University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

USGS Northern Prairie Wildlife Research Center

US Geological Survey

2005

Patterns of Habitat Use by Whooping Cranes During Migration: Summary from 1977-1999 Site Evaluation Data

Jane Austin
U.S. Geological Survey, jaustin@usgs.gov

Amy Richert
University of Nebraska-Lincoln

PATTERNS OF HABITAT USE BY WHOOPING CRANES DURING MIGRATION: SUMMARY FROM 1977–1999 SITE EVALUATION DATA

JANE E. AUSTIN[1], U.S. Geological Survey, Northern Prairie Wildlife Research Center, 8711 37th Street SE, Jamestown, ND 58401

AMY L. RICHERT[2], State Museum, University of Nebraska-Lincoln, 424 Morrill Hall, Lincoln, NE 68588

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

PROCEEDINGS NORTH AMERICAN CRANE WORKSHOP 9:79-104

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

---

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

The Cooperative Whooping Crane Tracking Project began in the United States and Canada in fall 1975. In 1977, the National Audubon Society organized a whooping crane reporting network to boost the effort to monitor sightings of whooping cranes. Data from earlier years, dating back to 1943, were compiled into the data sets, which have been coordinated and maintained by the U.S. Fish and Wildlife Service (USFWS). Also in 1977, the Whooping Crane Recovery Team initiated a pro-

[1] Email: jane_austin@usgs.gov

[2] Present address: Department of Integrated Science and Technology, MSC 4102, James Madison University, Harrisonburg, VA 22801; email richeral@jmu.edu

gram to collect habitat data at sites where observers had seen whooping cranes. These site evaluations greatly expanded the scope and detail of data collected on whooping cranes during migration to include information such as wetland type and size, water quality, substrate, water depths, visibility, vegetation, and land cover. More than 25 parameters were recorded for each site that observers evaluated (U.S. Fish and Wildlife Service 1980).

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

METHODS

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

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

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

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

Crane Groups

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

Wetland-Related Variables

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

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

Habitat Descriptors

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

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

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

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

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

Other Variables

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

RESULTS

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

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

Occurrence of Social Groups by Season

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

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

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

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

Table 2. Distribution of site evaluations among states, overall and by season, and percent of total season observations occurring in each state, 1977-1999. Sample sizes include multiple sub-observations.

	Total		Season			
			Spring		Fall	
State	N	%	N	%	N	%
Montana	20	2.0	13	2.5	7	1.4
North Dakota*	138	13.6	57	10.8	81	16.7
South Dakota	77	7.6	35	6.6	42	8.7
Nebraska	526	51.9	365	69.1	161	33.1
Kansas	165	16.3	51	9.7	114	23.5
Oklahoma	80	7.9	5	0.9	75	15.4
Texas	8	0.7	2	0.4	6	1.2
*Total**	*1014*	*100*	*528*	*100*	*486*	*100*

*excludes 1 summer record

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

Habitat Characteristics Relative to Site Use, Wetland System

All Records. - Palustrine wetlands accounted for 68.8% of site evaluation records; riverine wetlands accounted for 21.6% and lacustrine wetlands 9.6% of the records (n = 644). However, records from Nebraska dominated these percentages and comprised 50.2% of all records for which we were able to discern wetland system. Only 11 (7.9%) of the 139 riverine records were from outside of Nebraska: Kansas River, Kansas; Popular River, Montana (2 records under 1 main observation); Missouri River (2 in MT, 3 in ND); Souris River, North Dakota (J. Clark Salyer NWR), and Arkansas River, Oklahoma (2 records under 1 main observation). The distribution of observations among wetland systems clearly differed between Nebraska and other states. In Nebraska, the proportions of observations occurring on palustrine and riverine systems were both high (56.0 and 39.6% of state records, respectively), whereas in other states palustrine records accounted for > 75% of records. Only in Montana did the proportion of sightings on rivers (4 of 17, or 36%) approach the proportion observed in Nebraska, but the total number of observations were low.

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

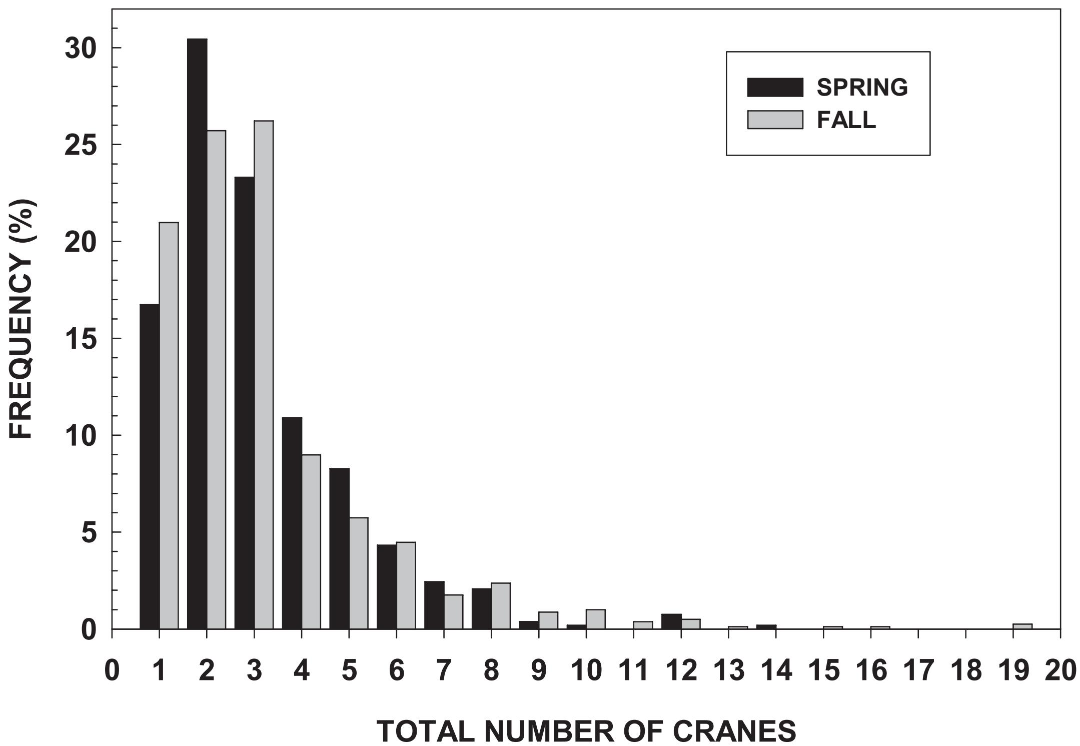

Fig.1. Frequency of crane group sizes (total number of cranes per observation) for spring and fall, 1943–1999.

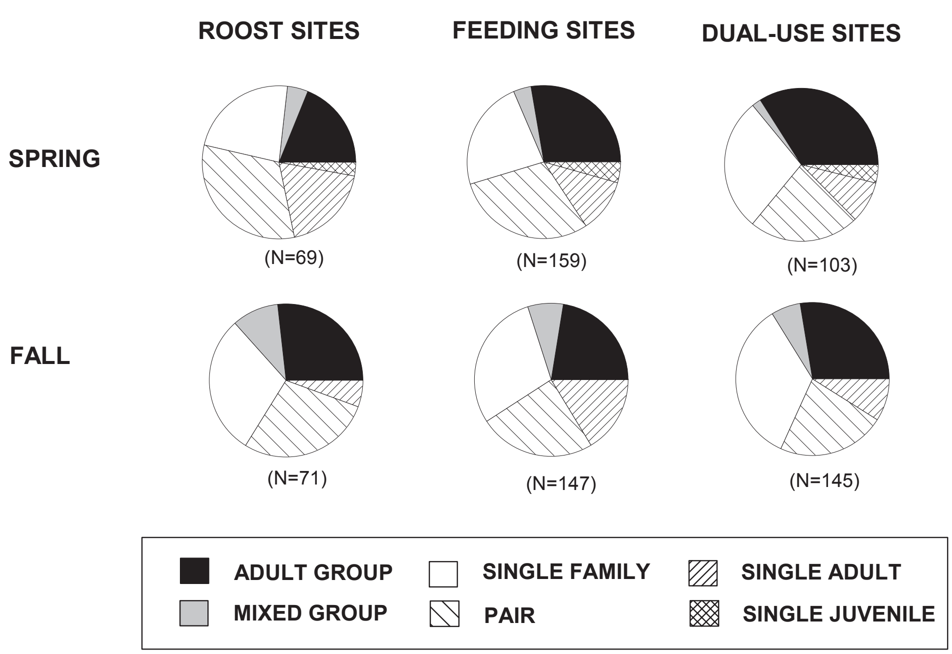

Fig. 2. Frequency of occurrence (%) of social groups observed in spring and fall, by site use, 1977–1999.

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

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

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

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

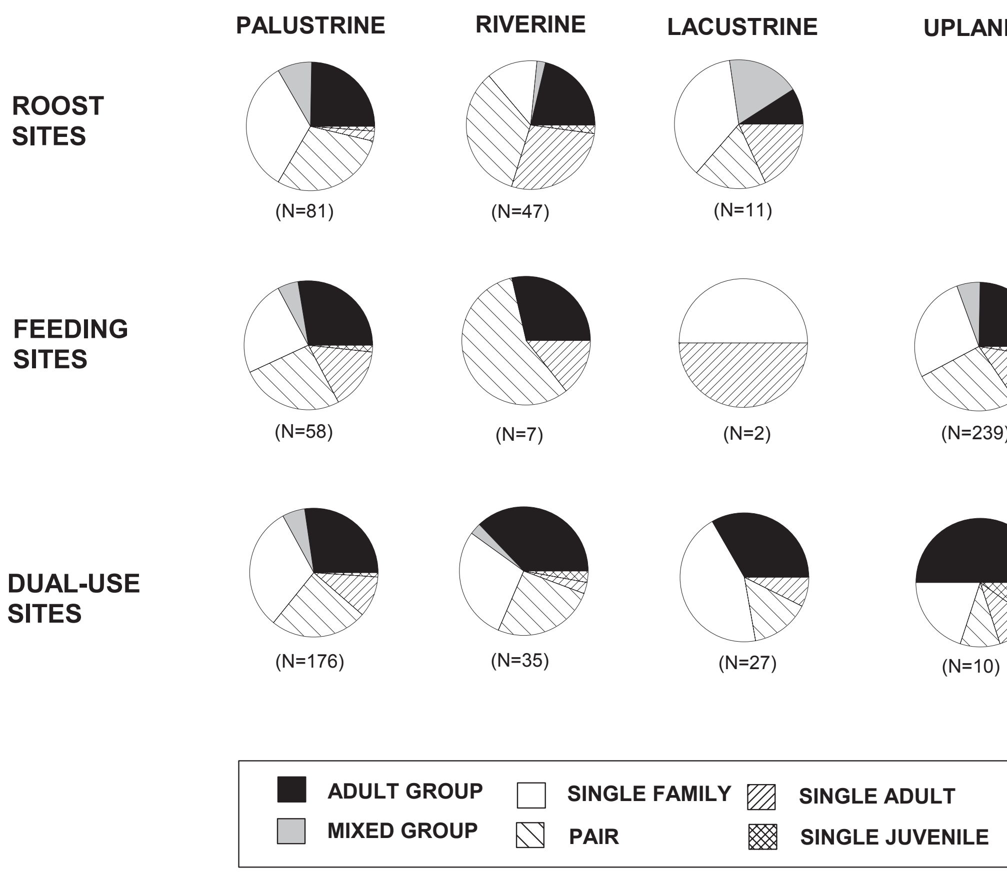

Fig. 3. Frequency of occurrence (%) of social groups observed on palustrine, riverine, and lacustrine systems and upland sites, by site use and season, 1977–1999.

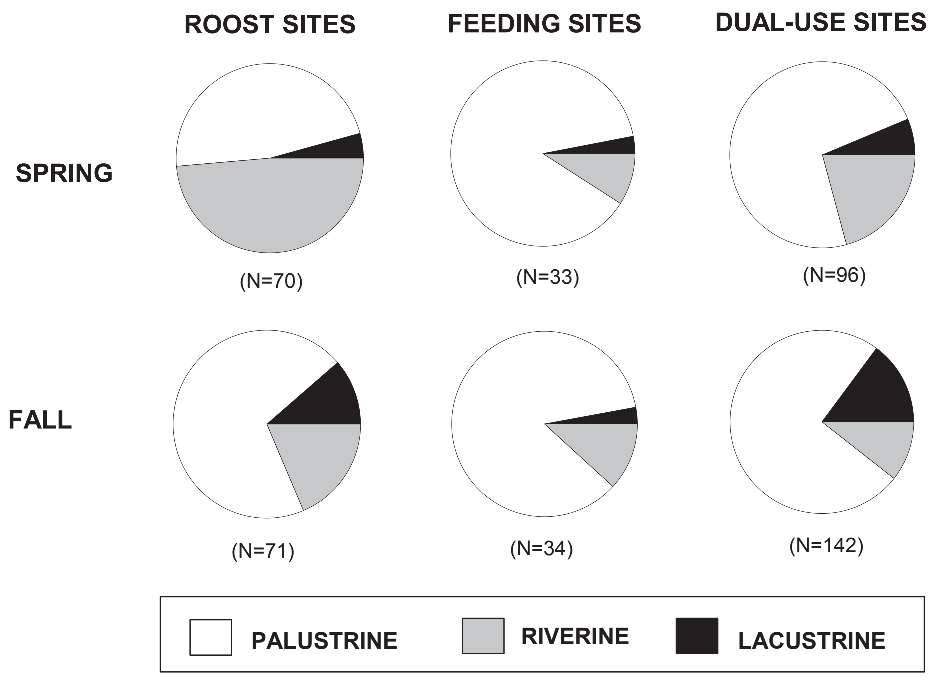

Fig. 4. Frequency of occurrence (%) of wetland classes, by season and site use, 1977–1999.

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

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

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

Dual-use Sites. - Palustrine systems (71.0%) again were the predominant wetland systems used by cranes for both roosting and feeding; use of lacustrine and riverine wetlands were similar (10.9 and 14.1%, respectively; n = 248). Palustrine wetlands accounted for > 67% of dual-use sites in all states. Lacustrine wetlands accounted for 25–28% of such records in North Dakota, Oklahoma, and South Dakota. No sites were described as flooded pasture or wooded draw; 2 were described as tailwater pit (Mead County, KS, and Sedgewick County, KS), and 14 were described as flooded cropland. One of the 14 had further description codes denoting marsh and oat stubble/green rye, 1 as seasonally flooded basin, and 2 as winter wheat.

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

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

Wetland Class

All Records. - Observers defined wetland class as emergent wetlands (50.7% of all records), unconsolidated bottom

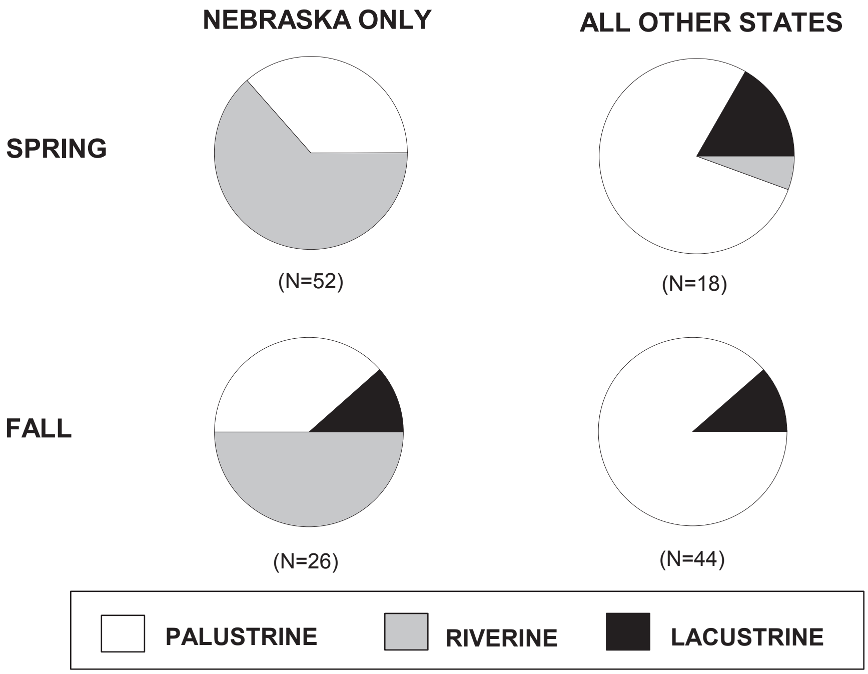

Fig. 5. Frequency of occurrence (%) of wetland classes, by season and site use, 1977–1999, comparing Nebraska with all other states.

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

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

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

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

Wetland Regime

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

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

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

Wetland Size

Roost sites. - Observers commonly sighted roosting cranes on large (> 40 ha) wetlands; frequency of occurrence on these larger wetlands was higher in fall than in spring (59% vs. 27%; Fig. 7). Closer examination of the records indicated that the

Table 3. Percent of wetland observations by wetland class: unconsolidated bottom, aquatic bed, unconsolidated shore, or emergent vegetation relative to wetland system, by site use, 1977-1999.

Wetland class	Roost sites (N = 108)			Feeding sites (N = 52)			Dual-use sites (N = 180)		
	Palustrine	Lacustrine	Riverine	Palustrine	Lacustrine	Riverine	Palustrine	Lacustrine	Riverine
Unconsolidated bottom	9.3	4.6	25.9	5.8	0	5.8	6.7	3.9	11.1
Aquatic bed	8.3	1.9	0	7.7	0	0	10.0	3.9	0
Unconsolidated shore	0.9	1.9	15.7	1.9	0	3.8	1.1	0.6	6.7
Emergent	31.5	0	0	73.1	1.9	0	56.0	0	0

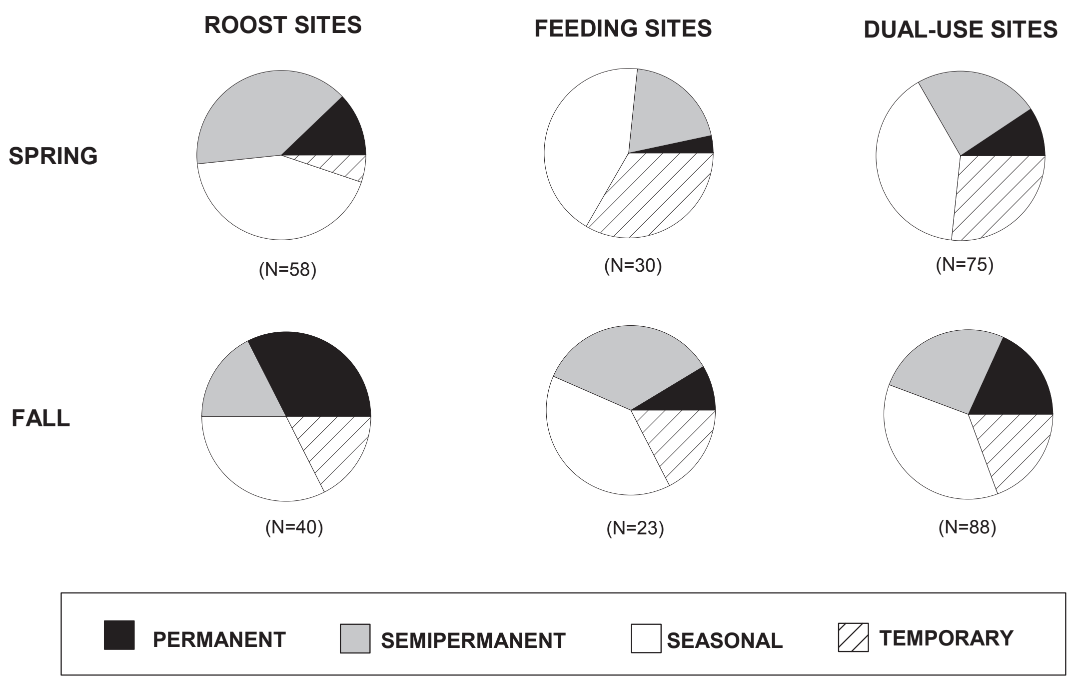

Fig. 6. Frequency of occurrence (%) of wetland water regimes, by site use and season, 1977–1999.

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

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

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

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

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

River Width

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

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

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

Dual-use sites. - Widths of rivers used for both roosting and feeding ranged from 91 to 411 m and averaged 229 + 82 m (n = 28). River width did not vary by season.

Water Depth

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

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

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

Dual-use sites. - Maximum depths of wetlands used for both roosting and feeding ranged from 3 to 28 cm and averaged 50 ± 39 cm (n = 116). Wetlands used by cranes tended to be shallower in spring (44 ± 32 cm; n = 56) than in fall (56 ± 43 cm; n = 60). Depths at specific sites ranged from 3 to 61 cm and averaged 18 ± 12 cm (n = 80).

Water Quality

Roost sites. - Overall, observers described 53.1% of roost

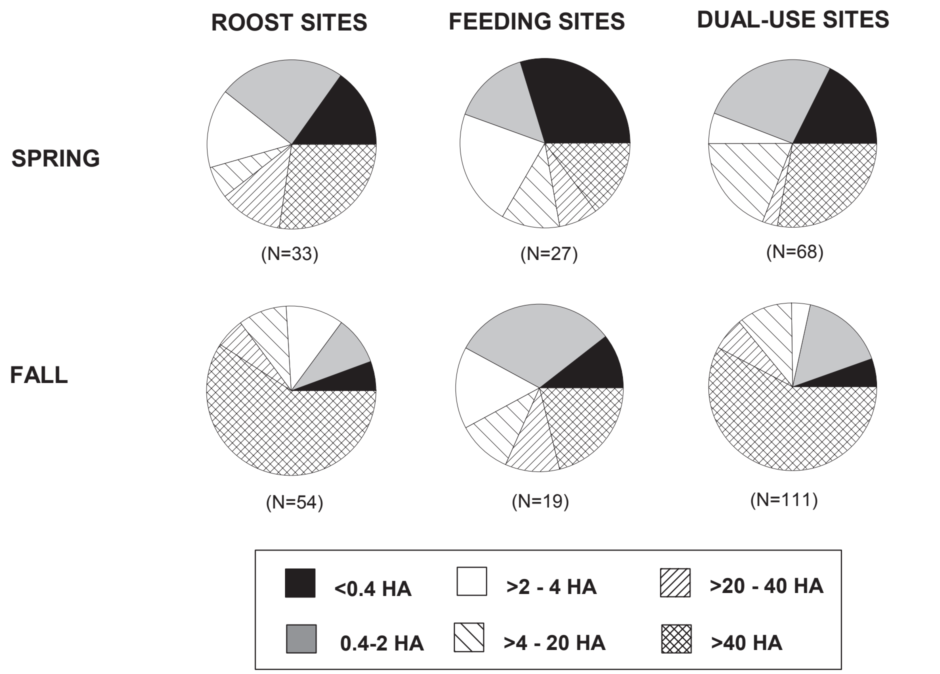

Fig. 7. Frequency of occurrence (%) of wetland size classes, by site use and season, 1977–1999.

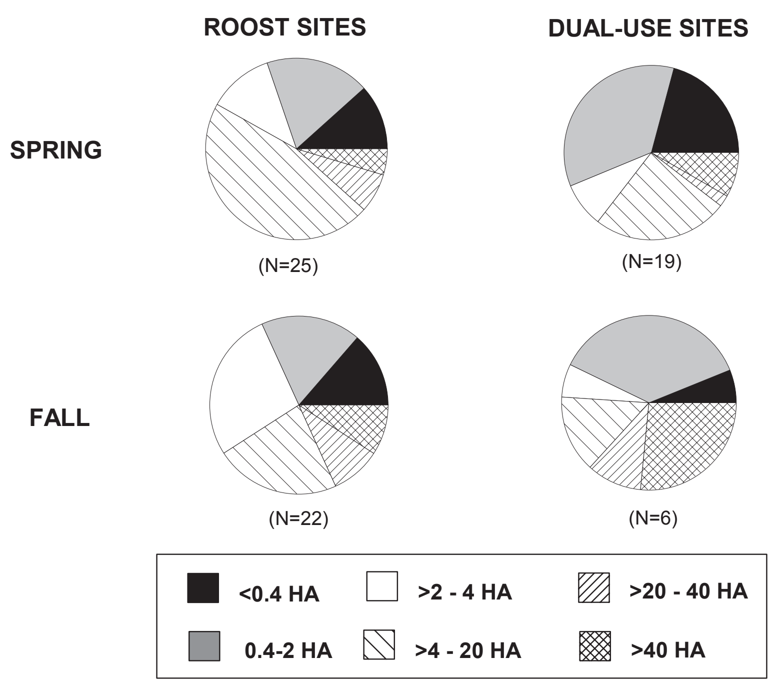

Fig. 8. Frequency of occurrence (%) of wetland size classes, by site use and season, 1977–1999, when records from Quivera NWR, Salt Plains NWR, Cheyenne Bottoms SWA, and Funk Lagoon WPA are excluded.

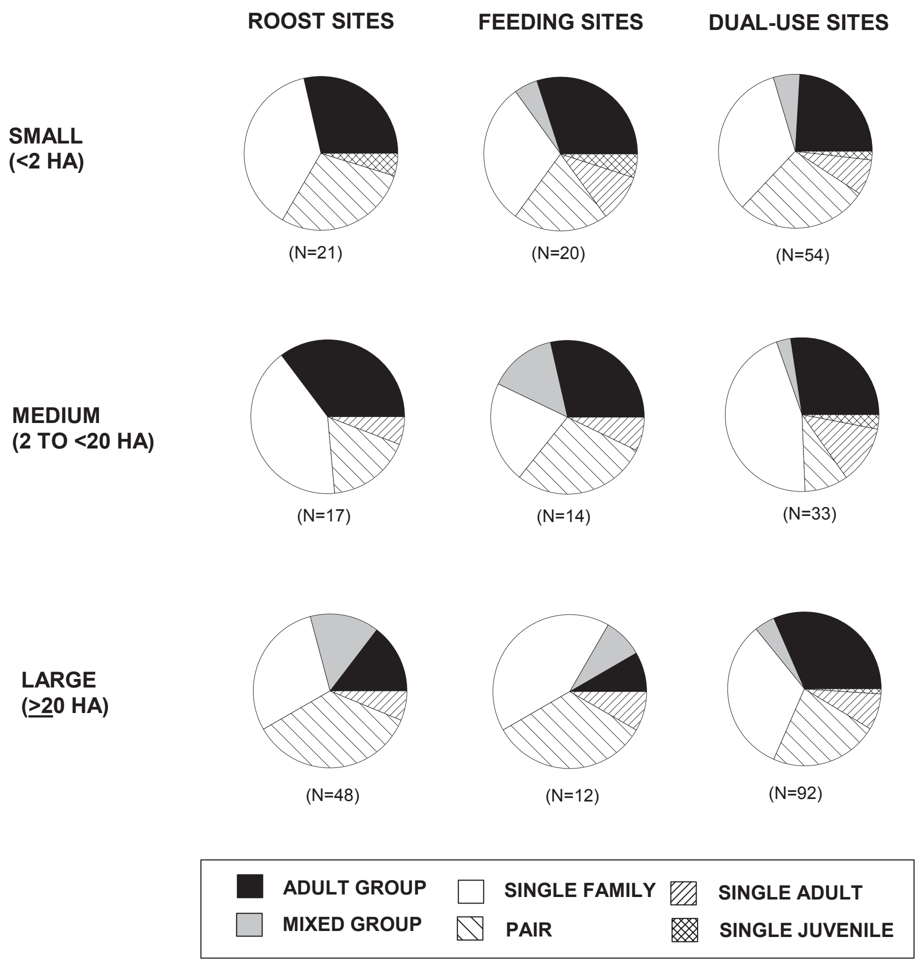

Fig. 9. Frequency of occurrence (%) of social groups relative to wetland size classes, by site use and season, 1977–1999.

sites as clear, 33.1% turbid, and 13.8% saline (n = 129). Water quality of roost sites clearly varied by wetland system (Fig. 10). Most turbid wetlands were palustrine, although 3 river sites (Niobrara River, Brown County, NE; 2 sites on Platte River near Doniphan, NE) and 7 lakes also were classified as turbid. All sites described as saline were on Salt Plains NWR or Quivera NWR (often Big Salt Marsh), except for 1 site on Stone Lake SWA, South Dakota.

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

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

Substrate

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

Feeding sites. - Most (62.1%) wetlands used for feeding had soft mud substrates; 13.8% had sand, 13.8% had hard mud, and 10.3% had other substrates. Substrate again was closely related to wetland system: 65.2% of palustrine wetlands (n = 46) had soft mud substrates, and 4 of 6 riverine systems had sand substrates. The 1 lacustrine system had soft mud.

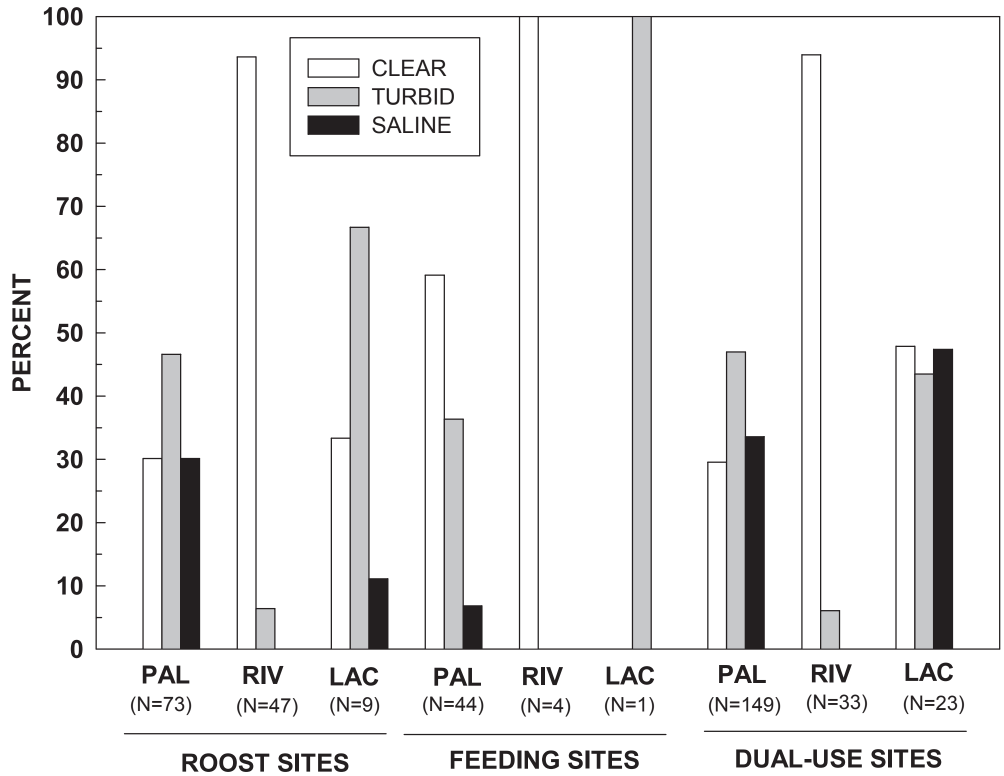

Fig.10. Frequency of occurrence (%) of water quality classes, by site use and wetland system, 1977–1999.

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

Shoreline Slope

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

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

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

Dominant Emergent Vegetation

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

Feeding sites. - In riverine systems, observers recorded feeding cranes primarily on unvegetated wetlands, but they also

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

	Roost sites			Feeding sites			Dual-use sites		
Vegetation Type	Palustrine	Lacustrine	Riverine	Palustrine	Lacustrine	Riverine	Palustrine	Lacustrine	Riverine
Grass	29.0	10.0	13.3	0	29.5	0	4.3	27.3	0
Sedge	17.7	10.0	4.4	0	29.5	0	4.3	22.4	0
Cattail	19.4	20.0	0	0	18.2	0	39.1	19.6	3.1
Rush	24.2	20.0	2.2	0	40.9	28.6	21.7	32.9	0
Smartweed	27.4	20.0	0	100	38.6	14.3	4.3	29.4	0
Other	6.5	0	11.1	100	9.1	14.3	13.0	11.9	6.2
None	30.6	50.0	84.4	0	9.1	57.1	39.1	19.6	93.7
N	*62*	*10*	*45*	*1*	*44*	*7*	*23*	*143*	*32*

observed cranes on sites with rush, smartweed, or other vegetation (likely willow) (Table 4). Palustrine sites used for feeding had a broader range of emergent vegetation types.

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

Distribution of Emergent Vegetation

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

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

Dual-use sites. - Distribution patterns of emergent vegetation at dual-use sites varied by wetland system (Fig. 11). Most riverine sites had no vegetation, as noted above, lacustrine sites were evenly split between no vegetation and scattered vegetation, and palustrine sites had a mix of patterns. No vegetation type dominated at palustrine sites.

Feeding Site Description

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

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

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

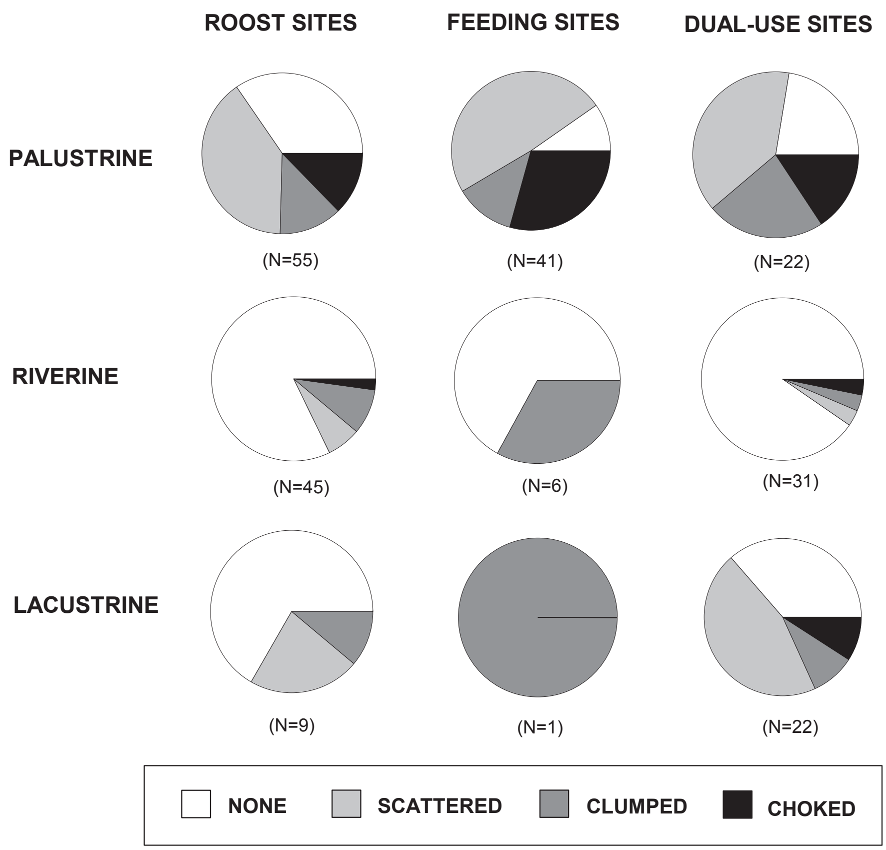

Fig.11. Frequency of occurrence (%) of distribution patterns of emergent vegetation, by site use and wetland system, 1977–1999.

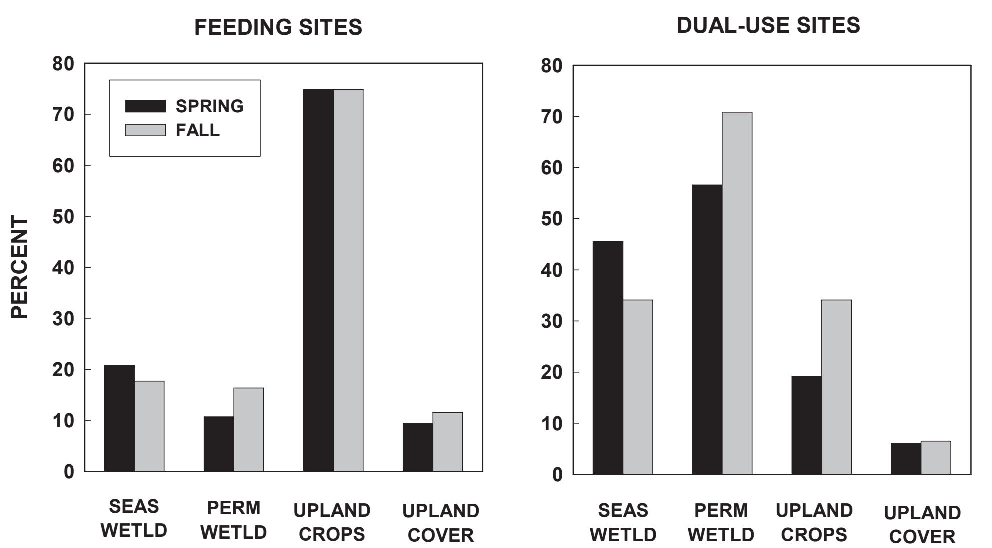

Fig. 12. Frequency of occurrence (%) of feeding and dual-use sites described as seasonal wetland, permanent wetland, cropland, or upland cover, by site use and season, 1977–1999.

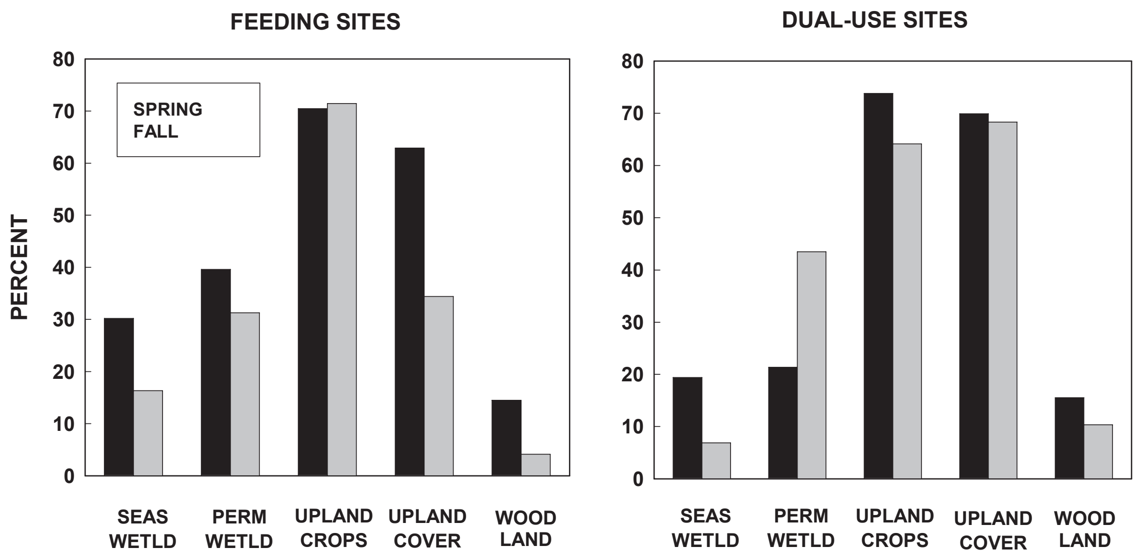

Fig. 13. Frequency of occurrence (%) of areas adjacent to feeding or dual-use sites described as seasonal wetland, permanent wetland, cropland, or upland cover, by site use, 1977–1999.

proportion of feeding cranes in cropland and upland cover than in wetlands. When we considered pooled social groups, we found no apparent difference in the distribution of family, nonfamily, and single groups among feeding habitat types.

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

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

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

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

Primary Adjacent Habitat

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

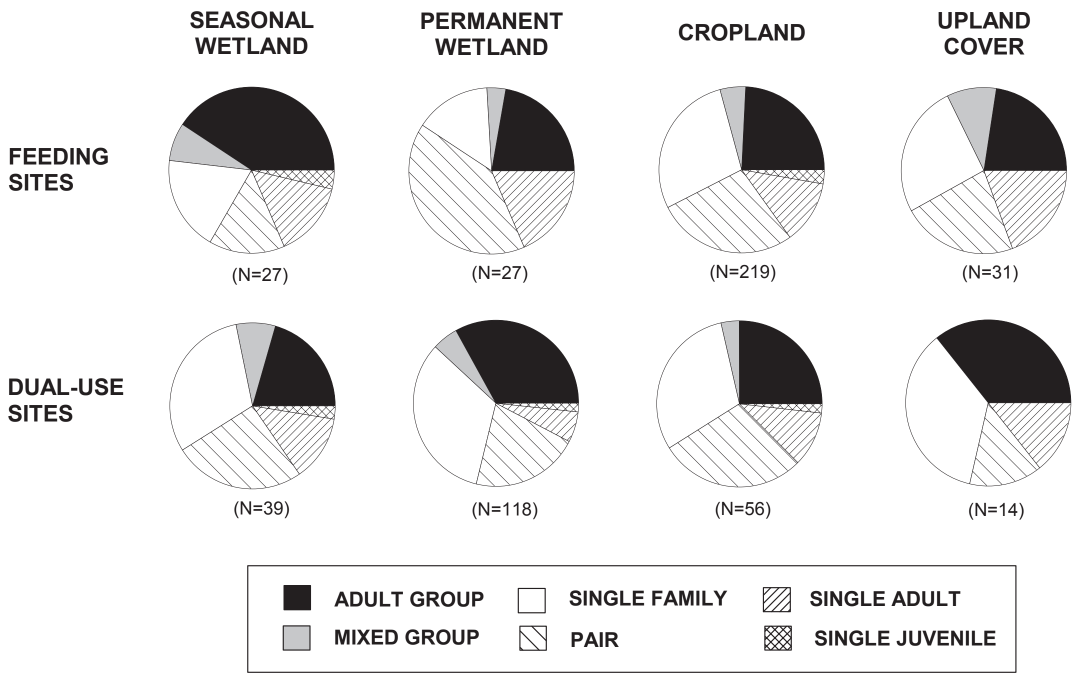

Fig. 14. Frequency of occurrence (%) of social groups occurring within each type of feeding habitat, by site use, 1977–1999.

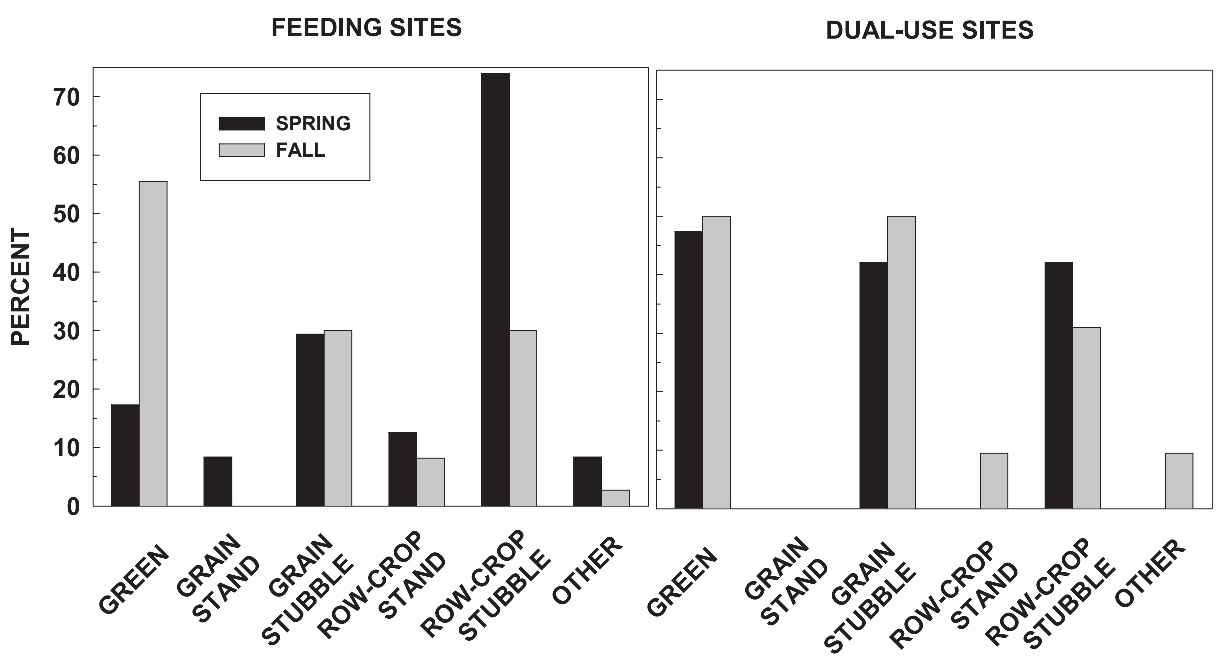

Fig. 15. Frequency of occurrence (%) of cropland types on feeding and dual-use sites, by season, 1977–1999.

toms SWA, Quivera NWR, and Salt Plains NWR, where habitat adjacent to roosts is more likely to be non-cropland habitat than on private lands, may be a factor in these seasonal differences.

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

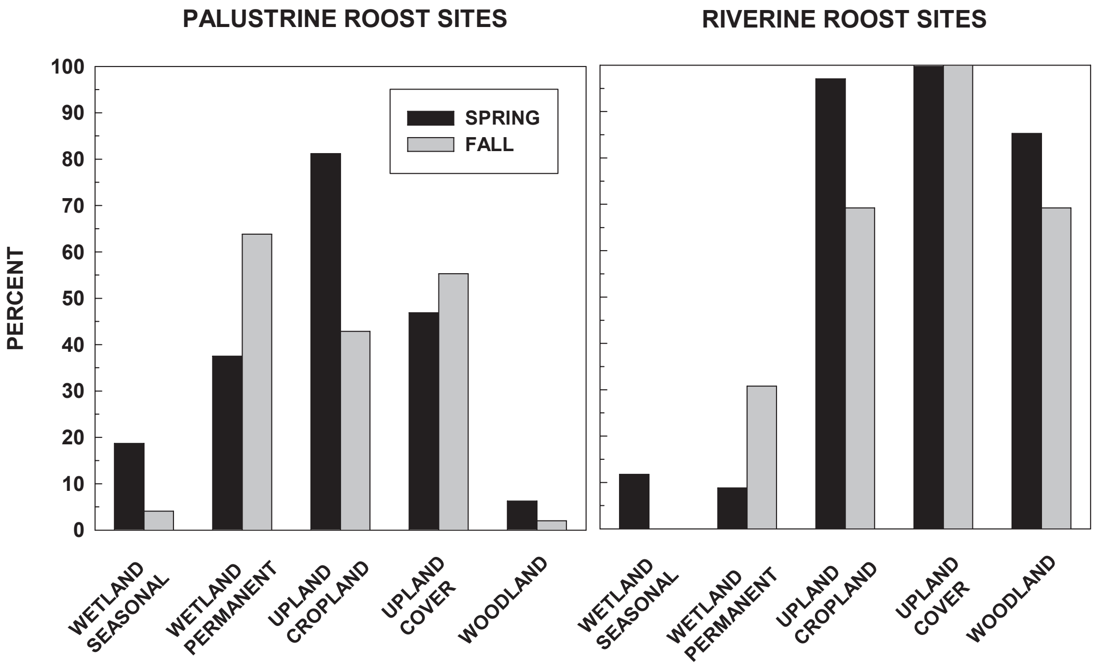

Fig. 16. Proportions of adjacent areas described as seasonal wetland, permanent wetland, cropland, or upland cover for palustrine and riverine roost sites, 1977–1999.

systems. Adjacent croplands were most likely to be green crops (winter wheat, alfalfa, winter rye, barley) or row-crop stubble (Fig. 17).

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

Similar Habitat Within 16 km (10 mi)

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

Distance to Feeding Sites

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

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

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

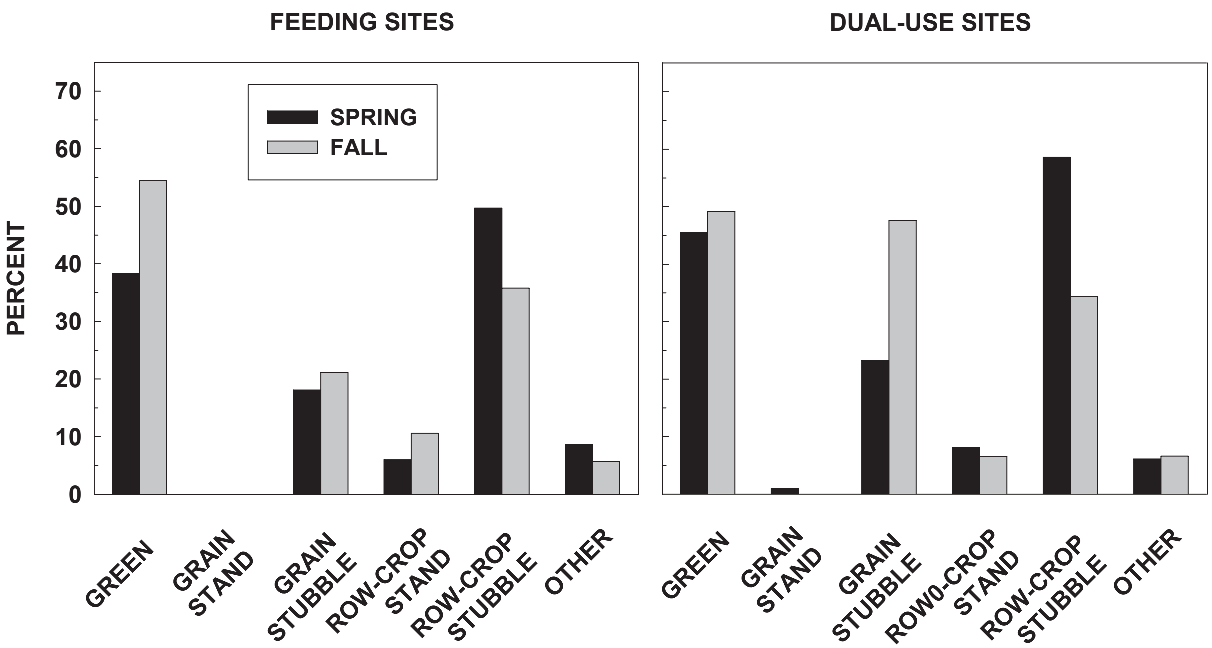

Fig. 17. Frequency of occurrence (%) of cropland types on adjacent areas of feeding and dual-use sites, by season, 1977–1999.

roosting: 49.2% of feeding sites were < 0.40 km of the site, 13.3% were 0.40–0.79 km away, 8.6% were 0.8–1.19 km away, 8.6% were 1.20–1.6 km away, and 20.3% were > 1.6 km away from the site (n = 128). Palustrine and lacustrine dual-use sites often were closer to feeding sites than riverine dual-use sites (Fig. 18).

Distance to Human Development

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

Distance to Utility Lines

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

Visibility

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

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

Dual-use sites. - Visibility was < 91 m for 21.9% of dual-

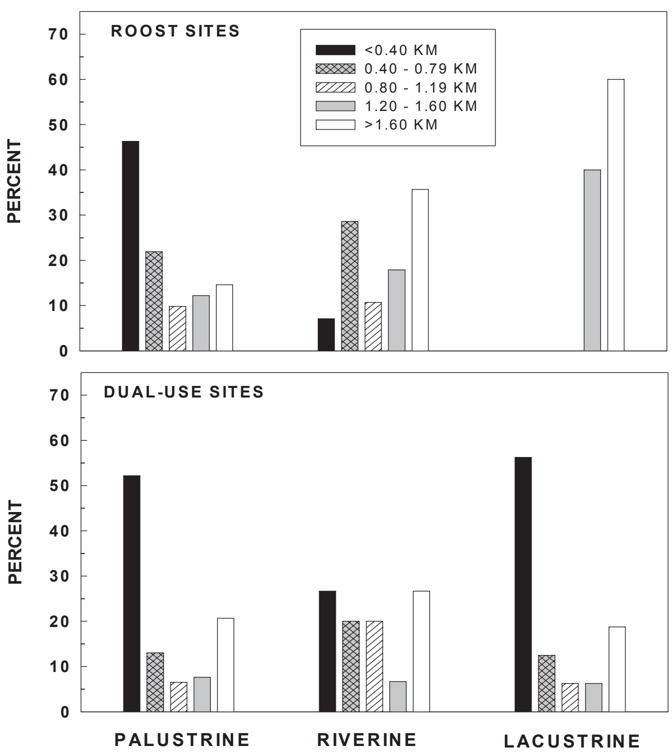

Fig. 18. Frequency of occurrence (%) of distances to feeding sites, by site use, 1977–1999.

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

Other Species Present

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

Feeding sites. - Feeding whooping cranes associated with other bird species in 31.7% of records (97 of 306). They most

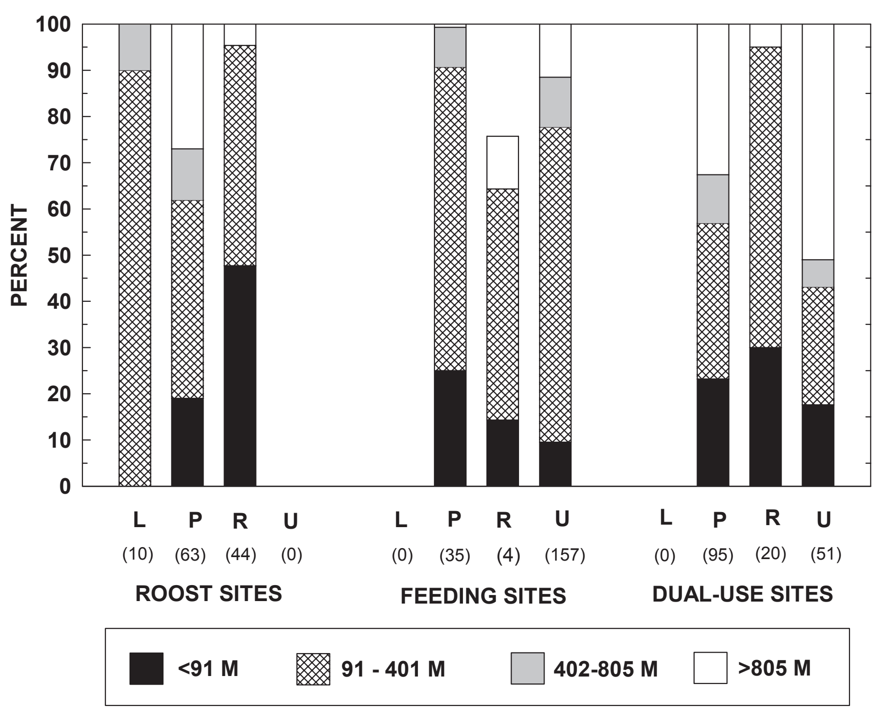

Fig. 19. Frequency of occurrence (%) of visibility classes, by site use and wetland system or upland site, 1977–1999.

commonly associated with sandhill cranes (94.8% of the 97 records), but observers also found them associated with geese (4.1%; identified as snow geese, Canada geese, or simply geese), ducks, American white pelicans, swans (*Cygnus* spp.), and great blue herons (*Ardea herodias*) (1 record each). Spring associations with sandhill cranes (n = 49) were primarily on and around the Platte River (n = 26) and Rainwater Basin (n = 6), but in fall observers found whooping cranes with sandhill cranes in a wide variety of areas. Observers found whooping cranes with geese in seasonally flooded basins and/or cropland on 2 sites in North Dakota (McLean and Divide counties), 1 in South Dakota (Pennington County), and 1 in Nebraska (Gleason WPA).

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

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

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

Site Ownership

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

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

Site Security

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

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

Dual-use sites. - Observers recorded >75% of sites used for both roosting and feeding as secure. Almost all federally-owned sites were considered secure but 28–32% of privately and state-owned sites were considered threatened (Fig. 21). A higher proportion of sites were considered secure in fall than in spring (82 vs. 69%; n = 242).

DISCUSSION

Early studies describing roost sites were generally limited to riverine sites (Aronson and Ellis 1979; Shoemaker et al. 1982; Lingle et al. 1984, 1986), especially along the Platte River and other Nebraska rivers. Studies of broader geographical scope have consistently demonstrated the significance of palustrine wetlands for both roosting and foraging (Howe 1987, Johns et al. 1997, Richert 1999, this study). The site evaluation data indicate that riverine roost sites were common only in Nebraska, primarily on the Platte, Niobrara, Middle Loup, and North Loup rivers. The higher use of riverine roosts in Nebraska may be related to the relatively unique geomorphic characteristics of rivers there, which include shallow, relatively slow-moving channel flows and sand bars with little vegetative cover. The other 2 studies examining flyway-wide habitat use also reported high use of palustrine wetlands. Radio-marked cranes roosted primarily on palustrine wetlands in most areas, and only 2 sites used by radio-marked cranes in the United States were riverine (Howe 1987). In Saskatchewan, 84% of observational records were on palustrine wetlands (Johns et al. 1997). In our study, all social groups of whooping cranes used palustrine wetlands

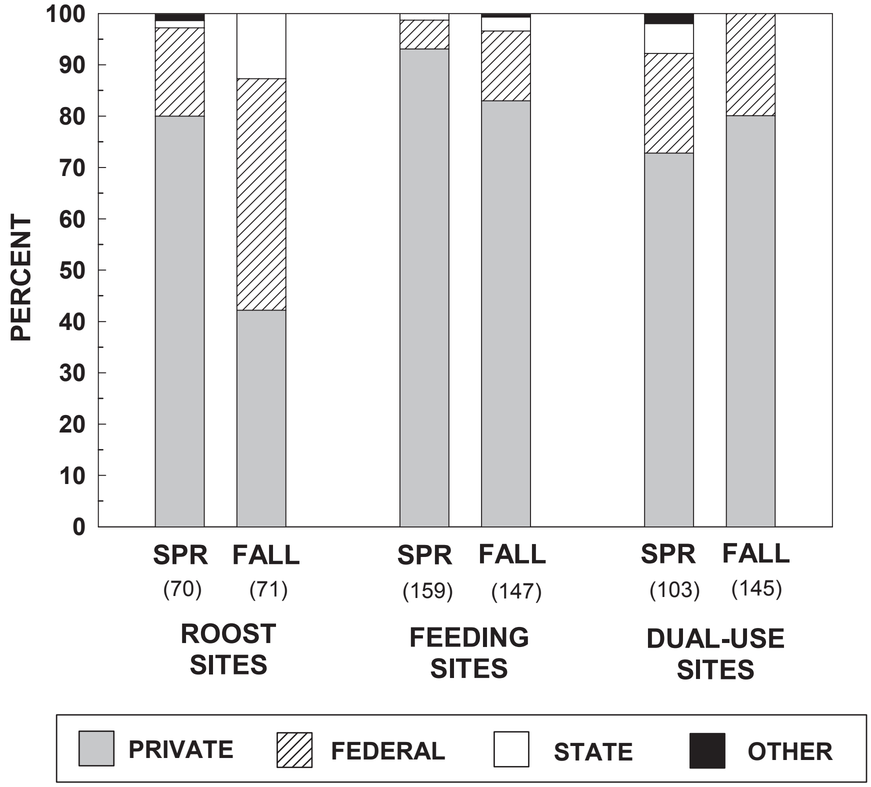

Fig. 20. Frequency of occurrence (%) of sites in private, federal, state, or other ownership, by season and site use, 1977–1999.

for both roosting and feeding. However, most of the whooping cranes found on riverine roosts were single cranes or nonfamily groups, particularly on the Platte, although social groups did not differ on feeding or dual-use sites. Richert (1999), using a subset of these data for Nebraska to assess habitat use at several landscape scales, noted that nonfamily groups were the primary social groups associated with the Rainwater Basin and Platte River areas, whereas family groups were more commonly associated with the Table Playa area in Custer County, Nebraska. That area contained a much larger proportion of grassland at both local and landscape scales than did the Rainwater Basin or Platte River areas. Further investigation of other regions of the flyway is needed to determine whether grassland may be an important landscape feature for use by family groups.

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

Observers found whooping cranes on a wide range of wetland sizes in both spring and fall. We found no real pattern of use by social groups among the different sizes of wetlands. Observers often found cranes roosting on large managed wetlands (e.g., moist-soil units, impoundments) on state or federal lands in fall, but cranes also used large lakes and natural wetlands in both seasons. Investigators also located radio-tracked cranes on a range of wetland sizes, but over 50% of those cranes were located on wetlands < 1 ha (Howe 1987). Unfortunately, investigators did not consistently record wetland sizes for all wetland sites in that study (Armbruster 1990:9). Although there was no consistent pattern suggesting cranes usually used smaller wetlands for feeding sites, dual-use sites usually were small (< 2 ha) wetlands; the latter might reflect lack of availability of larger wetlands for roosting in those areas. Investigating wetland densities and size classes available around sites, using archival remote sensing data, could reveal a clearer picture of site-use

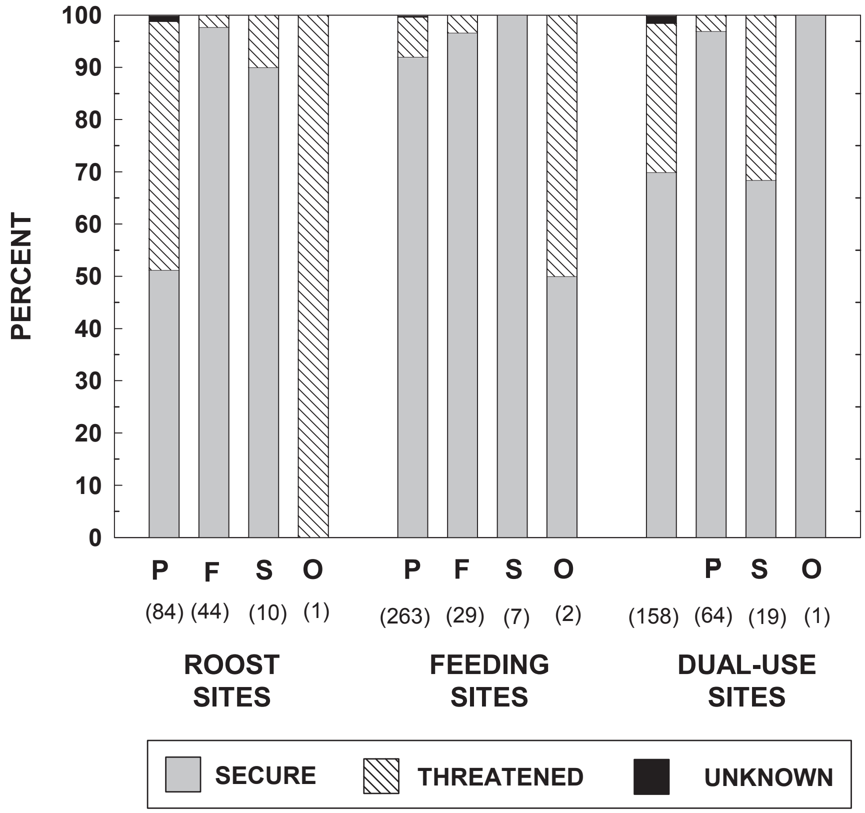

Fig. 21. Frequency of occurrence (%) of sites considered secure, threatened, or of unknown security that were under private (P), federal (F), state (S), or other (O) ownership, 1977–1999.

patterns.

Observers recorded water depths for either the entire wetland used during a stopover or for the location within the wetland where the cranes had been observed roosting or foraging. Unfortunately, there were no records where both water depths were recorded. Armbruster (1990:8) discussed the significance of shallow water sites for both whooping and sandhill cranes. Average water depths at specific sites within roost wetlands and feeding wetlands were similar to those reported earlier (Lingle et al. 1984, 1986, Howe 1987, Ward and Anderson 1987, Johns et al. 1997), but toward the high end of Johnson and Temple's (1980) optimum water depth of 7.6–20.3 cm (2.2–8.0 inches).

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

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

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

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

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

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

Private lands provide the vast majority of cropland and wetland habitats used by whooping cranes during migration (Howe 1987, Johns et al. 1997, this study). However, whooping cranes have been observed on a wide variety of state and federal lands over the years, and cranes have used some of these areas frequently. National wildlife refuges, WPAs, and state lands often provide roost locations (large, shallow natural or managed wetlands), and cranes forage on adjacent private croplands. Officials already have designated as critical habitat 3 public areas that have had many observations over the years (Cheyenne Bottoms SWA, Quivera NWR, and Salt Plains

NWR). Whooping cranes appear to obtain much of their food on cropland, much like sandhill cranes (Lovvorn and Kirkpatrick 1981, Howe 1987, Johns et al. 1997, this study; but see Lingle et al. 1991). We did not observe a difference among social groups for feeding habitat types as did Johns et al. (1997).

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

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

LITERATURE CITED

Armbruster, M. J. 1990. Characterization of habitat used by whooping cranes during migration. U.S. Fish and Wildlife Service Biological Report 90(4). 16 pages.

Aronson, J. G., and S. L. Ellis. 1979. Monitoring, maintenance, rehabilitation and enhancement of critical whooping crane habitat, Platte River Nebraska. Pages 168–180 *in* G. A. Swanson, technical coordinator. The Mitigation Symposium: A National Workshop on Mitigation Losses of Fish and Wildlife Habitat. July 16-20, 1979. Fort Collins, Colorado, USA. U.S. Forest Service General Technical Report RM 65.

Askins, R. A. 2000. Restoring North America's birds: lessons from landscape ecology. Yale University Press, New Haven, Connecticut. 288 pages.

Butler, W. I., R. A. Stehn, and G. R. Balogh. 1995. GIS for mapping waterfowl density and distribution from aerial surveys. Wildlife Society Bulletin 23:140–147.

Carlson, D., D. Holz, D. Woodward, and J. Ziewitz. 1990. Whooping crane roosting habitat simulation model for the Platte River in Nebraska. Unpublished report to the Biology Working Group, Platte River Management Joint Study. 31 pages.

Cowardin, L. M., V. M. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C., USA. FWS/OBS–79/31. 103 pages.

Faanes, C. A. 1992. Factors influencing the future of whooping crane habitat on the Platte River in Nebraska. Pages 101–109 *in* D. A. Wood, editor. Proceeding of the 1988 North American Crane Workshop, River Ranch Outdoor Resort, Lake Wales, Florida, February 22-24, 1988. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report 12.

_______ and D. B. Bowman. 1992. Relationship of channel maintenance flows to whooping crane use of the Platte River. Pages 111–116 *in* D. A. Wood, editor. Proceedings of the 1988 North American Crane Workshop, River Ranch Outdoor Resort, Lake Wales, Florida, February 22-24, 1988. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report 12.

_______, D. H. Johnson, and G. R. Lingle. 1992. Characteristics of whooping crane roost sites in the Platte River. Pages 90–94 *in* D. A. Wood, editor. Proceedings of the 1988 North American Crane Workshop, River Ranch Outdoor Resort, Lake Wales, Florida, February 22-24, 1988. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Technical Report 12.

Farmer, A. H., and A. H. Parent. 1997. Effects of landscape on shorebird movements at spring migration stopovers. Condor 99:698–707.

Frederick, R. B., W. R. Clark, and E. E. Klaas. 1987. Behavior, energetics, and management of refuging waterfowl: a simulation model. Wildlife Monograph 96. 35 pages.

Howe, M. A. 1987. Habitat use by migrating whooping cranes in the Aransas Wood Buffalo corridor. Pages 303–314 *in* J. C. Lewis, editor. Proceedings of the 1985 Inter national Crane Workshop. U.S. Fish and Wildlife Service, Grand Island, Nebraska, USA.

Johns, B. W., E. J. Woodsworth, and E. A. Driver. 1997. Habitat use by migrant whooping cranes in Saskatchewan. Proceedings North American Crane Workshop 7:123–131.

Johnson, K. A. 1982. Whooping crane use of the Platte River, Nebraska – history, status, and management recommendations. Pages 33–44 *in* J. C. Lewis, editor. Proceedings 1981 Crane Workshop. National Audubon Society, Taverner, Florida, USA.

_______ and S. A Temple. 1980. The migratory ecology of the whooping crane (*Grus americana*). Unpublished report prepared under contract to U.S. Fish and Wildlife Service (Contract No. 14–16–0009–78–034). University of Wisconsin, Madison, USA.

Krapu, G. L., D. A. Brandt, and R. R. Cox, Jr. 2004. Less waste corn, more land in soybeans, and the switch to genetically modified crops: trends with important implications to wildlife management. Wildlife Society Bulletin 32:127-126.

Lingle, G. R., P. J. Currier, and K. Lingle. 1984. Physical characteristics of a whooping crane roost site on the Platte River, Hall County, Nebraska. Prairie Naturalist 16:39-44.

_______, K . J. Strom, and J. W. Ziewitz. 1986. Whooping crane roost site characteristics on the Platte River, Buffalo County, Nebraska. Nebraska Bird Review 54:36-39.

_______, G. A. Wingfield, and J. W. Ziewitz. 1991. The migration ecology of whooping cranes in Nebraska, U.S.A. Pages 395–401 *in* J. Harris, editor. Proceedings of the International Crane Foundation, Workshop, 1-10 May, 1987, Qiqihar, Heilongjiang Province, People's Republic of China.

Lovvorn, J. R., and C. M. Kirkpatrick. 1981. Roosting behavior and habitat for migrant greater sandhill cranes. Journal of Wildlife Management 45:842–857.

Richert, A. L.-D. 1999. Multiple scale analyses of whooping crane habitat in Nebraska. Dissertation, University of Nebraska, Lincoln, USA. 175pp.

Shenk, T. M., and M. J. Armbruster. 1986. Whooping crane habitat criteria for the Big Bend area of the Platte River. Unpublished report to Biological Ad Hoc Workshop, Platte River Management Joint Study. U.S. Fish and Wildlife Service, National Ecological Research Center, Fort Collins, Colorado, USA. 34 pages.

Shoemaker, T. G., S. L. Ellis, and H. W. Shen. 1982. Development of minimum streamflow recommendations for maintenance of whooping crane habitat on the Niobrara River, Nebraska. Pages 155–174 *in* J. C. Lewis, editor. Proceedings of the 1981 Crane Workshop. National Audubon Society, Tavernier, Florida, USA.

Stahlecker, D. W. 1997. Availability of stopover habitat for migrating whooping cranes in Nebraska. Proceedings North American Crane Workshop 7:132–140.

U.S. Fish and Wildlife Service. 1980. Whooping Crane Recovery Plan. U.S. Fish and Wildlife Service. Region 2, Albuquerque, New Mexico, USA.

_______ . 1994. Whooping crane recovery plan. U.S. Fish and Wildlife Service. Region 2, Albuquerque, New Mexico, USA.

van der Zande, A. N., W. J. ter Kerus, and W. J. vander Weijden. 1980. The impact of roads on the densities of 4 bird species in an open-field habitat̹ evidence of a long-distance effect. Biological Conservation 18:299-321.

Ward, J. P., and S. H. Anderson. 1987. Roost site use versus preference by two migrating whooping cranes. Pages 283–288 in J. C. Lewis, editor. Proceedings of the 1985 International Crane Workshop. U.S. Fish Wildlife Service, Grand Island, Nebraska, USA.

Ziewitz, J. W. 1992. Whooping crane riverine roosting habitat suitability model. Pages 71–81 *in* D. A. Wood, editor. Proceedings of the 1988 North American Crane Work shop, River Ranch Outdoor Resort, Lake Wales, Florida, February 22-24, 1988. Florida Game Fresh Water Fish Commission Nongame Wildlife Program Technical Report 12.