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

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

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

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STUDY AREA AND METHODS

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

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

The 3 sites were viewed from blinds on the river bank with 10 × 50 binoculars or a 2X Noctron IV night vision scope. Observations of sandhill cranes were conducted from each blind every third day between 9 March and 15 April. Counts of all birds arriving at or departing from the roosts and the times of arrival or departure were recorded at 5-minute intervals. Evening counts were started 90 minutes prior to sunset and continued until all birds had

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arrived at the roost. The following morning, counts were made of the same roost, beginning 1 hour prior to sunrise and continuing until all sandhill cranes had left the roost or until 90 minutes after sunrise. In this paper, we define "flock" as all birds at 1 roost site during a single night.

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

Statistical tests were excecuted with SOLO (BMDP Statistical Software, Inc. 1988). Differences in departure and arrival times, flock size, and percentage of the flock leaving and arriving at the roost were examined with 1-way analysis of variance (ANOVA). If the ANOVA indicated a difference, Duncan's multiple-range test was used to separate means. Stepwise forward multiple regression (Kleinbaum et al. 1988) was used to compare date and climatological variables to time of initial arrival and departure and time when 11–20, 41–50, and 91–100% of the flock had departed or arrived. These flock sizes were selected to allow us best estimates of site usage. Eight independent variables were included in the analysis of departure and arrival times (Table 1). Initial departure time (IDT) and initial arrival time (IAT) also were used as independent variables in the regression analysis to estimate time at which 11–20, 41–50, and 91–100% of the flock had departed or arrived. Prior to analysis, each angle of the variable WINDDIR was converted to its sine and cosine equivalent (Table 1). Second order polynomial models were developed for arrival times of roosting flocks. Because preliminary analysis indicated collinearity between predictor variables DATE and DATE^2, a mean deviate transformation ($x_i - \bar{x}_i$) was applied to the predictors to reduce collinearity (Kleinbaum et al. 1988, Neter et al. 1989).

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

Variable	Description
DATE[b]	Day of the year, numbered in sequence with 1 January = 1.
DATE^2 [c]	Day of the year squared.
FOG/PREC[b]	Presence or absence of fog or precipitation.
CLOUDCOV[b]	Percentage of sky covered by clouds.
TEMP[b]	Air temperature in degrees C.
FLOCKSZE[a]	Number of sandhill cranes present at a roost on a given date.
WINDSPED[b]	Relative velocity of wind in km/hr.
WINDIR[b]	Direction of wind expressed at 1 of 8 cardinal directions.
SINE WD	Sine of wind direction.
COSIN WD	Cosine of wind direction.
MOON[b]	Fractional illumination of the moon expressed as a value between 0 and 1.
IDT[a]	Initial departure time in minutes before and after sunrise.
IAT[c]	Initial arrival time in minutes before and after sunset.

[a] Independent variable used in the analysis of departure times.
[b] Independent variable used in the analysis of both departure and arrival times.
[c] Independent variable used in the analysis of arrival times.

RESULTS

Estimated size of crane flocks differed among sites. The mean flock size at Site 1 was 1,647 ± 381 (SE) sandhill cranes (range = 355–4,695), whereas the mean flock size at Sites 2 and 3 was significantly larger ($P < 0.05$) at 4,383 ± 936 (range = 404–9,805) and 4,577 ± 878 birds (range = 1,492–13,190), respectively.

Flock Departure

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

Initial departure time varied temporally ($P < 0.0005$). Sandhill cranes left the roosts earlier and for a shorter period during 9–21 March than during 22 March–15 April (Fig. 1). The initial departure time averaged 15 and 23 minutes earlier from 9 to 21 March than during the

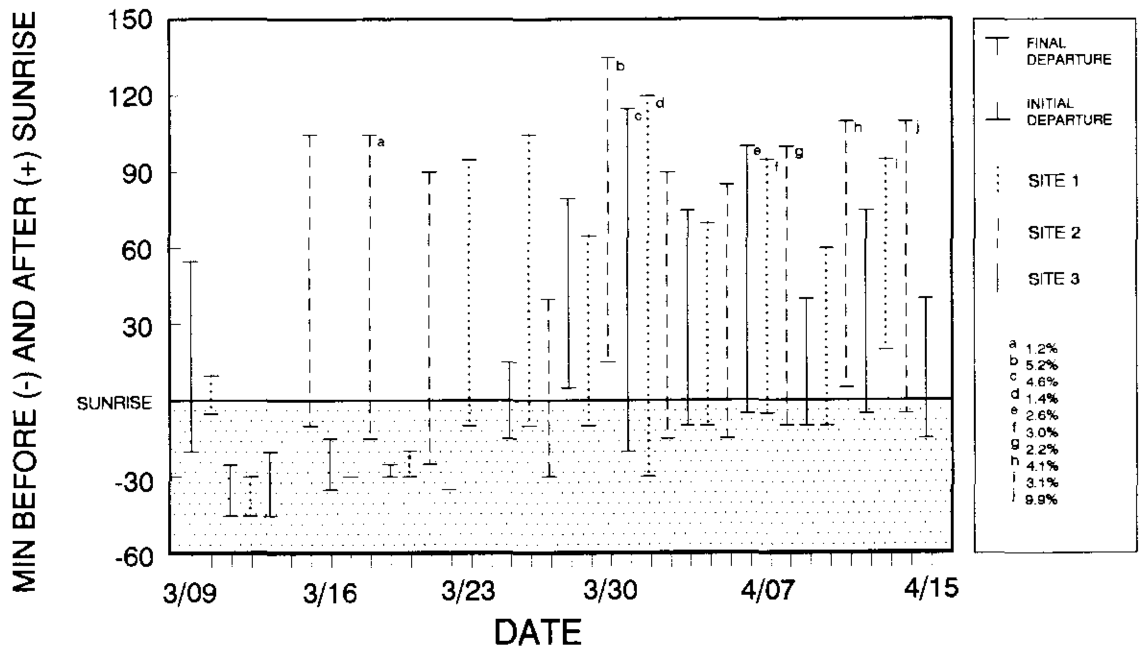

Fig. 1. Seasonal variation in the timing and duration of departure of sandhill cranes from the roost at different sites during spring staging along the Platte River, Nebraska, 1990. Letters a–j indicate the percentage of the flock remaining on the roost subsequent to the final departure time shown.

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

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

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

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

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

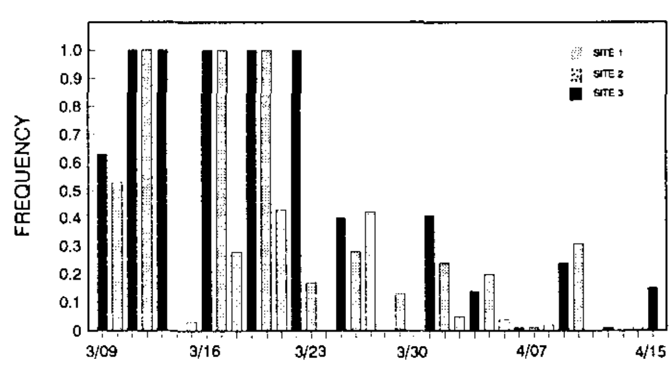

Fig. 2. The influence of the time of the staging season (date) on the proportion of sandhill cranes departing from the roost prior to sunrise at different sites during spring stopover along the Platte River, Nebraska, 1990.

Table 2. Regression equations accounting for variability in departure time (Y) for IDT, T20, T50, and T100 of sandhill cranes from the roost during spring staging along the Platte River, Nebraska, 1990. Departure time is described as time of initial departure (IDT),[a] time when 11–20 (T20), 41–50 (T50), and 91–100% (T100) of the flock had departed. Independent variables are Day of the Year (DATE), Presence or Absence of Fog or Precipitation (FOG/PREC),[b] Air Temperature (TEMP),[c] and Initial Departure Time (IDT).

Dependent variable	R^2	Equation
(IDT)	0.71	Y = −85.98 + 0.78(DATE) + 23.03(FOG/PREC) − 0.72(TEMP)
	0.67	Y = −85.98 + 0.78(DATE) + 23.03(FOG/PREC)
(T20)	0.84	Y = 14.18 + 1.30(IDT)
	0.47	Y = −118.14 + 1.26(DATE) + 17.10(FOG/PREC)
(T50)	0.57	Y = −110.64 + 1.39(DATE) + 33.03(FOG/PREC) − 2.11(TEMP)
(T100)	0.45	Y = 79.76 + 2.15(IDT)
	0.26	Y = −148.15 + 2.24(DATE)

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

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

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

Flock Formation

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

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

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

Abiotic Factors.—Time of initial arrival highly correlated with date and various climatic variables. Variability in time of initial arrival was best accounted for by DATE, $DATE^2$, CLOUDCOV, and TEMP (Table 3).

Time when 11–20% of the flock had formed highly correlated with IAT ($r = 0.97$). The variables DATE,

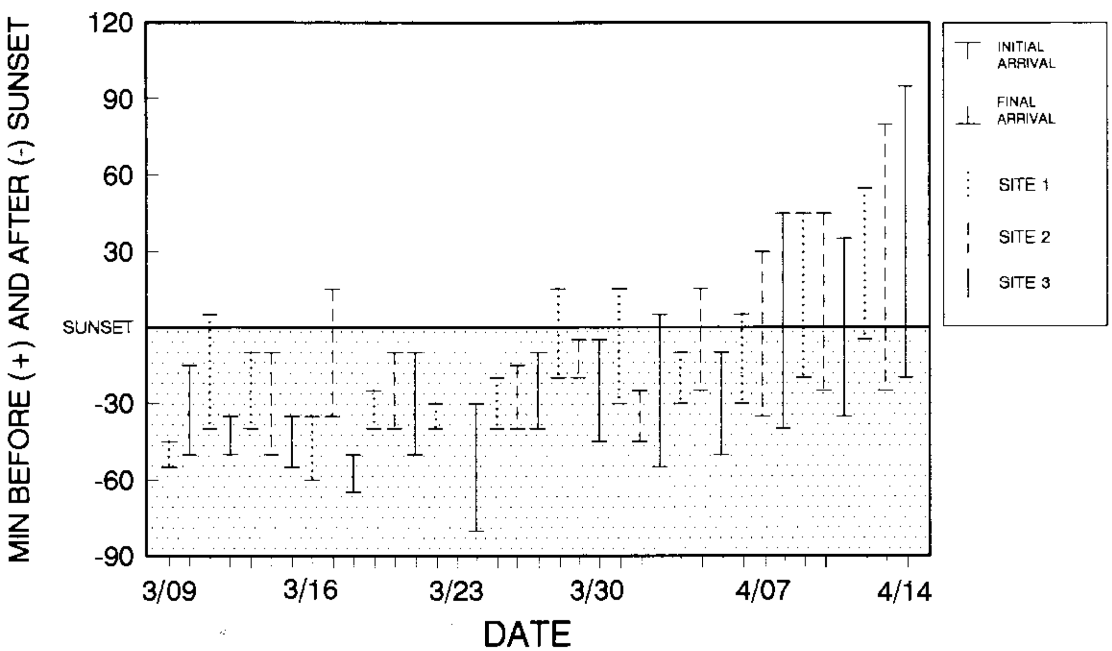

Fig. 3. Seasonal variation in the timing and duration of arrival of sandhill cranes at the roost among different sites during spring staging along the Platte River, Nebraska, 1990.

DATE^2, CLOUDCOV, and TEMP in combination also accounted for substantial variability in time at which 11–20% of the flock arrived at the roost and positively related to arrival time (Table 3).

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

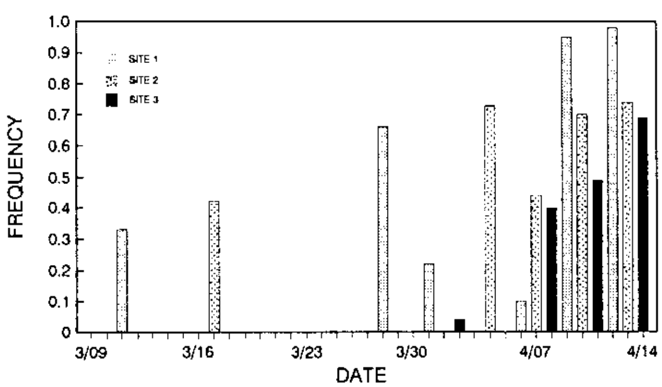

Fig. 4. The influence of the time of the staging season (date) on the proportion of sandhill cranes arriving at the roost prior to sunset at different sites during spring stopover along the Platte River, Nebraska, 1990.

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

DISCUSSION

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

Flock Departure

Daily departure rates differed among the 3 sites. Why sandhill cranes remained on 1 roost (Site 2) longer than on either of the other 2 sites is unknown, but cranes arrived at Site 2 a full week later than at the other 2 sites.

Initial departure times varied temporally. Sandhill

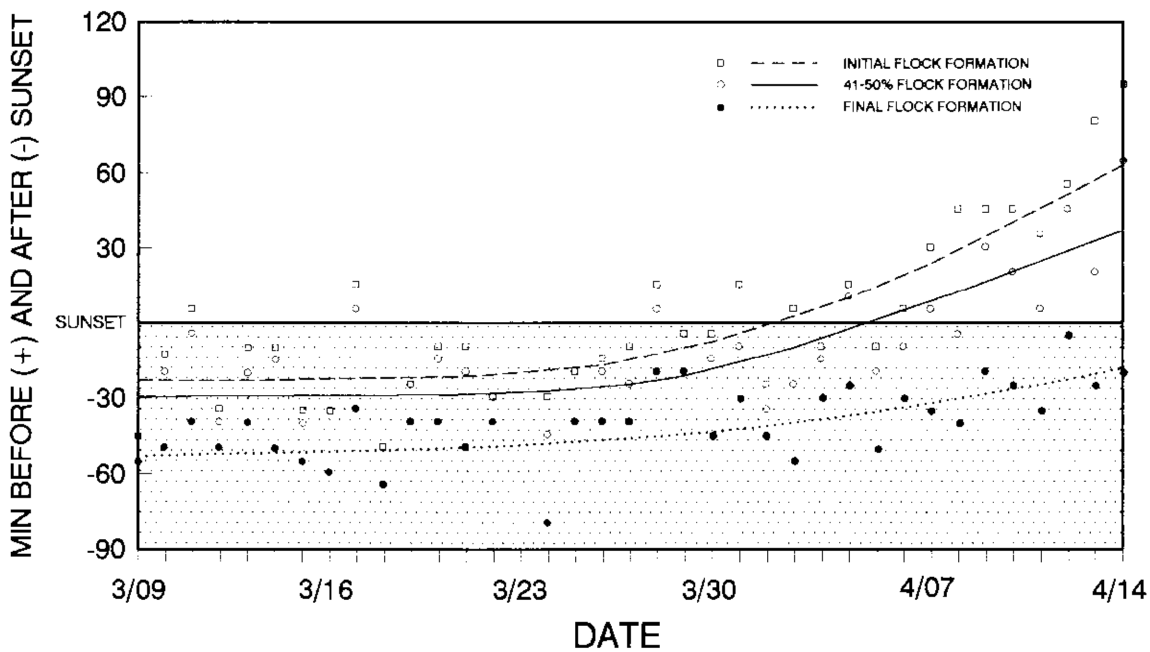

Fig. 5. Seasonal trend in the time of initial, mid, and final flock formation and the relative arrival rates (between lines) of sandhill cranes during their spring staging along the Platte River, Nebraska, 1990. Open squares denote initial arrival times; open triangles are times of 41 – 50% flock formation. Open circles depict final arrival times.

cranes were leaving the roost earlier at the beginning of the staging season, as early as 45 minutes before sunrise. Frith (1974) observed sandhill cranes leaving roosts along the Platte River as early as 2 hours before sunrise. The time of initial departure during the end of the staging season averaged 23 minutes later than at the beginning. Iverson et al. (1987) and Lewis (1974) reported similar initial departure times for sandhill cranes along the North Platte River in Nebraska and in Kansas and Oklahoma. Stephen (1967) found that in Saskatchewan, sandhill cranes began to leave the roost about 23 minutes before sunrise.

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

Flock Formation

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

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

On several occasions, large numbers of sandhill cranes were observed at Site 2 throughout the day. During this time, they were loafing, preening, drinking, and flying back

Table 3. Regression equations accounting for variability in arrival time (Y) for IAT, T20, T50, and T100 of sandhill cranes to the roost during spring staging along the Platte River, Nebraska, 1990. Arrival time is described as Time of Initial Arrival (IAT),[a] time when 11 – 20 (T20), 41 – 50 (T50), and 91 – 100% (T100) of the flock had formed. Independent variables are Day of the Year (DATE), Day of the Year Squared ($DATE^2$), Percent Cloud Cover (CLOUDCOV),[b] Air Temperature (TEMP),[c] and Initial Arrival Time (IAT).

Dependent variable	R^2	Equation
(IAT)	0.86	$Y = -37.44 + 2.54(DATE) + 0.10(DATE^2) + 4.26(CLOUDCOV) + 1.55\ (TEMP)$
(T20)	0.94	$Y = -4.16 + 0.84(IAT)$
	0.79	$Y = -36.78 + 2.09(DATE) + 0.08(DATE^2) + 4.18(CLOUDCOV) + 1.31(TEMP)$
(T50)	0.87	$Y = -12.36 + 0.69(IAT)$
	0.73	$Y = -40.70 + 1.68(DATE) + 0.72(DATE^2) + 3.80(CLOUDCOV) + 1.05(TEMP)$
	0.69	$Y = -33.53 + 1.58(DATE) + 0.93(DATE^2) + 3.54(CLOUDCOV)$
(T100)	0.56	$Y = -30.54 + 0.37(IAT)$
	0.42	$Y = -118.62 + 1.03(DATE)$

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

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

Abiotic Factors

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

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

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