BIOLOGY OF SANDHILL CRANES ON BREEDING AND FALL STAGING AREAS IN NORTHWESTERN MINNESOTA

by

Jodie L. Provost
Bachelor of Science
North Dakota State University, 1988

A Thesis
Submitted to the Graduate Faculty
of the
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Science

Grand Forks, North Dakota
May 1991

This thesis, submitted by Jodie L. Provost in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

Richard D. Crawford
(Chairperson)

[signature]

Stephen J. Mayson

This thesis meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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Date 4-25-91

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ACKNOWLEDGMENTS

I would like to sincerely thank my graduate studies advisor, Dr. Richard Crawford. Despite his busy schedule, he always found time to listen and offer words of advice and encouragement. I am also very grateful to Dr. Stephen Maxson for help with methodology and Dr. Robert Seabloom for serving on my committee.

I am also very appreciative of the support I received from fellow graduate students and faculty in the Biology Department. They made my stay at UND very memorable and enjoyable, as well as educational.

Stan Wood, Randy Prachar, other personnel at the Roseau River Wildlife Management Area, and the Minnesota Department of Natural Resources, also deserve much thanks. The provision of a study site, housing, vehicles, gas, and mechanical assistance, and the friendships which were formed, are all deeply appreciated.

Finally, I would like give a very special thanks to my family. My husband, Tom, was not only very supportive and understanding, but he also endured many hours of mosquito slapping and sweating as a field assistant. If it weren't for Tom, I would surely be a pile of bones in the marsh. My parents Richard and Diane Kohler, sister Andrea, brother

Mitchell, and mother-in-law Judy Zettervall, supported my studies and research whole-heartedly.

Funding for this study was provided by the Minnesota Nongame Wildlife Program, and Biology Department and Graduate School at the University of North Dakota.

ABSTRACT

Sandhill cranes (Grus canadensis) were studied on breeding and fall staging areas in northwestern Minnesota from 1 April 1989 to 21 October 1990. Principal objectives included documenting (1) location, population size and density of breeding cranes, (2) habitat use and preference of nesting cranes, (3) nest success, (4) fledging success, (5) presence, numbers, and locations of nonbreeding cranes, and (6) fall migration chronology.

At least 28 pairs nested on the primary study area (PSA, 111.4 km^2), resulting in a minimum density of 0.25 pair/km^2. Habitat characteristics recorded at nest sites and random sites included wetland classification; basin size; distance to upland, nearest shrub and tree; water depth; concealment by vegetation; plant species and density; and number of shrub clumps and stems within 1.5 m, and trees within 5 m. Except for distributions of distances to nearest shrub for nest and random sites, there were no statistically significant differences between mean values or distributions of variables measured at nest and random sites, and successful and unsuccessful nest sites.

Mean clutch size was 1.88 $\pm$ 0.332 (SD) eggs for 17 clutches in 1989 and 1990. Estimated hatch date for 13 clutches in 1990 ranged from 21 May - 12 June ($\bar{x}$ = 30 May $\pm$

6.6 days [SD] days). In 1990, apparent and corrected nest successes were 73.3% ($\underline{N}$ = 15 nests) and 53.8% ($\underline{N}$ = 14 nests), respectively, and apparent hatching success was 69.2% ($\underline{N}$ = 26 eggs). At least 15 young cranes fledged on the PSA in 1990. Two chicks banded in 1989 were observed on fall staging areas in 1990.

Some of 23 territorial pairs on the PSA, not proven to be breeding, were possibly nonbreeding pairs. Other nonbreeding cranes occurred in groups of 2 - 59 birds and their numbers were highest in mid-May and late July. Upland habitats in which groups were frequently observed foraging included bare or vegetated fallow field, green grain field, and grass or alfalfa hayfield.

Staging of local cranes on the PSA and surrounding secondary study area began in early to mid-August. Migrants arrived by mid-September and roost counts revealed that numbers of staging cranes peaked in mid- to late September. Upland habitats in which flocks were frequently seen foraging included harvested grain field, bare or fallow field, and grass or alfalfa hayfield. In 1990, the percentage of juveniles among staging flocks peaked at 16.4% ($\underline{N}$ = 1,602 cranes) on 15-16 September and the percentage of families with two juveniles was 24.4% ($\underline{N}$ = 623 families). The majority of cranes departed the study areas after goose hunting season began in late September.

INTRODUCTION

Prior to 1875 - 1880, greater sandhill cranes (*Grus canadensis tabida*) nested commonly south and west of the heavily wooded northeastern region of Minnesota (Roberts 1932). However, rapid settlement of the prairie and unregulated market and subsistence hunting resulted in a dramatic decrease in their numbers (Johnson 1976a). By 1900 sandhill cranes were described as rare in Minnesota (Swanson 1940). Drought and subsequent drainage and cultivation of large marshes in the 1930's probably led to further extirpation (Johnson 1976a). Walkinshaw (1949) estimated that only 10 - 25 pairs nested in the state in 1944. Meanwhile, greater sandhill cranes had disappeared from many other portions of their breeding range also. In 1966 this subspecies was officially listed as rare by the U.S. Fish and Wildlife Service.

In the 1950's and 1960's, sightings of sandhill cranes in Minnesota became increasingly frequent in the northwestern and east central portions of the state (Tacha and Tacha 1985). Outside of Minnesota, populations of greater sandhill cranes were also increasing. In 1973, this subspecies was removed from the list of rare and endangered species. In 1985, Tacha and Tacha (1985) estimated the northwestern Minnesota population to be 760 - 1,160 breeding pairs and the east central population to be 87 - 109 breeding pairs. The re-establishment of sandhill cranes in the state can be attributed to protection by the Convention for Protection of Migratory Birds since 1916 (Miller 1987), government land acquisition and restoration of marshes for waterfowl production which increased available nesting habitat (Johnson 1976a), and an increase in public awareness of wildlife conservation in general (Tacha and Tacha 1985). Sandhill cranes are now considered a species of special concern in Minnesota.

In the 1980's the Minnesota Department of Natural Resources (MDNR) realized the need to develop a sound management plan for its growing crane population. Information currently available on sandhill cranes in Minnesota and other information pertinent to their management was compiled, reviewed, and assessed. Research needs concerning the resident population, migration, and habitat requirements were identified (Tacha and Tacha 1985). This study was designed to help fulfill some of those research needs.

The principal objectives of this study included documenting (1) location, population size and density of breeding cranes on the primary study area, (2) habitat use and preference of nesting cranes, (3) nest success,

(4) fledging success, (5) presence, numbers and locations of nonbreeding cranes, and (6) fall migration chronology.

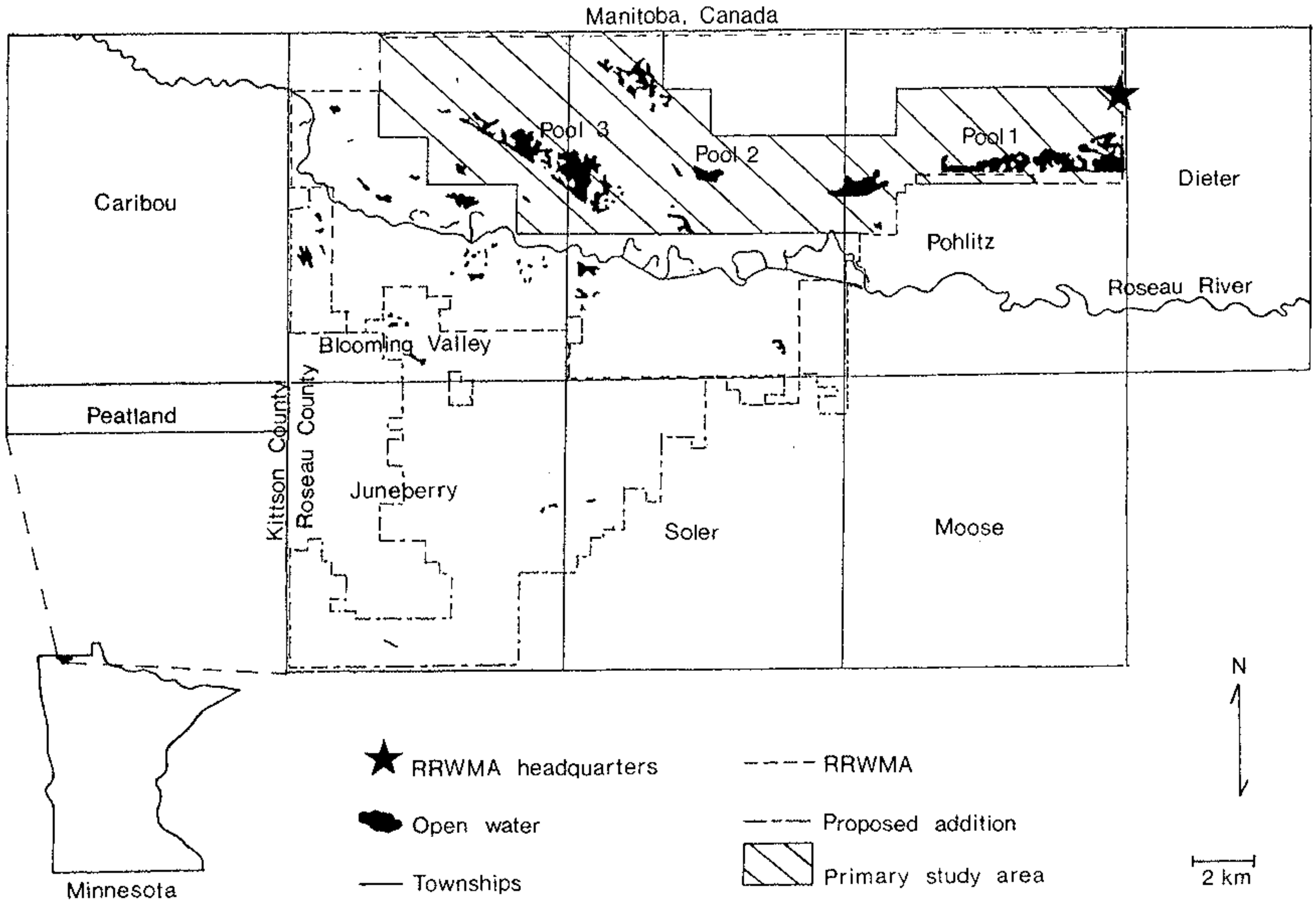
The study was conducted on and adjacent to the Roseau River Wildlife Management Area in northwestern Minnesota from 1 April through 8 October 1989 and 6 April through 21 October 1990. Greater sandhill cranes at this location are likely members of the Coastal Texas population (Drewien and Lewis 1987, DiMatteo, in press).

STUDY AREA

The primary study area (PSA) encompassed 111.4 km^2 and was located on the Roseau River Wildlife Management Area (RRWMA) in Roseau County of northwestern Minnesota (96^0 W, 49^0 N, Fig. 1). It was dominated by saturated, and seasonally and semipermanently flooded emergent wetlands, but scrub-shrub wetland, lowland brush, old fields, agricultural fields, and aspen and conifer stands were also present. Three impoundments (Pools 1, 2, 3), totalling 42.9 km^2, which were supplied by water from a diversion ditch from Pine Creek in Manitoba, Canada, were also located within the PSA. Approximately 4.3 km^2 of open water existed in these impoundments, and the watershed flowed into the Roseau River located south of the PSA. Deep and shallow peat were the principal soil types, but sandy, loam and clay soils were also present (MDNR 1980).

Nonbreeding and staging cranes were observed east, south, and west of the PSA. Subsequently, this surrounding expanse was designated as the secondary study area (SSA, Fig. 1). A portion of this area was located on the RRWMA and on state land which is a proposed addition to the RRWMA. This segment of the SSA included grass/fen, lowland brush,

Figure 1. Location of the primary study area and surrounding secondary study area in northwestern Roseau and northeastern Kittson Counties, Minnesota, 1989-90.


Manitoba, Canada
Caribou
Peatland
Kittson County
Roseau County
Blooming Valley
Juneberry
Pool 3
Pool 2
Pool 1
Soler
Moose
Pohlitz
Dieter
Roseau River
Minnesota
RRWMA headquarters
Open water
Townships
RRWMA
Proposed addition
Primary study area
N
2 km

and wetlands. The remainder was privately owned and was dominated by cultivated agricultural fields. The Roseau River flows west through the SSA.

The climate in northwestern Minnesota is characterized by short, mild summers and long, cold winters. Weather records from 1951 to 1980 for Roseau, located 24 km southeast of the RRWMA, show the average temperatures for January and July are -20.0 C and 19.3 C, respectively. The average growing season is 105 days and killing frosts are expected from mid-September to late May. Average yearly precipitation is 51.8 cm with 75% of it occurring from May to September (National Climatic Data Center, pers. commun.). More detailed descriptions of the RRWMA and the surrounding area are available in MDNR (1980) and Reid et al. (1974).

METHODS

Location, Population Size, and Density of Breeding Cranes

Field work began in early April when cranes first returned from wintering areas. Breeding pairs were located on the PSA in April and May when they were most vocal by listening for unison calls (a series of calls given by a pair of cranes) from one-half hour before sunrise to 2 hours after sunrise and by playing tape-recorded unison calls on a sound amplifier (Callin' Machine, Model WC-12) to elicit vocalizations (Bennett 1978a). They were also located by helicopter when searching for nests (May) and juveniles (August). Walking, all-terrain vehicles (ATVs), and a pickup were utilized throughout both summers for locating breeding pairs. Binoculars and spotting scopes were used to observe cranes. Observation of an active nest, a nest from a previous year, a single crane on territory during the nesting period, very broody pairs, and/or chicks and juveniles indicated that a pair was breeding. Locations of breeding pairs were plotted on a map.

Habitat Use and Preference of Nesting Cranes

Nest searches on the PSA were conducted on foot in May and early June of 1989 and by helicopter for 1 hour on 8 May 1989 and 3 and 3.5 hours on 11 May and 22 May 1990, respectively. During aerial surveys, nests were located by flushing cranes off them. Nest locations were then plotted on a map and marked by dropping weighted flagging tape from the helicopter into a nearby shrub. An observer following in a pickup marked locations on the road nearest to the nests and recorded compass bearings from these locations to the nests by watching the helicopter hover over them. Investigator activity on the first visit to an active nest from the ground included:

1) Marking it with flagging tape placed at least 5 m away.

2) Taking photos of the nest from distances of 2 m and 10 m.

3) Measuring water depth 1 m from the nest edge in each cardinal direction (Urbanek et al., in press).

4) Floating each egg to determine its stage of incubation (S. Swengel, pers. commun.) and to estimate its hatch date.

To prevent excessive disturbance at the nest site, further habitat analyses were conducted during the second visit, which occurred after the estimated hatch date. Data collection during this visit included:

1) Classifying the wetland according to Cowardin et al. (1979).

2) Measuring distance to nearest upland (Urbanek et al., in press).

3) Measuring distance to nearest shrub (1990 only) and tree if they were within 400 m.

4) Measuring water depth 1 m from the nest edge in each cardinal direction again (Urbanek et al., in press).

5) Measuring nest concealment by residual vegetation in each cardinal direction at each of three 33-cm height levels by placing a 25 x 99 cm density board at the nest edge. The board was then observed from a distance of 5 m and an eye height of 1 m. Each height level was divided into 25 rectangles and all rectangles 50% or more visible at each of the 3 height levels were counted. The 4 values for each height level were summed and subtracted from 100 to yield a concealment score for each height (Urbanek et al., in press).

6) Randomly locating a 0.25-m^2 quadrat within each of four 1-m by 5-m strips radiating from the nest edge in each cardinal direction. Within each quadrat, dead, emergent, herbaceous plants were identified and the stems of each plant species were counted.

7) Determining the species, number of clumps, and number of shrub stems 4 mm or more in diameter that were 30 cm above nest level and within 1.5 m of the nest edge (Urbanek et al., in press).

8) Determining the species and number of trees 3 cm or more diameter at breast height within 5 m of the nest edge (Urbanek et al., in press).

Basin sizes and distances to upland too large to measure from the ground were estimated from aerial photos and information in MDNR (1980).

Identical habitat analyses were performed at 1 randomly selected location per nest in 1989 and 2 per nest in 1990. The corresponding random sites were located in the same basin and analyzed on the same day as nest sites. They were located by placing a grid over a map of the basin, numbering all grid squares falling within the basin, randomly selecting a grid square, and locating the center of this square in the basin. A predetermined random direction and distance up to 10 m was then walked from this point. This second location was the random site. These sites allowed for comparison with nest sites and determination of what habitat characteristics nesting sandhill cranes had chosen. Small sample sizes did not allow for statistical testing of percent occurrences of sites in wetland classification categories or percent occurrences of plant species at sites. Means and distributions of variables were compared by using $\underline{t}$-tests and Kolmogorov-Smirnov 2-sample tests, respectively (Sokal and Rohlf 1981, SPSS Inc. 1988).

Nest Success

The second visit to a nest also included determining egg fate. A nest was considered successful if at least one egg hatched. Successful hatches were characterized by small shell fragments without attached membranes in the upper layers of the nest because parents often break shells into small pieces to feed to newly hatched chicks (Johnsgard 1983). Apparent hatching (proportion of eggs which hatched) and nesting success (proportion of nests which were successful) were determined. Mayfield corrected nest success (Klett et al. 1986) was also determined. Evidence remaining at nest sites was examined to determine cause of failure of unhatched eggs (Rearden 1951).

Banding Chicks and Fledging Success

From late June to early September, searches for young cranes were conducted by foot, ATVs, pickup and a 2-hour search of the PSA by helicopter on 1 August 1990. Chicks large enough to hold leg bands were run down, caught, and banded with size 9 aluminum USFWS bands and laminated plastic bands color-coded for the year and county in which they were captured.

Presence, Numbers and Locations of Nonbreeding Cranes

From mid-May through July, cranes observed in groups and not restricted to a particular area were considered nonbreeders. Groups in April and early May may be spring migrants; after early August groups may contain unsuccessful breeders and breeding pairs with juveniles. Walking, ATVs, and a pickup were used to locate nonbreeders on the PSA. On the SSA, a pickup and a 3.3 hour survey with a Cessna 172 from 0708 to 1025 on 9 August 1990 were used to locate nonbreeders. Areas known to be utilized by nonbreeders were checked regularly. Groups were counted and their locations plotted on a map.

Fall Migration Chronology

The location, size, and age structure of groups of cranes on the study areas were closely monitored beginning in early August to determine when resident cranes began staging, when migrants arrived, and when cranes departed for wintering areas. Groups were located by pickup and plotted on a map. Juveniles were easily distinguished by their brown nape feathers and crown feathers (Tacha and Vohs 1984). The tendency of family members to stay within close proximity of one another allowed for their identification (Tacha 1988). Roosts were located and cranes were counted weekly as they departed or returned.

RESULTS

Spring Arrival

The first sandhill crane of the spring was sighted on the RRWMA on 10 April 1989 and 31 March 1990 (RRWMA records). Most pairs returned 10-14 April 1989 and 6-8 April 1990 and immediately occupied their territories.

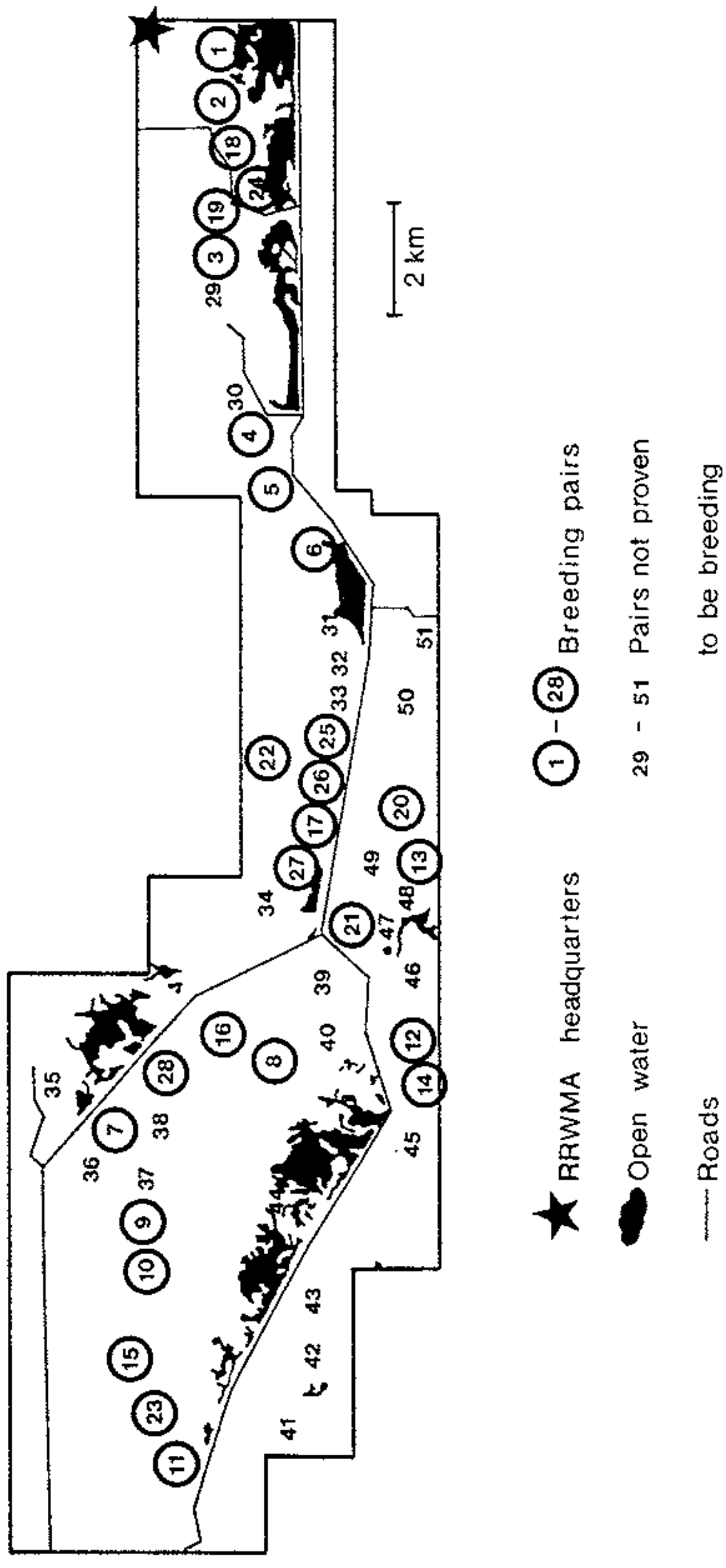
Location, Population Size and Density of Breeding Cranes

Territories occupied by pairs of cranes in 1989 were also occupied by pairs in 1990. At least 28 breeding pairs (1 - 28) were located on the PSA, resulting in a minimum density of 0.25 breeding pair/km^2 (Fig. 2). Pairs 29 - 51 appeared territorial based on unison calls and/or direct observation, but were not proven to be breeding. Density of territorial pairs on the PSA was 0.46 pair/km^2.

Nest Location

In 1989, 2 nests (pairs 7 and 17) were located during the 8 May aerial nest survey. Pair 17's nest was relocated from the ground, but pair 7's nest could not be found again. No active nests were located by searching on foot.

Figure 2. Locations of territorial pairs of sandhill cranes on the primary study area (Roseau River Wildlife Management Area, Minnesota), 1989-90.


2 km
RRWMA headquarters
Open water
Roads
1 - 28 Breeding pairs
29 - 51 Pairs not proven
to be breeding

In 1990, 12 and 5 nests were located on 11 and 22 May, respectively, during aerial nest surveys. Of the 17 nests (pairs 1 - 17), 15 were successfully relocated from the ground. Searches to relocate nests of pairs 5 and 8 were unsuccessful. Pair 7's 1989 nest was discovered 6 June 1990, only 23 m from their 1990 nest site. Pair 17's 1989 and 1990 nests were located approximately 260 m apart. The shortest distance between nests of 2 different pairs (1 and 2, 12 and 14) in 1990 was approximately 800 m.

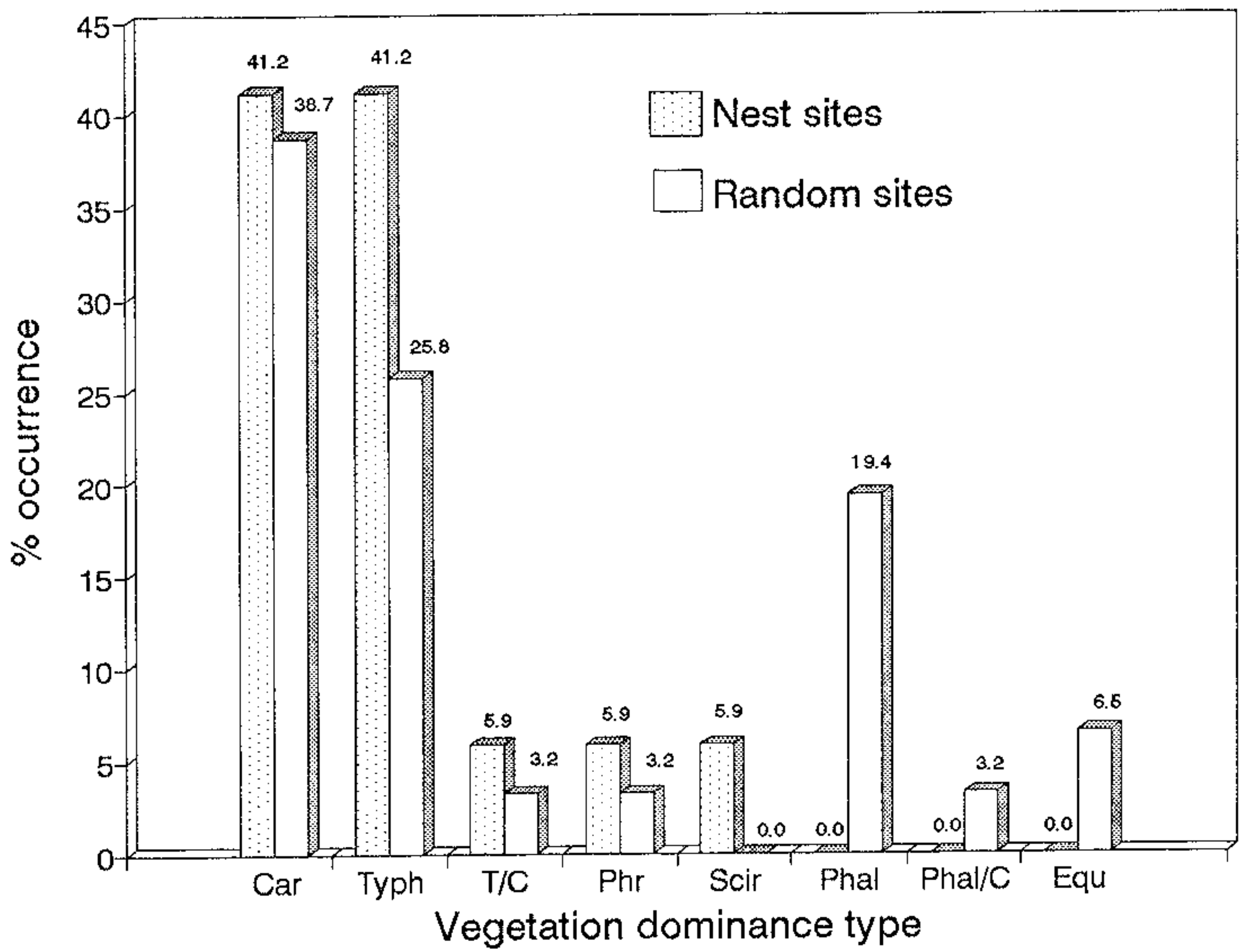
Nesting Habitat Use and Preference

Nest Sites vs. Random Sites

A total of 17 nest site and 31 random site habitat analyses were performed in 1989 and 1990. Data gathered at the sites can be found in Appendices I and II, respectively.

Sizes of nine basins in which nests were located ranged from 0.6 - 1,862.3 ha. All nests and random sites were located in the palustrine system, emergent class, and persistent subclass categories of the Cowardin et al. (1979) wetland classification system. The vegetation dominance types in which they occurred were *Carex* spp., *Typha* spp., *Typha* spp. and *Carex* spp. codominant, *Phragmites australis*, *Scirpus* sp., *Phalaris arundinacea*, *Phalaris arundinacea* and *Carex* spp. codominant, and *Equisetum fluviatile*. The percent occurrences of nest and random sites in these dominance types (Fig. 3) suggest nesting cranes may have

Figure 3. Percent occurrence of 17 sandhill crane nest sites and 31 random sites in vegetation dominance types on the Roseau River Wildlife Management Area, Minnesota, 1989-90 (Car = *Carex* spp., Typh = *Typha* spp., T/C = *Typha* spp. and *Carex* Spp., Phr = *Phragmites australis*, Scir = *Scirpus* sp., Phal = *Phalaris arundinacea*, Phal/C = *Phalaris arundinacea* and *Carex* spp., Equ = *Equisetum fluviatile*).



% occurrence
0
5
10
15
20
25
30
35
40
45
41.2
38.7
41.2
25.8
5.9
3.2
5.9
3.2
5.9
0.0
0.0
19.4
0.0
3.2
0.0
6.5
Nest sites
Random sites
Car
Typh
T/C
Phr
Scir
Phal
Phal/C
Equ
Vegetation dominance type

preferred areas dominated by *Typha* spp. and avoided areas dominated by *Phalaris arundinacea*. Nest and random sites occurred in both seasonally flooded and semipermanently flooded water regimes. There were no large differences between percent occurrences of sites in these water regimes (Fig. 4).

Dead stems of *Typha* spp., *Carex* spp., *Phalaris arundinacea*, *Phragmites australis*, *Scirpus* sp., *Cirsium arvense*, *Scutellaria galericulata*, and *Acorus calamus* were identified within 0.25-m^2 quadrats at nest and random sites. A preference for nesting in *Typha* spp. and avoiding *Phalaris arundinacea* is again suggested (Fig. 5).

Except for distributions of distances to nearest shrub (D = 0.429, P = 0.047; Fig. 6), no significant differences (P>0.05) existed between means (Table 1) or distributions of variables measured at nest and random sites. The range of distances to nearest shrub for nest sites was much narrower (0.0 - 55.5 m, Appendix I) than for random sites (0.0 - 235.0 m, Appendix II) and distances to nearest shrub for nest sites were more evenly distributed than those for random sites which were primarily located in the lower end of the distribution (Fig. 6). All shrubs within 1.5 m of the sites were *Salix* spp.

Some trends are suggested in Table 1. Compared to random sites, nest sites tended to be closer to upland, farther from shrubs, and less concealed by vegetation.

Figure 4. Percent occurrence of 18 sandhill crane nest sites and 31 random sites in water regimes on the Roseau River Wildlife Management Area, Minnesota, 1989-90.

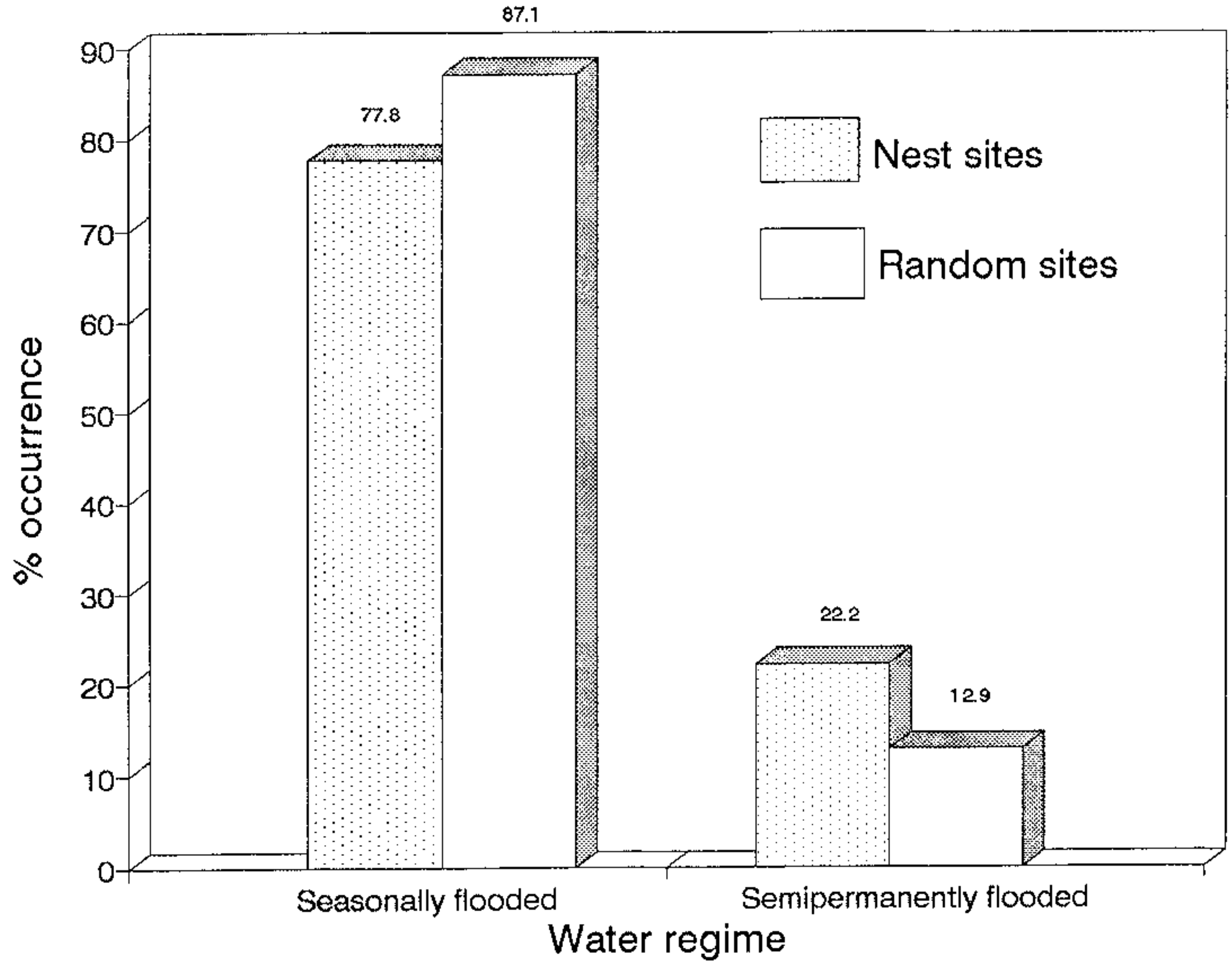
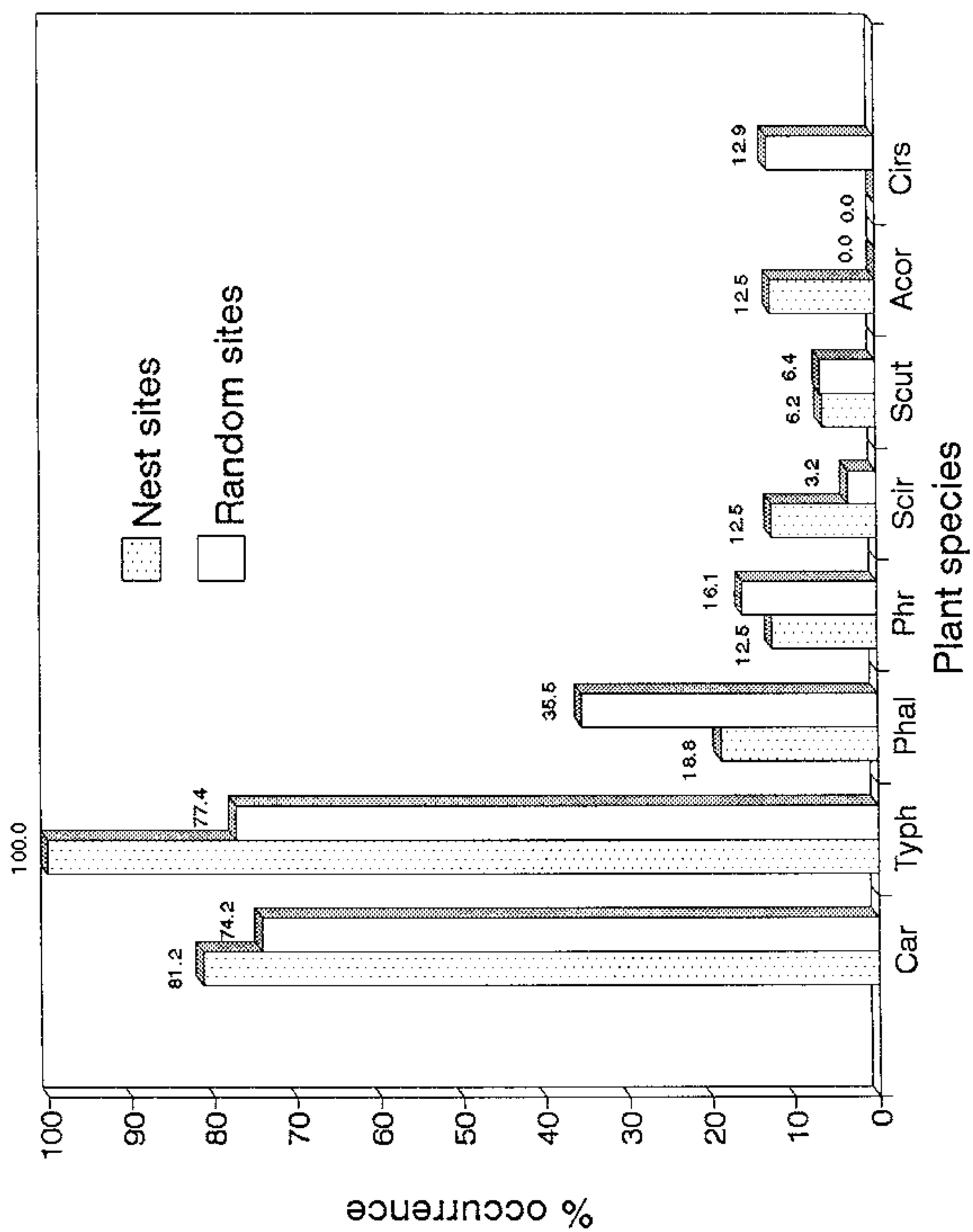

% occurrence
90
80
70
60
50
40
30
20
10
0
77.8
87.1
22.2
12.9
Nest sites
Random sites
Seasonally flooded
Semipermanently flooded
Water regime

Figure 5. Percent occurrence of plant species at 16 sandhill crane nest sites and 31 random sites on the Roseau River Wildlife Management Area, Minnesota, 1989-90. Plant species identified in at least one of four 0.25-m^2 quadrats at each site were included (Car = _Carex_ spp., Typh = _Typha_ spp., Phal = _Phalaris arundinacea_, Phr = _Phragmites australis_, Scir = _Scirpus_ sp., Scut = _Scutellaria galericulata_, Acor = _Acorus calamus_, Cirs = _Cirsium arvense_).



% occurrence
0
10
20
30
40
50
60
70
80
90
100
Nest sites
Random sites
81.2
74.2
100.0
77.4
18.8
35.5
12.5
16.1
12.5
3.2
6.2
6.4
12.5
0.0
0.0
12.9
Car
Typh
Phal
Phr
Scir
Scut
Acor
Cirs
Plant species

Figure 6. Frequency distributions of distance to nearest shrub from 16 sandhill crane nest sites and 27 random sites on the Roseau River Wildlife Management Area, Minnesota, 1989-90 ($\underline{D}$ = 0.429, $\underline{P}$ = 0.047). A random site located 235.0 m from the nearest shrub is not represented.

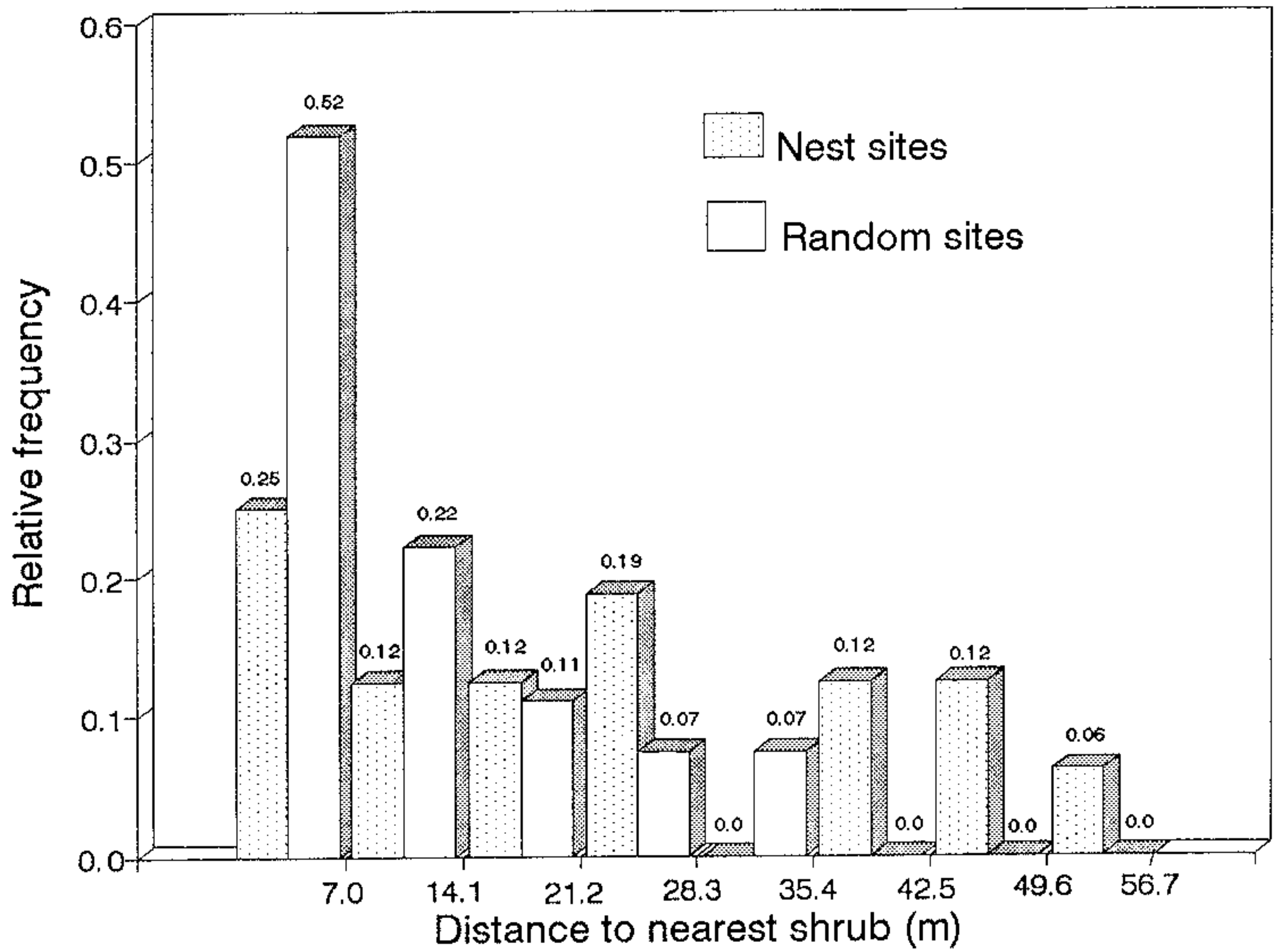

Nest sites
Random sites
Relative frequency
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.25
0.52
0.12
0.22
0.12
0.11
0.19
0.07
0.0
0.07
0.12
0.0
0.12
0.0
0.06
0.0
7.0
14.1
21.2
28.3
35.4
42.5
49.6
56.7
Distance to nearest shrub (m)

Table 1. Mean habitat values at sandhill crane nest sites and random sites on the Roseau River Wildlife Management Area, Minnesota, 1989-90.

	Nest sites			Random sites		
Variable	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Distance to upland (m)	286.9	250.41	17	335.2	246.95	31
Distance to nearest shrub (m)	22.6	17.43	16	17.7	43.77	28
Distance to nearest tree (m)	162.4	84.19	16	163.1	89.54	26
Water depth when found (cm)	12.2	8.98	15			
Water depth when analyzed (cm)	12.9	10.43	16	13.5	15.63	31
Concealment score low	59.3	29.40	16	62.7	31.74	31
Concealment score mid	23.8	22.96	16	31.2	36.75	31
Concealment score high	8.2	14.65	16	12.9	22.55	31
Shrub clumps within 1.5 m	0.7	1.93	17	0.4	0.88	31
Shrub stems within 1.5 m	4.2	15.96	17	3.0	8.41	31
Trees within 5 m	0.0		17	0.0		31
Stems/0.25 m^2 of:						
Typha spp.	11.1	9.90	16	7.1	7.20	31
Carex spp.	28.8	40.96	16	47.0	71.86	31
Phalaris arundinacea	2.3	6.66	16	32.2	63.16	31
Phragmites australis	1.5	4.06	16	1.1	3.19	31
Scirpus sp.	1.4	5.50	16	0.1	0.81	31
Cirsium arvense	0.0		16	0.1	0.23	31
Scutellaria galericulata	0.2	0.94	16	0.1	0.46	31
Acorus calamus	0.4	1.44	16	0.0		31

Nest sites also had a slightly higher density of *Typha* spp. stems and lower density of *Carex* spp. and *Phalaris arundinacea* stems than random sites.

Successful Nest Sites vs. Unsuccessful Nest Sites

Habitat comparisons were made at 12 successful and 5 unsuccessful nest sites. Due to small sample sizes, results must be considered cautiously. Successful nests occurred more frequently in areas dominated by *Typha* spp. and unsuccessful nests occurred much more frequently in areas dominated by *Carex* spp. (Fig. 7). No large differences occurred between percent occurrences of successful and unsuccessful nests in the water regimes (Fig. 8). *Phalaris arundinacea* was present at successful nests more often than at unsuccessful nests (Fig. 9), contradicting expectations based on comparisons of nest and random sites (Fig. 5). However, this may be due to small sample sizes.

There were no significant differences ($P>0.05$) between means (Table 2) or between distributions of variables measured at successful and unsuccessful nest sites. However, several trends are again suggested. Compared to unsuccessful nests, successful nests tended to be closer to upland, farther from shrubs, located in slightly deeper water when found, and more concealed by vegetation at the mid and high height levels. Successful nests also had fewer *Carex* spp. stems/0.25 m^2.

Figure 7. Percent occurrence of 12 successful and 5 unsuccessful sandhill crane nest sites in vegetation dominance types on the Roseau River Wildlife Management Area, Minnesota, 1989-90 (Car = Carex spp., Typh = Typha spp., T/C = Typha spp. and Carex spp., Phr = Phragmites australis, Scir = Scirpus sp.).

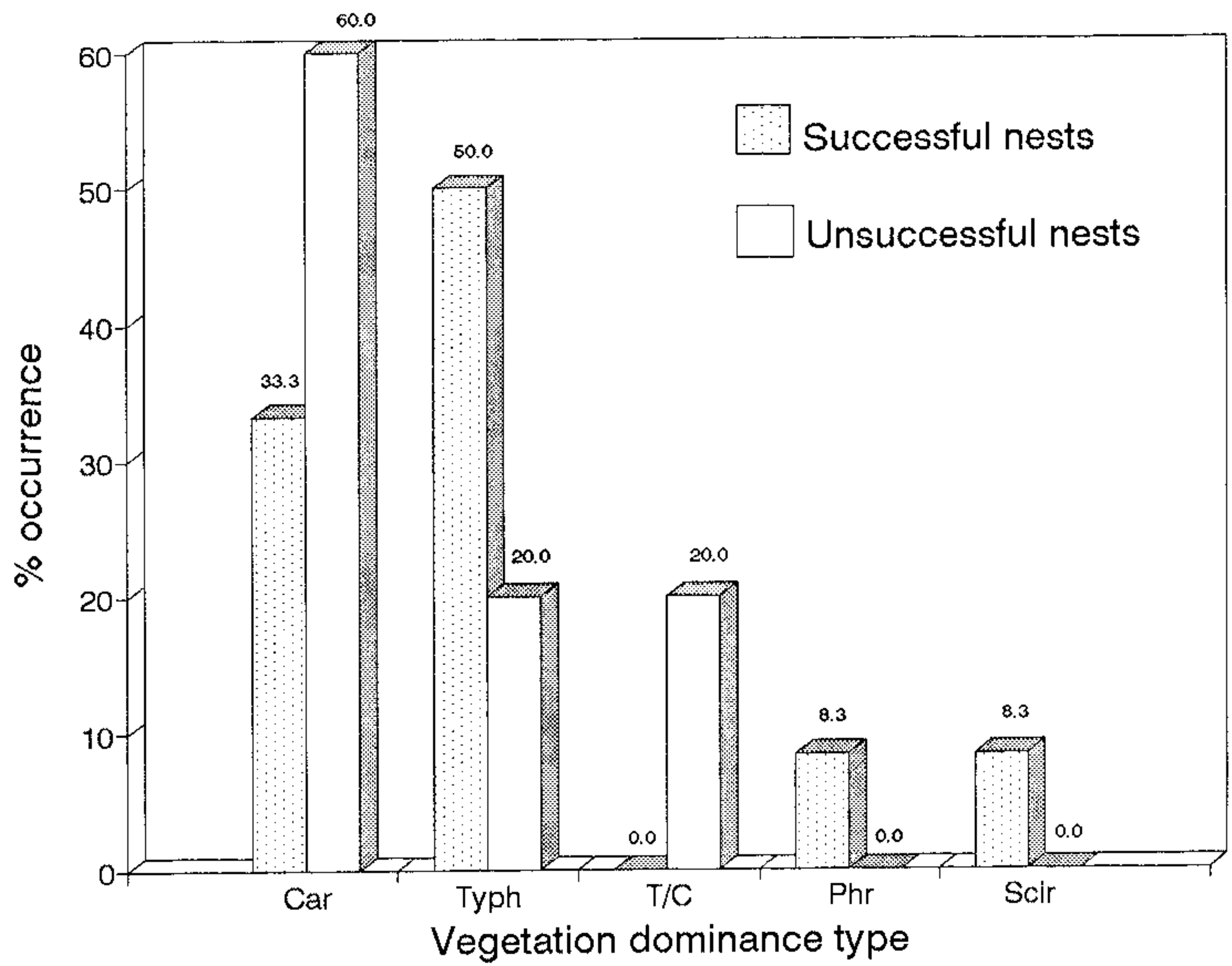
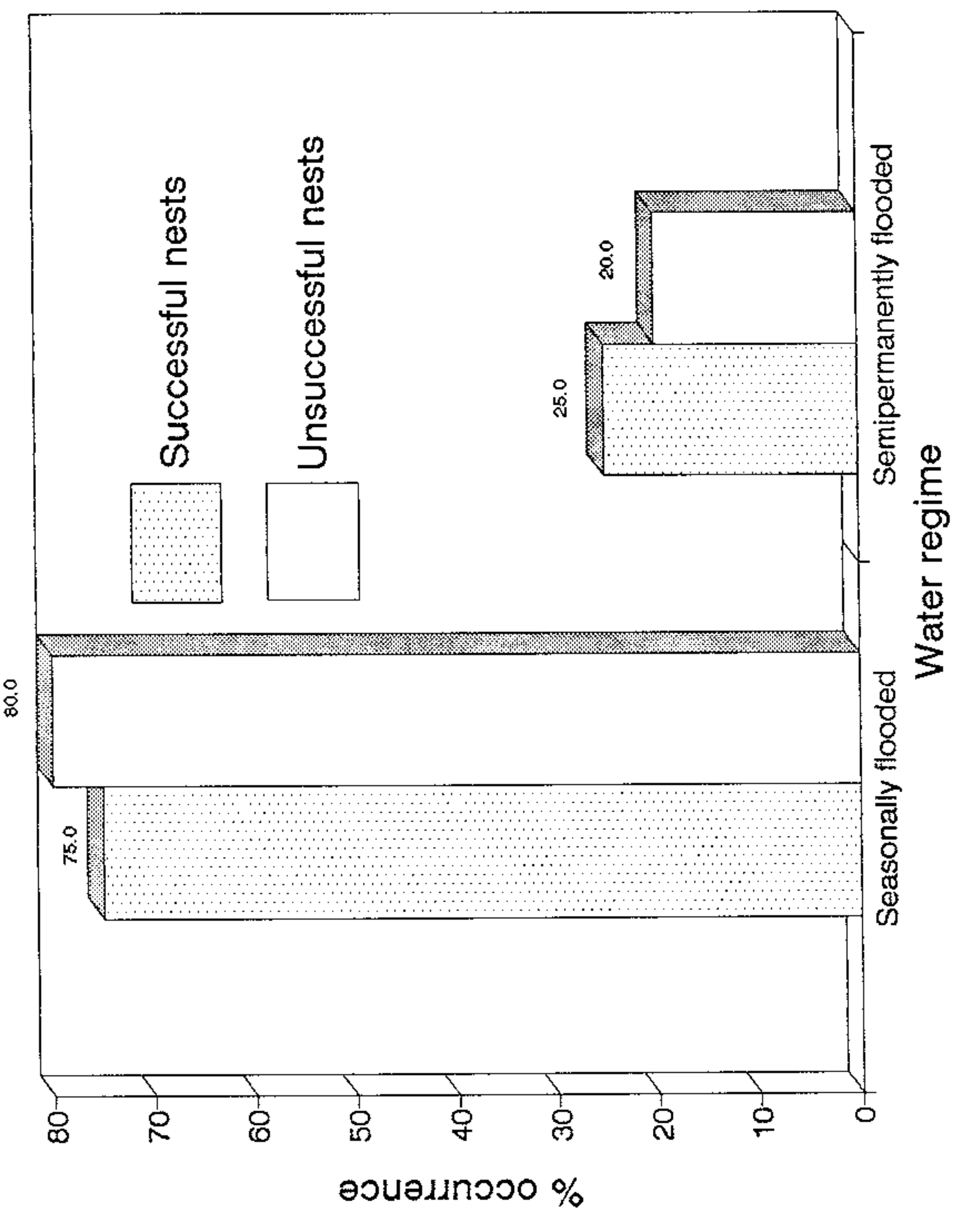
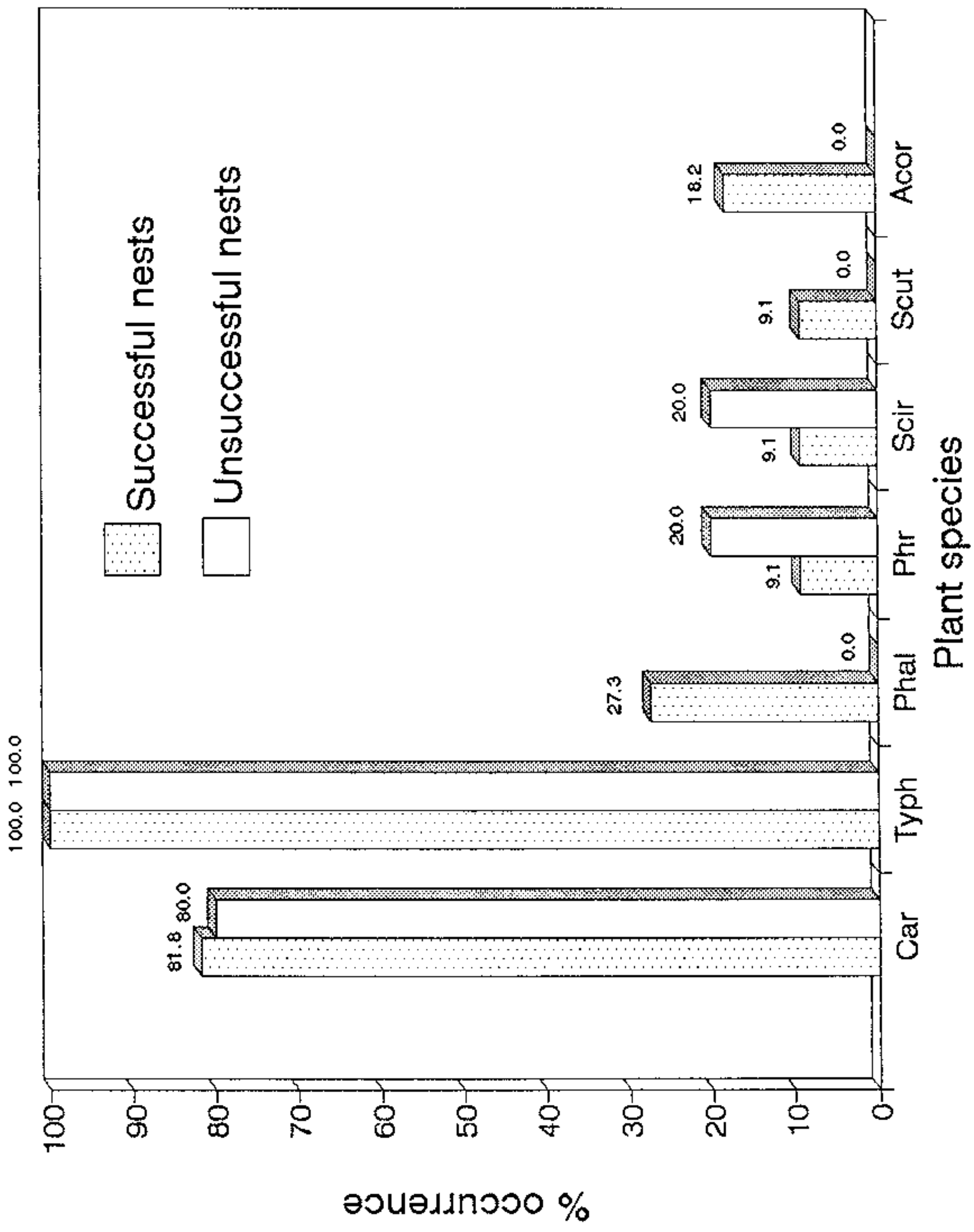

60.0
33.3
50.0
20.0
0.0
20.0
8.3
0.0
8.3
0.0
Successful nests
Unsuccessful nests
% occurrence
0
10
20
30
40
50
60
Car
Typh
T/C
Phr
Scir
Vegetation dominance type

Figure 8. Percent occurrence of 12 successful and 5 unsuccessful sandhill crane nest sites in water regimes on the Roseau River Wildlife Management Area, Minnesota, 1989-90.



% occurrence
0
10
20
30
40
50
60
70
80
Successful nests
Unsuccessful nests
75.0
80.0
25.0
20.0
Seasonally flooded
Semipermanently flooded
Water regime

Figure 9. Percent occurrence of plant species at 12 successful and 5 unsuccessful sandhill crane nest sites on the Roseau River Wildlife Management Area, Minnesota, 1989-90. Plant species identified in at least one of four 0.25-m^2 quadrats at each site were included (Car = *Carex* spp., Typh = *Typha* spp., Phal = *Phalaris arundinacea*, Phr = *Phragmites australis*, Scir = *Scirpus* sp., Scut = *Scutellaria galericulata*, Acor = *Acorus calamus*).



% occurrence
0
10
20
30
40
50
60
70
80
90
100
Successful nests
Unsuccessful nests
81.8
80.0
100.0
100.0
27.3
0.0
9.1
20.0
9.1
20.0
9.1
0.0
18.2
0.0
Car
Typh
Phal
Phr
Scir
Scut
Acor
Plant species

Table 2. Mean habitat values at successful and unsuccessful sandhill crane nest sites on the Roseau River Wildlife Management Area, Minnesota, 1989-90.

	Successful nests			Unsuccessful nests		
Variable	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Distance to upland (m)	281.0	237.46	12	301.0	308.88	5
Distance to nearest shrub (m)	26.5	18.16	12	10.8	8.00	4
Distance to nearest tree (m)	162.5	89.54	12	162.0	77.74	4
Water depth when found (cm)	13.1	9.60	10	10.3	8.29	5
Water depth when analyzed (cm)	12.6	7.94	11	13.7	15.79	5
Concealment score low	59.8	28.49	11	58.2	34.77	5
Concealment score mid	27.6	26.12	11	15.4	11.93	5
Concealment score high	10.3	17.37	11	3.6	3.58	5
Shrub clumps within 1.5 m	0.8	2.29	12	0.4	0.55	5
Shrub stems within 1.5 m	5.6	18.72	12	0.8	1.30	5
Trees within 5 m	0.0		12	0.0		5
Stems/0.25 m^2 of:						
Typha spp.	11.0	8.39	11	11.4	13.84	5
Carex spp.	16.7	20.48	11	55.6	62.79	5
Phalaris arundinacea	3.4	7.91	11	0.0		5
Phragmites australis	1.3	4.22	11	1.8	4.14	5
Scirpus sp.	2.0	6.63	11	0.5	0.11	5
Scutellaria galericulata	0.3	1.13	11	0.0		5
Acorus calamus	0.6	1.72	11	0.0		5

Clutch Size and Laying and Hatching Dates

Mean clutch size was 1.88 ± 0.332 (SD) eggs for 17 known completed clutches in 1989 and 1990. Fifteen nests contained 2 eggs and 2 nests contained 1 egg.

Estimated hatch dates for 13 clutches in 1990 ranged from 21 May - 12 June ($\bar{x}$ = 30 May ± 6.6 [SD] days). Initiation of egg laying ranged from 21 April - 13 May, based on an incubation period which averages 30 days for greater sandhill cranes and begins when the first egg is laid (Johnsgard 1983).

Two chicks, approximately 2 weeks old, found on 10 July 1989, were likely from a second nesting attempt by pair 12. The approximate egg laying and hatch dates for these chicks were 27 May and 26 June, respectively.

Nesting and Hatching Success

In 1989, one nest was successful and the other abandoned. The rediscovery of pair 7's 1989 nest in 1990 revealed it had hatched successfully. Pair 17's nest was relocated on 20 May, but no cranes were present, the eggs were cold, and the nest was beginning to float. The second visit on 30 May revealed a submerged nest and no eggs. Abandonment appeared to be caused by flooding of the nest.

In 1990, 11 of 15 nests had at least 1 egg hatch, resulting in an apparent nest success of 73.3%. Data for 14 nests met the Mayfield Method criteria for estimating nest success, resulting in a corrected nest success of 53.8%.

Of 4 unsuccessful nests in 1990, 2 (pairs 3 and 4) were deserted and empty when revisited, indicating predation. Mammalian predators are suspected because the eggs were removed intact. When pair 16's nest was revisited, no cranes were present and the single egg was cold and lying at the nest edge, indicating abandonment. The fourth unsuccessful nest (pair 2) contained an egg with a dead embryo and another egg with no detectable embryo. These eggs were still being incubated a week past the estimated hatch date.

Except for pair 10, all pairs with successful nests appeared to have all their eggs hatch. For 14 nests with known completed clutches and known nest fates in 1990, 18 (69.2%) of 26 eggs hatched. Four (15.4%) eggs were depredated.

Banding Chicks and Sightings of Banded Cranes

In 1989 and 1990, 3 and 8 (2 siblings) chicks, respectively, were captured and banded. Five were resighted the same year they were banded. The earliest observation of a banded juvenile off its natal territory was 10 August 1989. The farthest they were observed from their natal territories during staging was approximately 2.8 km. Although families with banded juveniles associated with staging flocks ranging in size from 10 - 265 birds, they appeared to separate themselves from the flock by staying at the perimeter. The latest sighting of a banded juvenile on the PSA or SSA was 23 September 1990.

None of the young banded in 1989 were sighted in 1990 until 2 September when 2 were observed in eastern Caribou among a group of 10 cranes. They stood approximately 1.5 m apart and about 4.5 m from them, also within the group of 10, was a juvenile banded in 1990.

Fledging Success

The proportion of chicks which survived to fledge is unknown. Monitoring a pair from nesting through fledging was difficult due to remoteness of most of the study area, tall, dense vegetation, and wariness of the cranes.

The first sightings of young cranes flying well were pair 1's offspring on 20 July 1989, when it was approximately 60 days old, and a juvenile in eastern Caribou on 21 July 1990. In 1989, at least 1 juvenile (pair 1's) was produced on the PSA. In 1990, 6 juveniles (2 sets of siblings) were observed on the PSA from the ground. Based on the absence of bands and their locations, 7 juveniles (3 sets of siblings) observed on the PSA and 3 juveniles (1 set of siblings) observed outside of it during the 1 August aerial survey, were believed to be different juveniles than those seen previously. Due to their location, the latter set of siblings were believed to be the offspring of pair 12 or 14 which nested on the PSA, resulting in the production of at least 15 juveniles on the PSA in 1990.

Presence, Numbers and Locations of Nonbreeding Cranes

Nonbreeding cranes were present on the PSA and SSA in 1989 and 1990 (Fig. 10). On the PSA, nonbreeders were observed from mid-May through July in both years. Some of pairs 29 - 51 (Fig. 2) on the PSA were probably nonbreeding pairs. On the SSA, southern Pohlitz and eastern Caribou were discovered to be utilized by nonbreeders on 8 July and 16 August 1989, respectively. These 2 areas and northwestern Moose received the most regular use by nonbreeders.

The aerial survey on 9 August 1990 was too late to locate only nonbreeding cranes, but it did reveal a field in eastern Caribou that we were unaware of cranes using. Although the aerial search covered agricultural fields, old fields, grass/fen, lowland brush, and wetlands, groups of cranes were only observed in agricultural fields. Upland habitats on the PSA and SSA in which nonbreeder groups were frequently seen foraging included bare or vegetated fallow field, green grain field, and grass or alfalfa hayfield (Table 3).

Nonbreeder groups in central Pohlitz roosted in sedge meadow located north of Pool 1 and Pool 1 on the RRWMA in

Figure 10. Locations of groups of nonbreeding sandhill cranes in northwestern Roseau and northeastern Kittson Counties, Minnesota, 1989-90.

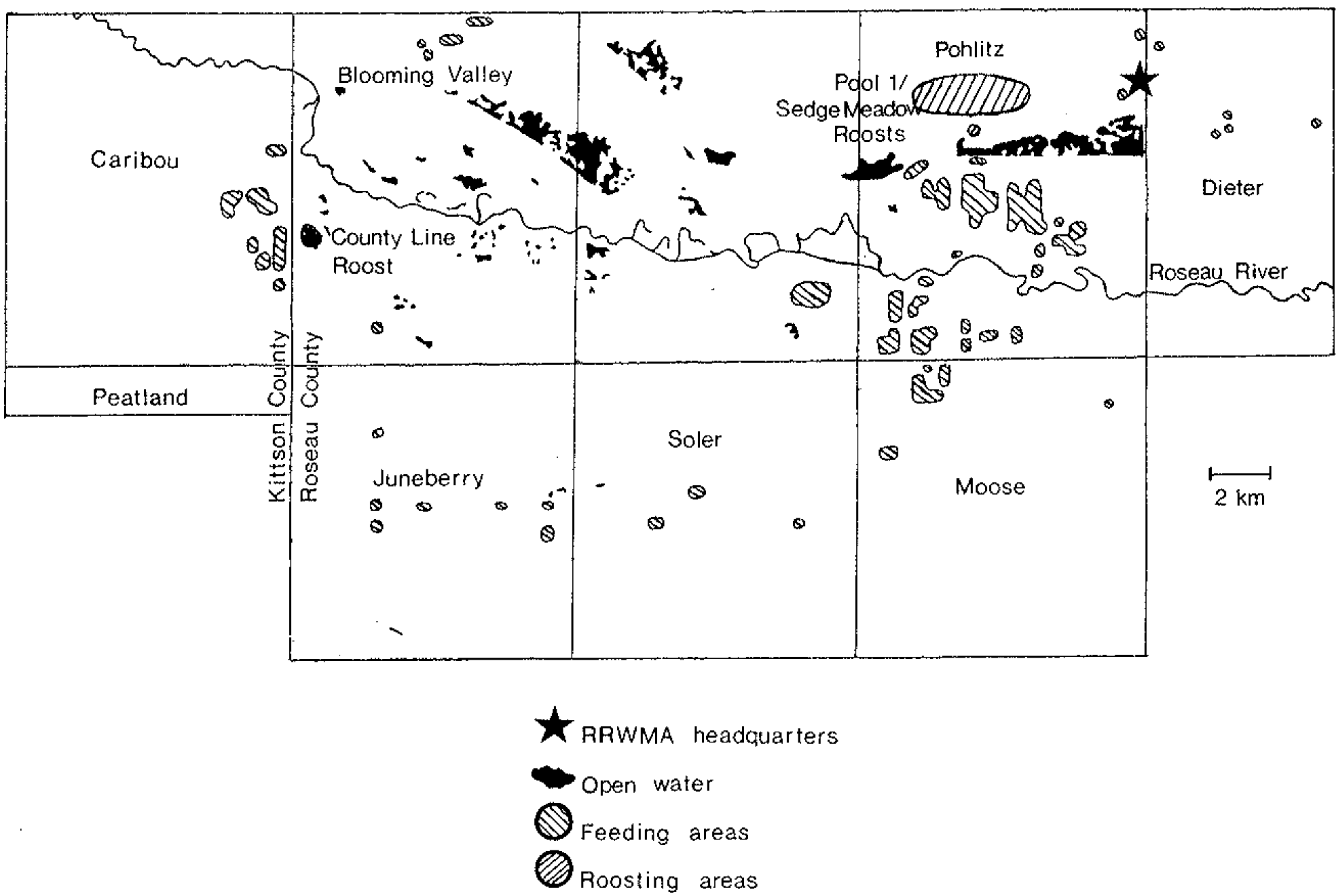

Caribou
Peatland
Kittson County
Roseau County
Blooming Valley
County Line
Roost
Juneberry
Soler
Pool 1/
Sedge Meadow
Roosts
Pohlitz
Moose
Dieter
Roseau River
2 km
RRWMA headquarters
Open water
Feeding areas
Roosting areas

Table 3. Relative frequency of sightings of nonbreeding and staging sandhill crane groups in upland habitats in northwestern Roseau and northeastern Kittson Counties, Minnesota, 1989-90.

	Relative frequency(%) of:	
Habitat	Nonbreeder group sightings (N = 164)	Staging crane group sightings (N = 349)
Grass or alfalfa hayfield	20.1	20.6
Bare or vegetated fallow field	37.8	21.2
Green grain	20.7	2.3
Mature grain	----	2.0
Swathed grain	----	6.3
Harvested grain	0.6	37.5
Pasture	3.0	3.2
Grassland/old field	7.3	2.3
Young sunflowers	2.4	----
Corn	----	0.3
Burned peat	3.7	0.6
Road/ditch	4.3	2.3
Harvested or burned Kentucky bluegrass (*Poa pratensis*)	----	1.4

northern Pohlitz (Fig. 10). Nonbreeder groups in southern Pohlitz and northwestern Moose were observed flying northwest in the evenings and likely roosted in the Roseau River or wetlands on the RRWMA. Groups in eastern Caribou were observed roosting in a wetland immediately to their east in western Blooming Valley (Fig. 10).

In 1989, the maximum number of nonbreeding cranes observed in Pohlitz and northwestern Moose was 98 on 25 July (Fig. 11b). In 1990, maximum numbers observed in Pohlitz and northwestern Moose, and eastern Caribou were 97 on 15 May and 70 on 27 July, respectively (Fig.s 11a, 11b). Nonbreeder group sizes ranged from 2 - 59 birds and groups were often scattered widely in fields. Subgroups of 3 or 4 cranes were often discerned, but pairs were the most frequently observed subgroup.

Fall Staging Areas

Staging cranes foraged in many of the same areas as nonbreeding cranes (Fig. 12). Upland habitats on the PSA and SSA in which groups of staging cranes were frequently seen foraging included harvested grain field, bare or vegetated fallow field, and grass or alfalfa hayfield (Table 3). Flocks of foraging cranes on staging areas reached sizes of up to 1,270 birds during peak migration.

Staging cranes also used some of the same roost sites which nonbreeding cranes had used (Figure 12). As fall

Figure 11a & b. Numbers of nonbreeding sandhill cranes in northwestern Roseau and northeastern Kittson Counties, Minnesota, mid-May through July 1989-90. Only counts in which most nonbreeders were believed to be located, were plotted.

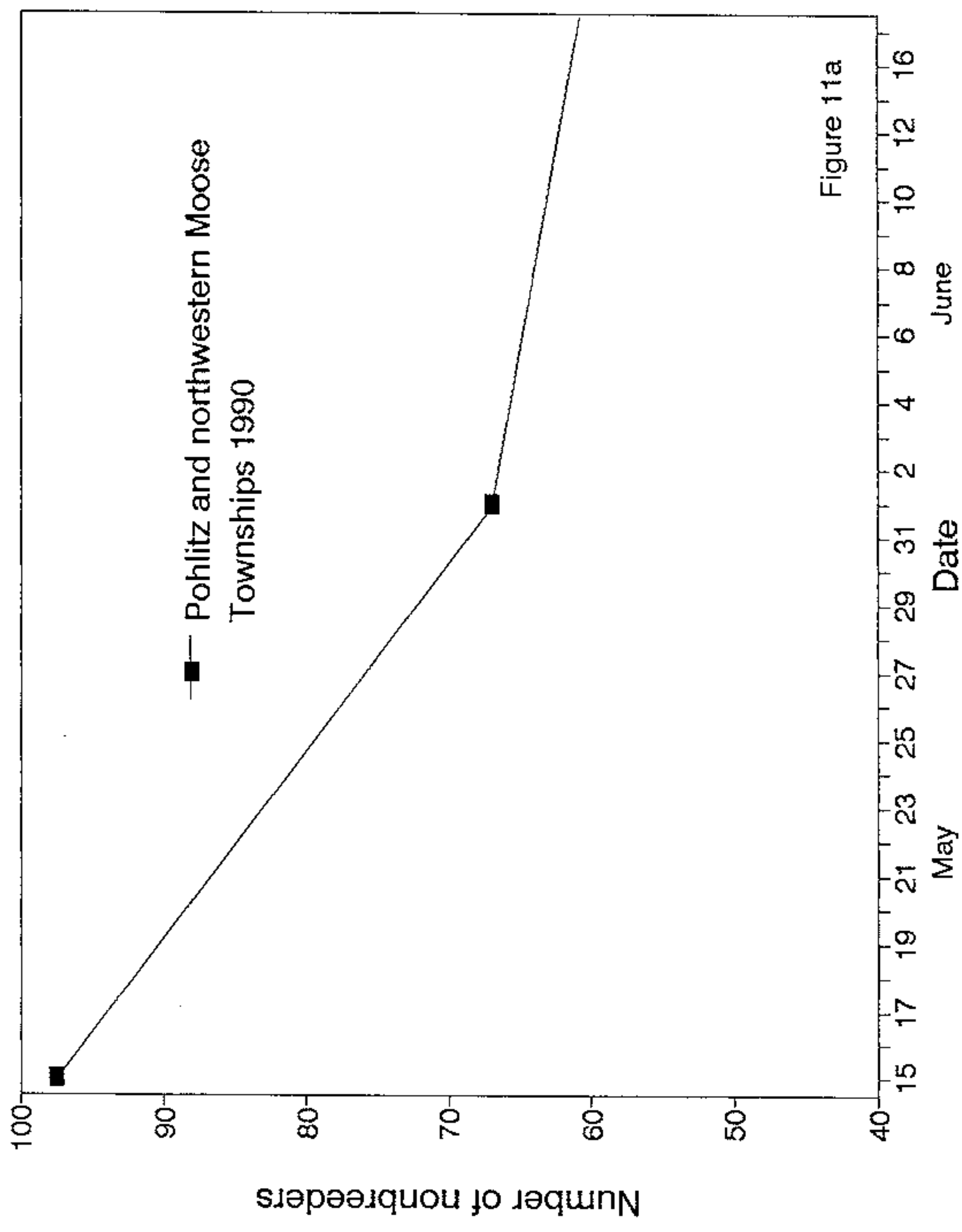

Pohlitz and northwestern Moose Townships 1990
Number of nonbreeders
100
90
80
70
60
50
40
15
17
19
21
23
25
27
29
31
2
4
6
8
10
12
16
May
June
Date
Figure 11a

Figure 12. Locations of fall staging cranes in northwestern Roseau and northeastern Kittson Counties, Minnesota, 1989-90.

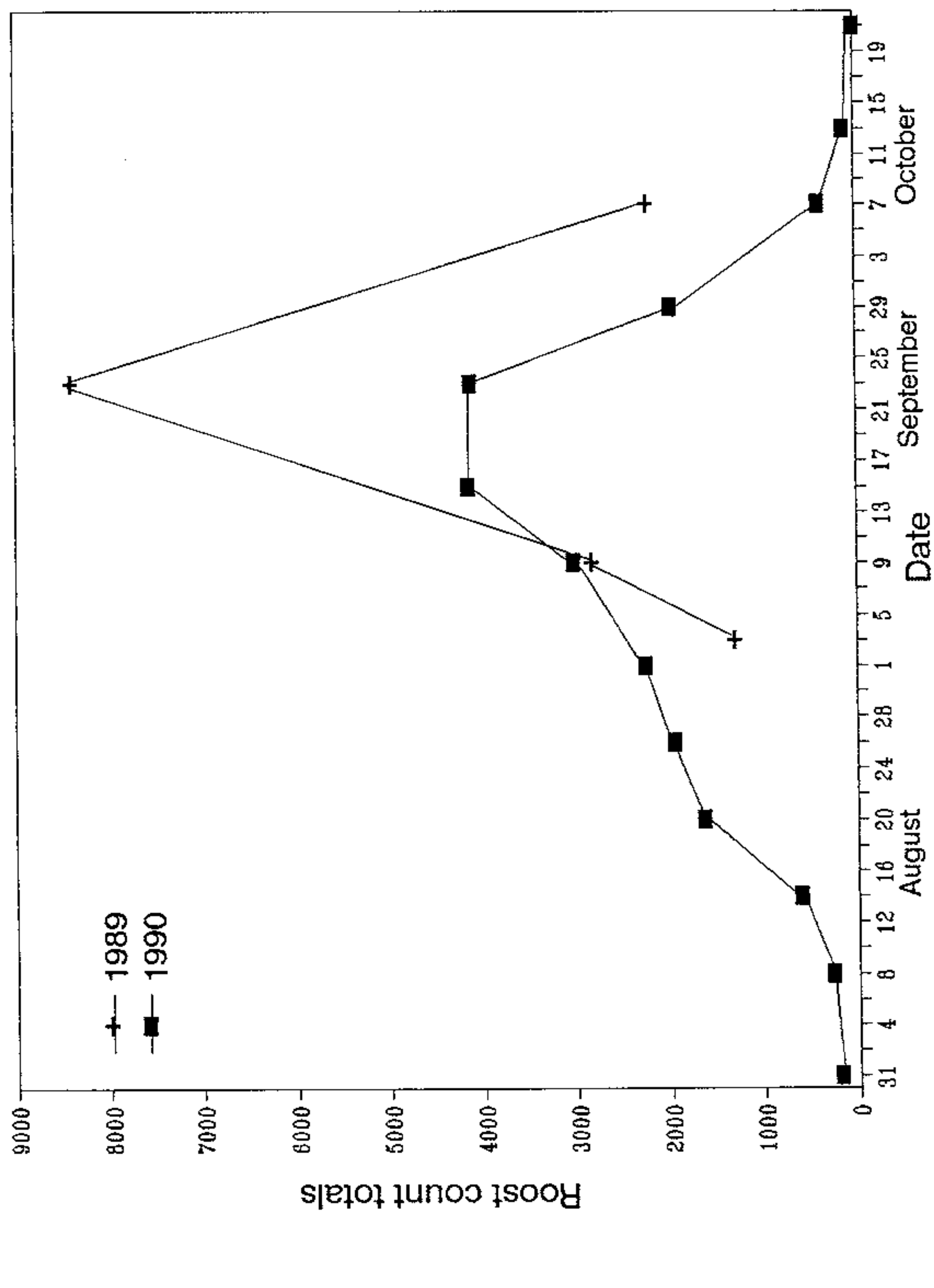
Table 5. Sandhill crane roost counts in northwestern Roseau County, Minnesota, late July through October 1990.

Date	ROOSTS Diversion ditch/ sedge meadow (departing)	Pool 1/ sedge meadow (departing)	Roseau River (returning)	County line (departing)	Weekend total
July 30	0	64	0		
July 31				110	174
Aug 7	2	88	2		
Aug 8				181	273
Aug 13	49	157	91		
Aug 14				301	598
Aug 20	175	494	472		
Aug 21				491	1632
Aug 26	31	421	904		
Aug 27				589	1945
Sept 1	176	612	670		
Sept 2				796	2254
Sept 8	30	1077	1044		
Sept 9				881	3032
Sept 15	93	1909	1445		
Sept 16				711	4158

Table 5. (cont.)

	ROOSTS				
Date	Diversion ditch/ sedge meadow (departing)	Pool 1/ sedge meadow (departing)	Roseau River (returning)	County line (departing)	Weekend total
Sept 22	308	1851	1757		
Sept 23				206	4122
Sept 29	225	1115	569		
Sept 30				50	1959
Oct 6	3	0	375		
Oct 7				0	378
Oct 13	0	0	115		
Oct 14				0	115
Oct 20	0	0	5		
Oct 21				0	5

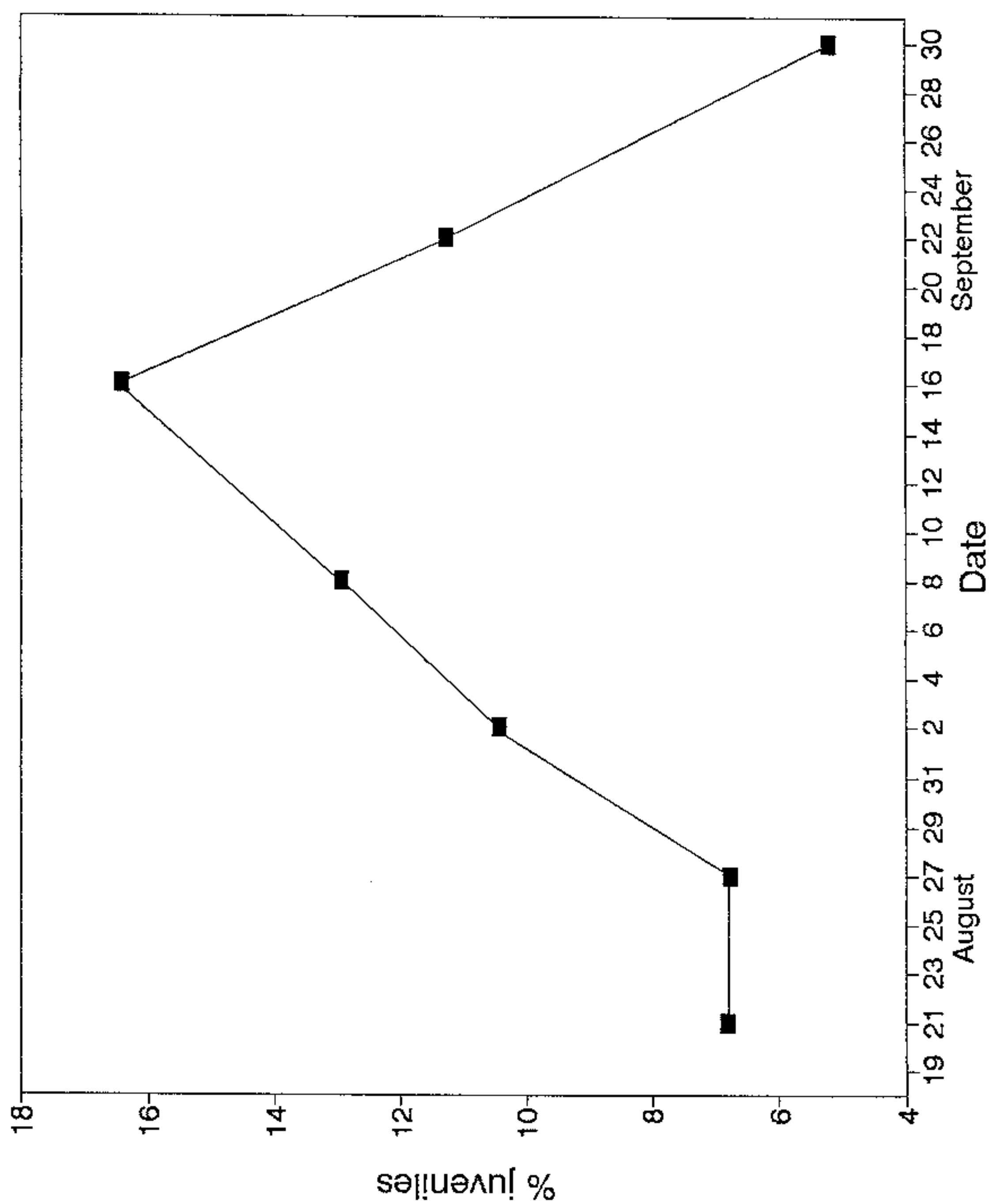
Figure 13. Summer and fall roost count totals of sandhill cranes in northwestern Roseau County, Minnesota, 1989-90.


Roost count totals
Date
August
September
October
1989
1990

The percentage of juveniles in flocks feeding in agricultural fields peaked at 16.4% (N = 1,602 cranes identified) on 15-16 September 1990 (Fig. 14). Numbers of cranes identified from 8 August to 13 October 1990 can be found in Appendix III. From 13 August to 14 October 1990, the percentage of families with two offspring in the flocks was 24.2% (N = 623 families). Some families used to obtain this percentage may have been observed more than once.

The majority of cranes vacated the area after goose hunting season opened on 30 September 1989 and 29 September 1990. Staging cranes immediately ceased using roosts and fields occupied by waterfowl hunters. Roseau River roosts and fields in northern Soler and northwestern Moose which were undisturbed by hunters were used by cranes until mid-October 1990. The last sightings of cranes on the study areas were 27 October 1989 (S. Wood, pers. commun.) and 21 October 1990.

Figure 14. Percentages of juveniles among fall staging sandhill cranes in northwestern Roseau and northeastern Kittson Counties, Minnesota, 1990. Only percentages obtained from $\underline{N} > 600$ cranes were plotted.


% juveniles
4
6
8
10
12
14
16
18
Date
August
September
19 21 23 25 27 29 31 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

DISCUSSION

Spring Arrival

Spring arrival of cranes at the RRWMA is similar to other arrival times in Minnesota. At Agassiz National Wildlife Refuge (NWR), located approximately 52 km south of the RRWMA, breeding pairs began to return by late March of 1984 and 1985 and most were on their territories by the first week of April (DiMatteo, in press). In 1973 - 1975, cranes returned and immediately occupied their territories in early April in Morrison County of central Minnesota (Johnson 1976b).

Evidence accumulated in other studies (Drewien 1973, Walkinshaw 1989) has suggested and confirmed that pairs of sandhill cranes return to the same territory annually. Although pairs on the PSA were not marked to irrefutably demonstrate that they behave similarly, they are probably not an exception.

Population Size and Density of Breeding Cranes

Sandhill cranes apparently persisted in the remote marshes of northwestern Minnesota while they were disappearing from other parts of their range in the state.

Resident cranes were observed and reported to nest on the RRWMA in the 1950's (Tacha and Tacha 1985) and in 1974 - 1975, an estimated 30 pairs summered there (Johnson 1976a). Based on the minimum breeding pair density of 0.25 pair/km^2 on the PSA, at least 62 pairs probably breed on the RRWMA (248.3 km^2) now.

The minimum breeding pair density of 0.25 pair/km^2 on the PSA is high relative to densities reported elsewhere in Minnesota and is in the midst of densities reported outside the state (Table 6). Differences in breeding pair densities throughout the breeding range of sandhill cranes are probably due to differences in habitat and population size and status.

Nest Location

Locating nests in large remote wetlands such as those on the RRWMA by ground searching is impractical. Searches conducted by helicopter are much more efficient and productive. Use of helicopters for conducting aerial nest surveys is encouraged in future studies.

The sample of nests obtained is believed to be representative of the habitat used for nesting. Based on radio-tagged nesting pairs, Urbanek et al. (in press) found that habitat characteristics were not as important as crane behavior as causes for nondetection of nests.

Table 6. Sandhill crane breeding pair densities.

Location	Breeding pairs/km^2 [a]	Date	Reference
Minnesota			
Agassiz NWR	0.13	1984-85	DiMatteo, in press
Kittson & Marshall Counties	0.14-0.20	1989-90	Maxson, unpubl. data
central Morrison County	0.06	1973-75	Johnson 1976b
Wisconsin			
southeastern Wisconsin	0.02	1976	Bennett 1978b
	0.03	1977	" "
Marquette & Green Lake Counties	>2.00		Swengel, pers. commun. in Armbruster 1987
Crex Meadow, Burnett County	0.13	1976	Crete & Grewe 1982
	0.12	1977	" " "
	0.13	1978	" " "
Fish Lake, Burnett County	0.10	1976	" " "
	0.12	1977	" " "
	0.15	1978	" " "
Michigan			
Seney NWR	0.43	1984-87	Urbanek et al., in press
Jackson County	0.20	1970	Hoffman 1983
	0.30	1982	" "
southeastern Michigan	0.10	1970	Halbeisen 1980 in Hoffman 1983
Alberta			
central Alberta	0.05	1976	Carlisle 1979
	0.03	1977	" "

Table 6. (cont.)

Location	Breeding pairs/km^2 [a]	Date	Reference
Idaho			
Grays Lake	2.00	1969-71	Drewien 1973
Oregon			
Sycan Marsh	1.35	1981-84	Stern et al. 1987
Malheur NWR	0.32	1975	Littlefield 1976
Northwest Territories			
Banks Island	0.19	1976	Reed 1988
Alaska			
Yukon-Kuskokwim Delta	0.54[b]	1975	Boise 1977
	0.78[b]	1976	" "
Florida			
central Florida	0.62	1938-75	Walkinshaw 1976

[a] Wetland and upland.
[b] Reported as nests/km^2.

Nesting Habitat Use and Preference

Sandhill cranes on the PSA nested in shallow, emergent wetlands. This habitat is only one example of the wide array of nesting habitats used throughout the breeding range of sandhill cranes (Table 7). Although varied, breeding habitats must always contain water, nesting cover, isolation, and a nearby feeding area (Armbruster 1987). Sizes of basins used by nesting cranes in this study varied widely (0.6 - 1,862.3 ha), as do the sizes of wetlands used by nesting cranes elsewhere (Table 8).

Typha spp. and *Carex* spp. were present most frequently at nest sites in this study. A great variety of plant species have been found adjacent to sandhill crane nest sites (Table 7) in other studies and it appears vegetation structure which provides concealment is more important than species composition. Nesting cranes seem to prefer tall, robust, emergent vegetation, which provides cover in the early spring after snow, rain, and wind have flattened other vegetation (Johnson 1976b, Bennett 1978b, Tebbel 1981).

A possible explanation for the predominant lack of statistically significant differences between means or distributions for the habitat variables measured in this study is that sample sizes were not large enough for the statistics to reflect differences. Larger sample sizes of 22 and 35 nests and the same number of corresponding random sites in Kittson and Marshall Counties in 1989 and 1990,

Table 7. Sandhill crane nesting habitats and plants adjacent to nests.

Location	General description of nesting habitat	Plants adjacent to nest	Reference
Minnesota			
Kittson & Marshall Counties		*Typha* spp., *Phragmites australis*, *Scirpus* spp., *Carex* spp., Grass, *Salix* spp.	Maxson, unpubl. data
central Morrison County	large open marshes	*Phragmites australis* and shrubs	Johnson 1976b
Wisconsin			
central Wisconsin	cranberry bog reservoirs, sedge (*Carex* or *Scirpus* spp.) meadows, cattail (*Typha latifolia*) marshes, or in transitional areas between wet upland meadows and deeper freshwater marshes	*Sphagnum* spp., *Carex rostrata*, *Scirpus cyperinus*, *Carex lasiocarpa*, *Salix* spp., *Spirea tomentosa*, *Typha latifolia*, *Carex oligosperma*, *Calamogrostis candense*, *Carex stricta*, *Chamaedaphne calyculata*	Howard 1977
southeastern Wisconsin	river basin wetlands, lake shore wetlands, sedge openings, margins of tamarack swamps, bogs and fens, seapage basins in agricultural fields, and seasonally flooded pastures	*Typha latifolia*, *Scirpus validus*, *Sparganium eurycarpum*, *Carex stricta* *Carex rostrata*	Bennett 1978b

Table 7. (cont.)

Location	General description of nesting habitat	Plants adjacent to nest	Reference
Michigan			
Seney NWR	cattail marsh, sedge marsh, and sphagnum bog	*Typha latifolia*, *Carex* spp., *Sphagnum* spp., *Chamaedaphne calyculata*, *Salix* spp.	Urbanek et al., in press
southern Michigan	shallow marshes or along marshy borders of small lakes and streams	*Typha latifolia*, sedges (*Carex* and/or *Scirpus*), *Scirpus validus*, *Decodon verticillatus*, grass, *Juncus* sp., *Phragmites australis*, *Sagittaria latifolia*, *Sparganium eurycarpum*	Walkinshaw 1965a
Ontario			
southern Algoma District	sphagnum bog, graminoid bog, low shrub bog, graminoid-rich treed bog, low shrub bog and shallow marsh and low shrub fen	*Sphagnum* spp., *Carex* spp., *Chamaedaphne calyculata*, *Typha latifolia*, *Myrica gale*, *Ledum groenlandicum*	Tebbel 1981
Alberta			
central Alberta	open sedge marsh	*Salix pedicellaris*, *Betula pumila*, *Sphagnum* spp., *Carex* spp., various forbs	Carlisle 1979

Table 7. (cont.)

Location	General description of nesting habitat	Plants adjacent to nest	Reference
Idaho Grays Lake	dry upland meadow, artificial dikes, islands, wet meadow-marsh edge, marsh	*Juncus balticus*, *Carex* spp., *Scirpus acutus*, *Potentilla anserina*, *Typha latifolia*, *Muhlenbergia asperifolia*, *Muhlenbergia filiformis*	Drewien 1973
Oregon Malheur NWR	open meadows and marshes	*Sparganium eurycarpum*, *Scirpus acutus*, *Typha latifolia*, grasses and forbs	Littlefield and Ryder 1968
Alaska Yukon-Kuskokwim Delta	heath/marsh mosaic, sedge/grass meadow	*Carex lyngbyaei*, *Elymus arenarius*, *Sphagnum* spp., *Carex rariflora*, *Festuca rubra*, *Arctagrostis latifolia*	Boise 1977
Northwest Territories Banks Island	dry sand dunes	sparse grasses and sedges	Walkinshaw 1965b

Table 7. (cont.)

Location	General description of nesting habitat	Plants adjacent to nest	Reference
Mississippi			
Jackson County	open savanna, swamp edge, pine plantation, and pine forest edge	grasses, sedges, and array of wet-acid-soil plants, *Scleria baldwinii*, *Ilex glabra*, *Myrica cerifera*, *Nyssa sylvatica*, *Ilex vomitoria*, *Pinus elliottii*, *Pinus palustris*, *Taxodium ascendens*	Valentine 1982
Florida			
central Florida	small ponds surrounded entirely or by patches of shallow water and emergent vegetation	*Pontedaria lanceolata*, *Panicum hemitomum*, *Hypericum fasciculatum*, *Sagittaria lancifolia*, *Andropogon floridanus*, *Eleocharis equisetoides*, *Juncus effusus*	Walkinshaw 1982

Table 8. Wetland sizes used by nesting sandhill cranes.

Location	Mean wetland size (ha)	Range (ha)	N	Reference
Minnesota				
Marshall & Kittson Counties	-----	0.04- 601.2	-----	Maxson, unpubl. data
central Morrison County	150.2	90 - 211	4 wetlands	Johnson 1976b
Wisconsin				
Wisconsin	137.3	4.0 - >1215	143 wetlands	Gleusing 1974
southeastern Wisconsin	126	-----	-----	Bennett 1978b
Jackson County	32	0.4 - 231	26 wetlands	Hoffman 1983
central Wisconsin	192	10 - 927	-----	Howard 1977
Michigan				
northern Michigan	-----	<0.8 - >405	-----	Walkinshaw 1978
northern Michigan	-----	0.2 - 810	-----	Taylor 1976
Ontario				
southern Algoma District	34.8	-----	14 wetlands	Tebbel 1981
Florida				
central Florida	3.8	0.2 - 48.6	131 nests	Walkinshaw 1982

respectively, resulted in some significant differences between mean habitat values at nest and random sites (S. J. Maxson, unpubl. data). Nearly all of the same habitat characteristics were measured as in this study. Another possible explanation is that measurements recorded in late May to mid-June, when nests were found and sites analyzed, may not have accurately represented what the habitat was like in mid- to late April when pairs selected nest sites. Also, cranes may have chosen where to nest based on habitat variables other than those which were studied. Finally, nesting cranes may show no preference for particular areas within basins, or basins where nests and their corresponding random sites were located may have been very homogenous. However, based on personal observation, the latter two possibilities seem unlikely.

Sandhill cranes generally nest in shallow water (Table 9). The apparent flooding of pair 17's nest and egg depredation of pairs 3 and 4, which had mean water depths at their nest sites when found of only 7.2 and 0.0 cm, respectively, suggest the importance of suitable water levels to prevention of nest abandonment and egg destruction by mammalian predators. Similar observations of abandonment caused by flooding and apparent selection by cranes for nest sites with stable water levels has been observed in several studies (Drewien 1973, Walkinshaw 1973, Bennett 1978b, Urbanek et al., in press). In Kittson and Marshall

Table 9. Mean water depth at sandhill crane nest sites.

Location	$\bar{x}$ (cm)	N(nests)	Date	Reference
Minnesota				
Marshall & Kittson	14.5	23	1989	Maxson, unpubl. data
Counties	8.1	35	1990	" " "
central Morrison County	47.0	6	1973-75	Johnson 1976b
Wisconsin				
Burnett County	18	17	1976-78	Crete & Grewe 1982
central Wisconsin	12.6	50	1974-75	Howard 1977
Michigan				
Seney NWR	7.0	49	1987	Urbanek et al., in press
northern Michigan	8.1	46	1937-77	Walkinshaw 1978
southern Michigan	27.4	194	1935-77	" "
Ontario				
southern Algoma District	8.7	14	1978-79	Tebbel 1981
Alberta				
central Alberta	16	12	1976-77	Carlisle 1979
Idaho				
Grays Lake	20.0	187[a]	1969-71	Drewien 1973
Oregon				
Malheur NWR	16.8	93	1966-67	Littlefield & Ryder 1968
Sycan Marsh	14.96	283	1981-84	Stern et al. 1987

Table 9. (cont.)

Location	$\bar{X}$ (cm)	N(nests)	Date	Reference
Florida				
Loxahatchee NWR	25.0	44	1964-68	Thompson 1970
central Florida	29.6	130	1938-81	Walkinshaw 1982

[a] Includes only nests located in water.

Counties in 1989, the mean water depth at nests was 14.5 cm and 13.0% of clutches were depredated (S. J. Maxson, unpubl. data). In contrast, 51.4% of clutches were destroyed by predators in 1990 when the mean water depth at nests was 8.1 cm. Maxson (unpubl. data) also observed nests to be in significantly deeper water than random sites in 1990. Stern et al. (1987) reported significantly higher nest success in deep water bulrush habitats in Oregon because the habitat apparently afforded protection from coyotes. On Isle of Pines where mammalian predators were not a threat, sandhill cranes nested on dry ground (Walkinshaw 1953).

Mean distances from nests to dry land in other studies are much lower than observed on the PSA (286.9 m). In central Florida, the mean distance for 79 nests was 61.5 m (Walkinshaw 1976). In the Upper Peninsula of Michigan, nests averaged 30.8 m from dry mainland (Walkinshaw 1978), and in central Alberta the mean distance was 50 m for 6 nests (Carlisle 1979). The larger mean distance from nests to dry land in this study is probably due to the extensive size of the wetlands on the PSA.

Shrubs can afford nesting cranes cover and isolation. In several studies nests were adjacent to or within patches of shrubs (Walkinshaw 1965a, Littlefield and Ryder 1968, Blake 1974, Johnson 1976b, Carlisle 1979). Two successful nests in this study (pairs 6 and 17) were located immediately adjacent to a large shrub or within patches of

Salix spp. stems, but they were also surrounded by water up to 70 cm deep. Where there is fire prevention and wetland drainage, however, shrubs may invade wetlands and form monotypic stands. Nesting cranes will then vacate the area (Bennett 1978b, Valentine 1982).

As in this study, Maxson (unpubl. data) found concealment by residual, herbaceous vegetation to be lower at nest sites than at random sites. In 1989 concealment was significantly lower at the 0 - 33 cm height level and in 1990, it was significantly lower for all three 33-cm height levels. Based on this information, it appears nesting cranes may be selecting sites with less concealment than expected. However, the lower concealment scores at nest sites may be caused by removal of some vegetation around nests to construct them. Cranes may have selected nest sites which were more concealed than expected. This idea is supported by this study's observation that successful nests were more concealed at two height levels than unsuccessful nests. At Seney NWR in Michigan, Urbanek et al. (in press) thought behavior patterns of predators on individual crane territories may have been more important than nest concealment to egg depredation susceptibility.

Clutch Size and Laying and Hatching Dates

The mean clutch size of 1.88 ± 0.332 (SD) eggs observed on the PSA in 1989 and 1990 compares favorably with mean clutch sizes recorded in other studies (Table 10). Laying and hatching dates on the PSA are similar to laying and hatching dates recorded elsewhere in Minnesota. At Agassiz NWR in 1984 and 1985, incubation began by mid-April, with most birds on eggs by the end of April. The majority of clutches hatched by the end of May (DiMatteo, in press). In Morrison County in 1973 - 1975, cranes were laying eggs in mid- to late April and the mean hatch date was 25 May (Johnson 1976b).

The possible renesting by pair 12 in 1989 is not an unusual event. Renesting by sandhill cranes is well documented (Drewien 1973, Valentine 1982, Nesbitt 1988, Bennett and Bennett 1990, Urbanek et al., in press). At Agassiz NWR, renesting attempts began as late as early June and some nests were still being incubated in early July (DiMatteo, in press). Chicks which were a week and less than a week old were observed in early and mid-July in Morrison County (Johnson 1976b).

Nesting and Hatching Success

The apparent hatching (69.2%) and nesting (77.3%) successes on the PSA in 1990 compare favorably to values documented in other studies (Tables 11, 12). However, apparent successes must be regarded with caution. An unknown number of nests may be destroyed early in incubation and go undiscovered (Mayfield 1961). Also, advanced

Table 10. Mean clutch sizes of sandhill cranes.

Location	Mean clutch size(eggs)	N(nests)	Date	Reference
Minnesota				
central Morrison County	2.00	6	1973-75	Johnson 1976b
Kittson & Marshall Counties	2.00	20	1989	Maxson, unpubl. data
	1.79	34	1990	" " "
Wisconsin				
cental Wisconsin	1.84	50	1974-75	Howard 1977
Wisconsin	1.79	33	1973	Gluesing 1974
southeastern Wisconsin	1.91	43	1976-77	Bennett 1978b
Burnett County	1.94	17	1976-78	Crete & Grewe 1982
Michigan				
northern Michigan	1.95	43	1937-77	Walkinshaw 1978
southern Michigan	1.95	236	1935-77	" "
Ontario				
southern Algoma District	1.94	17	1978-79	Tebbel 1981
Idaho				
Grays Lake	1.94	337	1969-71	Drewien 1973
Oregon				
Malheur NWR	1.92	108	1966-67	Littlefield & Ryder 1968
Colorado				
Routt County	1.94	---	1977	Bieniasz 1979

Table 10. (cont.)

Location	Mean clutch size(eggs)	N(nests)	Date	Reference
Alaska				
Yukon-Kuskokwim Delta	1.83	6	1975	Boise 1977
	1.61	28	1976	" "
Mississippi				
Jackson County	1.86	79	1965-81	Valentine 1982
Georgia				
Okefenokee Swamp	1.88	187	1985-88	Bennett & Bennett 1990
Florida				
central Florida	1.94	121	1938-81	Walkinshaw 1982
Paynes Prairie	1.72	99	1981-87	Nesbitt 1988
Loxahatchee NWR	1.84	64	1964-68	Thompson 1970
southcentral Florida	1.86	7	1973-79	Layne 1983

Table 11. Apparent hatching success of sandhill cranes.

Location	Apparent hatching success(%)	N(eggs)	Date	Reference
Minnesota				
central Morrison County	77.2	24	1973-75	Johnson 1976b
Kittson & Marshall Counties	75.0	40	1989	Maxson, unpubl. data
	41.0	61	1990	" " "
Wisconsin				
central Wisconsin	80.4	92	1974-75	Howard 1977
Burnett County	63.6	33	1976-78	Crete & Grewe 1982
southeastern Wisconsin	84	--	1976-77	Bennett 1978b
Michigan				
northern Michigan	69.7	33	1937-77	Walkinshaw 1978
southern Michigan	74.3	366	1935-77	" "
Ontario				
southern Algoma District	87.8	33	1978-79	Tebbel 1981
Colorado				
Routt County	30.4	--	1976	Bieniasz 1979
	33	--	1977	" "
Alaska				
Yukon-Kuskokwim Delta	63.6	44	1975-76	Boise 1977
Mississippi				
Jackson County	64.1	78	1965-81	Valentine 1982
Florida				
Paynes Prairie	38.8	--	1981-87	Nesbitt 1988
Loxahatche NWR	70	44	1964-68	Thompson 1970

Table 12. Apparent nesting success of sandhill cranes.

Location	Apparent nesting success(%)	N(nests)	Date	Reference
Minnesota				
Agassiz NWR	77.8	18	1984-85	DiMatteo, in press
Marshall & Kittson Counties	87.0 (84.5)[a]	23	1989	Maxson, unpubl. data
	37.1 (18.9)[a]	35	1990	" " "
Wisconsin				
central Wisconsin	80.0	15	1974	Howard 1977
	85.7	35	1975	" "
southeastern Wisconsin	83.7	43	1977	Bennett 1978b
Michigan				
Seney NWR	63.0	52	1987	Urbanek et al., in press
northern Michigan	66.7	18	1937-77	Walkinshaw 1978
southern Michigan	79.7	192	1935-77	" "
Ontario				
southern Algoma District	100.0	17	1978-79	Tebbel 1981
Idaho				
Grays Lake	75.0	4	1969	Drewien 1973
	78.3	152	1970	" "
	77.6	152	1971	" "
Oregon				
Malheur NWR	35.3	51	1966[b]	Littlefield 1976
	42.4	59	1967[b]	" "
	59.1	88	1969[b]	" "
	44.7	76	1970[b]	" "
	53.0	83	1971[b]	" "

clutches are more likely to hatch than younger clutches because of the shorter interval between discovery and hatching (Klett et al. 1986). The Mayfield Method attempts to remedy these problems and results in a more reliable estimate of nest success. Thus, the Mayfield corrected nest success on the PSA in 1990 (53.8%) is probably more accurate. Mayfield corrected nest success was calculated in only one other study conducted on the reproductive success of sandhill cranes (Maxson, unpubl. data).

The loss of 13.3% of clutches and 15.4% of eggs to predators in 1990 was relatively low compared to losses documented elsewhere (Table 13). Predators present on the PSA during the nesting season and known to destroy sandhill crane eggs include raccoons (*Procyon lotor*), crows (*Corvus brachyrhynchos*), coyotes (*Canis latrans*), and skunks (*Mephitis mephitis*).

Fledging Success

Pair 1's 1989 offspring flew at an early age (approximately 60 days) relative to fledging ages reported elsewhere for sandhill cranes. In Morrison County, young cranes were capable of flight at about 70 days of age (Johnson 1976b). In Burnett County, Wisconsin, young were observed flying in late July and early August, 65 - 75 days after the mean hatch date (Crete and Grewe 1982) and at

Table 13. Clutch depredation of sandhill cranes.

Location	Percent depredated	N	Date	Reference
Minnesota				
Marshall & Kittson Counties	13.0	23 nests	1989	Maxson, unpubl. data
	51.4	35 "	1990	" " "
Wisconsin				
southeastern Wisconsin	4.6	43 "	1977	Bennett 1978b
Michigan				
Seney NWR	25.0	52 "	1987	Urbanek et al., in press
Michigan	10.3	107 "	1935-64	Walkinshaw 1965a
Idaho				
Grays Lake	14.5	337 "	1969-71	Drewien 1973
Oregon				
Malheur NWR	51.0	51 "	1966[a]	Littlefield 1976
	55.9	59 "	1967[a]	" "
	36.4	88 "	1969[a]	" "
	50.0	76 "	1970[a]	" "
	47.0	83 "	1971[a]	" "
	75.5	49 "	1973	" "
	60.0	50 "	1974	" "
Alaska				
Yukon-Kuskokwim Delta	36.4	11 eggs	1975	Boise 1977
	24.2	33 "	1976	" "

Table 13. (cont.)

Location	Percent depredated	N	Date	References
Georgia				
Okefenokee Swamp	32.1	187 nests	1985-88	Bennett & Bennett 1990
Florida				
Loxahatchee NWR	11	44 eggs	1964-68	Thompson 1970

[a] Predator populations controlled.

not breeding because of failure to secure a territory containing all of the necessary components. Johnson (1976b) observed a pair in Morrison County which defended a small territory early each breeding season, but behavior indicating incubation was never seen and nests were never found. The latter possibility was suggested as a cause for their behavior.

Little is known about the distribution and abundance of nonbreeding cranes in Minnesota. Incidental observations of groups of 3 to nearly 60 have been made during the breeding season in counties where cranes are known to nest (Tacha and Tacha 1985). Numbers of nonbreeders on the study areas from mid-May through July were highest in May and late July and lowest in June and early July. Non-territorial nonbreeders have been observed to roam widely during the breeding season (Melvin 1978, Nesbitt and Williams 1990). This behavior may have been the cause of low nonbreeder numbers observed in June and early July.

Fall Staging Areas

The locations of staging cranes in eastern Caribou, western Juneberry, and central Pohlitz are similar to major fall staging areas located by Davis (1982) during aerial surveys of northwestern Roseau County and northeastern Kittson County in 1982 (Appendix IV). These similarities suggest these areas may be traditional sites. However, staging cranes were observed in additional areas of northwestern Roseau County during this study (Fig. 12). Use of staging areas probably varies from year to year depending on local availability of food and roost sites.

Fall Migration Chronology

Weekly counts of cranes as they return to or depart from roosts are a valuable way to quantify regional distribution, magnitude, and chronology of fall migration (Tacha and Tacha 1985). Air and ground counts of cranes at feeding areas tend to underestimate numbers (Davis 1982). Roost counts on 7 - 8 August 1990 indicated that at least 273 cranes were in the vicinity of the area surveyed by airplane on 9 August 1990. However, less than 100 cranes were seen from the air.

Observations made during this study indicate staging began in early to mid-August and migrants had certainly begun arriving by mid-September. In northwestern Roseau and northeastern Kittson Counties, Davis (1982, 1984) believed staging of resident cranes began in late August 1982 and migrants arrived in early September 1982 and mid- to late September 1983.

Peak numbers of staging cranes were encountered in mid- to late September in this study. These dates are similar to the 22 September 1982 and 26 September 1983 peaks observed in northwestern Roseau County and northeastern Kittson

County by Davis (1982, 1984). At Agassiz NWR, crane numbers were observed at their highest in late September or early October in 1984 and 1985 (DiMatteo, in press) and on 13 October 1990 (A. J. Bennett, unpubl. data). In 1989, ground and aerial surveys in Roseau, Kittson and Marshall Counties revealed that crane numbers peaked during the latter half of September (Maxson et al. 1990).

The peak of 16.4% juveniles on the study areas on 15 - 16 September 1990 is relatively high in comparison to percentages of juveniles used to estimate production of sandhill crane populations elsewhere (Table 14). The percentage of families containing 2 juveniles (24.2%) is also relatively high. At Malheur NWR in Oregon, Littlefield (1976) reported that 21% of families had 2 juveniles in 1970, 24% in 1971, 16% in 1972, and 0% in 1973 and 1974. In flocks observed in the Central Flyway in 1974 - 1976, 20.0% of the successful breeders were accompanied by 2 young (Buller 1979). At Agassiz NWR in 1984 and 1985, 16 of 20 pairs known to fledge young, fledged 2 of them (DiMatteo, in press).

Percentages of juveniles in staging flocks on the study areas cannot be used to estimate annual recruitment of the local population because it is unknown when all local breeding pairs joined staging flocks, where staging cranes originated, and exactly when migrants arrived. However, the percentages do give a general indication of the status of

Table 14. Annual recruitment among sandhill crane populations.

Location	Percent juveniles	N(cranes)	Date	Reference
Wisconsin				
central Wisconsin	13.14	898	1975	Howard 1977
southeastern Wisconsin	11.1		1976-77	Bennett 1978b
Burnett County	12.2	469	1976	Crete & Grewe 1982
	15.2	1,366	1977	" " "
Indiana				
Jasper-Paluski F & W Area	13.4	7,028	1979	Lovvorn & Kirkpatrick 1982
	11.9	14,502	1980	" "
	13.0	525	1976	Crete & Grewe 1982
	10.3	4,861	1977	" " "
Idaho				
Grays Lake	13.8		1970	Drewien 1973
	13.0		1971	" "
Oregon				
Sycan Marsh	0.0		1981	Stern et al. 1987
	3.1		1982	" "
	6.7		1983	" "
	8.0		1984	" "
Malheur NWR	10.7	636	1970[a]	Littlefield 1976
	7.0	654	1971[a]	" "
	5.1	846	1972	" "
	0.3	733	1973	" "
	0.4	503	1974	" "

Table 14. (cont.)

Location	Percent juveniles	N(cranes)	Date	Reference
Colorado				
Routt County	4.93	284	1976	Bieniasz 1979
	18.46	325	1977	" "
northwestern Colorado	27	119	1974	Blake 1974
	26	170	1974	" "
Georgia				
Okefenokee Swamp	7.7		1985	Bennett & Bennett 1990
	11.6		1986	" " "
	8.9		1987	" " "
Florida				
central Florida	15.6	192	1968-75	Walkinshaw 1976
Webb WMA	5.6	89	1984	Bishop & Collopy 1987
Myakka River State Park	8.3	169	1984	" " "
Kissimmee Prairie	10.05	398	1984	" " "
Central Flyway	10.7	35,890	1974	Buller 1979
	11.3	49,104	1975	" "
	12.0	111,240	1976	" "

[a] Predator populations controlled.

the population using the staging areas and timing of migration by families. Littlefield and Ryder (1968) considered the sandhill crane population in southeastern Oregon to be stable at an annual recruitment of 8 - 10%. Drewien (1973) and Lovvorn and Kirkpatrick (1982) suggested that recruitment rates of 10.0 - 12.0% were necessary to maintain stable breeding populations. Drewien (1973) believed the population in Idaho was increasing at an annual recruitment of 13 - 14%.

Fall departure of staging cranes coincides with the opening of waterfowl hunting seasons at other staging areas as well as at the RRWMA. At Jasper-Pulaski Fish and Wildlife Area in northwestern Indiana, there was a dramatic decline in numbers of cranes utilizing roosts within hunting zones when the waterfowl hunting season opened and shooting was allowed before sunrise (Lovvorn and Kirkpatrick 1981). Walkinshaw and Hoffman (1974), Johnson (1976b), Bennett (1978b), and Toepler and Crete (1979) noted similar phenomena in Minnesota, Wisconsin, and Michigan.

In northwestern Roseau County and northeastern Kittson County, no cranes were encountered on 8 October 1982 and on 9 October 1983 a major departure occurred (Davis 1982, 1984). In 1990, at Agassiz NWR where waterfowl hunting does not occur, the last cranes were present during roost counts on 27 October (A. J. Bennett, unpubl. data).

Crop Depredation

The future of sandhill cranes in Minnesota currently appears secure. If numbers of cranes in the state continue to increase, crop depredation may become a larger problem. The partiality of cranes for foraging in agricultural fields has been observed often (Drewien 1973, Lewis 1974, Hoffman 1976, Bennett 1978b, Reinecke and Krapu 1986, Sugden et al. 1988). In northwestern Roseau and northeastern Kittson Counties, depredation of grain crops by nonbreeders and staging cranes is currently a minor problem. Three complaints were reported in these areas in 1989 and 1990 and only 1 site was known to suffer an economic loss exceeding $100 (RRWMA records, G. H. Davis, pers. commun.). Harvest was not prolonged by wet weather in these years and the use of grain dryers speeds removal of wet swaths from fields, thus reducing the time they are exposed to cranes (G. H. Davis, pers. commun.).

Scare devices, such as acetylene exploders, are used in northwestern Roseau and northeastern Kittson Counties to keep cranes out of unharvested grain fields. However, they may only displace cranes to other unharvested fields. Other options include foregoing swathing and straight-cutting grain, delaying digging of harvested grain fields which cranes have been reported to prefer over unharvested grain fields (Sugden et al. 1988), and planting of lure crops near fall roosts sites (Drewien 1973).

APPENDIX I

Table 15. Nest fate and habitat data collected at 19 sandhill crane nest sites on the Roseau River Wildlife Management Area, Minnesota, 1989-90.

					Distance to:		
Nest no.	Nest fate[a]	Vegetation dominance	Water regime[b]	Basin size(km^2)	Upland(m)	Nearest tree(m)[c]	Nearest shrub(m)
1	S	*Typha* spp.	Semi. Fl.	9.312	200	215	55.5
2	U	*Carex* spp.	Seas. Fl.	9.312	150	134	10.9
3	U	*Carex* spp.	Seas. Fl.	---	800	N/A	0.5
4	U	*Carex* & *Typha* spp.	Seas. Fl.	---	400	251	11.8
5	-	----	Seas. Fl.	---	---	---	----
6	S	*Phragmites* spp.	Semi. Fl.	18.623	490	275	0.0
7	S	*Carex* spp.	Seas. Fl.	0.046	56	56	26.4
8	-	----	----	14.980	---	---	----
9	S	*Scirpus* sp.	Seas. Fl.	14.980	600	148	21.8
10	S	*Carex* spp.	Seas. Fl.	14.980	267	267	6.4
11	S	*Carex* spp.	Seas. Fl.	14.980	131	131	41.0
12	S	*Typha* spp.	Seas. Fl.	0.006	750	148	43.0
13	S	*Typha* spp.	Seas. Fl.	0.013	325	325	37.3
14	S	*Typha* spp.	Seas. Fl.	0.011	40	88	43.7
15	S	*Carex* spp.	Seas. Fl.	0.074	400	84	17.3
16	U	*Carex* spp.	Seas. Fl.	0.040	70	70	20.0
17	S	*Typha* spp.	Semi. Fl.	18.623	55	155	0.5
18	U	*Typha* spp.	Semi. Fl.	18.623	85	193	----
19	S	*Typha* spp.	Seas. Fl.	0.046	58	58	25.0

Table 15. (cont.)

Nest no.	Mean water depth when: Found(cm)	Analyzed(cm)	Concealment score: Low	Mid	High	Number of shrub: Clumps[d]	Stems[d]	Trees within 5m
1	32.5	25.8	97	58	25	0	0	0
2	16.2	16.8	65	21	3	0	0	0
3	7.2	3.0	58	8	1	1	3	0
4	0.0	0.0	90	31	5	1	1	0
5	----	----	--	--	--	-	-	-
6	20.2	25.2	69	59	56	1	1	0
7	4.5	6.2	57	8	0	1	1	0
8	----	----	--	--	--	-	-	-
9	21.2	21.2	62	2	0	0	0	0
10	12.0	14.0	17	0	0	0	0	0
11	9.0	10.2	9	0	0	0	0	0
12	15.8	8.8	55	44	6	0	0	0
13	10.2	8.2	97	66	19	0	0	0
14	5.2	10.2	52	12	3	0	0	0
15	----	3.8	87	41	1	0	0	0
16	7.2	9.2	78	17	9	0	0	0
17	0.2	5.0	56	14	3	8	65	0
18	21.0	39.5	0	0	0	0	0	0
19	----	----	--	--	--	0	0	0

Table 15. (cont.)

Nest no.	Mean number of stems / 0.25 m^2						
	Typha spp.	*Carex* spp.	*Phalaris arundinacea*	*Phragmites australis*	*Scirpus* sp.	*Scutellaria galericulata*	*Acorus calamus*
1	13.0	6.0	0.0	0.0	0.0	0.0	0.0
2	6.2	6.0	0.0	9.2	0.0	0.0	0.0
3	35.0	148.8	0.0	0.0	0.0	0.0	0.0
4	12.0	88.8	0.0	0.0	0.0	0.0	0.0
5	----	-----	----	----	---	---	---
6	0.8	0.0	25.0	14.0	0.0	0.0	0.0
7	25.0	33.2	0.0	0.0	0.0	0.0	0.0
8	----	----	----	----	---	---	---
9	6.0	1.0	1.2	0.0	22.0	0.0	0.0
10	7.5	36.2	0.0	0.0	0.0	0.0	0.0
11	2.0	30.2	0.0	0.0	0.0	0.0	0.0
12	25.0	0.0	0.0	0.0	0.0	0.0	0.0
13	16.2	0.2	11.2	0.0	0.0	0.0	5.8
14	10.8	10.2	0.0	0.0	0.0	0.0	0.5
15	11.2	61.2	0.0	0.0	0.0	3.8	0.0
16	2.5	34.5	0.0	0.0	0.0	0.0	0.0
17	3.5	5.0	0.0	0.0	0.0	0.0	0.0
18	1.2	0.0	0.0	0.0	0.2	0.0	0.0
19	----	-----	----	----	----	---	---

[a] S = Successful U = Unsuccessful
[b] Semi. Fl. = Semipermanently Flooded Seas. Fl. = Seasonally Flooded
[c] N/A = >400 m away
[d] Within 1.5 m of the nest.

APPENDIX II

Table 16. Habitat data collected at 31 random sites on the Roseau River Wildlife Management Area, Minnesota, 1989-90.

Random site no.[a]	Vegetation dominance	Water regime[b]	Distance to: Upland	Distance to: Nearest tree(m)[c]	Distance to: Nearest shrub(m)
1R-1	*Carex* spp.	Seas. Fl.	253	130	5.0
1R-2	*Carex* spp.	Seas. Fl.	240	136	2.0
2R-1	*Carex* spp.	Seas. Fl.	263	212	34.6
2R-2	*Carex* spp.	Seas. Fl.	240	149	20.0
3R-1	*Carex* spp.	Seas. Fl.	663	N/A	1.8
3R-2	*Carex* spp.	Seas. Fl.	868	N/A	7.5
4R-1	*Carex* & *Typha* spp.	Seas. Fl.	441	266	4.1
4R-2	*Carex* spp.	Seas. Fl.	260	328	2.0
6R-1	*Phragmites australis*	Semi. Fl.	495	275	9.1
6R-2	*Typha* spp.	Seas. Fl.	515	295	2.7
7R-1	*Typha* spp.	Seas. Fl.	58	58	25.5
7R-2	*Typha* spp.	Seas. Fl.	46	46	19.1
9R-1	*Phalaris arundinacea*	Seas. Fl.	475	46	0.0
9R-2	*Phalaris arundinacea*	Seas. Fl.	710	269	29.1
10R-1	*Typha* spp.	Seas. Fl.	455	N/A	----
10R-2	*Typha* spp.	Seas. Fl.	430	N/A	----

Table 16. (cont.)

Random site no.[a]	Vegetation dominance	Water regime[b]	Distance to: Upland(m)	Distance to: Nearest tree(m)[c]	Distance to: Nearest Shrub(m)
11R-1	_Phalaris arundinacea_	Seas. Fl.	256	256	235.0
11R-2	_Phalaris arundinacea_	Seas. Fl.	116	116	1.6
12R-1	_Carex_ spp. & _Phalaris arundinacea_	Seas. Fl.	658	112	20.0
12R-2	_Typha_ spp.	Seas. Fl.	800	89	9.5
13R-1	_Phalaris arundinacea_	Seas. Fl.	470	N/A	9.1
13R-2	_Phalaris arundinacea_	Seas. Fl.	241	241	0.6
14R-1	_Typha_ spp.	Seas. Fl.	67	47	10.9
14R-2	_Carex_ spp.	Seas. Fl.	30	168	28.2
15R-1	_Carex_ spp.	Seas. Fl.	410	170	1.0
15R-2	_Carex_ spp.	Seas. Fl.	580	164	0.3
16R-1	_Carex_ spp.	Seas. Fl.	36	36	2.3
16R-2	_Carex_ spp.	Seas. Fl.	27	27	9.1
17R-1	_Equisetum fluviatile_	Semi. Fl.	113	219	1.4
17R-2	_Equisetum fluviatile_	Semi. Fl.	75	175	3.6
18R-1	_Typha_ spp.	Semi. Fl.	99	210	-----

Table 16. (cont.)

Random Site no.[a]	Mean water depth when analyzed(cm)	Concealment score: Low	Mid	High	Number of shrub: Clumps[d]	Stems[d]	Trees within 5m
1R-1	4.5	40	0	0	0	0	0
1R-2	2.8	57	19	1	0	0	0
2R-1	18.5	35	0	0	0	0	0
2R-2	19.2	100	82	37	0	0	0
3R-1	6.8	49	3	0	0	0	0
3R-2	11.8	45	1	0	0	0	0
4R-1	0.0	93	48	11	1	1	0
4R-2	0.0	60	11	0	0	0	0
6R-1	34.0	72	20	5	0	0	0
6R-2	19.2	100	99	60	0	0	0
7R-1	11.8	100	100	44	0	0	0
7R-2	13.0	100	100	51	0	0	0
9R-1	0.0	27	19	20	2	26	0
9R-2	16.2	25	0	0	0	0	0
10R-1	28.8	93	50	6	0	0	0
10R-2	27.0	99	73	2	0	0	0

Table 16. (cont.)

Random site no.[a]	Mean water depth when analyzed(cm)	Concealment score: Low	Mid	High	Number of shrub: Clumps[d]	Stems[d]	Trees within 5m
11R-1	8.2	47	11	0	0	0	0
11R-2	8.5	68	9	0	0	0	0
12R-1	0.0	44	0	0	0	0	0
12R-2	1.0	100	95	52	0	0	0
13R-1	0.0	87	38	7	0	0	0
13R-2	0.0	50	5	0	3	27	0
14R-1	0.0	100	100	85	0	0	0
14R-2	4.2	56	10	0	0	0	0
15R-1	7.2	77	34	0	1	3	0
15R-2	5.2	80	17	0	3	31	0
16R-1	8.0	57	0	0	0	0	0
16R-2	6.5	82	23	18	0	0	0
17R-1	51.2	0	0	0	2	5	0
17R-2	54.0	0	0	0	0	0	0
18R-1	50.0	0	0	0	0	0	0

Table 16. (cont.)

Random site no.[a]	*Typha* spp.	*Carex* spp.	*Phalaris arundinacea*	*Phragmites australis*	*Scirpus* sp.	*Cirsium arvense*	*Scutellaria galericulata*
1R-1	0.0	40.5	9.8	0.0	0.0	0.0	0.0
1R-2	5.2	36.2	38.8	0.0	0.0	0.0	0.0
2R-1	1.5	37.8	0.0	0.0	0.0	0.0	0.0
2R-2	3.0	8.5	0.0	9.0	0.0	0.0	0.0
3R-1	4.8	212.5	0.0	0.0	0.0	0.0	0.0
3R-2	0.0	101.2	0.0	0.0	0.0	0.0	0.0
4R-1	11.5	236.2	0.0	0.0	0.0	0.0	0.0
4R-2	2.8	223.8	0.0	1.5	0.0	0.0	0.0
6R-1	6.0	1.0	0.0	14.0	0.0	0.0	0.0
6R-2	15.0	4.5	6.2	0.0	0.0	0.0	0.0
7R-1	18.2	0.0	0.0	0.0	0.0	0.0	0.0
7R-2	22.2	0.0	0.0	0.0	0.0	0.0	0.0
9R-1	2.0	0.0	186.2	0.0	0.0	0.2	0.0
9R-2	8.8	2.2	80.8	0.0	4.5	0.0	0.0
10R-1	11.5	0.0	0.0	0.0	0.0	0.0	0.0
10R-2	18.5	0.0	0.0	0.0	0.0	0.0	0.0

Table 16. (cont.)

Random site no.[a]	*Typha* spp.	*Carex* spp.	*Phalaris arundinacea*	*Phragmites australis*	*Scirpus* sp.	*Cirsium arvense*	*Scutellaria galericulata*
11R-1	6.0	23.5	42.8	0.0	0.0	1.2	0.5
11R-2	9.5	5.5	131.2	0.0	0.0	0.0	0.0
12R-1	1.0	93.8	91.2	0.0	0.0	0.0	0.0
12R-2	19.8	0.0	0.0	0.0	0.0	0.0	0.0
13R-1	16.5	12.2	197.5	2.0	0.0	0.2	0.0
13R-2	6.0	7.2	206.2	0.0	0.0	0.0	0.0
14R-1	18.8	0.0	0.0	0.0	0.0	0.2	0.0
14R-2	1.5	5.0	7.2	0.0	0.0	0.0	0.0
15R-1	0.5	150.0	0.0	0.0	0.0	0.0	2.5
15R-2	9.5	81.2	0.0	0.0	0.0	0.0	0.0
16R-1	0.0	131.5	0.0	0.0	0.0	0.0	0.0
16R-2	0.0	41.5	0.0	7.8	0.0	0.0	0.0
17R-1	0.0	1.0	0.0	0.0	0.0	0.0	0.0
17R-2	0.0	0.8	0.0	0.0	0.0	0.0	0.0
18R-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] First number corresponds to nest number in Table 14.
[b] Seas. Fl. = Seasonally Flooded   Semi. Fl. = Semipermanently Flooded
[c] N/A = >400 m away
[d] Within 1.5 m of the nest.

APPENDIX III

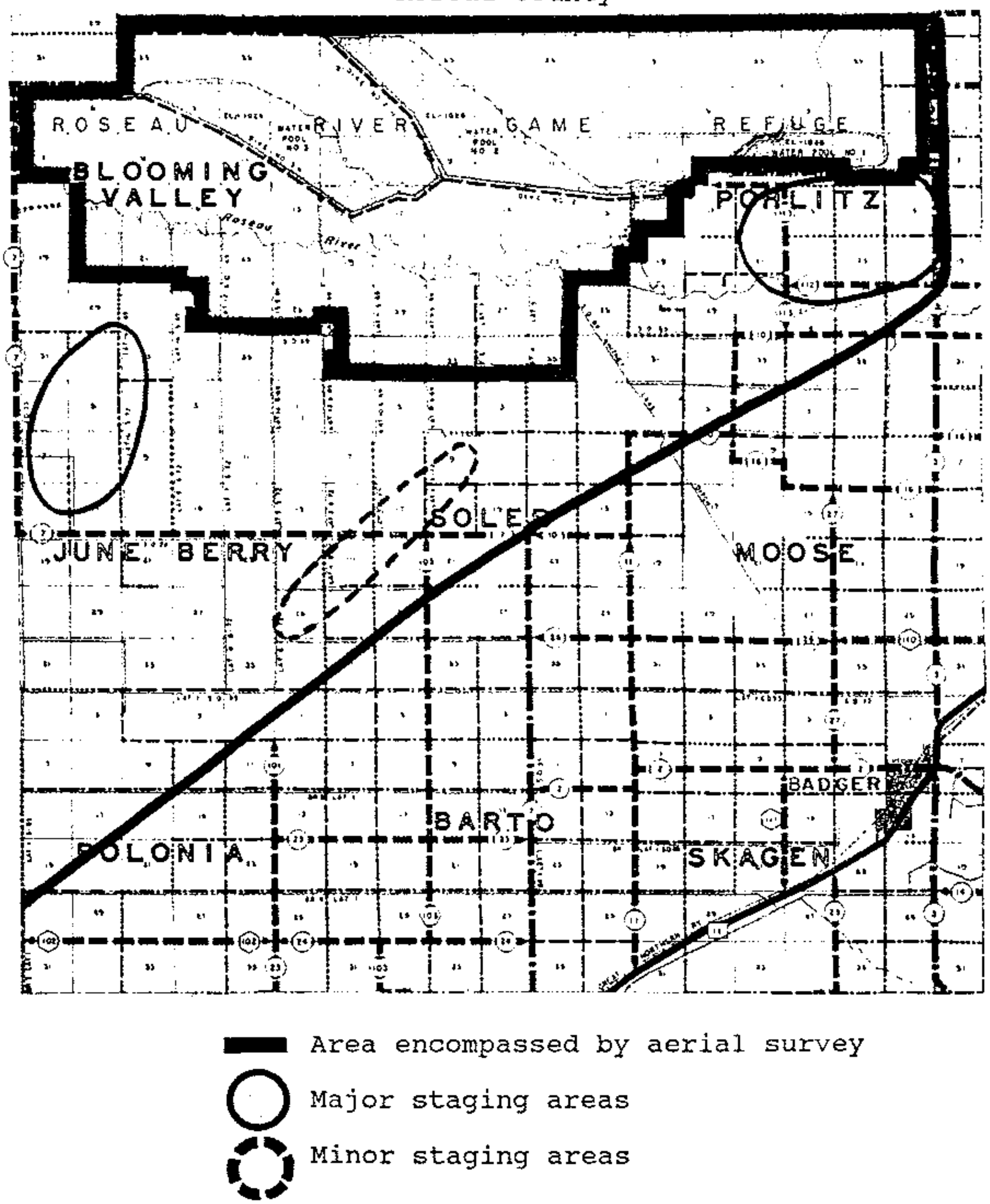
Table 17. Numbers of juveniles identified, total numbers of cranes identified, and percentages of juveniles among fall staging cranes in northwestern Roseau and northeastern Kittson Counties, Minnesota, 1990.

Date		Number of juveniles identified	Total number of cranes identified	Percent juveniles
Aug	10-11	4	94	4.26
	13-14	15	201	7.46
	20-21	46	674	6.82
	26-27	62	914	6.78
Sept	1-2	100	958	10.44
	8-9	101	780	12.95
	15-16	263	1602	16.42
	22-23	154	1366	11.27
	29-30	45	867	5.19
Oct	6-7	4	127	3.15
	13-14	2	24	8.33

APPENDIX IV

Figure 15a. Locations of sandhill crane fall staging areas in northwestern Roseau and northeastern Kittson Counties, Minnesota, 1982 (Davis 1982).

Roseau County



Kittson County

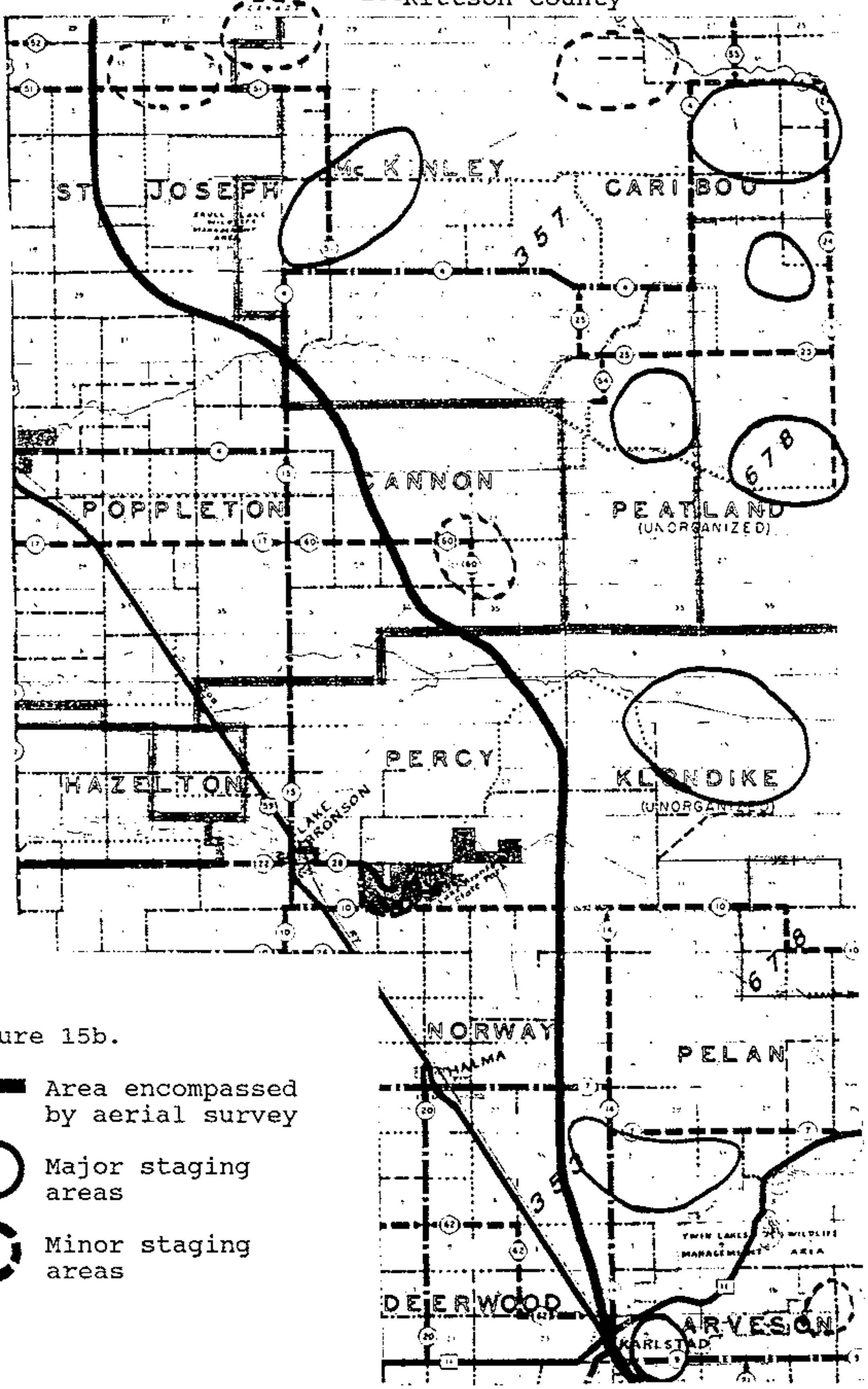


Figure 15b.

Area encompassed by aerial survey

Major staging areas

Minor staging areas

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