juveniles), and single cranes (single adults and single juveniles).

Wetland-Related Variables

We pooled wetland regimes (Cowardin et al. 1979) into 4 categories: permanent (intermittently exposed, permanently and artificially flooded), semipermanent, seasonal, and temporary (saturated, temporary, and intermittently flooded). For lacustrine and palustrine systems, we pooled the 6 size classes into 3 classes: <0.4−2 ha, 2−<20 ha, and 20−>40.5 ha. River width (m) was recorded for riverine systems. Maximum water depth (cm) was reported for the entire wetland and maximum depths at points within the wetland where observers recorded cranes. Water quality categories were clear, turbid, or saline; more than 1 category was recorded for some sites. Wetland substrate categories were sand, soft mud, hard mud, or other; although there were some records with more than 1 substrate.
category recorded, we used only the first category, assuming this was the dominant characteristic of that site. Observers reported shoreline slope as <1%, 1–< 5%, 5–< 10%, > 10%, not applicable, or other.

Observers classified vegetation types occurring in the wetland as grass, sedge (Carex), cattail (Typha), rush (Juncus), smartweed (Polygonum), other, or none. Many records included multiple types of emergent vegetation; therefore, the sum of percentages by type was often greater than 100%. Observers reported the distribution of emergent vegetation (originally referred to as vegetation density) as none, scattered, clumped, or choked; we found no specific definitions for these categories.

**Habitat Descriptors**

Observers used 2 category lists to describe roost sites, 1 list of general habitat types and 1 list of crop types. Habitat types included flooded pasture, wooded creek or draw, flooded cropland, stock pond, reservoir, lake, marsh, river, salt marsh, tailwater pit, seasonally flooded basin, cropland, pasture, wet meadow, hay meadow, woodland, or other; we found no definitions or descriptions for these types in the data files. Crop types included alfalfa, barley, corn, Conservation Reserve Program (CRP), rice, sunflower, fallow, milo, disked alfalfa, oat stubble, popcorn, green rye, soybean, bean stubble, sunflower (assumed to be stubble), winter wheat, wheat stubble, milo stubble, and corn stubble. We did not examine frequency of crop-type modifiers because they were rarely recorded.

Observers used the same list of habitat types and crop types to describe feeding sites. Unlike roost site data, however, the feeding site variable, as originally coded, was quite complex and included 15 numeric codes denoting habitat type and, for any 1 numeric code, 15 alphabetic codes denoting crop type. We determined whether each habitat or crop type occurred in a record and examined the frequency of occurrence of each type in feeding and dual-use site data. We pooled some habitat and crop types to facilitate comparison among seasons or site uses and, in particular, to pool appropriate types into a seasonal wetland type, permanent water type, and perennial upland cover (Table 1). Habitat classified as “Other” was very uncommon and thus ignored. We pooled crop types to facilitate comparisons among green crops, standing small grain or row crops, small grain or row-crop stubble, and other crop types.

Observers used the same list of habitat and crop type variables as noted above to describe habitats adjacent to the site. As occurred for feeding sites, this variable usually had multiple habitat and crop-type codes. We determined frequencies of occurrence for each site-use data set using the same methods noted above for feeding site description. Observers also ranked the extent of habitat similar to that of the site within a 16-km (10-mile) radius as none, little, moderate or common, abundant, or unknown.

### Table 1. Pooled categories of habitat and crop types for descriptions of feeding sites and adjacent habitats.

<table>
<thead>
<tr>
<th>New descriptor</th>
<th>Original description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Habitat type</strong></td>
<td></td>
</tr>
<tr>
<td>Seasonally flooded wetlands</td>
<td>Flooded pasture</td>
</tr>
<tr>
<td></td>
<td>Flooded cropland</td>
</tr>
<tr>
<td></td>
<td>Seasonally flooded wetland</td>
</tr>
<tr>
<td>Permanent water</td>
<td>Stock pond</td>
</tr>
<tr>
<td></td>
<td>Reservoir</td>
</tr>
<tr>
<td></td>
<td>Lake</td>
</tr>
<tr>
<td></td>
<td>Marsh</td>
</tr>
<tr>
<td></td>
<td>River</td>
</tr>
<tr>
<td></td>
<td>Salt marsh</td>
</tr>
<tr>
<td></td>
<td>Tailwater pit</td>
</tr>
<tr>
<td><strong>Crop type</strong></td>
<td></td>
</tr>
<tr>
<td>Cropland</td>
<td>Cropland (see below for crop types)</td>
</tr>
<tr>
<td>Upland perennial cover</td>
<td>Pasture</td>
</tr>
<tr>
<td></td>
<td>Wet meadow</td>
</tr>
<tr>
<td></td>
<td>Hay meadow</td>
</tr>
<tr>
<td>Upland woodland</td>
<td>Woodland</td>
</tr>
<tr>
<td><strong>Green crops</strong></td>
<td></td>
</tr>
<tr>
<td>Small grain – standing</td>
<td>Barley</td>
</tr>
<tr>
<td></td>
<td>Spring wheat</td>
</tr>
<tr>
<td>Small grain – stubble</td>
<td>Oat stubble</td>
</tr>
<tr>
<td></td>
<td>Barley stubble</td>
</tr>
<tr>
<td></td>
<td>Wheat stubble</td>
</tr>
<tr>
<td></td>
<td>Rice</td>
</tr>
<tr>
<td>Row-crop – standing</td>
<td>Corn</td>
</tr>
<tr>
<td></td>
<td>Sunflowers</td>
</tr>
<tr>
<td></td>
<td>Milo</td>
</tr>
<tr>
<td></td>
<td>Popcorn</td>
</tr>
<tr>
<td></td>
<td>Soybeans</td>
</tr>
<tr>
<td>Row-crop – stubble</td>
<td>Soybean stubble</td>
</tr>
<tr>
<td></td>
<td>Sunflower stubble</td>
</tr>
<tr>
<td></td>
<td>Milo stubble</td>
</tr>
<tr>
<td></td>
<td>Corn stubble</td>
</tr>
<tr>
<td>Other</td>
<td>Fallow</td>
</tr>
<tr>
<td></td>
<td>Disked alfalfa</td>
</tr>
<tr>
<td></td>
<td>Conservation Reserve Program cover</td>
</tr>
</tbody>
</table>

### Other Variables

Observers categorized distance to feeding site and distance to nearest human development as < 0.4 km, 0.4–< 0.8 km, 0.8–< 1.2 km, 1.2–1.6 km, > 1.6 km, or not applicable. The USFWS report forms gave no definition of human development, but the reporting form used by Nebraska listed paved and gravel road, single or urban (> 3) dwellings, railroad, commercial development, recreational area, and bridge. Observers categorized site security as the stability and security of the habitat and any nearby activities that could threaten the site or cranes there. Cat-
egories included stable, threatened, and unknown. Observers categorized ownership of a site as private, federal, state, and other. Many records included multiple types of site ownership; therefore, the sum of percentages by type often was greater than 100%. Observers assessed visibility from the site to the nearest obstruction that was > 1.4 m high and distance to power or phone lines. They categorized both measures as < 91 m, 91–401 m, 402–805 m, > 805 m, and “unlimited”; we pooled the latter 2 categories together. To assess how visibility might differ among main habitat types for roost sites, we summarized data for each wetland system. For feeding and dual-use sites, we used descriptors from the feeding habitat descriptions to define whether the cranes were in upland, wetland, or riverine habitat.

RESULTS

The site evaluations database included 1060 records. When we excluded multiple sub-observations and records, there were 141 records for roost sites, 306 for feeding sites, and 248 for dual-use sites. More than two-thirds of spring records were from Nebraska. In Nebraska and Montana, spring records were most common; in all other states, records were more common for fall than spring; 141 records for roost sites, 306 for feeding sites, and 248 for dual-use sites.  More than two-thirds of spring records were from Nebraska. In Nebraska and Montana, spring records were most common; in all other states, records were more common for fall than spring; (Table 2).

It is important to note that “use” in this report does not conote or imply habitat preference or selection. Because observations were a chance occurrence, patterns evident in the data must be considered with caution. We cannot assume these patterns are representative of actual habitat use or preferences.

Occurrence of Social Groups by Season

All records. - Most groups observed had 1–3 cranes (Fig. 1). Mixed groups in spring included as many as 14 (13 adults with 1 juvenile) and in fall included as many as 19 (18 adults with 1 juvenile).

Roost sites. - In the spring, observers most commonly found pairs at roost sites, followed by single families. They observed few mixed groups in the spring and sighted only 2 single juveniles (Fig. 2). In the fall, single families, pairs, and adult groups were equally common, but observers sighted few mixed groups or single adults and saw no single juveniles. Observers found single adults more commonly in the spring than in the fall. In both seasons, adults with juveniles occurred more commonly in single families than in the larger mixed groups.

Feeding sites. - Observers sighted pairs, adult groups, and single families most commonly in the spring and fall at feeding sites (Fig. 2). They found single adults somewhat more often in fall than in spring. They sighted seven single juveniles in spring.

Dual-use sites. - Adult groups, single families, and pairs were again the most commonly observed social groups at dual-use sites (Fig. 2). They observed 4 single juveniles in spring.

<table>
<thead>
<tr>
<th>State</th>
<th>Total</th>
<th>Spring</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montana</td>
<td>20</td>
<td>2.0</td>
<td>13</td>
</tr>
<tr>
<td>North Dakota*</td>
<td>138</td>
<td>13.6</td>
<td>57</td>
</tr>
<tr>
<td>South Dakota</td>
<td>77</td>
<td>7.6</td>
<td>35</td>
</tr>
<tr>
<td>Nebraska</td>
<td>526</td>
<td>51.9</td>
<td>365</td>
</tr>
<tr>
<td>Kansas</td>
<td>165</td>
<td>16.3</td>
<td>51</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>80</td>
<td>7.9</td>
<td>5</td>
</tr>
<tr>
<td>Texas</td>
<td>8</td>
<td>0.7</td>
<td>2</td>
</tr>
<tr>
<td>Total*</td>
<td>1014</td>
<td>100</td>
<td>528</td>
</tr>
</tbody>
</table>

*excludes 1 summer record

Maximum group sizes were similar to those noted above for roosting or feeding sites.

Habitat Characteristics Relative to Site Use, Wetland System

All Records. - Palustrine wetlands accounted for 68.8% of site evaluation records; riverine wetlands accounted for 21.6% and lacustrine wetlands 9.6% of the records (n = 644). However, records from Nebraska dominated these percentages and comprised 50.2% of all records for which we were able to discern wetland system. Only 11 (7.9%) of the 139 riverine records were from outside of Nebraska: Kansas River, Kansas; Popular River, Montana (2 records under 1 main observation); Missouri River (2 in MT, 3 in ND); Souris River, North Dakota (J. Clark Salyer NWR), and Arkansas River, Oklahoma (2 records under 1 main observation). The distribution of observations among wetland systems clearly differed between Nebraska and other states. In Nebraska, the proportions of observations occurring on palustrine and riverine systems were both high (56.0 and 39.6% of state records, respectively), whereas in other states palustrine records accounted for > 75% of records. Only in Montana did the proportion of sightings on rivers (4 of 17, or 26%) approach the proportion observed in Nebraska, but the total number of observations was low.

Roost sites. - Palustrine (58.2%) and riverine (33.3%) wetlands were the predominant wetland systems recorded for roosting cranes; only 11 (7.8%) records were on lacustrine wetlands (n = 141). Observers recorded 4 roost sites as flooded cropland, including 1 site they described also as winter wheat stubble and 1 as milo stubble. They classified all of these latter sites as emergent wetlands with seasonal (2) or temporary (2) water regimes. One site in Gray County, Kansas, they described as a tailwater pit. Another site described as flooded cropland had no wetland system recorded.

Table 2. Distribution of site evaluations among states, overall and by season, and percent of total season observations occurring in each state, 1977-1999. Sample sizes include multiple sub-observations.
Fig. 1. Frequency of crane group sizes (total number of cranes per observation) for spring and fall, 1943–1999.

Fig. 2. Frequency of occurrence (%) of social groups observed in spring and fall, by site use, 1977–1999.
All but 1 of the 47 records of riverine roosts were from Nebraska; the other record was from the Missouri River in Montana. In Nebraska, observer recorded 59.0% of roosts on riverine wetlands, 37.2% on palustrine, and 3.8% on lacustrine wetlands. In Montana, the riverine record was 1 of only 2 roost observations; the other record was for a palustrine wetland. In the remaining states, palustrine records account for 71–100% of roost sites and lacustrine wetlands for 12.9% of roost sites. No roost sites were described as flooded pasture, wooded creek or draw, or as upland types.

Single families and pairs each comprised >30% of observations on palustrine wetlands; observers recorded relatively few mixed groups or single cranes (Fig. 3). On riverine wetlands, pairs and single adults were most common; family groups (single families [13%] and mixed groups [2%]) were relatively uncommon. Cranes observed on lacustrine wetlands were mostly family groups (54.5% vs. 27.3% nonfamily groups and 18.2% singles). Cranes on palustrine wetlands were somewhat more evenly split between family (42.5%) and nonfamily groups (55.0%), with observers sighting only 2 single cranes (2.5%). On riverine wetlands, 56.5% were nonfamily groups, 28.3% were single cranes, and 15.2% were families. All single adults were recorded on rivers in spring.

When we examined all states together, use of wetland systems differed by season (Fig. 4). Observers sighted spring-migrant cranes with similar frequency on palustrine and riverine wetlands but only occasionally on lacustrine wetlands, whereas they observed fall-migrant cranes primarily on palustrine wetlands and infrequently on lacustrine and riverine wetlands. These seasonal patterns are largely driven by the large number of observations of cranes in Nebraska on the Platte, Niobrara, Middle Loup, and North Loup rivers in spring. In Nebraska alone, riverine sites accounted for 78% of roost site records in spring, and observers noted no cranes roosting on lacustrine wetlands. In fall, half of the records were of riverine wetlands, and 11% were on lacustrine wetlands (Fig. 5). For all other states, there was little seasonal difference; palustrine sites accounted for > 75% of roost records.

Feeding sites. - Most (239 of 306, or 78%) feeding sites were on non-wetland (upland) sites. Where observers sighted cranes feeding on wetlands (n = 67), palustrine wetlands were the predominant system used (86.6%); only 7 (10.4%) records

![Diagram showing roost sites, feeding sites, and dual-use sites by social group and wetland type.](image)

Fig. 3. Frequency of occurrence (%) of social groups observed on palustrine, riverine, and lacustrine systems and upland sites, by site use and season, 1977–1999.
were riverine wetlands and 2 (3.0%) were lacustrine systems (Calamus Reservoir, NE, and Lake Sakakawea, ND). Observers recorded cranes feeding on palustrine wetlands primarily in Nebraska (49.1%) and North Dakota (23.7%); there were ≤ 6 palustrine records for each of the other states (n = 68). Of the 7 riverine records, 4 occurred in fall and 3 in spring. In fall, observers sighted cranes feeding on the Souris River in North Dakota (J. Clark Salyer NWR), and on the South Loup River, North Platte River, and Birdwood Creek (Lincoln County), Nebraska. In spring, they observed cranes feeding on the Middle Loup, Platte, and Niobrara rivers. No sites were described as wooded creek or draw; 4 were described as flooded pasture, and 1 as tailwater pit (6 adults and 1 juvenile, Mead County, KS, in spring). No differences were apparent between seasons (Fig. 4).

Only 2 states had sufficient observations to consider differences among wetland systems within that state. In North Dakota, 87.5% of wetland feeding sites were palustrine, 6.3% were lacustrine, and 6.3% were riverine (n = 16). In Nebraska, 80.6% of wetland feeding sites were palustrine, 16.6% were riverine, and 2.8% were lacustrine (n = 36).

Adult groups, pairs, and single families each comprised about 25% of cranes observed on palustrine wetlands; observers sighted relatively few mixed groups and only 1 single juvenile (Fig. 3). Observers recorded only pairs, groups of adults, and 1 single adult feeding on riverine wetlands. Only 2 records of feeding occurred on lacustrine wetlands (1 single family, 1 single adult).

Dual-use Sites. - Palustrine systems (71.0%) again were

the predominant wetland systems used by cranes for both roosting and feeding; use of lacustrine and riverine wetlands were similar (10.9 and 14.1%, respectively; n = 248). Palustrine wetlands accounted for > 67% of dual-use sites in all states. Lacustrine wetlands accounted for 25–28% of such records in North Dakota, Oklahoma, and South Dakota. No sites were described as flooded pasture or wooded draw; 2 were described as tailwater pit (Mead County, KS, and Sedgewick County, KS), and 14 were described as flooded cropland. One of the 14 had further description codes denoting marsh and oat stubble/green rye, 1 as seasonally flooded basin, and 2 as winter wheat.

Use of wetland systems differed somewhat by season (Fig. 4). Observers sighted spring migrants primarily on palustrine systems, with proportionately fewer observations on riverine and lacustrine systems. In fall, use of palustrine systems remained similar to that in spring but use of lacustrine systems was somewhat lower and use of riverine systems somewhat higher.

Single families, adult groups, and pairs each comprised 24–31% of cranes observed on palustrine wetlands (Fig. 3). Cranes observed on lacustrine wetlands were largely single families and adult groups. Half of the 10 observations on upland sites were of adult groups. We noted little difference in the distribution of nonfamilies and singles among wetland systems.

Wetland Class

All Records. - Observers defined wetland class as emergent wetlands (50.7% of all records), unconsolidated bottom
(28.4%), aquatic bed (11.2%), and unconsolidated shore (9.3%); they defined 2 (0.4%) as streambed (2 sub-observations for a pair foraging in disked cornfield along unvegetated streambed; Kearney County, NE) (n = 493). Records from Nebraska comprised 61.4% of the data for this variable.

Roost sites. - Observers sighted cranes most often roosting on palustrine wetlands with unconsolidated bottoms and palustrine emergent wetlands (Table 3). No seasonal differences in wetland classes were apparent.

Feeding sites. - Where observers recorded cranes feeding on wetlands, they largely occurred on palustrine emergent wetlands (Table 3). Use of wetland classes differed between spring and fall. Use of unconsolidated bottom sites was lower in spring (3.2% [1]) than in fall (21.7% [5]), and use of emergent sites was higher in spring than in fall (87.1% [27] to 60.9% [14], respectively).

Dual-use Sites. - Palustrine wetlands with emergents or unconsolidated bottoms were the most common wetland classes used by cranes for both feeding and roosting (Table 3). Differences in use of wetland classes between seasons was slight, with a tendency for greater use of aquatic-bed wetlands in fall and unconsolidated-shore wetlands in spring.

Wetland Regime

Roost sites. - Roosting cranes most commonly used wetlands having seasonal and semipermanent water regimes (Fig. 6), although in lacustrine systems, 6 of 11 sites had permanent water regimes. Water regimes of roost wetlands roosting differed seasonally. Observers found many spring migrants roosting on seasonal and semipermanent wetlands (43.1 and 39.7%, respectively), with lesser use of permanent (6.9%) and temporary (6.1%) wetlands. Observations of roosting fall migrants were more equally distributed among water regimes (25.0% permanent, 32.5% seasonal, 17.5% semipermanent, and 25.0% temporary).

Feeding sites. - Feeding cranes used mostly seasonal, semipermanent, and temporary wetlands (Fig. 6). We noted no seasonal differences among permanent, seasonal, semipermanent, and temporary regimes.

Dual-use sites. - The most common water regimes of dual-use sites were seasonal and semipermanent for both spring and fall (Fig. 6). Crane use did not vary seasonally among permanent, semipermanent, seasonal, and temporary wetlands, although there was a trend toward higher use of permanent wetlands in fall than in spring.

Wetland Size

Roost sites. - Observers commonly sighted roosting cranes on large (> 40 ha) wetlands; frequency of occurrence on these larger wetlands was higher in fall than in spring (59% vs. 27%; Fig. 7). Closer examination of the records indicated that the
Table 3. Percent of wetland observations by wetland class: unconsolidated bottom, aquatic bed, unconsolidated shore, or emergent vegetation relative to wetland system, by site use, 1977-1999.

<table>
<thead>
<tr>
<th>Wetland class</th>
<th>Roost sites (N = 108)</th>
<th>Feeding sites (N = 52)</th>
<th>Dual-use sites (N = 180)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Palustrine</td>
<td>Lacustrine</td>
<td>Riverine</td>
</tr>
<tr>
<td>Unconsolidated bottom</td>
<td>9.3</td>
<td>4.6</td>
<td>25.9</td>
</tr>
<tr>
<td>Aquatic bed</td>
<td>8.3</td>
<td>1.9</td>
<td>0</td>
</tr>
<tr>
<td>Unconsolidated shore</td>
<td>0.9</td>
<td>1.9</td>
<td>15.7</td>
</tr>
<tr>
<td>Emergent</td>
<td>31.5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 6. Frequency of occurrence (%) of wetland water regimes, by site use and season, 1977–1999.
frequent use of large wetlands is affected by wetland system and, in fall, by frequent observation of cranes on large, managed wetlands within 3 public conservation areas. Nine of the 10 lacustrine sites were \( > 40 \) ha and the other site was \( > 20 \) ha; most of these sites were reservoirs or human-altered lakes. In palustrine systems, wetlands \( > 40 \) ha accounted for \( 43\% \) of all records (\( n = 77 \)). Observations of roosting cranes on the large wetland management units and reservoirs on Salt Plains NWR, Quivira NWR, and Cheyenne Bottoms State Wildlife Area (SWA) accounted for 27 (35\%) of the 78 records overall, and for 24 (92\%) of the 26 records in fall. When we excluded these 3 areas and Funk Waterfowl Production Area (WPA), which also has large managed wetlands and frequently hosted whooping cranes in fall, we found a more even distribution of palustrine wetland sizes used in both spring and fall (Fig. 8).

The composition of social groups differed somewhat among the 3 pooled wetland size classes (Fig. 9). All mixed groups (\( n = 7 \)) occurred only on wetlands \( > 20 \) ha, but groups of adults were relatively uncommon on these larger wetlands. Single families and pairs comprised the largest proportion of cranes observed on large wetlands.

Feeding sites. - Wetlands on which cranes fed were smaller than those used for roosting or for dual use (Fig. 7). Observers sighted feeding cranes more frequently on wetlands \( < 2.5 \) ha in spring than fall, but occurrence of other wetland sizes were similar between seasons.

The composition of social groups on feeding sites showed greater differences among 3 wetland size classes (Fig. 9) than on sites used for roosting or dual use. Observers found groups of adults least commonly and single families most commonly feeding on large (\( > 20 \) ha) wetlands. As noted for roost sites, we found that single families and pairs comprised the largest proportion of cranes observed on large wetlands.

Dual-use sites. - Similar to roost sites, dual-use sites were most commonly the larger wetlands, and they observed cranes more frequently on wetlands \( > 40 \) ha in fall than in spring (Fig. 7). Use of these large wetlands again was primarily due to frequent observations of cranes on the management units and reservoirs of Quivira NWR (9 of 20 records in spring, 26 of 64 records in fall), Cheyenne Bottoms SWA (1 record in spring, 5 in fall), and Salt Plains NWR (9 records in fall). Lakes and reservoirs accounted for many of the other sites \( > 40 \) ha in fall, but in spring the other sites were large palustrine wetlands on waterfowl production areas (WPAs) or private lands. When we examined only palustrine wetlands and excluded the 4 management areas noted above, we found that cranes occurred on a wide variety of wetland sizes in spring; in fall, \( > 30\% \) of the sites were wetlands \( > 40 \) ha (Fig. 8). There were relatively minor differences in occurrence of social groups on the 3 pooled wetland size classes (\( n = 179 \)) (Fig. 9).

**River Width**

All records. - Observers recorded river width at 117 (84\%) of the 139 riverine sites; 109 of these 117 records (93\%) were for sites in Nebraska. Widths ranged from 36 to 457 m and averaged \( 227 \pm 88 \) (SD) m.

Roost sites. - Widths of rivers at roost sites ranged from 76 to 457 m and averaged 233 \( \pm 84 \) m (\( n = 44 \)). River width tended to be slightly wider in spring (247 \( \pm 86 \); \( n = 31 \)) than in fall (200 \( \pm 74 \); \( n = 13 \)). Occurrence of larger rivers in spring are primarily due to predominance of the Platte River in spring observations (83.3\% of spring riverine observations having a width measurement); in fall, smaller rivers such as the Middle Loup, North Loup, and Niobrara rivers accounted for 7 of the 13 records for river width.

Feeding sites. - We had data on river width for only 4 riverine sites used for feeding, all in Nebraska (1 crane pair on Birdwood Creek, Lincoln County in fall; 3 cranes on Middle Loup River in spring; 1 pair on Platte River in spring; and 4 cranes on Niobrara River in spring). These ranged from 36 (Birdwood Creek) to 274 m wide and averaged 173 \( \pm 100 \) m.

**Water Depth**

All records. - Maximum depths of wetlands on which cranes were observed ranged from 3 to 305 cm and averaged 51 \( \pm 41 \) cm (SD) (\( n = 297 \)). Observers sighted cranes on shallower wetlands in spring (46 \( \pm 32 \) cm; \( n = 161 \)) than in fall (56 \( \pm 50 \) cm; \( n = 136 \)). Specific sites within wetlands where observers sighted cranes feeding or roosting averaged 18 \( \pm 11 \) cm (range 361 cm; \( n = 196 \)).

Roost sites. - Maximum depths of wetlands used for roosting ranged from 8 to 305 cm and averaged 67 \( \pm 54 \) cm (\( n = 69 \)). Wetlands used for roosting in spring (65 \( \pm 35 \) cm; \( n = 40 \)) were similar in depth to those used in fall (69 \( \pm 72 \) cm; \( n = 29 \)). Depths at specific roost sites within the wetland ranged from 5 to 46 cm and averaged 20 \( \pm 9 \) cm (\( n = 41 \)).

Feeding sites. - Maximum depths of wetlands cranes used for feeding ranged from 3 to 107 cm and averaged 31 \( \pm 25 \) cm (\( n = 31 \)). Wetlands used for feeding in spring (24 \( \pm 13 \) cm; \( n = 19 \)) were somewhat shallower than those used in fall (44 \( \pm 10 \) cm; \( n = 12 \)). Depths at specific sites where cranes had been observed feeding ranged from 3 to 30 cm and averaged 12 \( \pm 7 \) cm (\( n = 14 \)).

**Water Quality**

Roost sites. - Overall, observers described 53.1\% of roost
Fig. 7. Frequency of occurrence (%) of wetland size classes, by site use and season, 1977–1999.

Fig. 8. Frequency of occurrence (%) of wetland size classes, by site use and season, 1977–1999, when records from Quivera NWR, Salt Plains NWR, Cheyenne Bottoms SWA, and Funk Lagoon WPA are excluded.
sites as clear, 33.1% turbid, and 13.8% saline (n = 129). Water quality of roost sites clearly varied by wetland system (Fig. 10). Most turbid wetlands were palustrine, although 3 river sites (Niobrara River, Brown County, NE; 2 sites on Platte River near Doniphan, NE) and 7 lakes also were classified as turbid. All sites described as saline were on Salt Plains NWR or Quivera NWR (often Big Salt Marsh), except for 1 site on Stone Lake SWA, South Dakota.

Feeding sites. - Overall, observers described 59.3% of feeding sites as clear, 37.0% turbid, and 3.7% saline (n = 58). The majority of the 46 palustrine sites had clear water, however, data for lacustrine and riverine were sparse (Fig. 10). Saline sites were located on Loucks WPA, North Dakota, and Quivera NWR, Kansas.

Dual-use sites. - Of the 211 dual-use sites with information, observers defined 42.2% as clear, 39.3% turbid, and 18.5% saline. Water quality of dual-use sites clearly varied by wetland system (Fig. 10). Most riverine systems had clear waters whereas a high proportion of lacustrine systems were turbid. Most saline sites were on Salt Plains NWR or Quivera NWR, although there were a number of smaller saline wetlands in North and South Dakota, Kansas, and Nebraska.

Substrate

Roost sites. - Most wetlands used for roosting had soft substrates (38.5% sand, 52.6% soft mud), 7.4% had hard mud substrates, and 1.5% had other substrate types (n = 135). Substrates were closely associated with wetland systems: 95.7% of riverine wetlands (n = 46) had sand substrates, 80.3% of palustrine wetlands (n = 77) had soft mud substrates, and 6 (63.6%) of the 11 lacustrine wetlands had soft mud substrates. Hard mud substrates occurred in lacustrine (n = 3) and palustrine wetlands (n = 7).

Feeding sites. - Most (62.1%) wetlands used for feeding had soft mud substrates; 13.8% had sand, 13.8% had hard mud, and 10.3% had other substrates. Substrate again was closely related to wetland system: 65.2% of palustrine wetlands (n = 46) had soft mud substrates, and 4 of 6 riverine systems had sand substrates. The 1 lacustrine system had soft mud.
Dual-use sites. - Most sites used for both roosting and feeding had soft substrates (23.2% sand, 63.9% soft mud); 8.9% had hard mud, and 4.0% had other substrates. Substrate was closely associated with wetland system: 91.2% of riverine wetlands (n = 34) had sand substrates, 75.9% of palustrine systems (n = 158) had soft mud substrates, 58.3% of lacustrine systems (n = 25) had soft mud substrates, and 29.2% had sand substrates. Hard mud substrates occurred in lacustrine (n = 2) and palustrine systems (n = 18).

Shoreline Slope

Roost sites. - Observers classified most (78.7%) shorelines of roost sites as having a slight slope (1–< 5% slope); they classified 18.5% as having no slope (< 1%), and 2.8% had 5–10% slope (n = 108). The latter included 1 roost site on the Niobrara River (Rock County, NE) and 2 stock ponds (Furnas County, NE; Jackson County, SD).

Feeding sites. - Most (70.7%) wetland shorelines of feeding sites had a slight slope (1–< 5% slope); 17.1% had no slope (< 1%), 9.8% had 5–10% slopes (seasonal wetland in McLean County, ND; Stone Lake [seasonal wetland], SD; and 1 marsh in Sully County, ND), and 1 (2.4%) had > 10% slope (< 6-ha marsh near Gibbon, NE) (n = 41). Nearly all of these records were for palustrine systems. Observers recorded slope for only 1 lacustrine system (pool at Cheyenne Bottoms SWA) and 2 riverine sites (Platte River and Birdwood Creek, NE).

Dual-use sites. - Most (65.4%) wetland shorelines of dual-use sites had a slight slope (1–< 5% slope); 23.5% had no slope (< 1%), 6.2% had 5–10% slope, and 4.9% had > 10% slope (n = 162). Observers classified all 23 riverine sites, 68.4% of lacustrine sites, and 58.3% of palustrine systems at dual-use sites as having 1–< 5% slope.

Dominant Emergent Vegetation

Roost sites. - In riverine systems, observers recorded roosting cranes more often on unvegetated sites than on vegetated sites, but in palustrine sites they observed cranes on sites having a broad range of emergent vegetation types (Table 4). Emergent vegetation characteristics of lacustrine sites were intermediate between those of palustrine and riverine sites. Where vegetation did occur on riverine sites, it usually consisted of grasses or “other.”

Feeding sites. - In riverine systems, observers recorded feeding cranes primarily on unvegetated wetlands, but they also
observed cranes on sites with rush, smartweed, or other vegetation (likely willow) (Table 4). Palustrine sites used for feeding had a broader range of emergent vegetation types.

Dual-use sites. - Emergent vegetation on dual-use sites varied among wetland systems (Table 4). Most riverine dual-use sites were unvegetated. Palustrine wetlands had a variety of vegetation types. Lacustrine systems used for both roosting and feeding tended to be unvegetated or vegetated with cattail or rush.

### Distribution of Emergent Vegetation

Roost sites. - At roost sites, distribution patterns of emergent vegetation varied by wetland system (Fig. 11). Although most riverine sites were unvegetated, palustrine sites often had scattered vegetation. Palustrine sites having clumped or choked vegetation had a variety of vegetation types, with no single type dominating.

Feeding sites. - Distribution patterns of emergent vegetation at feeding sites varied by wetland system (Fig. 11). Although most riverine sites had no vegetation, as noted above, palustrine feeding sites often had scattered or choked vegetation. No vegetation type dominated at palustrine sites.

### Feeding Site Description

All data. - Most sites where observers recorded cranes feeding were in upland crops whereas cranes observed at dual-use sites were more often in wetlands (see below). Seasonally flooded habitat was largely comprised of flooded pasture (47% of records) and seasonal wetlands (42%). Permanent wetlands were largely marshes (30–40%) and reservoirs (30–40%). Observers described 60% of upland cover as pasture. For upland crops, wheat comprised 83% of small grain stubble, corn comprised about 75% of row-crop stubble, and winter wheat comprised 80% of green crops.

Feeding sites. - Most sites where observers recorded cranes feeding were upland crops, with lower occurrence of seasonally flooded wetlands, permanent water, or upland perennial cover (Fig. 12). No cranes were recorded feeding in woodland. Proportions of habitat types varied little between seasons. Although upland crops occurred in similar high proportions in descriptions of both feeding sites and adjacent habitat, it is apparent that cranes were less frequently observed in upland cover or on wetlands than occurred in adjacent habitat (see below) (Fig. 13).

There was little difference in the proportions of social groups observed feeding on permanent wetlands, cropland, and upland cover (Fig. 14). In seasonal wetlands, groups of adults comprised 40% of cranes observed, with fewer pairs than in other habitat types. Single families tended to comprise a higher

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Roost sites</th>
<th>Feeding sites</th>
<th>Dual-use sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Palustrine</td>
<td>Lacustrine</td>
<td>Riverine</td>
</tr>
<tr>
<td>Grass</td>
<td>29.0</td>
<td>10.0</td>
<td>13.3</td>
</tr>
<tr>
<td>Sedge</td>
<td>17.7</td>
<td>10.0</td>
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<tr>
<td>Cattail</td>
<td>19.4</td>
<td>20.0</td>
<td>0</td>
</tr>
<tr>
<td>Rush</td>
<td>24.2</td>
<td>20.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Smartweed</td>
<td>27.4</td>
<td>20.0</td>
<td>0</td>
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<tr>
<td>Other</td>
<td>6.5</td>
<td>0</td>
<td>11.1</td>
</tr>
<tr>
<td>None</td>
<td>30.6</td>
<td>50.0</td>
<td>84.4</td>
</tr>
</tbody>
</table>

N: 62 10 45 1 44 7 23 143 32

Table 4. Frequency (%) of emergent vegetation types, by wetland system and site use. Percentages within a column do not sum to 100% for a wetland system within a site use because more than 1 type often was recorded per site.
ROOST SITES  FEEDING SITES  DUAL-USE SITES

PALUSTRINE

(N=55)  (N=41)  (N=22)

RIVERINE

(N=45)  (N=6)  (N=31)

LACUSTRINE

(N=9)  (N=1)  (N=22)

Fig. 11. Frequency of occurrence (%) of distribution patterns of emergent vegetation, by site use and wetland system, 1977–1999.

FEEDING SITES  DUAL-USE SITES

Fig. 12. Frequency of occurrence (%) of feeding and dual-use sites described as seasonal wetland, permanent wetland, cropland, or upland cover, by site use and season, 1977–1999.
proportion of feeding cranes in cropland and upland cover than in wetlands. When we considered pooled social groups, we found no apparent difference in the distribution of family, non-family, and single groups among feeding habitat types.

In spring, observers most frequently recorded cranes feeding on row-crop stubble, with lesser use of small grain stubble and green crops; < 10% of records were for standing small grain, standing row-crops, or other (Fig. 15). In fall, observers most frequently recorded cranes on green crops, small-grain stubble, and row-crop stubble; they infrequently observed cranes in standing small grain, small-grain or row-crop stubble, or in other habitats such as CRP.

Dual-use sites. - Most dual-use sites were permanently or seasonally flooded wetlands, with lesser use of upland crops; no cranes were recorded feeding in woodland (Fig. 12). Use of seasonal wetlands for both feeding and roosting was somewhat higher in spring whereas use of permanent wetlands and upland crop were higher in fall. Cranes were observed feeding in wetlands more frequently and in upland crops less frequently than occurred in adjacent habitat (see below) (Fig. 13).

Similar to feeding sites, observations of groups of adults on dual-use sites comprised a larger proportion of cranes recorded on seasonal wetlands than on other habitat types. Pairs were the most commonly observed group on cropland and least commonly observed group on seasonal wetlands (Fig. 14). When we considered pooled social groups, we found no apparent difference in the distribution of nonfamily, family, and single groups among feeding habitat types.

At spring dual-use sites, observers recorded cranes with similar frequency on green crops, small-grain stubble, and row-crop stubble but they did not observe cranes on other crop types (Fig. 15). At fall dual-use sites, proportions of crane observations were similar between small-grain stubble and greens crops, with lower frequency of row-crop stubble, and cranes infrequently occurred in standing row crops and other cropland habitat.

**Primary Adjacent Habitat**

Roost sites. - Observers described habitats adjacent to roost sites (≤ 1.6 km) most frequently as cropland (73.8%) and upland perennial cover (69.5%); permanent wetlands (36.2%) and upland cover (30.5%) were also common. We then examined riverine and palustrine systems separately because we suspected the main river roost sites, used primarily in spring (and represented almost entirely by Nebraska records), would differ in occurrence of woodland habitat along the river perimeter. As anticipated, woodland habitat occurred adjacent to > 70% of riverine roost sites but adjacent to < 8% of palustrine roost sites (Fig. 16). All riverine roosts also had adjacent upland cover, whereas only about half of palustrine roost sites had such adjacent cover; however, upland cropland was common. For both wetland systems, seasonal wetlands occurred more frequently in adjacent habitat for spring roost sites, probably reflecting their seasonal occurrence in the landscape, and permanent wetlands occurred more frequently adjacent to roost sites in fall. Upland cropland was more common in spring than in fall, but we caution that the large number of fall records from Cheyenne Bot-
toms SWA, Quivera NWR, and Salt Plains NWR, where habitat adjacent to roosts is more likely to be non-cropland habitat than on private lands, may be a factor in these seasonal differences.

Feeding sites. - The most common habitats adjacent to feeding sites were cropland and upland perennial cover; permanent and seasonal wetlands and woodland were less common (Fig. 13). Occurrences of seasonal wetlands and upland cover in adjacent habitat were higher in spring than in fall. The higher occurrence of woodland in spring likely relates to greater occurrence of feeding observations in spring on Nebraska river

![Fig. 14. Frequency of occurrence (%) of social groups occurring within each type of feeding habitat, by site use, 1977–1999.](image)

![Fig. 15. Frequency of occurrence (%) of cropland types on feeding and dual-use sites, by season, 1977–1999.](image)
systems. Adjacent croplands were most likely to be green crops (winter wheat, alfalfa, winter rye, barley) or row-crop stubble (Fig. 17).

Dual-use sites. - Habitats adjacent to dual-use sites were largely cropland, upland perennial cover, and permanent water areas, with lesser occurrence of seasonally flooded wetlands and woodland (Fig. 13). Occurrence of seasonal wetlands nearby was higher in spring whereas occurrence of permanent wetlands was higher in fall. Upland cover and row-crop stubble were the most common adjacent crop types (Fig. 17).

Similar Habitat Within 16 km (10 mi)

We examined similar habitat within 16 km for all records combined, regardless of site use, because distances between feeding and roost sites usually were much less than 16 km. Observers categorized habitat similar to that of the evaluation site as moderately abundant (41.2%) to abundant (23.3%) within 16 km of the sites, and extent of similar habitat was low for 33.9% of sites (n = 561). Two sites (0.4%) had no similar habitat and 7 (1.2%) were recorded as unknown. Those sites recorded as having no similar habitat included 1 record on or near the Platte River southeast of Kearney, Nebraska (apparently considered a wetland, but no data on system or regime) and 1 record in Sully County, South Dakota, which from other information appeared to be a flooded corn field (recorded as palustrine wetland and corn as emergent vegetation).

Distance to Feeding Sites

Roost sites. - We found no apparent pattern in distances between roost and feeding sites: 28.4% were < 0.40 km, 23.0% were 0.40–0.79 km, 8.1% were 0.80–1.19 km, 16.2% were 1.20–1.6 km, and 24.3% were > 1.6 km from roost sites (n = 74; percentages sum to > 100 because of multiple distances given for a single roost site). However, distances obviously varied with wetland system (Fig. 18). On palustrine roost sites, about two-thirds of feeding sites were < 0.8 km from the roost, likely reflecting wetlands situated in cropland areas, whereas over half of riverine roost sites were > 1.2 km from feeding sites. All riverine roosts that were > 1.6 km from feeding sites occurred on the Platte River (1 in fall, 9 in spring). Roost sites on the Middle Loup and North Loup rivers were usually < 0.8 km from feeding sites. All 5 of the lacustrine records where observers recorded distances to feeding sites were > 1.2 km from the roost.

Feeding sites. - Ten records included distances to feeding sites; we assumed these refer to distance to other feeding sites. Five sites were < 0.40 km, 1 was 0.40–0.79 km, 1 was 0.80–1.19 km, and 3 were > 1.6 km from the first feeding site.

Dual-use sites. - A higher proportion of dual-use sites were < 0.40 km from other feeding sites than for sites used only for
Distance to Human Development

More than two-thirds of sites where observers found cranes were <0.8 km from human developments (32.5% < 0.4 km, 37.5% 0.4 – < 0.8 km), 7.8% were 0.8 to < 1.2 km away, 3.8% were 1.2–1.6 km away, and 7.9% were > 1.6 km away; 10.8% were classified as not applicable (n = 554, using 1 record for each main observation). We noted no apparent differences in distance to human development among roost, feeding, and dual-use sites.

Distance to Utility Lines

Fifty-eight percent of cranes observations were > 805 m from utility (power or phone) lines; 2.5% were < 91 m away, 16.3% were 91–401 m away, and 22.4% were 402–805 m away (n = 362, using 1 record for each main observation). We noted no apparent differences in distance to utility lines among roost, feeding, and dual-use sites.

Visibility

Roost sites. - Overall, observers classified nearly half (48.7%) of roost sites as having visibility of 91–402 m, 28.2% had visibility of < 91 m, 6.9% had 402–805 m, and 16.2% had > 805 m or unlimited visibility (n = 117). Because of the potential influence of trees that are often closely associated with river edges, we separately examined visibility of roost sites by wetland system. Roost sites with the greatest visibility distances were on palustrine and lacustrine areas, whereas riverine roost sites had the lowest visibility distances (Fig. 19). No riverine roost sites were ranked as having visibility > 800 m; woody growth along the shorelines likely limited visibility. We found no difference in the distribution of nonfamily, family, and single groups among visibility classes at roost sites.

Feeding sites. - Observers classified two-thirds of feeding sites (67.0%) as having 91–402 m visibility, 10.7% < 91 m, 10.1% 402–805 m, and 12.2% with > 805 m or unlimited visibility (n = 197). Visibility distances were quite similar among palustrine, riverine, and upland habitats (Fig. 19). The distribution of nonfamily, family, and single groups were similar among visibility classes for feeding sites.

Dual-use sites. - Visibility was < 91 m for 21.9% of dual-
use sites, 91–402 m for 37.7% of sites, 402–805 m for 7.7% of sites, and > 805 m or unlimited visibility for 32.7% of sites (n = 183). Dual-use sites with the greatest visibility distances were on uplands or palustrine wetlands, whereas riverine dual-use sites tended to have the lowest visibility distances (Fig. 19). The distribution of nonfamily, family, and single groups were similar among visibility classes at dual-use sites.

Other Species Present

Roost sites. – Roosting whooping cranes were associated with other bird species in 33.3% of records (47 of 141). They were most commonly associated with sandhill cranes (89.4%) but also were also associated with American white pelicans (Pelicanus erythrorhynchus; 6.4%) and geese (6.4%; included snow geese [Chen caerulescens] and Canada geese [Branta canadensis]). Spring associations with sandhill cranes were primarily on Platte River roost areas (24 of 32); whooping cranes also shared 6 palustrine sites in the Rainwater Basin and other areas with sandhill cranes. In fall, observers found whooping cranes with sandhill cranes on 6 palustrine sites (Quivera NWR and Funk WPA), 1 riverine site, and 4 lacustrine sites. Whooping cranes roosted with geese in 2 palustrine sites in Kansas and 1 in South Dakota.

Feeding sites. – Feeding whooping cranes associated with other bird species in 31.7% of records (97 of 306). They most
We compared habitat types for records where whooping cranes were feeding in association with sandhill cranes and those unassociated with sandhill cranes. Differences were not large but suggested that whooping cranes associated with sandhill cranes had somewhat lower use of seasonally flooded wetlands (14.3% vs. 21.5%) and upland cover (8.8% vs. 11.2%), higher use of permanent wetlands (15.0% vs. 9.9%), and higher use of cropland (82.4% vs. 71.5%) than whooping cranes not associated with sandhill cranes.

Dual-use sites. - Whooping cranes associated with other bird species in 24.2% of dual-use site records (60 of 248). They were most commonly associated with sandhill cranes (85.0%) but also associated with geese (8.3%; included snow goose and Canada geese), American white pelicans (6.5%), great blue herons (3.3%), ducks (3.3%), and swans (1.6%). Spring associations with sandhill cranes occurred on palustrine (n = 10), riverine (n = 6), and upland sites (n = 2). In fall, observers most often found whooping cranes with sandhill cranes on palustrine sites (n = 23) and occasionally on lacustrine (n = 3), riverine (n = 6), and upland sites (n = 2). Observers recorded whooping cranes with white-fronted geese (Anser albifrons) at Medicine Lake NWR, Montana, Canada geese and snow geese in North Dakota (Lake Arena WPA and Divide Co.), and unspecified geese species in Nebraska (Gleason WPA).

We compared habitat types for dual-use site records associated with sandhill cranes and those unassociated with sandhill cranes. For dual-use sites, whooping cranes associated with sandhill cranes had lower use of seasonally flooded areas (17.6% vs. 35.6%) and permanent water areas (43.1% vs. 60.1%), but higher use of cropland (45.0% vs. 19.2%), than whooping cranes not associated with sandhill cranes; use of upland cover was similar (7.8% and 5.0%).

Site Ownership

Private ownership accounted for > 60% of sites used by whooping cranes, followed by federal ownership (Fig. 20). More than 80% of feeding sites were on private land, reflecting the high use of crop fields. Federal ownership accounted for most ownership of roost sites. Seasonal differences were apparent, but they are probably due to the seasonal dominance of observations for some areas, such as the large number of observations on national wildlife refuges in Kansas and Oklahoma in fall but not in spring.

A number of feeding site records indicated multiple ownership (e.g., federal and The Nature Conservancy, federal and private, federal and state). These were situations where the observed crane(s) moved from a tract of land under 1 ownership to a second under a different ownership (W. Jobman, personal communication).

Site Security

Roost sites. - Observers considered most roost sites as secure, but they considered nearly one-third as threatened. Observers recorded > 90% of roost sites that were under federal or state ownership as secure, whereas security of roosts on private lands was evenly split between secure and threatened (Fig. 21). A higher proportion of roost sites in fall were considered secure than those used in spring (83 vs. 53%; n = 139); this likely is related to the more frequent sightings of cranes in fall on national wildlife refuges in Kansas and Oklahoma.

Feeding sites. - Observers recorded few feeding sites as threatened, although most occurred on private lands (Fig. 21). There were no seasonal differences in site security of feeding sites (94% in fall vs. 91% in spring; n = 301).

DISCUSSION

Early studies describing roost sites were generally limited to riverine sites (Aronson and Ellis 1979; Shoemaker et al. 1982; Lingle et al. 1984, 1986), especially along the Platte River and other Nebraska rivers. Studies of broader geographical scope have consistently demonstrated the significance of palustrine wetlands for both roosting and foraging (Howe 1987, Johns et al. 1997, Richert 1999, this study). The site evaluation data indicate that riverine roost sites were common only in Nebraska, primarily on the Platte, Niobrara, Middle Loup, and North Loup rivers. The higher use of riverine roosts in Nebraska may be related to the relatively unique geomorphic characteristics of rivers there, which include shallow, relatively slow-moving channel flows and sand bars with little vegetative cover. The other 2 studies examining flyway-wide habitat use also reported high use of palustrine wetlands. Radio-marked cranes roosted primarily on palustrine wetlands in most areas, and only 2 sites used by radio-marked cranes in the United States were riverine (Howe 1987). In Saskatchewan, 84% of observational records were on palustrine wetlands (Johns et al. 1997). In our study, all social groups of whooping cranes used palustrine wetlands
for both roosting and feeding. However, most of the whooping cranes found on riverine roosts were single cranes or nonfamily groups, particularly on the Platte, although social groups did not differ on feeding or dual-use sites. Richert (1999), using a subset of these data for Nebraska to assess habitat use at several landscape scales, noted that nonfamily groups were the primary social groups associated with the Rainwater Basin and Platte River areas, whereas family groups were more commonly associated with the Table Playa area in Custer County, Nebraska. That area contained a much larger proportion of grassland at both local and landscape scales than did the Rainwater Basin or Platte River areas. Further investigation of other regions of the flyway is needed to determine whether grassland may be an important landscape feature for use by family groups.

Most palustrine wetlands used for roosting were seasonal or semipermanent wetlands; feeding sites also included many temporary palustrine wetlands. Howe (1987) reported radio-marked cranes used intermittently-exposed and semipermanent wetlands more than any other water regimes for both feeding and roosting; they often used temporarily-flooded wetlands in fall. In Saskatchewan, observers most frequently sighted migrant cranes on seasonal and temporary wetlands in spring and on semipermanent and permanent wetlands in fall (Johns et al. 1997). Differences among areas, years, or studies likely were affected at least in part by availability of wetland regimes, which is related to climate variation on seasonal and yearly basis. However, no study has assessed the availability of wetlands with habitat use patterns; therefore, we cannot objectively evaluate wetland selection.

Observers found whooping cranes on a wide range of wetland sizes in both spring and fall. We found no real pattern of use by social groups among the different sizes of wetlands. Observers often found cranes roosting on large managed wetlands (e.g., moist-soil units, impoundments) on state or federal lands in fall, but cranes also used large lakes and natural wetlands in both seasons. Investigators also located radio-tracked cranes on a range of wetland sizes, but over 50% of those cranes were located on wetlands < 1 ha (Howe 1987). Unfortunately, investigators did not consistently record wetland sizes for all wetland sites in that study (Armbruster 1990:9). Although there was no consistent pattern suggesting cranes usually used smaller wetlands for feeding sites, dual-use sites usually were small (< 2 ha) wetlands; the latter might reflect lack of availability of larger wetlands for roosting in those areas. Investigating wetland densities and size classes available around sites, using archival remote sensing data, could reveal a clearer picture of site-use
Observers recorded water depths for either the entire wetland used during a stopover or for the location within the wetland where the cranes had been observed roosting or foraging. Unfortunately, there were no records where both water depths were recorded. Armbruster (1990:8) discussed the significance of shallow water sites for both whooping and sandhill cranes. Average water depths at specific sites within roost wetlands and feeding wetlands were similar to those reported earlier (Lingle et al. 1984, 1986, Howe 1987, Johns et al. 1997), but toward the high end of Johnson and Temple's (1980) optimum water depth of 7.6–20.3 cm (2.2–8.0 inches).

Results of this study also concur with previous findings that cranes usually were associated with sites having scattered or no vegetation (Johnson and Temple 1980, Howe 1987, Johns et al. 1997). Riverine roost sites and dual-use sites were consistent in their lack of vegetation, but feeding sites tended to have more vegetation. Most of the commonly occurring vegetative types were of low stature and thus would not likely obstruct visibility for cranes. Willow, which is of interest relative to island management on the Platte River, was not a defined category, and there were only a few occurrences when willow was specifically denoted under “other” vegetation. We surmise from this that willow probably does not commonly occur on wetlands used by whooping cranes.

Whooping cranes appear similar to sandhill cranes in their frequent use of cropland for feeding, particularly corn and wheat stubble (Howe 1987, Johns et al. 1997, this study). However, data from dual-use sites indicated that wetlands may provide important feeding areas for some whooping cranes. Howe (1987) did not distinguish between feeding-only and dual-use sites for radio-marked whooping cranes. He noted that the importance of cropland for feeding-only sites was likely higher than the 42% he reported because many feeding sites were actually categorized as roost sites. That is consistent with the frequent occurrence of permanently or seasonally flooded wetlands used for both roosting and feeding in this study. The similarity of results between roost and dual-use sites in this study suggests the 2 site uses could be merged for this database. However, we suspect closer examination of sites (i.e., longer observations at a site to verify roost-only or roost-and-feeding activity) may reveal important differences between sites used exclusively for roosting and those used for both feeding and roosting. Roost site characteristics may also differ between sites used as day roosts and as night roosts.

We cannot assess the relative value of cropland, wetland, or...
grassland habitats for foraging cranes with these data because we lack any measure of total time spent feeding in each habitat type. We also do not have data on available habitats around each site. Foraging strategies likely vary depending on season (nutritional needs of cranes, seasonal availability of food), juxtaposition of roost and feeding habitats, availability of habitats, and availability of suitable foods. A more definitive evaluation of the relative use and value of cropland, wetland, and grassland habitats would require a study of color- or radio-marked cranes combined with time-activity budgets, similar to those conducted by Howe (1987) and Lingle et al. (1991). In the latter study, which they conducted in south-central Nebraska, diurnal habitat use was nearly evenly divided between upland and wetland habitats; 37% of bird-hours were on corn stubble, 18% on tilled wetlands, and 17% on natural wetlands. It would be interesting to conduct comparative studies elsewhere in the flyway, particularly in areas with varying proportions of cropland and native habitats. Further examination of the site evaluation data set using GIS also could provide some additional insights into availability of wetland, grassland, or upland habitats relative to site use.

Distance to feeding sites varied with roost type. Palustrine roosts usually were within 0.8 km of feeding sites, similar to distances reported by Howe (1987). Riverine roost sites, however, tended to be farther from feeding sites. Observers recorded distances as categories rather than as a continuous variable, and thus we lack actual maximum distances between roost and feeding sites. Distances between roosts and feeding sites will be influenced by the availability of habitats and foods (e.g., Frederick et al. 1987). On the Platte River, changes in habitat and food availability over time may have increased distances between frequently-used roosts and feeding sites. G. Krapu (U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND, personal communication) has documented that sandhill cranes roosting on the Platte River in the late 1990s flew longer distances to forage in corn fields than they did 20 years previously. He relates this directly to reduced availability of corn in the fields due to improved harvest efficiencies. Palustrine wetlands in the Great Plains often are surrounded by croplands (e.g., Richert 1999, this study). Johns et al. (1997) suggested areas of relatively high wetland density may attract cranes, in particular family groups, and this is suggested by the distribution of whooping crane observations in areas of Oklahoma, Kansas, Nebraska (Table Playa Lakes, Rainwater Basin), and northwestern North Dakota. We recommend using remote sensing and GIS techniques, similar to the work conducted by Richert (1999) for Nebraska, to examine availability and juxtaposition of habitats relative to roost and feeding sites elsewhere in the flyway.

Scientists have long considered horizontal visibility an important aspect defining optimum and secure habitat for whooping cranes (Shenk and Armbruster 1986, Armbruster 1990). However, in nearly half of the roost site records and two-thirds of feeding site records, visibility was < 0.4 km. These distances are within the range given for sandhill cranes on roosts surrounded by vegetation (140 m) or visible from a road (380 m) (Lovvorn and Kirkpatrick 1981). They suggested that sandhill cranes avoid disturbance by maximizing either distance to human development or visual isolation from human activities. This bears further examination for whooping crane migration habitat, particularly for application to habitat management and interpretive development (e.g., placement and management of crane viewing sites). However, such relationships cannot be adequately examined using the site evaluation data. The scale of measures used here were categorical and relatively coarse, and the smallest distance to human development was 0.4 km. Over 80% of the sites were within 0.8 km of some human development. This distribution may reflect a relatively high intensity of human development (most likely section roads) and associated human activity, or it may reflect detectability of cranes. A better sample size of long distances would be needed to test for an interaction between visibility and distances. Moreover, the type of human development was not defined for the site evaluation data forms, although it was in the Nebraska data reporting forms. Cranes’ perception and reactions to, or avoidance of, disturbances likely include a combination of factors such as frequency (e.g., number of vehicles passing per hour), noise level, lighting at night, distance to disturbance source, and visibility of the disturbance and surrounding habitat, and in certain areas also may be influenced by the cranes’ habituation to disturbances. More detailed examination of types of disturbances or human developments and their relationship to visibility would be valuable. A study combining surveys and behavioral observations, such as used in Europe to examine effects of disturbances to field-feeding geese (e.g., van der Zande et al. 1980), would be feasible on the Platte River and other areas of concern.

Whooping cranes are commonly associated with sandhill cranes on both palustrine and riverine wetlands (Johns et al. 1997, this study), but the co-occurrence was most frequent for nonfamily groups on riverine sites, primarily on or around the Platte River in spring. These species likely share some preferences for roost habitat, such as shallow water and open visibility for feeding and roost sites (Lovvorn and Kirkpatrick 1981, Armbruster 1990). Single whooping cranes also may be attracted to sandhill crane flocks because their presence would reflect appropriate habitat and they provide additional sentinels to alert birds to threats.

Private lands provide the vast majority of cropland and wetland habitats used by whooping cranes during migration (Howe 1987, Johns et al. 1997, this study). However, whooping cranes have been observed on a wide variety of state and federal lands over the years, and cranes have used some of these areas frequently. National wildlife refuges, WPAs, and state lands often provide roost locations (large, shallow natural or managed wetlands), and cranes forage on adjacent private croplands. Officials already have designated as critical habitat 3 public areas that have had many observations over the years (Cheyenne Bottoms SWA, Quivira NWR, and Salt Plains
Whooping cranes appear to obtain much of their food on cropland, much like sandhill cranes (Lovvorn and Kirkpatrick 1981, Howe 1987, Johns et al. 1997, this study; but see Lingle et al. 1991). We did not observe a difference among social groups for feeding habitat types as did Johns et al. (1997).

We are reluctant to interpret the results of site security because the meaning of this variable may vary among some observers. For example, S. Kohn (personal communication) had interpreted this term to infer immediate threat to whooping cranes, including the presence of hunters, human disturbances, or threats from utility lines. W. Jobman, however, interpreted this variable to mean that the particular site was threatened with degradation (e.g., drainage, cultivation of wetland or upland habitat). Interestingly, observers considered most feeding sites, which was largely private cropland, as secure. Although availability of croplands is unlikely to seriously decline in the Great Plains in the foreseeable future, grain type and abundance in fields may decline (Krapu et al. 2004). The future quality and security of wetlands used for feeding or roosting are much less clear. Continued loss and degradation of wetlands in intensively-cropped areas of the Great Plains may reduce availability of natural foods and secure roost sites to migrant cranes.

Other biologists have stated the need to better understand habitat selection of migratory species (Lingle et al. 1991, Askins 2000), and interests in studies of migration ecology have increased since the application of remote sensing and GIS has become more prevalent within wildlife research (Butler et al. 1995, Farmer and Parent 1997). Further investigations of whooping crane migration would not only increase the knowledge base about this species, but also would contribute to information about migration in general. The works of Lingle et al. (1991), Armbruster (1990), and Richert (1999) suggest that patterns of habitat selection involve recognition of landscape components. Mapped information from observation data also suggests that habitat selection is influenced by landscape structure. For example, North Dakota data suggest a relationship between whooping crane stopovers and the path of the Missouri River and geomorphic features of the Missouri Coteau. We recommend further work, using remotely-sensed data and other digital databases, such as the NWI and various data layers created for state GAP analyses, to better understand general migration patterns and to investigate relationships between whooping crane sighting locations and landscape features.

**LITERATURE CITED**


BREEDING BIOLOGY OF RE-INTRODUCED NON-MIGRATORY WHOOPING CRANES IN FLORIDA

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Abstract: In the face of record-setting drought, the re-introduced flock of non-migratory whooping cranes in Florida has shown slow but steady progress toward achieving the first natural recruitment to the flock. Fourteen nests were initiated between 1999 and 2002. Two clutches have hatched a total of 4 chicks and 1 chick was raised to fledging. Captive-raised, soft-released whooping cranes have shown that they are capable of forming pair bonds, defending territories, building nests, laying fertile eggs, and hatching and rearing young. The key to the success of the project will be to have enough pairs producing enough young to offset annual flock mortality.

Key Words: breeding biology, Florida, Grus americana, whooping crane

A goal of the Whooping Crane Recovery Plan is to establish a self-sustaining population of 25 pairs of non-migratory whooping cranes in central Florida (in prep.). This necessitates long-term tracking of the flock to monitor for appropriate breeding behaviors. In this paper we describe the breeding biology of this re-introduced flock. Due to record-setting drought, the flock has yet to show significant natural recruitment. However, breeding behavior data that we have collected so far indicate that this is not an unreasonable goal.

METHODS

We tracked soft-released whooping cranes fitted with radio transmitters daily for the first 4-6 months post-release and 2-3 times per week thereafter. During the breeding season we monitored pairs more intensively in order to document breeding behaviors.

In this paper we describe the biological “steps” the cranes made as they progressed toward reproduction, beginning with pairing. For our purposes we identified a pair minimally as a male and female that consistently spent time together, were in close proximity, and whose behaviors were synchronized. Stronger behaviors indicating a pair bond included unison-calling, defending a common personal space or territory, and copulation. The most definitive indicators of a pair bond were nest-building through egg-laying, hatching, and brood-rearing.

RESULTS

Pairing

The first pairing of re-introduced whooping cranes took place in the 1994 breeding season (Table 1) when a female (USFWS band 629-16772) used pre-copulatory postures to attract a male (USFWS band 629-16780), who responded by mounting her back for a second or two (incomplete copulation).

Territory Establishment

In March 1996, the pair set up a territory near Moss Park in Southeast Orange County (just southeast of Orlando). On 3 April 1996 we witnessed and videotaped the pair in full copulation. Since then, observations of territorial whooping cranes showed that copulation took place one to several times each
day, most often early in the morning. After copulating, the pair
unison-called to announce to neighboring cranes that they now
occupied the territory.

Defended territory sites varied substantially in size. The
smallest territories were < 40 ha while others covered > 200
ha. Territorial defense behavior also showed great variation.
Some pairs defended their territories against all other cranes
and even wading birds, while others tolerated sandhill cranes
nearby. The pair that successfully hatched their eggs in 2000
nested within 100 m of an active sandhill crane nest. The close
proximity of those nests was probably facilitated by the high
quality of the habitat.

Nest-building

Re-introduced whooping cranes selected appropriate
breeding habitats consisting of shallow marshes with emergent
vegetation that allowed for nest-building. The first pair began
building nest platforms on 1 April 1996. We routinely saw pairs
build nest platforms a breeding season prior to laying their first
clutch of eggs. Whooping crane pairs, like Florida sandhill
crane pairs, often built several platforms (in the nest marsh) be-
before egg-laying. In 2002 the pair (629-23800/629-23798) that
fledged their chick (the first for the project) built a number of
post-hatching platforms. This was the first time we’ve docu-
mented this behavior and, as far as we know, it has not previ-
ously been described. The post-hatching platforms were built
in new locations as water levels declined in the nesting marsh.
The platforms were primarily used by the crane family for noc-
turnal roosting (the chick rested at night on the platforms, often
being brooded by the female). The platforms also allowed the
female to brood the chick during cool or wet weather during
daylight hours. Finally, the platforms served as places for the
chick to rest during the day on dry substrate while the parents
captured food items to bring the chick.

Egg-laying/incubation

The earliest egg-laying was by a 3-year-old bird (Fig. 1).
Our sample size is not large (19), but it appears that Florida
whoopers begin egg-laying at an age similar to birds in the Wood
Buffalo/Aransas population. The whoopers laid eggs from 11
February – 11 May. Following nest failure on 26 March 2002, a
female re-paired and re-nested (with her new mate) by 22 April
2002. Of 14 clutches we could determine the number of eggs in
10 clutches with some confidence. Seven clutches held 2 eggs
and 3 held one egg.

It was not possible to determine fertility for 7 of 14 failed
clutches due to lack of evidence (no egg remains were found at
nest site). Based on hatching and evidence from eggs recovered
from failed nests we determined that 5 of 7 eggs were fertile.
Two of 14 clutches successfully hatched, resulting in 4 chicks.

We were able to precisely document the timing of nest ini-
tiation and hatch for the successful 2002 nest. The incubation
period for the first egg laid was 29.5 days. The second egg
hatched 2 days later.

A plot of the locations of whooping crane nests shows them
clustered around release sites, especially those in south Osceola
County (Fig. 2). A distant out-lying nest was along the SW
edge of Lake Okeechobee. The pair nested 122 km from the
release site of the male and 118 km from the release site of the
female. Another pair nested in Pasco and Hillsborough Coun-
ties to the W of release sites. It is possible that drought condi-
tions affected how far some pairs were forced to travel before
Fig. 1. Frequency of whooping cranes at age of first breeding in Florida (10 males, 9 females), Wood Buffalo National Park (WBNP, 33 males, 34 females) and Patuxent Wildlife Research Center (PWRC, 22 females). Data for WBNP are from B. Johns (this proceedings) and for PWRC are from J. Chandler.

Fig. 2. Release sites (shaded circles) and nesting locations (asterisks) for 14 pairs of whooping cranes in Central Florida.
settling on a territory.

**Hatch and Brood-rearing**

A pair of re-introduced whooping cranes hatched two chicks in rural Osceola County in March 2000. This was the first hatch for the project. By 10 days post-hatch only one chick remained. The parents raised their chicks within a relatively confined area of the nest marsh, perhaps an area of 1 ha. On several occasions we observed the family making brief visits to a neighboring marsh. However, we never observed them foraging in uplands. The sandhill crane nest near the whooper’s nest hatched before the whooping crane nest; the sandhills daily brought their 2 chicks into adjacent uplands to forage. The male whooping crane interacted (defended an area of the marsh) with that sandhill family and other whooping cranes and sandhill cranes in the area.

By mid-May the nest marsh was nearly dry, the natural drying exacerbated by the continuing drought. The family began walking the chick to various marshes in the area in search of water. On 22 May we captured the chick in order to attach a small radio-transmitter. It was returned to its parents within 15 minutes. Tracking efforts over the next few days showed that the family wandered in search of water and food. By this time almost all marshes in the area were nearly dry. On 25 May we recovered the remains of the chick (68 days of age) which had apparently been killed by a bobcat (*Felis rufus*).

Another pair hatched 2 chicks in March 2002. The second chick survived for only a few hours before it was taken from the nest by a bald eagle. The parents were away from the nest with the first chick at the time. In contrast to the remote site selected by the pair that hatched a clutch in 2000, this pair selected an urban area (city of Leesburg, Lake County) for nesting. The pair nested in a high quality marsh (14 ha) that contained a diversity of wetland plants and water depths. The edge of the marsh bordered on residential yards and the birds did some foraging there, finding primarily earthworms and insects.

Rainy weather brought out nest-building behavior in the parents. Late in the pre-fledging stage (chick 70 days of age), the chick also participated in the nest-building, by positioning the nesting materials that the parents heaped onto the platform.

**Fledging**

The surviving chick from the 2002 hatch, given the name Lucky by project volunteers, took its first flight (30 m distance at 2m off the ground) at 77 days of age. Within 10 days it was an accomplished flier, capable of skillfully flying for several hundred meters. Several feral dogs tested the family on a number of occasions both before and after Lucky fledged. In fact it was on 7 June, when Lucky flew several hundred meters to avoid the attack of a dog that we felt confident that it was time to declare him “fledged”. This was the project’s first chick to be fledged by soft-released parents. It was also the first chick to fledge in the wild in the United States since 1939, when the non-migratory population in Louisiana produced the last chicks.

**DISCUSSION**

The Florida whooping cranes’ age at first egg-laying more closely mirrored what occurs in the Wood Buffalo-Aransas flock, than it does whooping cranes breeding in captivity. This is an important consideration when determining the potential for the population to become self-sustaining.

The breeding season for whooping cranes in Florida (laying date range 11 February-11 May) coincided, not surprisingly, with that of Florida sandhill cranes (1 February – 15 May, Nesbitt 1988). One benefit of a long season is the potential for re-nesting if a first attempt fails. We documented re-nesting in Florida whooping cranes in 2002. Our sample size for determining clutch size was small (n = 10 clutches) but the 7 clutches with 2 eggs and 3 with one egg compared with 454 nests with 2 eggs, 43 with one egg, and 3 nests with 3 eggs for the Wood Buffalo/Aransas flock 1966-1991 (Kuyt 1995).

The Kissimmee Prairie whooping crane flock came into breeding age about the same time that a prolonged drought period began in central Florida. Florida sandhill cranes, during drought, showed low recruitment levels (4% chicks in fall population vs. 13% chicks in non-drought years, unpublished data). During drought, older more experienced sandhill crane pairs probably were the ones that provided what little recruitment was seen. When typical nesting marshes were dry, Florida sandhill cranes nested in low-quality habitats (borrow pits, ditches, canals, lake edges, and even dry ground) or made no attempt to nest. The re-introduced whooping cranes had no prior breeding experience so it came as no surprise that they were unable to recruit new members into the population. First-time nesting attempts by sandhill cranes usually are unsuccessful (Nesbitt et al. 2001).

Several breeding seasons with normal wetland water levels or higher will be necessary before we can judge the breeding potential of the re-introduced flock. Despite the worse drought in historic times, which began in 1998 and continued into 2002, the central Florida flock showed slow but continual progress by demonstrating that captive-reared, soft-released whooping cranes were able to pair, set up territories in appropriate habitat, build nest platforms, lay fertile eggs, hatch young, and raise young to fledging. The key to the success of the project will be to have enough pairs producing enough young to offset annual flock mortality.

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LITERATURE CITED


