BROOD-REARING HABITAT AND FALL-WINTER MOVEMENTS OF LESSER PRAIRIE CHICKENS IN EASTERN NEW MEXICO

by

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"BROOD-REARING HABITAT AND FALL-WINTER MOVEMENTS OF LESSER PRAIRIE CHICKENS IN EASTERN NEW MEXICO," a thesis prepared by Gary Gale Ahlborn in partial fulfillment of the requirements for the degree, Master of Science, has been approved and accepted by the following:

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ABSTRACT

BROOD-REARING HABITAT AND FALL-WINTER MOVEMENTS OF
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by

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MASTER OF SCIENCE IN WILDLIFE SCIENCE
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Lesser prairie chicken (*Tympanuchus pallidicinctus*) brooding habitat, brood movements, and fall-winter use of grain fields in eastern New Mexico were investigated during 1979. Livestock grazing is the foremost land-use influencing vegetation in and around the study area. Eight principal vegetation types were delineated, 4 of which received most of the use by prairie chickens. Shinnery Oak-Bluestem is in the good and excellent range condition classes (near climax), with bluestem grasses composing a large percentage of the total grass composition. Shinnery Oak-Midgrass is a deteriorated form of Shinnery Oak-Bluestem (poor and fair range condition classes), due to heavier grazing by livestock. The third type, Sandhills, is characterized by a hummocky topography and high composition of shrubs and forbs. This type is in fair to good range condition. The Cultivated type is land used primarily for cultivation of grain sorghum under dryland conditions.

Based on 90 brood-use sites, 25 from cross-country transects and 65 from 5 radio-tagged broods, it was determined that hens with broods strongly preferred the Sandhills type. Selection for Sandhills by broods is influenced primarily by its undulating topography and abundant shrubs and forbs.

Based on 256 radio locations of 16 female prairie chickens, 97% of all prenesting, nesting, and brood movements were within 1.5 km of dominant (regularly used) leks. The distribution of vegetation types within 1.5 km surrounding 9 dominant leks was different from that in the study area as a whole. Sandhills (preferred brooding habitat) and Shinnery Oak-Bluestem (preferred nesting habitat) were far more abundant in the vicinity of leks (radius = 1.5 km) than in the overall study area.

Characteristics of the vegetation at 65 brood-use sites in 4 vegetation types were compared to those in the overall types. Broods selected for similar vegetational attributes across all vegetation types. These characteristics included canopy cover 25%, canopy height 30 cm, basal shrub (shinnery oak) composition 30-35%, and basal plant cover 5%.

Eleven of 15 (73%) radio-tagged prairie chickens moved to feed in grain (sorghum) fields during fall and winter. Comparisons of the movements of these birds with the distribution of grain fields in and around the study area suggest that a traditional wintering area exists.

Management efforts for maintaining, enhancing, and expanding nesting and brooding habitat should be concentrated on restoration of near-climax

vegetation in the Shinnery Oak-Grassland community. The principal management technique to achieve this goal should be the reduction of livestock grazing pressure followed by a flexible grazing strategy such as the best-pasture system.

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INTRODUCTION

The lesser prairie chicken (*Tympanuchus pallidicinctus*) is presently restricted to parts of a relatively small area in southeastern Colorado, southwestern Kansas, eastern New Mexico, western Oklahoma, and northwestern Texas (Sharpe 1968 and Crawford 1974). Since pristine times, its range has shrunk more than 90% (Taylor and Guthery 1980).

Efforts to stop or reverse the decline in overall abundance of lesser prairie chickens must be based on knowledge of their habitat needs. Limited information is available on preferred brood-rearing habitat and on the vegetational attributes of brood-use sites. In New Mexico, about 55 km southwest of the present study area, Davis et al. (1979) and Riley (1978) found that broods preferred shrubby cover. Riley also noted that broods favored areas with low sandhills. Sell (1979) found that 14 female prairie chickens in western Texas (1 with brood and 13 without) used the vegetation type characterized by dunes and the highest shinnery oak (shrub) cover available. Copelin (1963) found that lesser prairie chicken broods in western Oklahoma often spent midday in shinnery oak motts during warm summer months. Jones (1963) observed that prairie chicken broods in western Oklahoma preferred areas of high shrub and forb composition.

Movements of lesser prairie chicken broods have received little attention and the few investigations have yielded scant information. Sell (1979) reported movement data for 1 brood in west Texas. Candelaria (1979) presented tentative data for 3 broods in eastern New Mexico. Candelaria (1979) and Sell (1979) also reported prenesting and nesting movements of prairie chickens.

The importance of cultivated grains as a fall-winter food is sufficiently documented (Davison 1940, Martin et al. 1951, Frary 1957, Copelin 1963, Jackson and De Arment 1963, Jones 1963, Crawford and Bolen 1976). Crawford (1974) found that the density of displaying males on leks in western Texas was higher in areas with 5 to 35% cultivated grains, where minimum tillage was practiced. From banding studies in New Mexico, Campbell (1972) noted that fall-winter movements were influenced by the location of grain fields. Birds traveled "several miles" from leks to feed in fields (Campbell 1972:698). In western Texas, Taylor (1978) found that completion of fall lekking and use of grain fields coincided with increased fall-winter movements of radio-ragged prairie chickens.

The present study was conducted with the following objectives: (1) to identify preferred brooding habitat; (2) to determine movements of broods; (3) to determine movement patterns during prenesting, nesting, and brooding periods as they relate to leks; (4) to determine fall-winter movement patterns as they relate to grain fields; (5) to develop management recommendations for enhancing lesser prairie chicken habitat. Field work was conducted during the entire 1979 calendar year. Conclusions and recommendations presented herein are based on the first year of a 2-year study and are therefore subject to revision.

STUDY AREA

The study area (Fig. 1) is in southern Roosevelt and northern Lea counties, on the western edge of the southern High Plains. The area includes approximately 14,500 ha centered on the state-owned Milnesand Prairie Chicken Restoration Area (3,108 ha), 65 km south of Portales.

Land-use in and around the study area includes livestock grazing and dryland cultivation of sorghum, cotton, and winter wheat. There is also extensive petroleum production and refining in the area. In the recent past, small farmers made numerous attempts at cultivation, which altered the land and added to the vegetational diversity of the area.

Climate is semi-arid with an average annual rainfall of 38.4 cm (U.S. Dept. of Com. 1979). Over 75% of the precipitation occurs during the growing season, April through October. Much of it falls in the form of torrential rain or hail during intense thunderstorms. Prevailing surface winds are from the southeast in the warm half of the year and from the southwest during the cool half.

Precipitation during 1979 (39.7 cm) was slightly above the 32-year average of 38.4 cm (U.S. Dept. of Com. 1979) reported for Crossroads, about 4 km south of the study area. The 1979 precipitation pattern deviated in several ways from the average. January and February rainfall was approximately 38% above average, but by the end of May the cumulative amount was near average. During the early months of the growing season (June, July, and August), rainfall was 27.9 cm, approximately 68% above average. Conversely, rainfall during the remainder of the year (2.0 cm) was 83% below average.

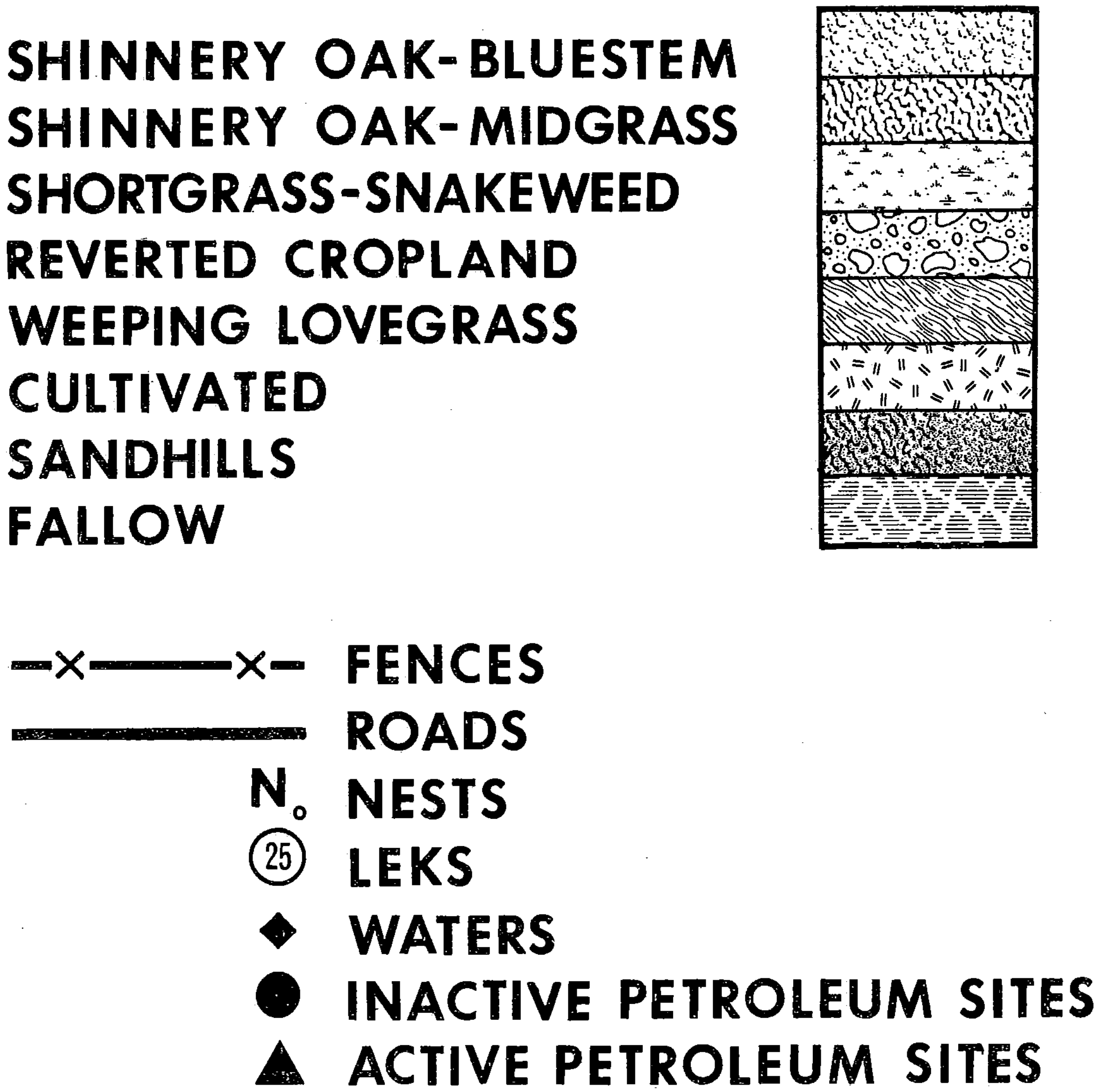
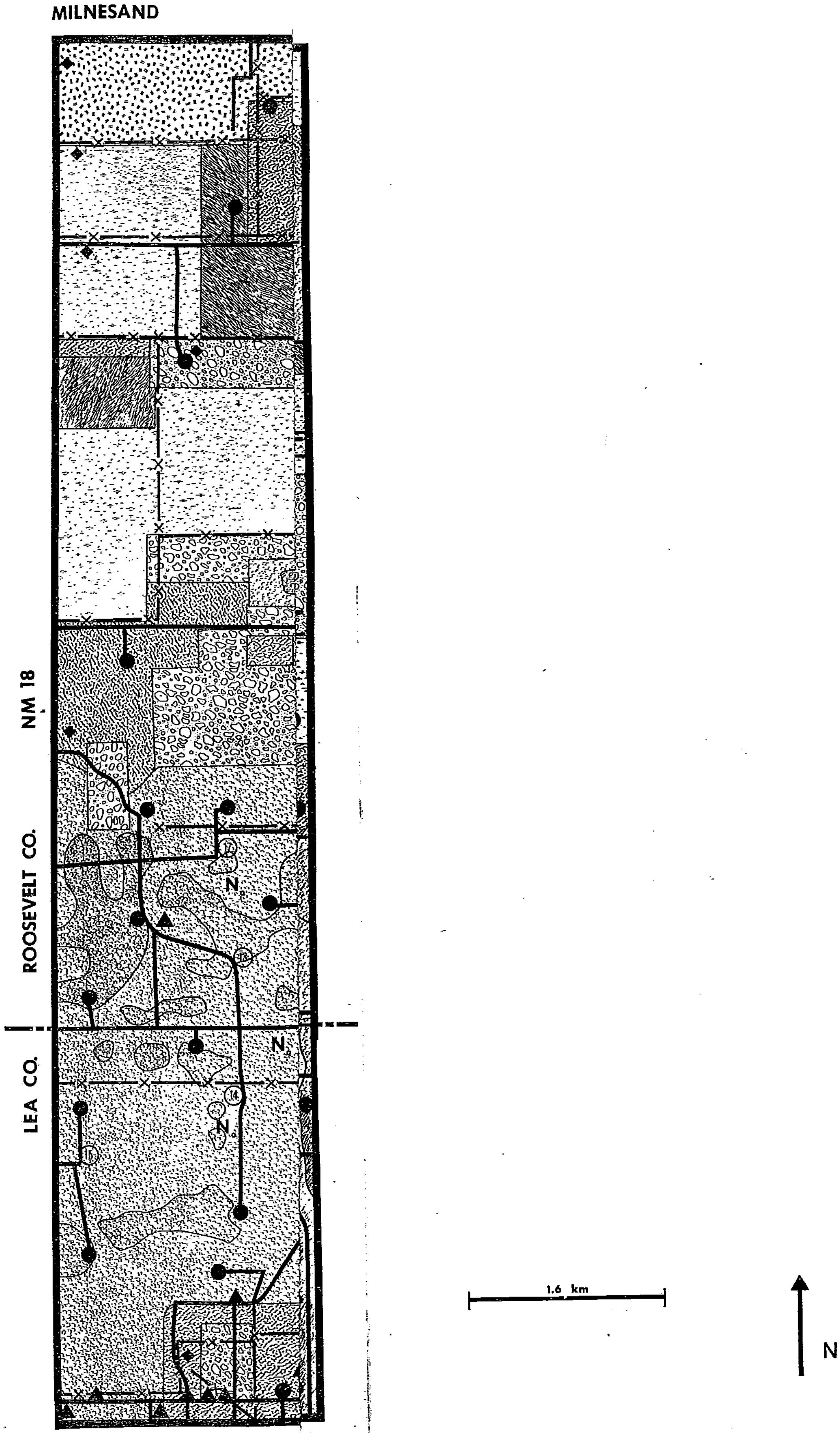


Figure 1. Study area.


MILNESAND
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Abundant spring rains probably were responsible for the abundant forbs, especially early vernal species such as Easter daisy (Townsendia exscapa).[1] Plentiful summer rains also favored above-average grasshopper densities (J. Banfill, New Mexico Dept. of Agri., pers. comm.) and vigorous plant growth.

Vegetation of the study area was stratified into 8 principal types (Fig. 1). Characteristics of the vegetation and comparisons among the 4 types thought to be most essential to prairie chickens, Shinnery Oak-Bluestem, Shinnery Oak-Midgrass, Sandhills, and Reverted Cropland, are reported in Tables 1-4 and the Appendix. Brief descriptions and the percentage of each vegetation type in the total area are given below.

Shinnery Oak-Bluestem (21.14%). This type is dominated by a homogeneous cover of shinnery oak (Quercus havardii) interspersed with little bluestem (Schizachyrium scoparius), sand bluestem (Andropogon hallii), purple three-awn (Aristida purpurea), hairy grama (Bouteloua hirsuta), and sand dropseed (Sporobolus cryptandrus). Bluestem grasses account for nearly 40% of all grass present. Using the Soil Conservation Service range condition classification (Ross and Bailey 1967), Shinnery Oak-Bluestem is primarily in the good condition class and to a lesser extent in the excellent condition class, representing an area where vegetation is near its potential (climax). This type has the highest percentage basal plant cover. Fine sandy soils form a nearly level topography.

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[1] Common and scientific plant names follow Correll and Johnston (1970).

Table 1. Percentage basal cover in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

	Vegetation type				
Categories	Shinnery Oak-Bluestem (170)	Sandhills (120)	Shinnery Oak-Midgrass (100)	Reverted Cropland (220)	Probability[a] and X^2 values
Vegetation	10.9 ± 0.8*[b]	2.8 ± 0.5*	6.8 ± 0.7	7.2 ± 0.6	$\ll 0.001$ $X^2 = 57.73$
rank	1	4	3	2	d.f. = 6
Bare	50.2 ± 1.8*	57.5 ± 2.2	58.5 ± 2.3	59.9 ± 1.9	< 0.001 $X^2 = 57.74$
rank	4	3	2	1	d.f. = 27
Litter	38.9 ± 1.7	39.0 ± 2.2	34.7 ± 2.1	32.2 ± 1.8*	< 0.001 $X^2 = 72.68$
rank	2	1	3	4	d.f. = 21

[a] Probabilities calculated by chi-square test.

[b] Indicates the vegetation types with the greatest deviation between the observed and expected distributions.

Table 2. Percentage canopy cover in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

Plant categories	Shinnery Oak-Bluestem (170)	Sandhills (120)	Shinnery Oak-Midgrass (100)	Reverted Cropland (220)	Probability[a] and X^2 values
	Vegetation type				
Total cover	36.3 ± 1.4	37.5 ± 1.8	32.7 ± 1.8	27.3 ± 1.4*[b]	<0.001
rank	2	1	3	4	$X^2 = 55.68$ d.f. = 21
Shrub cover	18.6 ± 1.2	32.9 ± 1.7*	23.2 ± 1.7	9.4 ± 1.2*	$\ll 0.001$
rank	3	1	2	4	$X^2 = 221.75$ d.f. = 15
Grass cover	16.0 ± 1.2	3.6 ± 0.6*	7.9 ± 1.1	14.9 ± 1.0	$\ll 0.001$
rank	1	4	3	2	$X^2 = 91.12$ d.f. = 12
Forb cover	1.6 ± 0.4	1.0 ± 0.3	1.6 ± 0.4	2.7 ± 0.4	<0.05
rank	2.5	4	2.5	1	$X^2 = 9.03$ d.f. = 3

[a] Probabilities calculated by chi-square test.

[b] Indicates the vegetation types with the greatest deviation between the observed and expected distributions.

Table 3. Percentage basal composition of plant categories in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

Plant categories	Vegetation type: Shinnery Oak-Bluestem (170)	Sandhills (120)	Shinnery Oak-Midgrass (100)	Reverted Cropland (220)	Probability[a] and X^2 values
Total shrub	23.0 ± 1.3	46.6 ± 2.2*[b]	29.2 ± 2.1	13.4 ± 1.6*	$\ll 0.001$ $X^2 = 314.82$
rank	3	1	2	4	d.f. = 18
Total grass	63.3 ± 1.5	36.1 ± 1.8*	60.8 ± 2.0	65.2 ± 1.8	$\ll 0.001$ $X^2 = 178.15$
rank	2	4	3	1	d.f. = 18
Total forb	13.5 ± 1.0	16.6 ± 1.7	9.9 ± 1.2	21.3 ± 1.4*	< 0.001 $X^2 = 57.48$
rank	3	2	4	1	d.f. = 12

[a] Probabilities calculated by chi-square test.

[b] Indicates the vegetation type with the greatest deviation between the observed and expected distributions.

Table 4. Height (cm) of canopy cover in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

Plant categories	Vegetation type: Shinnery Oak-Bluestem	Sandhills	Shinnery Oak-Midgrass	Reverted Cropland	Probability[a] and F values
Total canopy cover	(123) 27.2 ± 0.7 A[b]	(113) 33.8 ± 0.9 B	(96) 25.5 ± 0.8 A	(201) 33.6 ± 1.1 B	< 0.0001 F = 17.59
rank	3	1	4	2	
Shrub canopy cover	(130) 26.6 ± 0.7 A	(107) 33.6 ± 0.9 B	(85) 26.9 ± 0.9 A	(68) 38.1 ± 1.9 C	< 0.0001 F = 24.99
rank	4	2	3	1	
Grass canopy cover	(118) 28.8 ± 1.1 A	(35) 33.6 ± 3.0 AB	(49) 24.1 ± 1.7 A	(155) 33.2 ± 1.3 B	< 0.0007 F = 5.96
rank	3	1	4	2	
Forb canopy cover	(21) 17.8 ± 1.3 A	(12) 31.2 ± 4.9 B	(15) 17.9 ± 1.2 A	(46) 24.9 ± 1.7 B	< 0.0014 F = 5.68
rank	4	1	3	2	

[a] Probabilities calculated by AOV test.

[b] $\bar{X} \pm SE$ followed by the same letter in a row indicates no difference ($P \leq 0.05$) using least significant difference.

Shinnery Oak-Midgrass (25.46%). The conspicuous lack of bluestem grasses and high relative abundance of grama (Bouteloua spp.), dropseed (Sporobolus spp.), and three-awn (Aristida spp.) grasses in this type distinguish it from Shinnery Oak-Bluestem. Shinnery Oak-Midgrass and Shinnery Oak-Bluestem types occur on the same soils and have the same topography and range site classifications (Ross and Bailey 1967, Turner et al. 1974). However, several significant differences were found between their vegetational characteristics (Tables 1-4, Appendix). These differences are attributed to the intensity of grazing by cattle. In contrast with Shinnery Oak-Bluestem, this type is in the poor and fair range condition classes (Ross and Bailey 1967) having lost much of its climax vegetation to heavy grazing by cattle.

Sandhills (6.71%). This type is unique in several respects. It is dominated by shinnery oak and has relatively scant grass cover. Sandhills have the highest basal composition of shrubs (46.6%) and shinnery oak (44.8%), and the lowest composition of grasses (36.1%). Percentage basal plant cover is lowest among types (2.8%), while the percentage canopy cover is highest (37.5%). Topography also is unique, characterized by rolling dunes 1 to 4 m high or higher, formed by windblown deep, fine sand. The range condition class of this type is mostly fair to good (Ross and Bailey 1967). Even in the excellent condition class, the naturally eroding sands of this type would maintain climax vegetation lower in perennial grass composition than that of Shinnery Oak-Bluestem and Shinnery Oak-Midgrass. Species composing the sparse grass cover include mostly purple three-awn, hairy grama, fall witchgrass (Leptoloma cognatum), and sand paspalum (Paspalum stramineum).

Reverted Cropland (16.25%). This type comprises severely eroded fields not recently cultivated. Wind erosion has exposed the red, sandy clay loam subsoil and caused the formation of dunes and hummocks. Wind-formed dunes are covered with shinnery oak, while surrounding exposed subsoil supports a veriety of grasses and forbs. This type is distinctive because of the diversity of plants present and because vegetation is clumped rather than distributed in a continuum, as in the three types previously described.

Shortgrass-Snakeweed (12.38%). Vegetation is composed largely of grama grasses, false buffalograss (Munroa squarrosa), sandbur (Cenchrus incertus), buffalograss (Buchloe dactyloides), snakeweed (Xanthocephalum sarothrae), and scattered mesquite (Prosopis glandulosa).

Weeping Lovegrass (8.68%). This type occupies mechanically leveled areas seeded to weeping lovegrass (Eragrostis curvula var. ermela) or, less commonly, a combination of weeping lovegrass and sideoats grama (Bouteloua curtipendula).

Fallow Fields (6.25%). Most vegetation on this recently cultivated land is invading annuals. Sunflowers (Helianthus annuus), cocklebur (Xanthium saccharatum), four-point evening primrose (Oenothera rhombipetala), and wild buckwheat (Eriogonum annuum) are dominant species. This type is extremely susceptible to wind erosion in its present condition.

Cultivated (3.13%). Sorghum is the primary crop grown under dryland conditions.

METHODS

Describing Vegetation Types

Characteristics of plants in 4 vegetation types (Shinnery Oak-Bluestem, Shinnery Oak-Midgrass, Sandhills, and Reverted Cropland) of the Shinnery Oak-Grassland community were sampled using line-point transects (Heady et al. 1959). Random sampling coordinates were plotted on 2.54 cm:220 m (1":660') scale aerial photographs using a grid overlay covering 110 m^2 per segment, and sample segments were selected by use of a random numbers table. The sample point was assumed to be at the center of a grid segment. After locating the sample point in the field, the procedure described below was followed. First, a random angle was selected, then a random number of paces (from 4 to 20) were taken along that angle, then another random angle was selected, along which a 300-cm transect line was placed. At the end of the transect, the procedure was repeated 9 times beginning with a random angle. Each 300-cm transect line was stratified into 5 equal intervals, with 2 random data points per interval, producing 10 points per transect.

At each data point, 4 attributes were recorded: basal cover (bare ground, litter, or plant species on point), nearest plant species on or ahead of point (Evans and Love 1957), plant species with canopy on point, and height (cm) of canopy species where it intersected the point. Statistical analyses follow Sokal and Rohlf (1969). Contingency tables were used to analyse differences between the observed and expected distributions of basal and canopy cover and composition values among types. The vegetation type or types contributing the most to significantly

(P 0.05) large chi-square values were identified. Statistical differences in height of vegetation among types were determined using analysis of variance for unequal sample sizes. Least significant differences were computed for comparison of means where differences (P 0.05) were found.

Trapping

Between 31 March and 16 April, 26 prairie chickens (including 16 females) were captured on leks by using cannon nets (Dill and Thornsberry 1950). Twenty-three man-days were spent trapping at five leks. All 26 birds captured were sexed, aged (Campbell 1972), weighed, and banded.

The vegetation on most leks was sparse and usually consisted of a few individual plants and small patchs of plants. Observations of lekking during February and March revealed that displaying males often crouched in or beside one or more of these plants. On cold, windy mornings they apparently used these plants as shelter from the wind. Males crouched among these plants when harriers (*Circus cyaneus*)[2] passed overhead, possibly using the plants for camouflage. They also occasionally perched on plants during display periods. By repositioning plants, I thought that I could concentrate males in front of the net and that they would attract females to where they could be captured. However, observations of females during late March and early April showed that they also frequently confined their movements to the vicinity of these plants or patchs of plants, and commonly traversed leks by moving from one plant to the next.

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[2]Common and scientific names of birds follow the American Ornithologists' Union (1976).

Trapping efforts were facilitated by removing some of the plants and transplanting others, thereby directing females in front of the cannon net. This technique seemed to be most effective on leks with sparse vegetation and before females were ready to copulate, after which their movements were difficult to influence.

Cannon nets were again used to trap prairie chickens on 7 leks in fall. Trapping began on 2 September and continued until 24 October, when lekking activities ceased. Repositioning plants on leks again facilitated the trapping of male and female birds of all age classes. A total of 24 birds were captured, requiring 24 man-days.

Radio Tracking

Sixteen females (3 adults and 13 juveniles) in spring and 2 juvenile females, 12 juvenile males, and 5 adult males in fall were fitted with solar-powered radio transmitters weighing approximately 13 g each (from Wildlife Materials, Inc., Carbondale, Illinois). Transmitters were carried in a "backpack" fashion, attached by an elastic harness looped under each wing.

A whip antenna mounted on a truck, and a portable receiver (Wildlife Materials, Inc.) were used to determine general locations of radio-tagged birds. More exact locations within a radius of approximately 25 m were determined by using a hand-held yagi antenna to triangulate the radio signal. Lost birds were radio-located from a plane provided by the New Mexico Department of Game and Fish.

When locating radio-tagged birds, considerable effort was made to minimize disturbance which could bias movement and habitat selection data. Broods were approached only closely enough to confirm their location within a 50-m radius, unless their proximity to 2 or more vegetation types necessitated greater accuracy. This method increased the error polygon inherent in radio tracking (Heezen and Tester 1967), but I believed it to be a necessary sacrifice. To find exact locations for sampling vegetation at brood-use sites and for determination of the status of hens and chicks, it was necessary for broods to be periodically flushed or otherwise visually located.

Describing Brood Habitat

Radio telemetry was used to determine successive locations for broods of hens carrying transmitters. Areas of use for these broods were calculated by the minimum area method (Mohr 1947). In this method all locations are plotted on a map and outermost locations are connected by a continuous line which represents the perimeter of the area used.

To obtain data for identifying preferences among vegetation types, the study area was traversed on horseback at one-third-mile intervals beginning on 7 June, and encounters with broods or brood sign were recorded. The proportion of transect line in a vegetation type approximated the percentage occurrence of that type in the study area. Number of brood encounters per km and preference for each type were calculated. Habitat preference was computed by subtracting the percentage of transect line in each type from the percentage encounters in each type. Positive preference values indicate selection and negative values indicate non-selection. It should be noted that the absence of observed brood use in a vegetation type does not mean this type is unsuitable.

Radio location data (number of brood encounters in each vegetation type) were used for a second analysis of preferences among types. The first step in this analysis was calculation of the area of each vegetation type available to each brood. Total area available to a brood was delineated by a method described by Svedarsky (1969:19) for early broods:

> The area contained by a circle using the nest site as a locus and a radius equal to the mean of the maximum straight-line distance the broods of all radio-tagged hens had moved away from the nest...

In two cases, brood movements exceeded this radius (located outside the circle) and another circle had to be drawn with its diameter connecting the nest site and the outermost brood location. That part of the second circle not encompassed by the first was considered available to the brood and was added to the original circle. The area of each vegetation type present (available) within the circle(s) was computed using a planimeter.

A method derived from that of Maxson (1978) was used to calculate habitat preference of broods. The area of each vegetation type available to each brood (expressed as percentage of available area occupied by the type) was weighted by the percentage of the total radio locations attributable to that brood. The mean percentage availability of the type was then subtracted from the percentage of all radio locations that occurred in a type to compute positive or negative preference indices, as for data on brood encounters gathered from horseback.

Vegetation at all brood-use sites (located by horse transect, telemetry, and accident) was sampled using a line-point transect placed along the path of brood activity. The 300-cm transect was divided into 50 intervals of 60-cm each. Two random points were located in each interval, yielding a total of 100 data points per transect. At each point, the same 4 attributes were recorded as at points used in sampling vegetation types. Vegetation at brood-use sites (most of which appeared to be foraging sites) was compared with vegetation in overall types by using Student's t-test for equal or unequal variances (Sokal and Rohlf 1969:374).

BROOD RANGES

The brooding period was considered to extend from the date of hatching until mid-August when interbrood movements and flocking were frequently observed. Five radio-tagged hens with broods were monitored for an average of 48.2 days (Table 5), and the area of use for broods $\leq$4 weeks of age was 23.4 ha and for broods $>$4 weeks of age was 34.1 ha. For the entire brood period, the mean cumulative area of use was 47.0 ha.

In close agreement with these findings, Sell (1979) reported the mean area of use for 1 brood in western Texas during June, July, and August as 43 ha. In a previous study in New Mexico, Candelaria (1979) found that the mean area used by 1 brood in 1976 and 2 in 1977 was 118.9 ha. However, brood ranges reported by Candelaria may have been artificially large due to disturbance by researchers (C.A. Davis, New Mexico State Univ., pers. comm.).

In 1979, environmental conditions for broods appeared nearly optimal. Summer foods, mostly grasshoppers (Ahlborn 1980), were abundant and favorable climatic conditions resulted in high diversity and production of vegetation. Broods could therefore meet food and cover requirements without moving long distances. Thus, brood ranges observed in this study should be considered minimal. Copelin (1963) observed that in dry years with sparse cover, lesser prairie chicken broods are more mobile.

Table 5. Areas of use for 5 radio-tagged hens with broods.

			Brood ranges (ha)					
			≤4 weeks of age		≥4 weeks of age		Entire Brood period	
Band number	Date of hatch to last brood location	No. of days	No. of locations	Brood range	No. of locations	Brood range	No. of locations	Brood range
1463	5 Jun-17 Jul	43	8	33.5	5	17.7	13	48.0
1293	7 Jul-8 Aug	33	8	30.4	1	—	9	41.6
1430	5 Jun-17 Jul	43	7	11.2	9	40.5	12	39.6
1489	1 Jun-2 Aug	63	7	7.1	5	53.0	16	54.0
1292	17 Jun-14 Aug	59	9	34.8	6	25.1	15	51.8
		48.2 ± 5.6[a]		23.4 ± 5.9		34.1 ± 7.9		47.0 ± 2.8

[a] Mean and standard error.

BROOD PREFERENCES AMONG TYPES

Cross-Country Brood Transects

The 191 km of brood-use transect produced 25 encounters, 8 with broods and 17 with brood sign. A chi-square analysis was used to compare the observed distribution of brood locations among types with their "expected" distribution. Expected values were calculated by multiplying the total number of brood encounters (25) by the percentage of transect line in each type. The values for Cultivated and Fallow types were combined for chi-square analysis to avoid low expected values, which is justified by the similarities between these types. Observed values were the number of brood encounters per type. These data produced a chi-square value of 65.278 (Table 6), suggesting strongly that availability of vegetation types cannot explain their use by broods, and therefore, that definite preferences among types existed.

Only two vegetation types had positive preference ratings (Table 6), Sandhills with +43.1 and Shinnery Oak-Bluestem with +9.8. Shinnery Oak-Midgrass and Reverted Cropland were used by broods, but at levels far below their respective availabilities, resulting in negative preference ratings. More than one-fourth the transects were placed in the four remaining types, but no evidence of brood-use was found in these types.

Results from these cross-country transects most accurately reflect habitat preferences by young broods, a few days to 5 or 6 weeks of age, during morning hours. The sampling period was 21 June through 19 July, omitting days with adverse weather conditions, such as strong winds or rain, which might distort the detectability of broods or their sign.

Since young broods were sampled, it is suspected that there was a tendency to overestimate brood selection for vegetation types representing preferred nesting habitat and to underestimate those types with low nesting preference. Previous studies (Riley 1978, Davis et al. 1979, Wisdom 1980) suggested that Shinnery Oak-Bluestem is preferred nesting habitat with respect to Shinnery Oak-Midgrass. Hence, results might have been biased favoring Shinnery Oak-Bluestem and against Shinnery Oak-Midgrass.

Table 6. Preference indices and chi-square analysis of relative use of vegetation types, by lesser prairie chicken broods found by cross-country transects.[a] Percentage of transect line per vegetation type in parentheses.

Vegetation type	km of transect per type	Expected[b] No. of brood encounters per type	Observed No. of brood encounters per type	% of brood encounters per type	Brood encounters per km of transect	Preference index[c]
Shinnery Oak-Bluestem	50.1	6.6 (26.2)	9	36.0	0.18	+ 9.8
Sandhills	17.0	2.2 (8.9)	13	52.0	0.76	+ 43.1
Shinnery Oak-Midgrass	43.7	5.7 (22.9)	2	8.0	0.05	- 14.9
Reverted Cropland	26.6	3.5 (13.9)	1	4.0	0.04	- 9.9
Shortgrass-Snakeweed	21.1	2.8 (11.0)	0	0	0	- 11.0
Weeping Lovegass	16.4	2.2 (8.6)	0	0	0	- 8.6
Fallow	10.5	1.4 (5.5)	0	0	0	- 5.0
Cultivated	5.7	0.8 (3.0)	0	0	0	- 3.0
Chi-square = 65.278[d]						

[a] Data collected from 21 June to 19 July.

[b] Expected number of brood locations per type was calculated by multiplying the total number of brood locations (25) by the percentage of transect line in each vegetation type.

[c] Percentage brood encounters per type (Observed) - percentage transect per type (Expected). Positive values indicate selection and negative values indicate non-selection.

[d] Chi-square (P = 0.05, with 6 degrees of freedom) = 12.592.

Radio-Tagged Broods

Seven of the 11 radio-tagged hens that nested produced broods; all chicks of 2 broods apparently died, from unknown causes, within 72 hours of hatching. The 5 remaining broods were radio-tracked for an average of 48.2 days, the total number of days per brood ranging from 33 to 59 days. The average maximum distance moved during this entire period was 1148 m $\pm$ SE 107.6 m. This value was used to calculate the mean area available to broods. Then, the mean percent of this area occupied by each vegetation type was calculated by the method described previously.

In a chi-square analysis, the mean percent of available area occupied by a vegetation type was used to calculate the number of brood encounters "expected" in the type. Observed values were the number of encounters which actually occurred in the type. The chi-square value showed that observed use (number of encounters in various types), did not differ significantly ($P > 0.05$) from the expected (Table 7). In the calculation of chi square, expected values for Reverted Cropland, Shortgrass-Snakeweed, and Weeping Lovegrass types were pooled. This avoided small expected values and was justified by the dissimilarity between these types and all others.

Preference ratings calculated from the above data (Table 7) agreed with those from cross-country transects by assigning the highest rating (+9.1) to Sandhills. In contrast with results from cross-country transects, Shinnery Oak-Midgrass received a +3.6 rating and Shinnery Oak-Bluestem -5.8. No use by radio-tagged broods occurred in the 3 other available types.

Table 7. Preference indices and chi-square analysis of relative use of vegetation types by 5 radio-tagged hens with broods.[a] Percentage of available area occupied by the vegetation type in parentheses.

Vegetation type	Expected[b] No. of brood locations per vegetation type	Observed No. of brood locations per vegetation type	% of brood locations per vegetation type	Preference index[c]
Shinnery Oak-Bluestem	24.8 (38.1)	21	32.3	- 5.8
Sandhills	15.1 (23.2)	21	32.3	+ 9.1
Shinnery Oak-Midgrass	20.7 (31.8)	23	35.4	+ 3.6
Reverted Cropland	4.1 (6.3)	0	0	- 6.3
Shortgrass-Snakeweed	0.4 (0.6)	0	0	- 0.6
Weeping Lovegrass	0.1 (0.1)	0	0	0

Chi-square = 7.743[d]

[a] Radio-tagged broods located from 7 June to 14 September.

[b] Expected number of brood locations per type was calculated by multiplying the total number of brood locations (65) by the percentage of available area occupied by the vegetation type.

[c] Percentage brood locations per type (Observed) - percentage type available (Expected). Positive values indicate selection and negative values indicate non-selection.

[d] Chi-square ($P = 0.05$, with 3 degrees of freedom) = 7.815.

Percentage of available types is affected, in part, by placement of nests, from which all brood movements originate. For these 5 broods, 2 nests were located in Shinnery Oak-Bluestem, 2 in Shinnery Oak-Midgrass, and 1 in Sandhills.

These results reflect type preferences of 5 radio-tagged broods, ranging from 1 through 59 days of age, located at any hour of the day, independent of weather conditions. Despite the differences in the 2 techniques used to evaluate type selection by broods, results show that Sandhills are greatly preferred. Topography and vegetational composition and structure of Sandhills combine to provide superior brooding habitat, and their influence is described below.

Factors Influencing Preferences

The unique requirements of young birds dictate the attributes of quality brood habitat. First, brood habitat must provide protection from extreme weather. This factor probably is most important to young birds still in natal plumage. Edminister (1947), working on ruffed grouse (Bonasa umbellus), concluded that inclement weather was the most critical factor causing death of young chicks. The summer weather in eastern New Mexico is somewhat harsh in terms of its possible effect on broods. During June, July, and August average maximum temperatures at nearby Portales (Ross and Bailey 1967, Turner et al. 1974) are high (exceed 32° C on two-thirds of the days), prevailing southeasterly winds average about 19 km per hr, humidity is low (average about 30%), and evaporation is high (average 234 cm per yr). Evaporative loss is greatest in June at 31.8 cm. Approximately 43% of the mean annual rainfall occurs during these 3 months, often as intense rain or hail storms accompanied by high winds.

Second, quality brood habitat must provide concealment. Potential predators of broods include at least the coyote (Canis latrans),[3] great horned owl (Bubo virginianus), and white-necked raven (Corvus cryptoleucus). Optimal cover for broods should provide enough overhead canopy for concealment from predators, but still enable the birds to see their surroundings. In the Shinnery Oak-Grassland community, dominated by open expanses above the shrub canopy, visual detection of predators by prairie chicken hens certainly should be adaptive.

Finally, this same habitat must supply ample food for broods. Summer foods consumed by lesser prairie chickens, especially by young birds, consist primarily of insects (Ahlborn 1980).

Influence of Topography

The area inhabited by lesser prairie chickens in eastern New Mexico is strikingly devoid of topographic relief, aside from that provided by Sandhills. Although I collected no quantitative data describing the microclimate of Sandhills (the preferred type), I believe that they provide sufficient topographic relief to moderate harsh weather. It seems obvious the Sandhills should be valuable to the survival of broods if they furnish microclimates which modify the summer weather.

Sisson (1976) working in Nebraska, found differences in mean temperature, wind velocities, relative humidity, and evaporation among 4 microclimates associated with Sandhills. North slopes of dunes had higher relative humidity and lower mean daily temperatures, wind move-

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[3] Common and scientific names of mammals follow Findley et al. (1975).

ment, and evaporation. Also, sharptail grouse (Pedioecetes phasianellus) broods used north slopes of Sandhills significantly more than other sites (Sisson 1976).

In eastern New Mexico, (about 55 km southwest of the present study area), Riley (1978) observed that prairie chicken broods were most abundant in low sandhills. Sell (1979) reported that during summer months in western Texas, female prairie chickens (including 1 brood) used the vegetation type characterized by dunes.

Influence of Vegetation

Composition and structure of vegetation also influence the use of vegetation types by broods. Selection of use-sites by broods probably is based more on the shrub component of the vegetation (Shinnery Oak) (Appendix), than on grass or forb composition.

Shrubs, sometimes in combination with topography, provide a microclimate more favorable to broods than the ambient summer weather. In Nebraska, Sisson (1976) found that in shrub stands on north and south slopes of Sand Hills, evaporation rates were less than half those on south slopes and ridge tops. Copelin (1963) noted that lesser prairie chicken broods in western Oklahoma sought the shade provided by shinnery oak motts when the temperature was high and soil moisture low. He drove 900 miles through shinnery oak searching for broods; he found 27 in the shade of oak motts and 1 in low shinnery oak. Sell (1979) found that 14 female prairie chickens in western Texas (1 with brood and 13 without), used the vegetation type with the highest percentage shinnery oak cover. He believed this preference was due, in part, to the amount of shade and protection from high temperatures provided by shrubs.

Areas high in shrub and forb composition should favor high numbers of insects and thus provide broods with an abundant food supply. Jones (1963) reported that insects were most abundant in areas of high shrub and forb composition in western Oklahoma. He also found that lesser prairie chickens commonly selected the shrub and half-shrub life forms during summer months.

Davis et al. (1979) noted that lesser prairie chicken broods in eastern New Mexico were found most commonly in shrubby (shinnery oak) areas. They speculated that the need for concealment cover (from potential predators) influenced this selection.

Distribution and height, as well as abundance, of shrubs might influence selection of vegetation types by broods. As mentioned earlier, the vegetational structure of Reverted Cropland is unique among types because vegetation is conspicuously "patchy" in its distribution. Although oak-covered sand dunes occur in this type, I believe that in general the sparse oak composition (Table 2), and particularly the lack of continuous oak cover, account for the shortage of brood-use in this type.

Very low vegetation would not provide protection from weather or concealment from predators. Very tall canopy cover might provide protection from weather, concealment from predators, and ease of movement, but also would limit visual detection of predators. An optimal height satisfying all these needs might be a strong factor influencing the selection of sites by broods.

DISTRIBUTION AND USE OF PREFERRED NESTING AND BROOD-REARING HABITAT IN RELATION TO LEKS

The study area contained 19 known leks in the spring of 1979. Fourteen of these leks were "dominant" (used regularly), and 5 were "temporary" (used sporadically) (Hamerstrom and Hamerstrom 1973). All leks were located on inactive petroleum well sites. There were 159 inactive sites in the study area in 1979 (Fig. 1), all of which had been covered with a calcium deposit called "caliche." This covering provides a hard surface and inhibits most plant growth. Inactive well sites were also reported to be used as leks by lesser prairie chickens in a nearby area in New Mexico (Davis et al. 1979), and in western Texas (Taylor 1978, Sell 1979).

It has been shown that nesting of lesser prairie chickens in eastern New Mexico tends to be concentrated in Shinnery Oak-Bluestem habitat (Davis et al. 1979), and that brood-rearing is concentrated in Sandhills (Tables 6,7). Further, most of the prenesting, nesting, and brood-rearing locations of radio-tagged females in this study were clustered around "dominant" leks. Twelve of the 16 females radio-tagged during spring 1979 and monitored for prenesting movements remained near the leks on which they were captured. Four hens (band nos. 1292, 1293, 1463, 1487) made relatively long movements ($\overline{X}$ = 2.31 km $\pm$ SE = 0.52) almost immediately after capture, before nesting. However, these movements brought them near other leks ($\overline{X}$ = 0.51 km $\pm$ SE 0.15) which they remained near throughout the summer. These movements may have been a reaction to capture and handling (Svedarsky 1969), or possibly an anti-predator tactic (Artmann 1970).

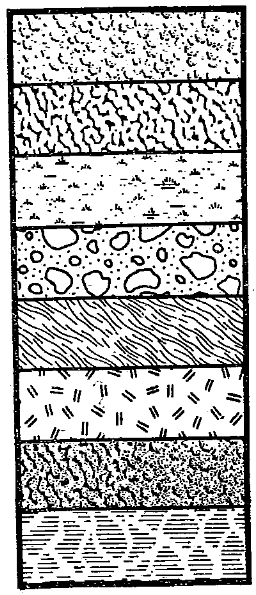
Fifty prenest locations (88%) were < 1.5 km from leks (Table 8). Hens were never located far from their nests; as a result, 100% of nest movements were within 1.5 km of leks. The average maximum distance moved during the brooding period was 1148 m ± SE 107.6 m, and 100% of brood movements were recorded < 1.5 km from leks. Nearly all (97%) locations for all these periods combined were within 1.5 km of leks. Because most of these locations were in Shinnery Oak-Bluestem and Sandhills, I theorized that the proportions of these vegetation types encompassed by a circle having a radius of 1.5 km might be substantially different from the proportions in the overall study area.

The proportion of each vegetation type in the 706.5 ha (radius = 1.5 km) surrounding 9 "dominant" leks was determined by using a planimeter. Leks were somewhat clustered in the study area (Fig. 2), so only 9 could be characterized without extensive (> 17%) overlap of areas. The total area around these leks (nearly 5122 ha) represents approximately 35% of the total study area (using overlapping areas only once, and excluding portions outside the study area). Preference indices were calculated by subtracting the percentage of the type in the study area from the percentage of the type within 1.5 km of leks. Positive values indicate that a type is more abundant within 1.5 km from leks than in the overall study area, and negative values indicate the opposite. Sandhills and Shinnery Oak-Bluestem were far more abundant around leks and thus were assigned the highest preference values, + 11.0 and + 8.1, respectively (Table 9). Shinnery Oak-Midgrass was slightly more abundant around leks (+ 2.8), while Shortgrass-Snakeweed (- 3.1) types were much less abundant around leks than that in the study area as a whole. The abundance of preferred

Table 8. Movements of radio-tagged female lesser prairie chickens from dominant leks during the prenesting, nesting, and brooding periods.

	Reproductive period							
	Prenesting/16 hens (5 Apr-20 May)		Nesting/11 hens (24 Apr-6 Jul)		Brooding/5 hens (1 Jun-14 Aug)		Entire period (5 Apr- 14 Aug)	
Distance from lek	No. locations	Cumulative %	No. locations	Cumulative %	No. locations	Cumulative %	No. locations	Cumulative %
< 1.0 km	37	65	126	94	49	75	212	83
< 1.5 km	13	88	8	100	16	100	37	97
< 2.0 km	5	96					5	99
> 2.0 km	2	100					2	100

SHINNERY OAK-BLUESTEM
SHINNERY OAK-MIDGRASS
SHORTGRASS-SNAKEWEED
REVERTED CROPLAND
WEEPING LOVEGRASS
CULTIVATED
SANDHILLS
FALLOW



N. NESTS
(25) LEKS

Figure 2. Distribution of vegetation types within a 1.5 km radius of 9 dominant leks.

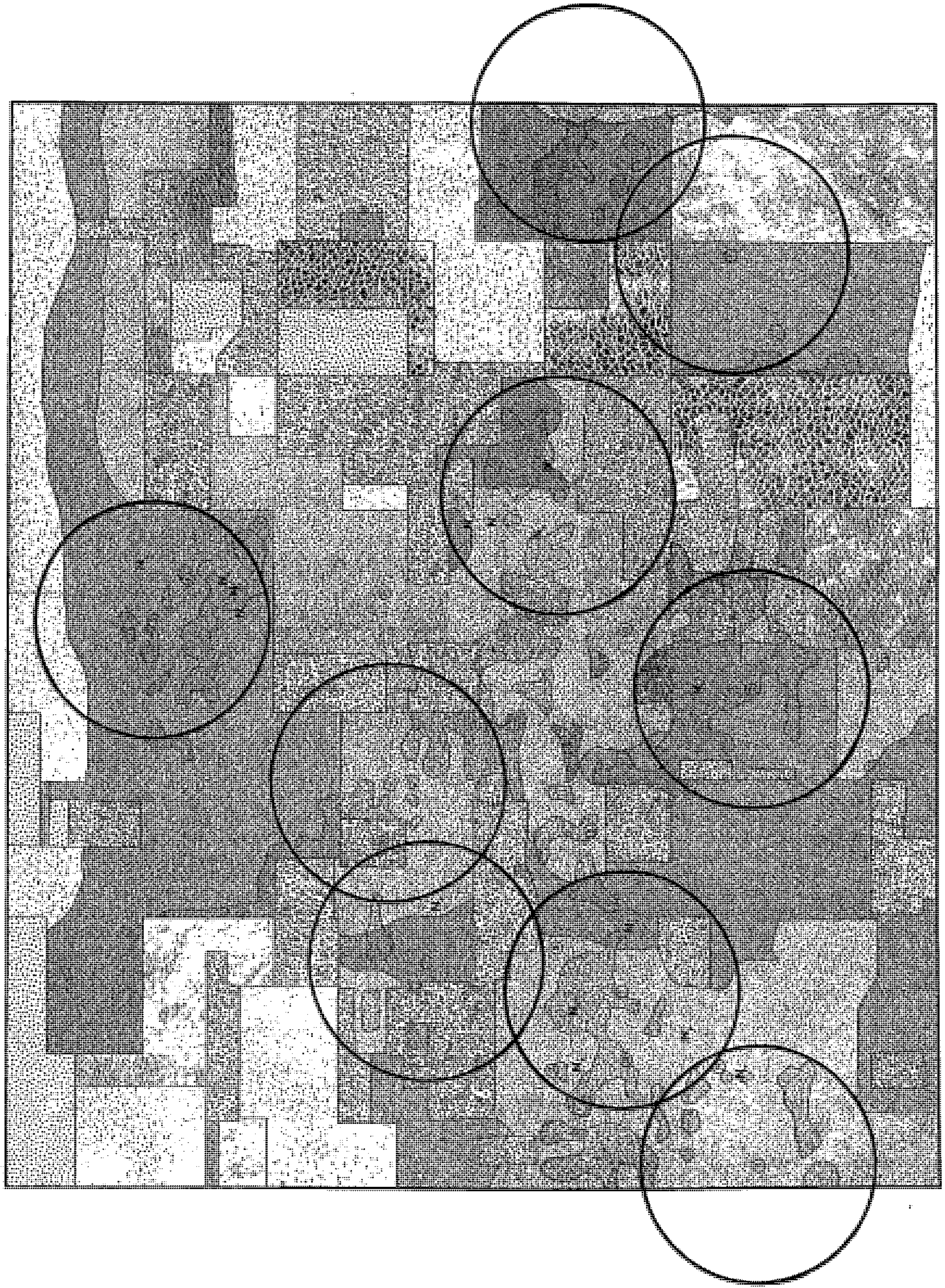


Table 9. Mean percent of vegetation types within the area (706.5 ha) surrounding 9 leks (radius = 1.5 km) versus percent of vegetation types in the study area.

Vegetation type	Mean % type in study area (Expected)	Mean % type surrounding leks (Observed)	Preference index[a]
Shinnery Oak-Bluestem	21.1	29.2	+ 8.1
Sandhills	6.7	17.7	+ 11.0
Shinnery Oak-MIdgrass	25.5	28.3	+ 2.8
Reverted Cropland	16.2	15.7	- 0.6
Shortgrass-Snakeweed	12.4	2.7	- 9.7
Weeping Lovegrass	8.7	5.3	- 3.4
Fallow	6.2	1.5	- 4.8
Cultivated	3.1	0	- 3.1

[a] (Observed - Expected) positive values indicate that a type is more abundant in the area surrounding leks than in the overall study area and negative values indicate that a type is less abundant in the area surrounding leks than in the overall study area.

habitat (Shinnery Oak-Bluestem and Sandhills) influences the observed clustering of leks in the study area by guaranteeing the perpetuation and expansion of leks in these areas through greater nesting success and brood survival.

The 706.5 ha (radius = 1.5 km) surrounding leks does not constitute a management unit for lesser prairie chickens, as preliminary data from this study, and data from other studies (Davis et al. 1979, Taylor 1979), show clearly that fall, winter, and early spring movements greatly exceed the area within 1.5 km of leks. However, the area around dominant leks is apparently the most crucial nesting and brooding habitat for lesser prairie chickens, and should therefore receive special management considerations.

VEGETATION AT BROOD-USE SITES

This section examines selection, by hens with broods, for specific vegetational attributes. Cumulative coefficients of variation were computed for each vegetational attribute by summing the coefficients across types for a given attribute. The cumulative coefficients for vegetational attributes in overall types were consistently greater than for those at brood-use sites (Table 10), indicating selection by broods for specific vegetational characteristics. Hens with broods selected sites characterized by a relatively open canopy about 30 cm in height. These sites generally had a relatively high percentage basal composition of shrubs and forbs, and sparse basal plant cover. The influence of these vegetational attributes on the selection of sites, by hens with broods, was discussed in a previous section.

Canopy Cover

At brood sites, considerable uniformity was found among types for shrub and total cover (Table 11), despite the variability in these in the overall vegetation (Table 3). This trend was not observed for percentage canopy of grasses, indicating that broods are more selective in relation to shrub and total cover than for grass cover. Forbs provided scant canopy cover and are not considered important for cover.

In all vegetation types, hens with broods selected sites with a relatively low percentage of total canopy cover. Differences in total canopy cover, between overall types and brood sites, were significant for all types except Reverted Cropland, where canopy cover in the overall type is lowest among types (Tables 11,12). Hens with broods select for

Table 10. Cumulative coefficient of variation[a] for vegetational attributes in 4 vegetation types vs. brood-use sites in 4 vegetation types.

	Cumulative coefficient of variation	
Vegetational attributes	Overall type	Brood-use sites
Percentage canopy cover		
Total shrub	347	182
Total grass	508	403
Total forb	1081	547
Total	223	153
Canopy height		
Total shrub	133	68
Total grass	194	114
Total forb	160	125
Total	141	59
Percentage basal composition		
Total shrub	383	214
Total grass	161	106
Total forb	424	210
Percentage basal cover		
Vegetation	510	231
Bare	175	72
Litter	261	142

[a] Cumulative coefficient of variation $= \sum_{i=1}^{4} \frac{\text{standard deviation}}{\text{mean}} \times 100$

Table 11. Percentage canopy cover at brood-use sites in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

Plant categories	Vegetation type: Shinnery Oak-Bluestem (25)	Sandhills (25)	Shinnery Oak-Midgrass (8)	Reverted Cropland (7)	Probability[a] and F values
Total cover	28.2 ± 1.5 A[b]	25.4 ± 2.1 AB	19.8 ± 1.9 B	18.7 ± 4.0 B	< 0.04 F = 3.15
rank	1	2	3	4	
Shrub cover	18.4 ± 1.1 A	21.9 ± 1.8 A	16.9 ± 2.2 AB	11.3 ± 3.9 B	< 0.014 F = 3.83
rank	2	1	3	4	
Grass cover	8.3 ± 0.9 A	2.7 ± 0.6 B	1.9 ± 1.0 B	4.6 ± 1.3 B	< 0.0001 F = 10.82
rank	1	3	4	2	
Forb cover	1.6 ± 0.3 A	0.7 ± 0.2 A	1.0 ± 0.6 A	2.9 ± 1.6 AB	< 0.0424 F = 2.88
rank	2	4	3	1	

[a] Probabilities calculated by AOV test.

[b] $\overline{X} \pm SE$ followed by the same letter in a row indicates no difference ($P \leq 0.05$) using least significant difference.

a relatively open canopy cover, approximately 25%. A relatively open canopy might aid broods in visually detecting predators, while providing sufficient protection from weather and concealment from predators. Results suggest that this preference is met within each type in the most expedient manner, as described in the following paragraph.

In types with the heaviest grass canopy, Shinnery Oak-Bluestem and Reverted Cropland, the difference in total cover (between brood sites and the overall type) was due to hens with broods selecting sites with less grass canopy (more shrub canopy). Similarly, in Sandhills, where shrubs provide the predominant canopy, lower total canopy cover at brood sites is attributable to fewer shrubs in the brood site canopy than in the type. In Shinnery Oak-Midgrass, quantities of shrubs and grasses in the canopy are similar and intermediate (Table 11); the lower total canopy cover at brood sites is due almost equally to selection for less shrub cover and less grass cover.

Regardless of type, percentage grass canopy at brood sites was relatively low when compared with that of the overall vegetation (Table 12). These differences were significant in all types except for Sandhills.

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[4] Herein, "significant" indicates $P \leq 0.05$.

Table 12. Percentage canopy cover at brood-use sites vs. overall vegetation in 4 vegetation types. Mean and standard error values eported. Sample size in parentheses.

Plant categories	Shinnery Oak-Bluestem Overall type (170)	Shinnery Oak-Bluestem Brood site (25)	Sandhills Overall type (120)	Sandhills Brood site (25)	Shinnery Oak-Midgrass Overall type (100)	Shinnery Oak-Midgrass Brood site (8)	Reverted Cropland Overall type (220)	Reverted Cropland Brood site (7)
Total canopy	36.3 ± 1.4	28.2 ± 1.5*[a]	37.5 ± 1.8	25.4 ± 2.1*	32.7 ± 1.8	19.8 ± 1.9*	27.3 ± 1.4	18.7 ± 4.0NS[b]
rank	2	1	1	2	3	3		
Shrub canopy	18.6 ± 1.2	18.4 ± 1.1NS	32.9 ± 1.7	21.9 ± 1.8*	23.2 ± 1.7	16.9 ± 2.2*	9.4 ± 1.2	11.3 ± 3.9NS
rank	3	2	1	1	2	3	4	4
Grass canopy	16.0 ± 1.2	8.3 ± 0.9*	3.6 ± 0.6	2.7 ± 0.6NS	7.9 ± 1.1	1.9 ± 1.0*	14.9 ± 1.0	4.6 ± 1.3*
rank	1	1	4	3	3	4	2	2
Forb canopy	1.6 ± 0.4	1.6 ± 0.3NS	1.0 ± 0.3	0.7 ± 0.2NS	1.6 ± 0.4	1.0 ± 0.6NS	2.7 ± 0.4	2.9 ± 1.6NS
rank	2	1	1	2	3	3	4	4

[a] Significant difference between means ($P \leq 0.05$) using Student's t-test with equal or unequal variances.

[b] Means not significantly different ($P \leq 0.05$) using Student's t-test with equal or unequal variances.

Canopy Height

For brood sites, no significant differences among types were found for the height of the total canopy cover, or the grass, shrub, or forb component of the canopy (Table 13). This was despite several significant differences detected among heights of vegetation in overall types (Table 4), indicating that broods were selecting for canopy height. A canopy height of approximately 30 cm apparently is preferred by hens with broods (Table 13). This probably is tall enough to allow unobstructed movement and short enough to allow hens to maintain visual contact with their surroundings. The recent study conducted 55 km southwest of the present study area indicated that average height of vegetation of lesser prairie chicken brood-foraging sites was 29.0 cm (Riley 1978:45), and ranged from 25.1 to 29.9 cm (Davis et al. 1979:114).

The height of shrubs in the canopy should be considered a more critical factor in the selection of cover than grass or forb height, because of the high percentage of shrubs (56.5% to 87.2%) in the canopy at brood sites (Table 14) and because previous studies note the importance of shrubs. Broods selected shrub canopy cover within a definite height range. Where the shrub canopy available to birds was relatively short (Shinnery Oak-Bluestem and Shinnery Oak-Midgrass), broods selected taller shrub cover; and where available shrub cover was tall (Sandhills and Reverted Cropland), they selected shorter shrubs. These differences were significant for Shinnery Oak-Bluestem and Sandhills (Table 15). An identical pattern was found for brood selection of total canopy height, and all differences were significant except for Reverted Cropland (Table 15).

Table 13. Height (cm) of canopy cover at brood-use sites in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

Plant categories	Vegetation type: Shinnery Oak-Bluestem	Sandhills	Shinnery Oak-Midgrass	Reverted Cropland	Probability[a] and F values	Pooled $\bar{X} \pm SE$
Total canopy cover	(25) 31.3 ± 0.9 A[b]	(25) 30.9 ± 0.9 A	(8) 28.9 ± 0.5 A	(7) 29.5 ± 2.8 A	< 0.5589 F = 0.70	30.7
rank	1	2	4	3		
Shrub canopy cover	(25) 30.6 ± 1.3 A	(25) 30.2 ± 0.9 A	(8) 29.3 ± 0.6 A	(6) 30.6 ± 3.5 A	< 0.9341 F = 0.14	30.3
rank	1.5	3	4	1.5		
Grass canopy cover	(24) 33.5 ± 1.5 A	(18) 34.1 ± 2.7 A	(4) 33.6 ± 4.3 A	(6) 27.6 ± 3.6 A	< 0.5161 F = 0.77	32.9
rank	2	3	1	4		
Forb canopy cover	(20) 22.1 ± 2.0 A	(11) 23.8 ± 2.5 A	(3) 20.7 ± 2.2 A	(4) 26.8 ± 4.3 A	< 0.7135 F = 0.46	23.0
rank	3	2	4	1		

[a] Probabilities calculated by AOV test.

[b] $\bar{X} \pm$ SE followed by the same letter in a row indicates no difference ($P \leq 0.05$) using least significant difference.

Table 14. Percentage canopy composition[a] at brood-use sites in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

Plant categories	Vegetation type: Shinnery Oak-Bluestem (25)	Sandhills (25)	Shinnery Oak-Midgrass (8)	Reverted Cropland (7)
Percentage shrub	65.8 ± 2.7	87.2 ± 2.6	84.6 ± 6.2	56.5 ± 11.2
Percentage grass	28.6 ± 2.8	9.8 ± 2.2	8.5 ± 4.7	22.5 ± 6.7
Percentage forb	5.6 ± 1.0	3.0 ± 0.8	7.0 ± 5.1	21.0 ± 11.4

[a] $\text{Percentage canopy composition} = \frac{\text{Percentage total canopy}}{\text{Percentage canopy due to plant category}}$

Table 15. Height (cm) of canopy cover at brood use sites vs. canopy height in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

Plant categories	Vegetation type							
	Shinnery Oak-Bluestem		Sandhills		Shinnery Oak-Midgrass		Reverted Cropland	
	Overall type	Brood site	Overall type	Brood site	Overall type	Brood site	Overall type	Brood site
Total canopy	(163) 27.2 ± 0.7	(25) 31.3 ± 0.9*[a]	(113) 33.8 ± 0.9	(25) 30.9 ± 0.9*	(96) 25.5 ± 0.8	(8) 28.9 ± 0.5*	(201) 33.6 ± 1.1	(7) 29.5 ± 2.8NS[b]
rank	3	1	1	2	4	4	2	3
Shrub canopy	(130) 26.6 ± 0.7	(25) 30.6 ± 1.3*	(107) 33.6 ± 0.9	(25) 30.2 ± 0.9	(85) 26.9 ± 0.9	(8) 29.3 ± 0.6NS	(68) 38.1 ± 1.9	(6) 30.6 ± 3.5NS
rank	4	1.5	2	3	3	4	1	1.5
Grass canopy	(118) 28.8 ± 1.1	(24) 33.5 ± 1.5*	(35) 33.6 ± 3.0	(18) 34.1 ± 2.7NS	(49) 24.1 ± 1.7	(4) 33.6 ± 4.3NS	(155) 33.2 ± 1.3	(6) 27.6 ± 3.6NS
rank	3	2	1	3	4	1	2	4
Forb canopy	(21) 17.8 ± 1.3	(20) 22.1 + 2.0NS	(12) 31.2 + 4.9	(11) 23.8 ± 2.5NS	(15) 17.9 ± 1.2	(3) 20.7 ± 2.2NS	(46) 24.9 ± 1.7	(4) 26.8 ± 4.3NS
rank	4	3	1	2	3	4	2	1

[a] Significant difference between means ($P \leq 0.05$) using Student's t-test with equal or unequal variances.

[b] Means not significantly different ($P \leq 0.05$) using Student's t-test with equal or unequal variances.

Basal Composition

At brood sites, more uniformity among types was found for percentage composition of shrubs than for grass or forbs (Table 16), despite the shrub composition in the types being more variable than that of grasses or forbs (Table 2). Again, the indication is that the shrub category was the primary criterion for selection at brood sites. Hens with broods apparently prefer sites with about 30-35% shrub composition (Table 16).

Hens generally selected areas with relatively high percentage basal composition of shrubs and forbs. Brood sites were shrubbier, although not significantly, than the overall vegetation in all types except Sandhills, where the trend was reversed (Table 17). Shrub composition in Sandhills was 46.7% (Table 2), the highest among types, and hens with broods selected sites with significantly lower shrub composition. Forb composition at brood sites also was higher than in surrounding vegetation in all types except Sandhills, although none of these differences were significant (Table 17).

Grass composition at brood sites might be an artifact of brood selection for shrubs. Except in Sandhills, brood sites were less grassy than the overall vegetation type, although differences were significant only for Reverted Cropland. However, in Sandhills, where the percentage grass composition is lowest among types, broods typically used areas with significantly higher grass and lower shrub composition than available.

The apparent discrepancy of selection trends presented by brood-use sites in Sandhills (described above) might simply indicate that there are

Table 16. Percentage basal composition of plant categories at brood-use sites. Mean and standard error values reported Sample size in parentheses.

Plant categories	Vegetation type: Shinnery Oak-Bluestem (25)	Sandhills (25)	Shinnery Oak-Midgrass (8)	Reverted Cropland (7)	Probability[a] and F values
Total shrub	24.0 ± 2.1 A[b]	39.1 ± 2.7 B	32.6 ± 8.6 AB	26.3 ± 6.1 A	< 0.0045 F = 4.84
rank	4	1	2	3	
Total grass	59.8 ± 2.2 A	46.5 ± 2.5 B	48.5 ± 6.4 B	47.4 ± 4.3 B	< 0.0027 F = 5.32
rank	1	4	2	3	
Total forb	14.9 ± 1.4 A	12.6 ± 1.3 A	17.9 ± 3.3 AB	26.3 ± 5.9 B	< 0.0032 F = 5.14
rank	3	4	2	1	

[a] Probabilities calculated by AOV test.

[b] $\bar{X} \pm SE$ followed by the same letter in a row indicates no difference ($P \leq 0.05$) using least significant difference.

Table 17. Percentage basal composition of plant categeorics at brood-use sites vs. composition in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

Plant categories	Shinnery Oak-Bluestem		Sandhills		Shinnery Oak-Midgrass		Reverted Cropland	
	Overall type (170)	Brood site (25)	Overall type (120)	Brood site (25)	Overall type (100)	Brood site (8)	Overall type (220)	Brood site (7)
Total shrub	23.0 ± 1.3	24.0 ± 2.1NS[a]	46.6 ± 2.2	39.1 ± 2.7*[b]	29.2 ± 2.1	32.6 ± 8.6NS	13.4 ± 1.6	26.3 ± 6.1NS
rank	3	4	1	1	2	2	4	3
Total grass	63.3 ± 1.5	59.8 ± 2.2NS	36.1 ± 1.8	46.5 ± 2.5*	60.8 ± 2.0	48.5 ± 6.4NS	65.2 ± 1.8	47.4 ± 4.3*
rank	2	1	4	4	3	2	1	3
Total forb	13.5 ± 1.0	14.9 ± 1.4NS	16.6 ± 1.7	12.6 ± 1.3NS	9.9 ± 1.2	17.9 ± 3.3NS	21.3 ± 1.4	26.3 ± 5.6NS
rank	3	3	2	4	4	2	1	1

[a] Means not significantly different ($P \leq 0.05$) using Student's t-test with equal or unequal variances.

[b] Significant difference between means ($P \leq 0.05$) using Student's t-test with equal or unequal variances.

limits on the composition of shrubs tolerated by broods. Sandhills have the highest composition of shrubs and the lowest of grasses. Hence, selection for lower shrub composition in Sandhills may be due to the percentage shrubs exceeding an upper preferred limit.

Basal Cover

Although plant cover varied somewhat among types, from 10.9% in Shinnery Oak-Bluestem to 2.8% in Sandhills (Table 1), hens with broods selected sites with less plant cover in all types but Sandhills, where they used areas with more cover than available in the type. Differences were significant for all types except Shinnery Oak-Midgrass (Table 18). Broods selected sites with approximately 5% basal plant cover (Table 19). In shrubby areas as exemplified by Sandhills, selection for sparse basal cover would ease mobility for broods without sacrificing canopy cover. Davis et al. (1979) reported that in a nearby area of eastern New Mexico, broods foraged in relatively dense plant cover where available basal cover was low, and in relatively sparse cover where basal cover was dense.

Table 18. Percentage basal cover at brood-use sites vs. overall vegetation in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

Categories	Vegetation type							
	Shinnery Oak-Bluestem		Sandhills		Shinnery Oak-Midgrass		Reverted Cropland	
	Overall type (170)	Brood site (25)	Overall type (120)	Brood site (25)	Overall type (100)	Brood site (8)	Overall type (220)	Brood site (7)
Vegetation	10.9 ± 0.8	5.4 ± 0.5*[a]	2.8 ± 0.5	4.9 ± 0.4*	6.8 ± 0.7	5.8 ± 1.3NS[b]	7.2 ± 0.6	2.7 ± 0.7*
rank	1	2	4	3	3	1	2	4
Bare	50.2 ± 1.8	60.6 ± 2.1*	57.5 ± 2.2	58.5 ± 2.7 NS	58.5 ± 2.3	59.9 ± 3.9NS	59.9 ± 1.9	80.9 ± 4.0*
rank	4	2	3	4	2	3	1	1
Litter	38.9 ± 1.7	34.0 ± 1.9NS	39.0 ± 2.2	36.3 ± 2.6NS	34.7 ± 2.1	34.4 ± 3.1NS	32.2 ± 1.8	16.7 ± 3.4*
rank	2	3	1	1	3	2	4	4

[a] Significant difference between means ($P \leq 0.05$) using Student's t-test with equal or unequal variances.

[b] Means not significantly different ($P \leq 0.05$) using Student's t-test with equal or unequal variances.

Table 19. Percentage basal cover at brood-use sites in 4 vegetation types. Mean and standard error values reported. Sample size in parentheses.

	Vegetation type				
Categories	Shinnery Oak - Bluestem (25)	Sandhills (25)	Shinnery Oak - Midgrass (8)	Reverted Cropland (7)	Probability[a] and F values
Vegetation	5.4 ± 0.5 A[b]	4.9 ± 0.4 A	5.8 ± 1.3 A	2.7 ± 0.7 B	< 0.0405 F = 2.92
rank	2	3	1	4	
Bare	60.6 ± 2.1 A	58.5 ± 2.7 A	59.9 ± 3.9 A	80.9 ± 4.0 B	< 0.0006 F = 6.71
rank	2	4	3	1	
Litter	34.0 ± 1.9 A	36.3 ± 2.6 A	34.4 ± 3.1 A	16.7 ± 3.4 B	< 0.0013 F = 5.96
rank	3	1	2	4	

[a] Probabilities calculated by AOV test.

[b] $\bar{X} \pm SE$ followed by the same letter in a row indicate no difference ($P \leq 0.05$) using least significant difference.

FALL-WINTER USE OF GRAIN FIELDS

Prairie chickens were first observed feeding in grain (sorghum) fields on 18 September. Sporadic use of sorghum continued until the last week in October, when feeding in the fields became routine. Coincident with the sudden increased use of grain were the first fall nights (22 and 23 Oct) with temperatures below freezing, and completion of fall lekking, as noted by Taylor (1978).

Eleven (6 adults and 5 juveniles) of 15 radio-tagged birds located on 14 November had moved to fields. The other tagged birds (all adults) continued to use native vegetation throughout 1979. Only 2 of the 11 birds utilizing sorghum moved to fields closest to their fall ranges. A t-test for unequal variances was used to compare the observed distances that birds moved to feed in fields to the "expected" distances, i.e., to nearest available grain. Using the 14 November locations, a highly significant difference ($P \leq 0.001$) was found between the observed (11.0 km) and the expected (3.6 km) distances (Table 20).

Observations of radio-tagged birds suggested a general movement to the southeast, toward a large area with relatively abundant sorghum; possibly a traditional wintering area. Existence of such a tradition would explain why most birds failed to feed in fields nearest to their fall ranges. Hamerstrom and Hamerstrom (1949:335) found through banding studies that greater prairie chickens (Tympanuchus cupido) in Wisconsin fed in the same fields year after year, and speculated that "old timers" might be responsible for leading other birds to these areas. In fall, flocks composed primarily of juvenile birds of both sexes, ranging in size from 15-80 individuals, were observed frequently on leks with dis-

Table 20. Distance (km) to nearest grain fields and actual distance and angle travelled to grain fields by 11 radio-tagged lesser prairie chickens.

Band number	Date captured	Age and sex	Distance to nearest grain field (Expected)	Distance moved to grain field (Observed)	Angle of movement to grain field (0° due east)[a]
1463	13 Apr	Adult	5.0	21.1	94°
1410	24 Sep	Juvenile	1.6	1.6	84°
1404	24 Sep	Adult	1.6	1.6	84°
1423	17 Oct	Juvenile	5.7	16.5	334°
1299	15 Sep	Juvenile	2.3	7.3	338°
1292	6 Apr	Adult	1.6	9.7	330°
1418	18 Sep	Juvenile	3.7	9.9	17°
1424	10 Apr	Adult	5.7	15.2	334°
1432	2 Apr	Adult	3.7	10.9	325°
1421	26 Sep	Adult	3.7	10.9	349°
1420	2 Sep	Juvenile	5.0	15.9	3°

[a] Observed angle of travel to grain fields corrected to the center of the study area to allow statistical comparison with the direction of most abundant sorghum.

[b] Mean and standard error.

playing males. Fall lekking activities might serve to concentrate birds and bring into association young and old birds prior to fall movements. This function would be similar to that of traditional staging areas used by waterfowl (Bellrose 1976). Large areas of abundant sorghum might be necessary to establish and maintain the use of a traditional wintering site. Enough birds would use the area to insure perpetuation of the tradition.

To determine whether birds moved toward the most abundant grain source, the mean direction traveled by birds was compared to the angle bisecting the area of greatest abundance of cultivated land. Nearly all cultivated land in and around the study area is devoted to grain sorghum, so it was assumed, for this comparison, that all fields were sorghum fields.

Distribution of fields in and around the study area was determined by the following procedure. The area in a circle (Fig. 3) centered at the middle of the study area, with a radius of 19.4 km (the distance required to encompass the movements of all birds), was divided into 18 segments of 20^{o} each and the area of cultivated land in each segment was determined with a planimeter. A chi-square goodness-of-fit-test indicated ($P \leq 0.001$) that fields were not uniformly distributed around the center of the study area.

Approximately 55% of the total cultivated land within the circle was situated in 3 intervals, 20^{o} north of each to 40^{o} south of east (Fig. 3). Of the 11 birds that moved to grain, 72% (8 birds) traveled to this area. The angle bisecting this area is 10 SE and it appeared that birds might be moving at approximately this angle in response to abundant grain.

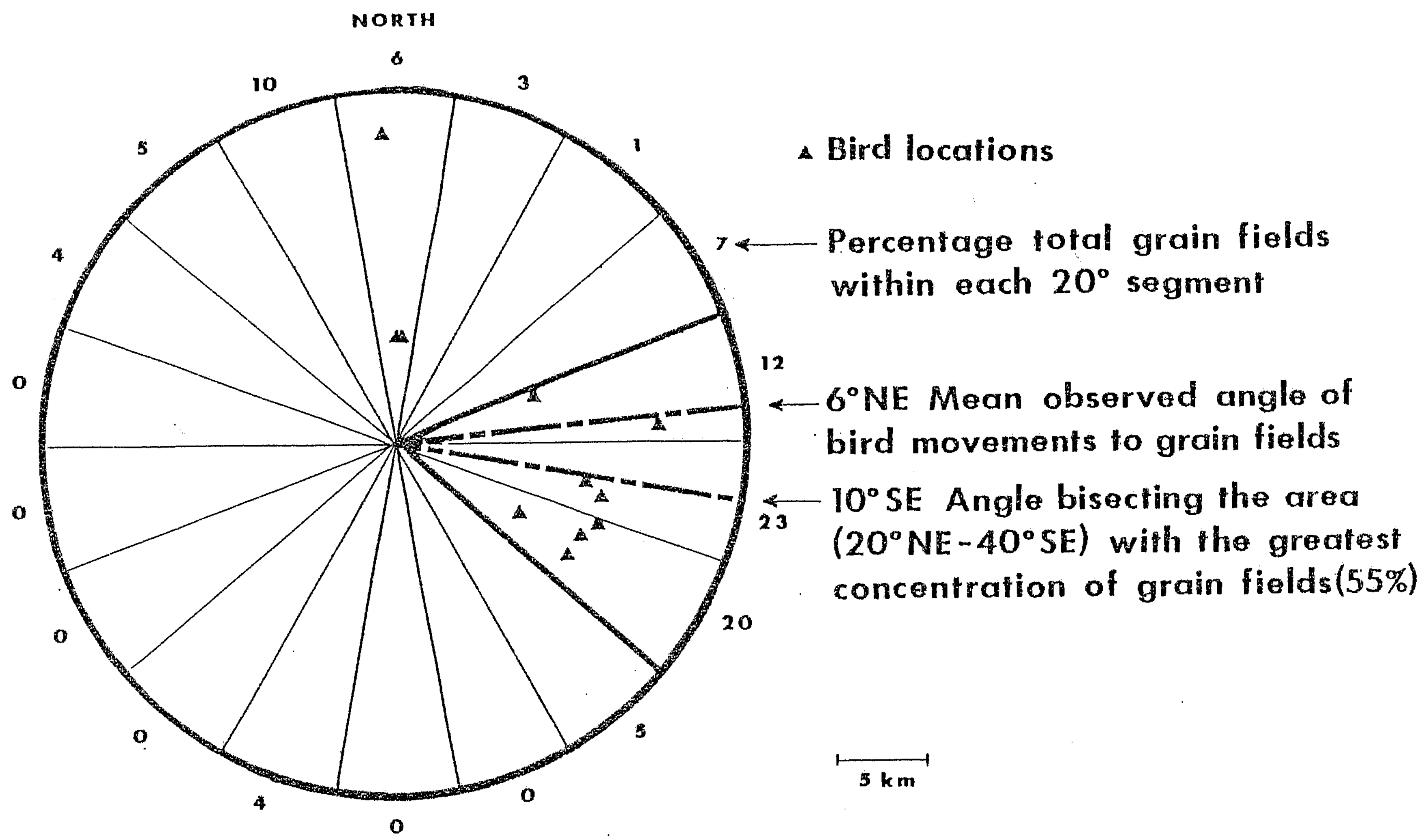

Figure 3. Distribution of grain fields and observed movements of 11 radio-tagged lesser prairie chickens, 14 nov 1979.

A modification of Rayleigh's test, the V test (Batschelet 1972) was used to statistically compare the mean angle of bird movements with the "expected" angle of 10 SE. The angle of bird movements was standardized to assume the middle of the study area as the starting point; this adjustment was necessary to allow for comparison of movements to grain distribution. The mean angle that the 11 birds traveled was 6 NE (Zar 1974:313). A significant ($P \leq 0.005$) relationship was found between the expected (10 SE) and observed (6 NE) direction of movement.

These results indicate a definite movement pattern to a traditional wintering area. One characteristic of this area is a relatively high proportion of cultivated land, where minimum tillage is practiced. Even in years of very low grain production, expected occasionally with dryland cultivation, minimum tillage results in substantial amounts of waste grain that should provide food for enough prairie chickens to perpetuate the movement pattern.

It is not known precisely what proportion of prairie chickens inhabiting the vicinity of the study area annually winter in and near sorghum fields, but in 1979 it was observed that bird occurrence was low in native vegetation, while large flocks were common around grain fields. At least two factors, in addition to the success of the sorghum crop, may influence these activities. First, use of grain by lesser prairie chickens possibly varies inversely with the abundance of natural foods. In Oklahoma, Copelin (1963) observed that the use of sorghum fields by lesser prairie chickens decreased in years when the production of natural foods (acorns and forbs) was high. Similarly, Davison (1940:87) reported that, in Oklahoma, "Years of plentiful acorns lessen the field migration."

Although some birds would move to grain by habit, scarcity of natural foods might greatly increase this number. A second factor was demonstrated by Hamerstrom et al. (1941:194), working with greater prairie chickens in Wisconsin. They found that as temperatures decreased in fall, "high-concentrate" foods, such as cultivated grain, were required to maintain the birds' health. Importance of this factor is increased by the predictable decline of insects with declining temperatures. From these considerations, it should be expected that the heaviest use of grain would occur in cold winters when the natural food supply has failed.

Assuming that minimum tillage is practiced, the importance of sorghum as a fall-winter food for prairie chickens in Shinnery Oak-Grasslands is enhanced by the fact that it is available on a reliable basis. New Mexico agriculture records show considerable variation in sorghum yields but, in 22 years, dryland production has not failed in Roosevelt County and has failed only once (1964) in adjacent Lea County (New Mexico Department of Agriculture 1960-78). In contrast, annual acorn production apparently fluctuates drastically (Davison 1940, Riley 1979). Hence, sorghum might serve as an alternate food supply when circumstances cause low abundance of acorns (Jackson and De Arment 1963) and might even sustain geographic populations at levels above those found in areas without cultivation (Crawford 1974).

CONCLUSIONS AND RECOMMENDATIONS

Brood Habitat

Sandhills were identified as highly preferred brooding habitat for lesser prairie chickens. The undulating topography and abundant shrubs and forbs of the Sandhills type combine to form a habitat supplying broods with the necessary protection from inclement weather, concealment from predators, and ample foods.

The majority (97%) of prairie chicken movements during the prenesting, nesting, and brooding periods were within 1.5 km of dominant (regularly used) leks. Within this same area (1.5 km) surrounding 9 dominant leks, the abundance of Sandhills and Shinnery Oak-Bluestem (superior brooding and nesting habitat, respectively) is far greater than that in the overall study area. Criteria that should be considered in making decisions as to which areas would have priority for habitat maintenance or improvements are:

1. Areas in the vicinity of leks ($\leq$ 1.5 km) probably are the most valuable nesting and brooding habitat.
2. Areas interspersed with Sandhills probably have greater potential for production (nesting and brooding), of lesser prairie chickens, than areas lacking this type.

Broods apparently prefer similar vegetational attributes across all vegetation types. These characteristics include canopy cover, 25%; canopy height, 30 cm; basal shrub (shinnery oak) composition, 30 to 35%; and basal plant cover, 5%. Although Sandhills are preferred by broods, data describing vegetational attributes at brood sites indicate that broods prefer areas in Sandhills with fewer shrubs, less overhead cover, and slightly more basal cover than that generally available in this type. Sandhills in excellent range condition would support more native tall grass cover and less shrub cover, thereby providing brooding areas even more satisfactory than those presently available. Sandhills would naturally remain somewhat shrubby due to the deep, unstable sandy soils.

From other studies in eastern New Mexico (Davis et al. 1979, Wisdom 1980), Shinnery Oak-Bluestem approximates prime nesting habitat but could be improved by increasing the percent composition of native tall grasses, especially sand bluestem. Evidence from the present study, as well as other studies cited, suggests that optimal nesting and brooding habitat for lesser prairie chickens is a combination of Shinnery Oak-Bluestem interspersed with Sandhills. Management efforts for maintaining, enhancing, and expanding nesting and brooding habitat should concentrate on restoration of near-climax vegetation in the Shinnery Oak-Grassland community. The principal management tool to achieve this goal should be reduction of grazing pressure by livestock followed by a flexible grazing system. This recommendation is based on the fact that overgrazing has been the predominant cause of deterioration of the Shinnery Oak-Grassland community (Duck and Fletcher 1944, Hamerstrom and Hamerstrom 1961, and Jackson and De Arment 1963), and without eliminating this cause, present conditions will persist or worsen.

A second technique to improve range condition is the application of herbicides coupled with strict cutbacks in livestock grazing. This method outlined in Pettit (1979) and Doerr (1980) is designed to reduce shinnery oak composition, thereby allowing rapid recovery of native tall grasses. Application of herbicides to the Sandhills or Shinnery Oak-Midgrass types is not recommended (Pettit 1979, Doerr 1980). However, future research may provide informtion as to the proper use of herbicides to enhance these deteriorated and unstable areas.

Doerr (1980) reports that 95% of the range currently occupied by lesser prairie chickens is privately owned and management practices must be planned accordingly. The situation in New Mexico is unique for managing prairie chicken habitat. Since the 1940's, New Mexico has acquired 18 scattered tracts of land occupied by prairie chickens, totaling approximately 9,645 ha (New Mexico Dept. of Game and Fish 1967). The express management purpose for this land is for maintenance and enhancement of lesser prairie chicken habitat.

Grazing practices in areas where good range conditions prevail (Shinnery Oak-Bluestem with or without Sandhills) should be similar regardless of land ownership. An opportunistic grazing strategy known as the "best-pasture" system (Herbel et al. 1974) might be the most appropriate system to use in the Shinnery Oak-Grassland community. This grazing plan, developed at Jornada Experimental Range in New Mexico, was designed for semidesert ranges. In this region, variable weather conditions can greatly affect plant growth and vigor, necessitating a flexible grazing plan. Time of grazing and stocking rates are adjusted for each grazing unit to take advantage of the erratic distribution and amount of rainfall and to insure against overuse of vegetation, especially perennial grasses, in drought years.

On privately owned land in poor and fair range condition (Shinnery Oak-Midgrass with or without Sandhills), livestock exclosures (75-150 ha) would allow recovery of native tall grasses to a level where suppression of some oak, by use of herbicides, might expedite grass recovery. Where the range condition of state-owned prairie chicken restoration areas is in poor and fair condition, livestock grazing should be deferred until tall grasses have been reestablished. Following recovery, private and state lands could again be grazed in a manner similar to that mentioned above.

Use of Grain Fields

Grain sorghum can be important to prairie chickens because it is provided on a comparatively reliable basis at the time of year when food is most likely to be limiting, but it is essential that minimum tillage methods be used. On two separate occasions during 1979, radio-tagged prairie chickens using sorghum left the vicinity of the field within 48 hours after sorghum stalks were shredded. The shredding process chops and buries sorghum stalks, making much of the remaining grain unavailable to prairie chickens. Where minimum tillage methods are used, sorghum can be available for 5 months, from mid-October through mid-February. Crawford (1974) pointed out that minimum tillage also reduces soil loss and cultivation costs, in addition to enhancing wildlife habitat by providing winter food. Reduction of native vegetation (Shinnery Oak-Grassland community) to increase the acreage of cultivated sorghum is not recommended, as it would reduce the amount of habitat usable for purposes other than winter feeding.

Results from monitoring radio-tagged birds suggest that traditional wintering areas exist in the vicinity (east) of the study area and probably elsewhere. Because these areas concentrate geographic populations of lesser prairie chickens, they are potentially very important to the management of the species. In 2 previous studies (Frary 1957, Copelin 1963), attempts to supply lesser prairie chickens with winter grain by maintaining food plots resulted in only limited success. The low degree of success might have been related, in part, to placement of food plots outside traditional winter areas and/or to the small size of fields used. Therefore, if a management program is initiated to increase the amount of sorghum available to prairie chickens, primary emphasis should be directed toward these traditional areas.

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APPENDIX

PERCENTAGE BASAL COMPOSITION OF VEGETATION TYPES

Table 21. Percentage basal composition of vegetation in 4 types. Mean and standard error values (plants with ≥ 5% composition) reported. Sample size in parentheses.

Species	Vegetation type			
	Shinnery Oak-Bluestem (170)	Sandhills (120)	Shinnery Oak-Midgrass (100)	Reverted Cropland (220)
Grass and grass-like plants				
Little bluestem (*Schizachyrium scoparium*)	15.3 ± 1.1	3.8	3.3	9.9 ± 1.4
Sand bluestem (*Andropogon hallii*)	9.2 ± 1.0	1.9	0.5	8.4 ± 1.3
Purple three-awn (*Aristida purpurea*)	7.6 ± 0.7	8.8 ± 1.0	16.9 ± 1.5	13.0 ± 1.2
Sand dropseed (*Sporobolus cryptandrus*)	6.3 ± 0.7	1.5	8.9 ± 1.0	5.4 ± 0.9
Fall witchgrass (*Leptoloma cognatum*)	3.9	3.8	5.4 ± 0.9	1.3
Sand paspalum (*Paspalum stramineum*)	5.3 ± 0.8	3.2	7.1 ± 0.1	3.9
Hairy grama (*Bouteloua hirsuta*)	6.1 ± 0.8	6.2 ± 0.8	6.0 ± 1.1	2.0
Red lovegrass (*Eragrostis secundiflora*)	4.9	2.2	6.1 ± 1.0	5.8 ± 0.9
Tumble lovegrass (*Eragrostis sessilispica*)	0.8	0.4	1.4	1.4
False buffalo grass (*Munroa squarrosa*)	0.2	0.7	0.6	t[a]
Red three-awn (*Aristida longiseta*)	0.2	0.7	0.1	1.8
Side-oats grama (*Bouteloua curtipendula*)	2.6	t	3.4	—

Table 21. (continued)

Species	Vegetation type			
	Shinnery Oak-Bluestem (170)	Sandhills (120)	Shinnery Oak-Midgrass (100)	Reverted Cropland (220)
Spike and Giant dropseed (*Sporobolus contractus* & *giganteus*)	—	1.8	—	2.6
Tumble grass (*Schedonnardus paniculatus*)	t	—	0.1	t
Silver bluestem (*Bothriochloa saccharoides*)	—	—	—	2.5
Windmill grass (*Chloris verticillata*)	—	—	—	t
Sandbur (*Cenchrus incertus*)	—	0.2	—	1.6
Weeping lovegrass (*Eragrostis curvula* var. *ermela*)	—	—	—	2.0
Gummy lovegrass (*Eragrostis curtipedicellata*)	—	—	0.1	—
Proverty three-awn (*Aristida divaricata*)	—	—	—	0.2
Switch grass (*Panicum virgatum*)	—	—	—	0.1
Buffalo grass (*Buchloe dactyloides*)	—	—	—	0.5
Sedge spp. (*Cyperaceae* spp.)	0.9	0.8	0.9	1.7
Total	63.3 ± 1.5	36.1 ± 1.8	60.8 ± 2.0	65.2 ± 1.8

Table 21. (continued)

Species	Vegetation type			
	Shinnery Oak-Bluestem (170)	Sandhills (120)	Shinnery Oak-Midgrass (100)	Reverted Cropland (220)
<u>Shrubs</u>				
Shinnery Oak (*Quercus havardii*)	22.5 ± 1.3	44.8 ± 2.2	29.1 ± 2.1	13.0 ± 1.6
Sand sage (*Artemisia filifolia*)	0.6	1.8	—	t
Yucca (*Yucca glauca*)	0.3	—	0.1	0.4
Total	23.0 ± 1.3	46.6 ± 2.2	29.2 ± 2.1	13.4 ± 1.6
<u>Forbs</u>				
Western ragweed (*Ambrosia psilostachya*)	3.0	3.2	0.4	4.0
Fringed sage (*Artemisia frigida*)	0.8	0.3	0.6	4.7
Wild buckwheat (*Eriogonum annuum*)	1.1	1.3	1.7	0.3
James nailwort (*Paronychia jamesii*)	1.4	0.8	—	0.3
Yellow evening primrose (*Calylophus serrulata*)	0.3	2.9	0.2	2.4
Prairie puccoon (*Lithospermum incisum*)	1.0	0.2	0.4	0.2
Erect dayflower (*Commelina erecta*)	0.3	0.8	—	0.1

Table 21. (continued)

Species	Vegetation type			
	Shinnery Oak-Bluestem (170)	Sandhills (120)	Shinnery Oak-Midgrass (100)	Reverted Cropland (220)
Woolly gaura (*Gaura villosa*)	0.1	t	—	0.5
Greenthread (*Thelesperma megapotamicum*)	—	0.8	—	0.2
Daisy fleabane (*Erigeron annuus*)	t	1.7	—	t
Broom groundsel (*Senecio riddellii*)	0.2	0.6	—	t
Four point evening primrose (*Oenothera rhombipetala*)	0.2	t	0.1	0.1
Prickly pear (*Opuntia polyacantha*)	0.2	—	0.1	t
Black-foot (*Melampodium leucanthum*)	0.2	—	0.1	0.2
Bastard toad-flax (*Comandra pallida*)	0.2	—	0.4	—
Camphor weed (*Heterotheca latifolia*)	—	0.9	—	0.2
Dove weed (*Croton corymbulosus*)	t	t	—	t
Woolly-white (*Hymenopappus* spp.)	—	t	—	t
Spurge (*Euphorbia fendleri*)	0.1	—	—	0.3
Easter daisy (*Townsendia excapa*)	t	t	—	—

Table 21. (continued)

Species	Vegetation type			
	Shinnery Oak-Bluestem (170)	Sandhills (120)	Shinnery Oak-Midgrass (100)	Reverted Cropland (220)
Reverchonia (*Reverchonia arenaria*)	—	0.8	—	t
Evolvulus (*Evolvulus nuttallianus*)	—	t	—	0.1
Golden aster (*Heterotheca villosa*)	t	—	—	—
Bluets (*Hedyotis nigricans*)	—	—	1.0	—
Sensitive brier (*Schrankia uncinata*)	—	t	—	—
Flax (*Linum rigidum*)	—	—	—	0.2
Hog potato (*Hoffmanseggia jamesii*)	—	—	—	t
Sunflower (*Helianthus* sp.)	—	—	—	0.7
Spectacle pod (*Dithyrea wislizeni*)	—	—	—	t
Pin-weed (*Lechea mucronata*)	—	—	—	0.2
Spurge (*Spurge* spp.)	—	—	—	t
Spurge (*Euphorbia missurica*)				t
Others	0.2	1.1	0.2	0.8
Total	13.5 ± 1.0	16.6 ± 1.7	9.9 ± 1.2	21.3 ± 1.4

[a] Trace (less than 0.1 percent)