

BREEDING ECOLOGY AND HABITAT USE OF GREATER
PRAIRIE-CHICKENS IN RELATION
TO HABITAT PATTERN

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of the requirements for the degree
Master of Science

By
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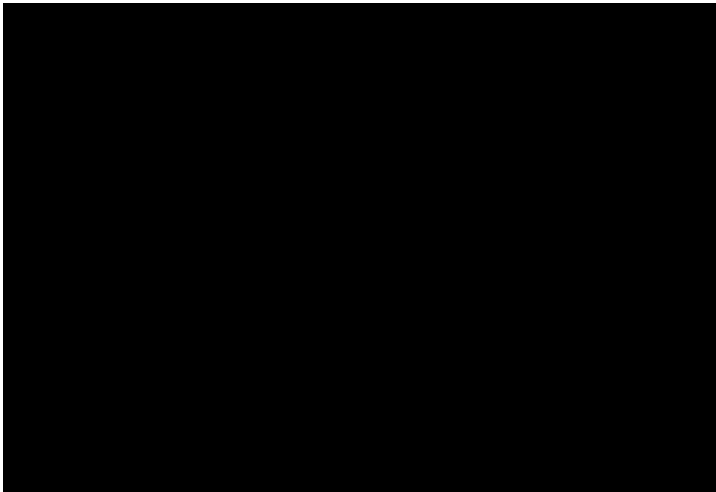
The undersigned, appointed by the Dean of the Graduate Faculty, have examined a thesis entitled

BREEDING ECOLOGY AND HABITAT USE OF GREATER PRAIRIE-CHICKENS
IN RELATION TO HABITAT PATTERN

presented by David Paul Jones

a candidate for the degree of Master of Science

and hereby certify that in their opinion it is worthy of acceptance.



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CHAPTER I
INTRODUCTION

The status of the greater prairie-chicken (Tympanuchus cupido) in Missouri is precarious because of widespread habitat loss and alteration (Cannon and Christisen 1984a). The decimation of native prairie ecosystems has resulted in significant declines in prairie-chicken populations in Missouri as well as throughout its range (Yeatter 1943, Baker 1953, Hamerstrom and Hamerstrom 1973, Kirsch et al. 1973, Christisen 1984). Furthermore, the fragmentation of the remnant native prairies contributes to the instability of populations as they become increasingly isolated (Hamerstrom et al. 1957, Yeatter 1963, Cannon and Christisen 1984a). Cannon and Christisen (1984a) reported that most of the isolated populations in Missouri surveyed by Schwartz (1945) have been extirpated. The severity of population declines and habitat loss has resulted in listing this species as "rare" in the state of Missouri (Wilson 1984).

The historical range of the greater prairie-chicken in Missouri can be described as expansive. Prior to the twentieth century, the species probably occurred in every county of Missouri which had prairies (Christisen 1985). Prairie-chickens inhabited regions

wherever prairies existed as tracts greater than a few thousand ha and with an interspersion of less than 10% woodland (Christisen 1985). These occupied tracts included small Ozark grasslands in southern Missouri, as well as the extensive prairies of northern and western Missouri. Thus, the historical range of this species encompassed at least 4.8 million ha (Cannon and Christisen 1984a).

The range of the greater prairie-chicken in Missouri has steadily declined since the late 1800's. Schwartz (1945) stated that by the early 1940's only 13.5% (650,000 ha) of the species former range remained. The most recent survey indicated that the northern Missouri range has declined by 94% since the 1940's (Cannon and Christisen 1984a). Habitat loss in southern Missouri has not been as extensive as in the north. The range in southern Missouri has been reduced by 34% and has been stable since 1979 (Christisen 1985).

The current breeding range of the greater prairie-chicken in Missouri comprises only 4% of its presettlement distribution (Cannon and Christisen 1984b). Cannon and Christisen (1984a) reported that approximately 187,000 ha of breeding range remains, as defined by a 1.6 km radius around an active lek. The current range is greatly disjointed and is comprised of

65-70 segments that vary from 800-20,000 ha (Cannon and Christisen 1984b). A large portion of the breeding range is located in southwestern Missouri where 3,000 ha of native prairie exist (Christisen 1981). However, 97 % of the breeding range is in private ownership. Consequently, preservation of this critical component is questionable (Cannon and Christisen 1984b).

Population declines have been coincident with habitat losses. Schwartz (1945) estimated the prairie-chicken population at over 13,000 birds during the years 1941-1944. An estimated population of 7,000 prairie-chickens in southern Missouri and another 500 in northern Missouri remained in 1970 (Christisen 1985). Based on lek censuses, Cannon and Christisen (1984a) calculated a 1983 spring breeding population of 5,000-6,000 birds in southern Missouri and a 1984 population of 400-500 birds in northern Missouri.

Land-use patterns related to agriculture are the primary factors determining the stability of prairie-chicken habitat and populations in Missouri (Christisen 1985). Population densities of greater-prairie chickens in relation to land-use have been examined in Wisconsin (Hamerstrom et al. 1957), Illinois (Yeatter 1943), and Missouri (Arthaud 1968, Christisen and Krohn 1980, Christisen 1985). Agricultural trends in Missouri during

the last decade have been toward increased acreage in cropland. Concurrently, acreage of native prairie and other grassland habitats has declined (Christisen 1985). Less conspicuous than habitat loss is habitat degradation as a result of the conversion of native prairie to cool-season grasses (primarily Festuca sp.). Additionally, grazing and haying practices that reduce the floristic diversity of grasslands contribute to habitat deterioration. Consequently, alterations of vegetation cover-types in relation to land-use patterns negatively affect the ability of prairie-chickens to exploit adequate nesting and brood-rearing cover (Christisen 1985).

The importance of the proportion of permanent grass cover to tilled land for the prairie-chicken in Missouri has been well-documented (Schwartz 1945, Arthaud 1968, Drobney 1973, Drobney and Sparrowe 1977, Christisen and Krohn 1980, Christisen 1985). Schwartz (1945) suggested that 39% grass cover was required for maximum carrying capacity. Christisen and Krohn (1980) stated that less than 25% permanent grass cover is a limiting factor for prairie-chicken populations.

Qualitative elements of grassland cover-types also are significant in determining carrying capacity for prairie-chickens. Specifically, the species of grasses

and floristic diversity are as important as the quantity of permanent grass cover (Drobney 1973, Drobney and Sparrowe 1977, Christisen and Krohn 1980, Christisen 1985).

Lack of suitable permanent grass cover for nesting and brood-rearing have been cited as limiting factors for prairie-chickens in Missouri (Christisen 1981, 1985; Cannon and Christisen 1984a, b). The situation is similar for this species in other states (Yeatter 1943, Hamerstrom and Hamerstrom 1973, Kirsch et al. 1973). Vegetation structure and not necessarily species composition may be the critical factor in determining suitable cover. Research in several states has indicated nesting hens use residual vegetation of heights between 25-40 cm (Jones 1963, Arthaud 1968, Svedarsky 1979, Buhnerkempe et al. 1984,). For brood-rearing, patchy vegetative structure permits movement by the hen and brood (Christisen 1981).

Restoration of this species will require an approach that integrates disjointed habitats into a functional complex. Hamerstrom et al. (1957) developed a management strategy using scattered tracts of native prairie as nesting and brood-rearing cover that they called "ecological patterning." The basis of this strategy is to benefit local prairie-chicken populations

by preserving a network of small-acreage grassland habitats among agricultural blocks rather than developing one large block of prairie. Public prairies are pivotal to this management strategy. Application of "ecological patterning" using more than 20% managed native prairie has been successful in maintaining viable populations in Wisconsin (Hamerstrom and Hamerstrom 1973).

A restoration plan has been developed by the Missouri Department of Conservation for the greater prairie-chicken that incorporates the strategy of ecological patterning (Cannon and Christisen 1984b). Although the success of ecological patterning has been documented, there is a paucity of research relative to habitat-use, seasonal movements, and population dynamics prior to the implementation of this management strategy (Cannon and Christisen 1984b). Consequently, a research project was initiated to comprehensively examine the ecology of the prairie-chickens that are exploiting a mosaic of private and public lands. The project has been based on a comparison of prairie-chickens inhabiting an isolated block of native prairie with a population occupying a scatter pattern of habitats.

Objectives

This research has compared the ecology of prairie-chickens exploiting different patterns of habitat interspersion. The objectives of this research were to:

1) Determine annual habitat-use and preference of radio-collared greater prairie-chicken hens at the 2 study areas;

2) Determine reproductive parameters associated with each population.

Thesis Format

This thesis consists of an introduction and 2 separate manuscripts written in a style and format to facilitate publication. The first manuscript reports on the reproductive ecology of the 2 populations. The second manuscript concerns habitat-use and preference. Management implications and recommendations conclude the thesis. The plural pronoun "we" is used in the manuscripts because they are intended for publication with coauthors.

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CHAPTER II
BREEDING ECOLOGY OF GREATER PRAIRIE-CHICKENS
IN RELATION TO HABITAT PATTERN

Native prairie habitats of the greater prairie-chicken (Tympanuchus cupido) have been fragmented into disjoint remnants throughout much of its range. Consequently, the dispersion pattern of nesting habitats is an important consideration in the implementation of management strategies (Hamerstrom et al. 1957, Kirsch 1974, Cannon and Christisen 1984). Hamerstrom et al. (1957) developed a management strategy using scattered tracts of native prairie as a regional network of nesting and brood-rearing cover that they called "ecological patterning." An alternative approach is to preserve large, isolated blocks of native prairie as a refuge system.

The basis of "ecological patterning" is to benefit several local prairie-chicken populations by preserving a mosaic of high quality, small-acreage grassland habitats among agricultural blocks. The underlying assumption to this approach is that these small scattered tracts will be used intensively for nesting and brood-rearing. Application of this strategy in Wisconsin has been successful in maintaining viable

populations (Hamerstrom and Hamerstrom 1973).

Maintaining large blocks of prairie emphasizes the preservation of a single, insular population within the confines of the preserve. This strategy has been implemented in the management of the Attwater's prairie-chicken (*T. c. attwateri*) in Texas and has been successfully applied in Missouri (Christisen 1985).

Although each management strategy has been implemented, there is an absence of research that compares the reproductive ecology of greater prairie-chickens relative to these 2 habitat patterns. Our research compared a population of greater prairie-chickens that inhabited a prairie-agricultural mosaic to one that occupied an isolated block of native prairie habitat.

STUDY AREA

The prairie mosaic (Fig. 2-1) was located in northwest Dade County, Missouri. The area was 112 km² with 15 km² (13%) in native prairie cover. The prairie-island study area (Fig. 2-2) was located in southwest St. Clair County, Missouri. This latter study area was 52.5 km² with 6.5 km² (12.5%) of native prairie contained in a single block. The boundaries of each study area were defined by prairie-chicken radio-locations and homeranges. Distance between the 2 areas

Figure 2-1. The prairie mosaic study area. Scattered tracts of native prairie are outlined. State-managed prairies are designated by cross-hatching.

Prairie-Agriculture Mosaic

Study Area

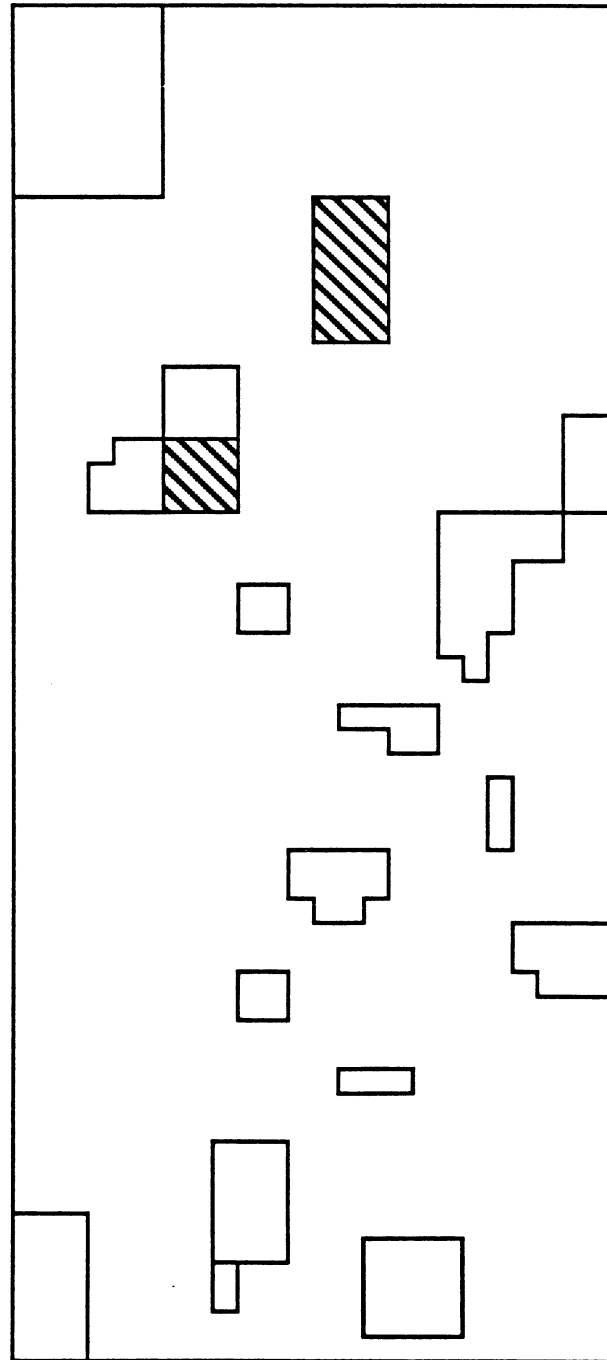
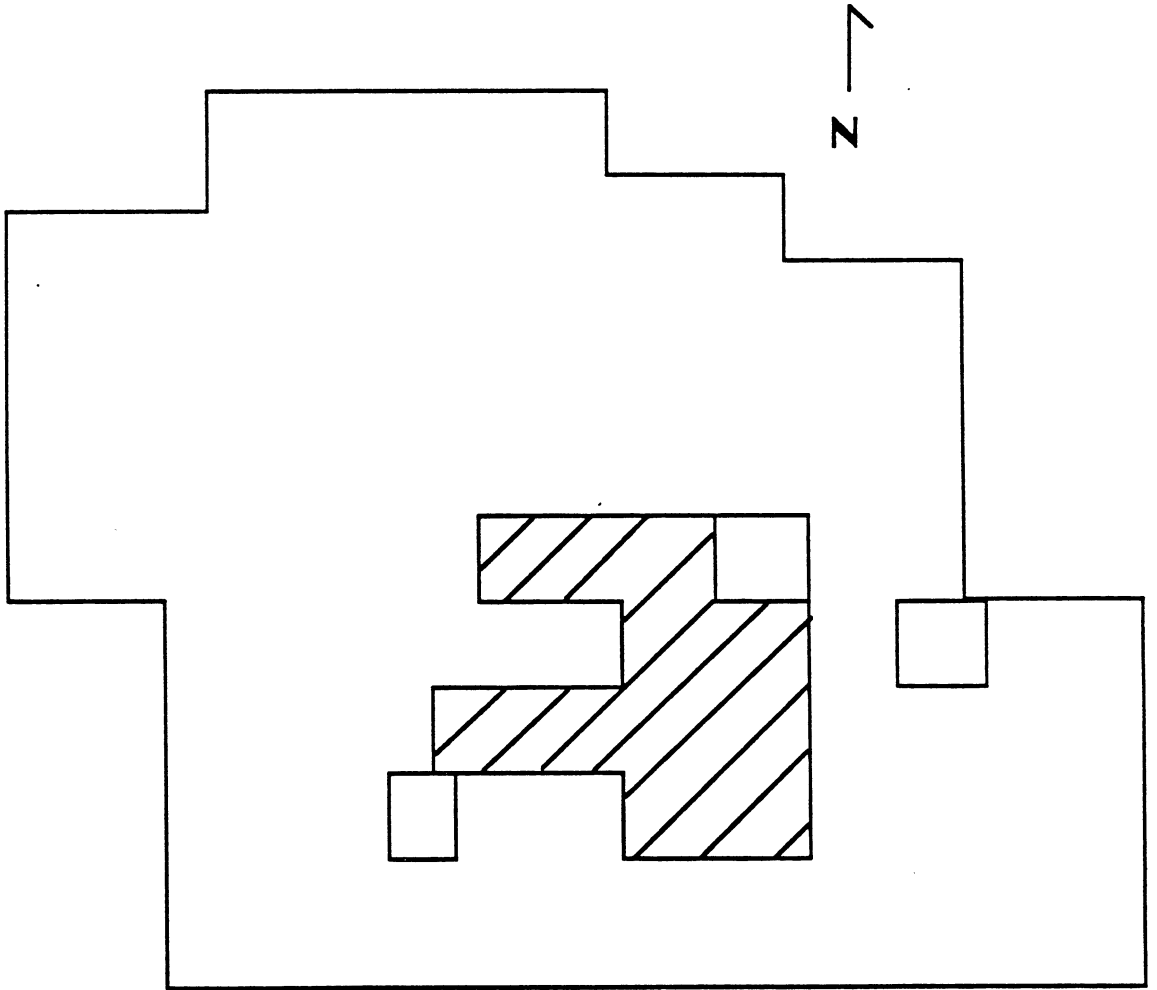


Figure 2-2. The prairie island study area. Native prairie is represented. The large tract of state-managed prairie is designated by the cross-hatching.

PRAIRIE ISLAND
STUDY AREA



was 88 km. Average annual precipitation (40-45 cm) and temperature (12 °C) were similar at the study areas.

The prairie mosaic was characterized by a scatter pattern of native prairie, row and grain crops, exotic grass pasture and hayland (primarily Festuca sp.), mixed grass pasture (mixed exotic and native prairie grass) and woodland. The primary land-use on the prairie-mosaic study areas was agriculture. Eighty-seven % of the native prairie was privately-owned. The area included 194 ha of state-managed prairie. Tract size of the prairies ranged from approximately 10 ha to 269 ha. Distance between the tracts ranged from 0.8 to 3.2 km.

The state-managed areas were managed to provide nesting and brood-rearing cover for prairie chickens. Roughly one-half of the acreage of these prairies was maintained in 2nd year's growth of native covertypes by rotational haying. Prescribed burns were applied to approximately 1/3 of each area every 3 years. Private prairies were managed as pastures or for annual hay crops. The timing of grazing, burning, and haying varied on the privately-owned prairies.

The prairie-island study area was comprised of the same habitats as the prairie mosaic but most of the native prairie (75%) was contained in a single, large block. This block of native prairie habitat was high-

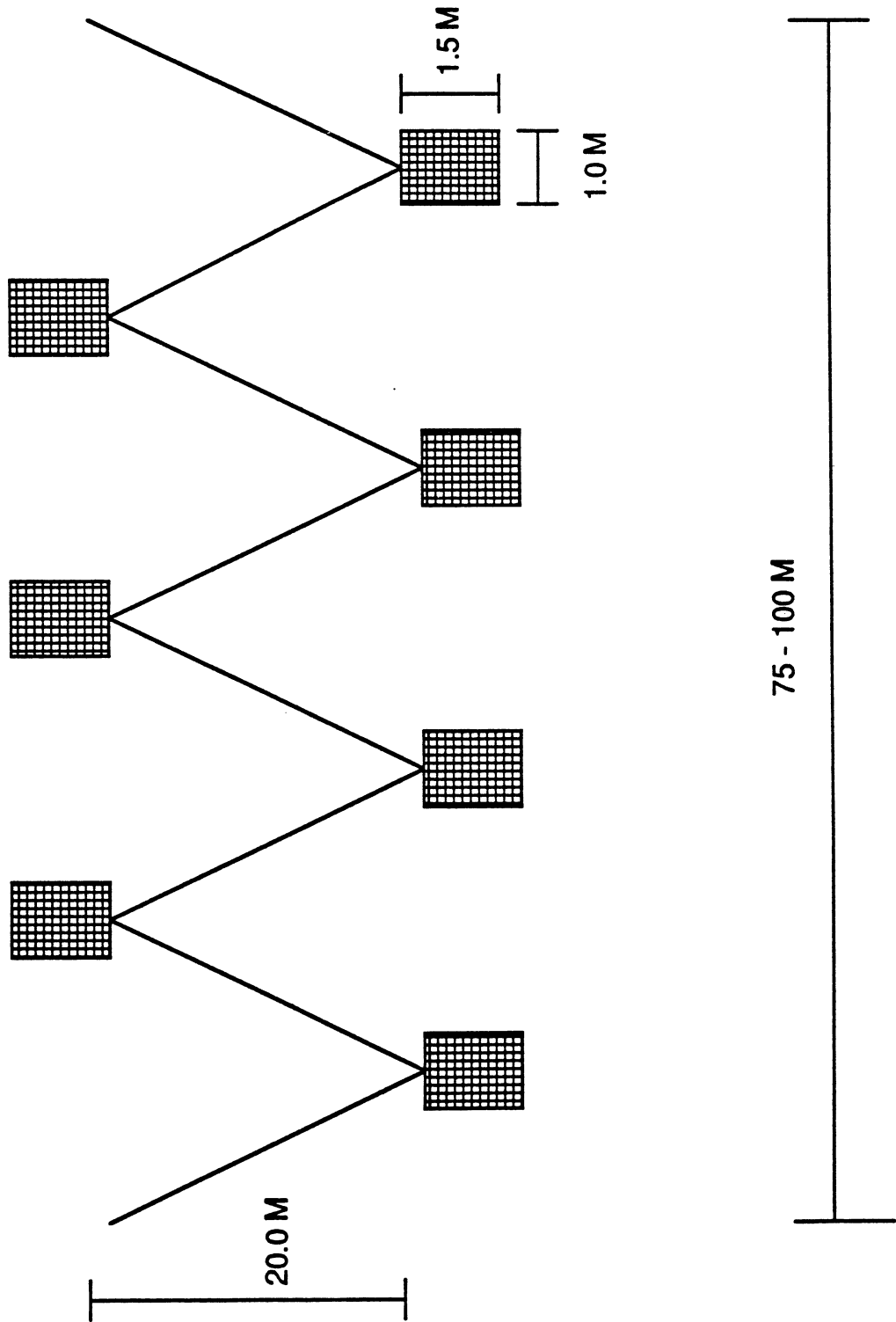
quality grassland managed specifically to provide prairie-chicken nesting and brood-rearing cover. Management practices included haying and prescribed burning. Approximately one-half of the acreage was hayed, in treatment units averaging 32 ha, on an annual basis. Haying occurred during July. The hayed tracts were interspersed among the unhayed units. Burning of various sized tracts was prescribed on a 3-year rotational basis. Approximately 120 ha were burned during 1986 by a spring arson-fire. Twenty-four ha were maintained in cropland.

The principal grasses on the prairie island included big bluestem (Andropogon gerardi), little bluestem (Andropogon scoparius), Indian grass (Sorghastrum nutans), Switchgrass (Panicum virgatum), wild rye (Elymus canadensis), June grass (Koeleria cristata), dropseed (Sporobolus heterolepis), and sloughgrass (Spartina pectinata).

METHODS

We captured female prairie-chickens on leks during the spring using walk-in funnel traps during 1986 and 1987 (Fig. 2-3). Supplemental capture techniques were used during the summer and fall. These included modified

Figure 2-3. Schematic diagram of a typical string of walk-in funnel traps.



OVERVIEW OF A TYPICAL TRAPLINE

cloverleaf traps and nightlighting from an All Terrain Vehicle. Forty-seven hens at the prairie-agricultural mosaic and 55 hens at the prairie island were captured during the project (Appendix 1).

The traps were constructed of wire fencing with a mesh of 2.5 cm x 5 cm. Dimensions of the trap were 1.25 m x 1 m x 1 m. Funnel entrances were made of wire and were approximately 15-20 cm at the highest point and approximately 12 cm at the narrowest. Funnel lengths were 25-30 cm. Sixty cm high chicken wire was used as drift fencing to connect the traps.

Poncho-mounted (Ampstrup 1980) flatpack solar/NiCd radio transmitters were fitted onto captured hens. These packages weighed 16-20 g (2 to 2.5% body weight). Ponchos were made of herculite. An oblong neck-hole was cut to fit tightly over the head of the female. The transmitters emitted a signal at 164-165 MHz. We used a programmable scanning receiver and hand-held 4-element yagi antenna to locate birds on a daily basis. Data collection alternated between the two study areas on a 3 (1986) or 4-day (1987) rotational basis. Egg-laying and nesting periods were ascertained by closely monitoring the movement and behavior patterns of radio-collared hens. When nesting was suspected, the hens were checked and flushed from the concealing vegetation. Nests were

marked with 60 cm high electric-fence posts at 15 paces on two sides of the nest.

Nest covertypes were categorized broadly based on the predominant plant associations and land-use. Distance of nest-site from capture lek and nearest lek was recorded and tranformed logarithmically to normalize data for Analysis of Variance.

A nest was considered successful if at least one egg hatched. Cause of loss (if determinable) was categorized as a nest depredation, depredation of the hen, or agricultural-related loss. Clutch sizes were derived from nests that reached incubation. Egg hatching rates were calculated as the percentage of eggs that hatched from successful nests. Hen success was calculated as the percentage of hens that hatched a clutch in 1 or more nesting attempts.

The probability of survival of nests, through the entire nesting period, was calculated with the Mayfield approach (Mayfield 1961) using Heisey and Fuller's (1985) MICROMORT software package. Nest success in each area was compared by using variances to derive a z-statistic per area per year.

Each radio-collared hen is treated as a pseudo-replicate. Treatment effects could not be replicated. Therefore, results and conclusions of this research are

applicable only to these specific study areas.

RESULTS

Nest-site Use

Hens associated with the prairie mosaic nested in 8 different covertypes that included several agricultural habitats (Table 2-1). The diversity of covertypes used for nesting by hens at the prairie mosaic is in contrast to the 3 covertypes used by the hens at the prairie island. Another important aspect of these results was that native prairie was not used as frequently by the prairie-mosaic hens (28% of nests) as by the hens associated with the island prairie (92% of nests).

Patterns of habitat use for nesting by the hens at the prairie-mosaic were comparable between years (Appendix 2). These data support a consistent trend of diverse nest-site use by prairie-mosaic hens.

Distances of nest sites from capture leks were greater ($P > 0.0002$, $F = 15.42$) at the prairie-agriculture mosaic ($\bar{X} = 2.1 \pm 0.31$ km) than at the prairie island ($\bar{X} = 1.2 \pm 0.18$ km) (Fig. 2-4a). Sixty-two % (19 of 31) of prairie-mosaic hens nested at distances greater than 1.6 km from capture lek. The island-habitat hens were clumped primarily around their capture leks. Seventy-six percent (29 of 38) of these

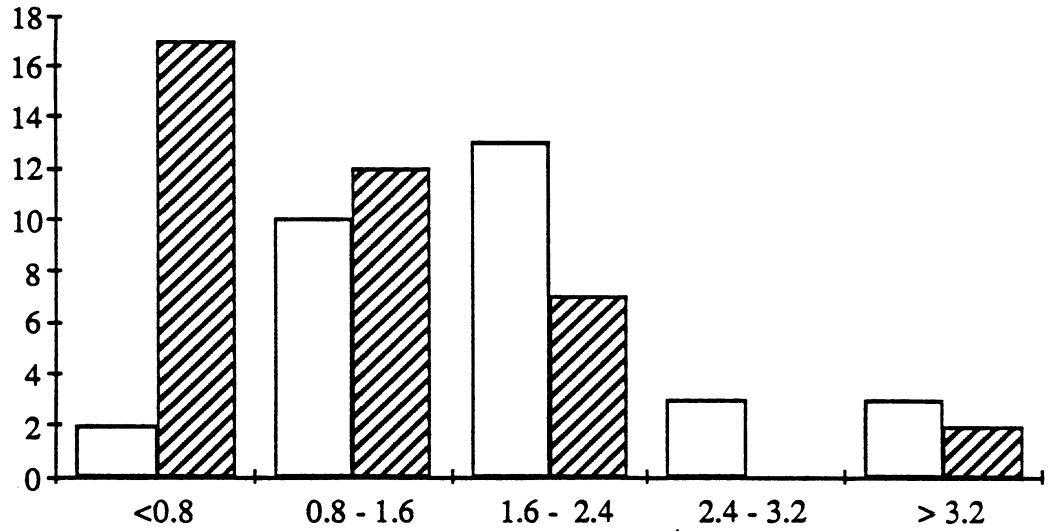
Table 2-1. Nest site use by greater prairie-chicken hens at the prairie mosaic and at the prairie island, Missouri, 1986-1987.

Coverttype	Prairie mosaic N = 32	Prairie island N = 40
Native Prairie	9	37
Exotic grass	5	2
Wheat	4	0
Brush / Field Edge	3	0
Mixed grass ^a	5	1
Fallow cropland	3	0
Sweet clover	2	0
Disked field	1	0

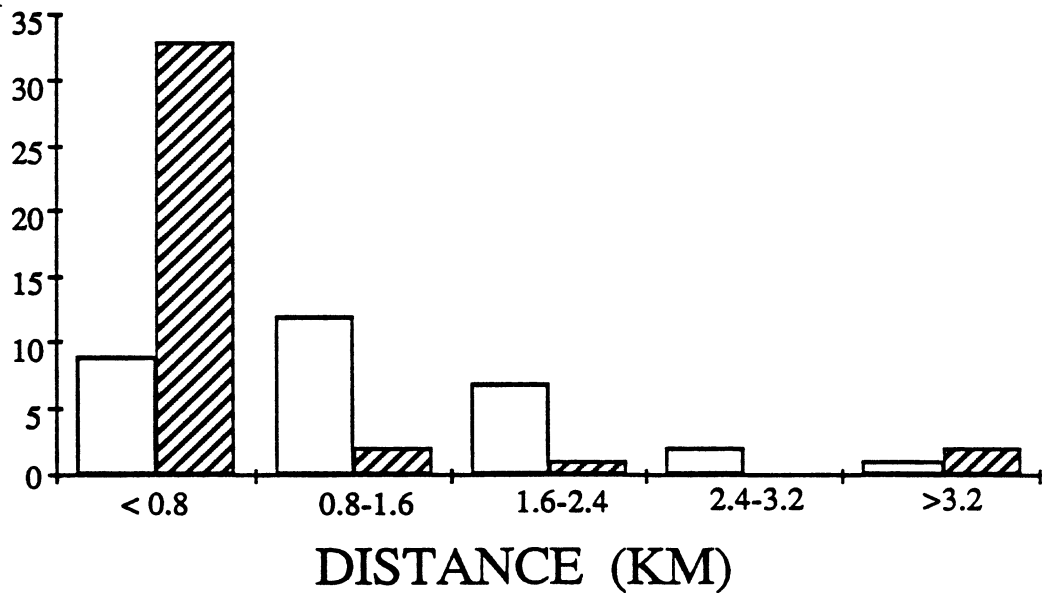
^a Mixed exotic and native prairie grass.

Figure 2-4. Distance of nest-site from capture lek (2-4a) and from nearest lek (2-4b) at the prairie mosaic and at the prairie island, Missouri, 1986-1987.

NUMBER OF NESTS

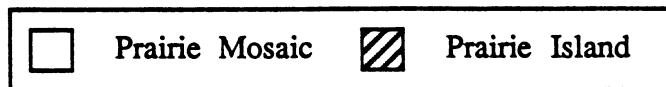


(4a)



DISTANCE (KM)

(4b)



hens nested within 1.6 km of capture lek.

Four hens at the prairie mosaic nested 3.2 km or more from their capture lek but only 1 hen associated with the block-habitat moved this distance for nesting. One prairie-mosaic hen nested nearly 13 km from her capture lek.

The pattern of distribution of nest-site from nearest lek was consistent with that of distance from capture lek (Fig. 2-4b). The distances were greater ($P > 0.0001$, $F = 17.47$) at the prairie-mosaic than at the prairie island. Prairie-mosaic hens nested an average distance of 1.6 ± 0.32 km, whereas, the prairie-island hens nested an average of 0.8 ± 0.17 km. The largest percentage (39%) of prairie-mosaic nests was located 0.8 to 1.6 km from the nearest lek. In contrast, 87% of the prairie-island nests were located within 0.8 km of a lek. Thirty-two % of the nests at the prairie mosaic were over 2.4 km from any lek, whereas, only 8% of the prairie-island nests were over 2.4 km.

Reproductive parameters

Mayfield nest success was lower ($Z = 1.30$, $P = 0.10$) at the prairie mosaic (0.15) than at the island habitat (0.39) during 1986 (Table 2-2). No difference was detected between the areas in 1987 ($Z = 0.29$, $P = 0.61$)

Table 2-2. Mayfield nest success at the prairie mosaic and at the prairie island, Missouri, 1986-1987.

	1986		1987	
	Prairie mosaic	Prairie island	Prairie mosaic	Prairie island
	N=17	N=16	N=14	N=23
No. Successful	4	8	6	9
% Successful	23	50	43	39
Mayfield Nest				
Success	0.15	0.39	0.31	0.26
	P = 0.10		P = 0.60	

Nest success was related to nest-site use (Table 2-3). Nest success within agricultural covertypes was lower than either native prairie ($Z = 2.61$, $P < 0.01$) or mixed grass pastures ($Z = 4.88$, $P < 0.01$). Agricultural habitats included wheat, fallow cropland, field edges, exotic grass, sweet clover, and disked field. Reproductive success within native prairie covertypes was not different between areas ($Z = 0.10$, $P = 0.50$).

The causes of nest loss differed between the 2 study areas ($X^2 = 5.38$, $P = 0.08$) (Table 2-4). Nest destruction incurred from agricultural practices was an important factor at the prairie mosaic. One of these losses was a hen mortality during mowing of sweet clover. Predation on the nesting hen was a major cause of nest loss at both areas but there were no significant differences between study areas in regard to nest depredation or predation on the nesting hen.

The percentage of hens nesting successfully was not different between study areas during either year (1986 $X^2 = 1.13$, 1987 $X^2 = 0.005$) or when data from both years were pooled ($X^2 = 0.45$) (Table 2-5). However, the trend was for lower nesting success at the prairie-mosaic study area (31%) than at the prairie island (50%) during 1986 and when data from both years were pooled (prairie mosaic = 38%, prairie island = 47%). Renesting

Table 2-3. Mayfield nest success (N) of greater prairie-chickens among covertypes at the prairie mosaic and at the prairie island, Missouri, 1986-1987.

Covertypes	Prairie mosaic	Prairie island	Total
Native			
prairie	0.29 (9)	0.31 (35)	0.31 (44) ^a
Agricultural			
habitats	0.07 (18)	0.05 (2)	0.07 (20)
Mixed grass			
pasture ^b	0.69 (5)	^c (1)	0.51 (6) ^a

^a Data are not significantly different ($P > 0.05$).

^b Mixed exotic and native prairie grass.

^c Sample size inadequate for valid analysis.

Table 2-4. Cause of nest loss of greater prairie-chicken hens at the prairie mosaic and at the prairie island, Missouri, 1986-1987.

Nest loss factor	<u>Prairie mosaic</u>			<u>Prairie island</u>		
	1986	1987	TOTAL	1986	1987	TOTAL
Agri-culture	4	1	5 24%	0	0	0 0%
Predation on hen	5	2	7 33%	4	6	10 50%
Predation on nest	4	5	9 42%	2	8	10 50%

30.8% *12.5* *49*

Table 2-5. Percent hen success (N) at the prairie mosaic and at the prairie island, Missouri, 1986-1987.

Area	1986	1987	TOTAL
Prairie mosaic	31 (13)	46 (13)	38 (26)
Prairie island	50 (16)	45 (20)	47 (36)

attempts at the prairie mosaic were less successful (1 of 6) than at the prairie island (3 of 3).

Clutch sizes were derived from 20 and 27 nests that reached incubation at the prairie mosaic and prairie island, respectively, during the project (Table 2-6). Mean clutch size of combined first nests and renests at the prairie mosaic and prairie island was 11.2 and 11.6, respectively. Clutch sizes of first nests at both areas were significantly greater than renests. Clutch sizes of first nests at the prairie mosaic ranged from 8 to 15 and from 9 to 19 at the prairie island. Clutch sizes of renests varied from 8 to 11 at the prairie mosaic and from 8 to 10 at the island habitat.

Egg hatching rates were derived from 9 (112 total eggs) and 11 (122 eggs) successful nests at the prairie mosaic and prairie island, respectively, during the entire project. Egg success rates were 94% and 93% at the prairie mosaic and prairie island, respectively. The lowest hatching rate recorded was 72% (2 nests).

DISCUSSION

One major result of our study was the infrequent use of native prairies for nesting at the prairie-agricultural mosaic. This could be a reflection of quantitative and qualitative deficiencies of the existing prairie-mosaic. Kirsch (1974) recommended that

Table 2-6. Mean clutch size (N) of 1st nests and renests of greater prairie chicken hens at the prairie mosaic and prairie island, Missouri, 1986-1987.

	Combined	1st nests	renests
Prairie			
mosaic	11.2 (20)	11.7 (16)	9.5 (4)
Prairie			
island	11.6 (27)	12.0 (23)	9.2 (4)

management units be comprised of at least 25% native prairie contained in blocks larger than 65 ha.

"Ecological patterning" in Wisconsin used more than 20% native prairie. Annual haying that reduces residual nesting cover and the lack of burning are 2 factors that reduce the quality of prairie-chicken habitat (Kirsch 1974, Burhnekempe et al. 1980).

The following quantitative factors could have reduced nesting in native prairie at the prairie-agricultural mosaic, (1) the amount of native prairie (12%) relative to the availability of other covertypes was too low and, (2) the sizes of the individual tracts were too small. Fifty % of the native prairie tracts were equal to the minimum recommended size. Also, rotational mowing of one-half the state-managed prairie effectively reduced the sizes of those tracts below or equal to the minimum recommended size.

Qualitative deficiencies of the privately-owned prairie probably influenced habitat use. Forty % of the native prairie was annually hayed and prescribed burning was seldom applied.

The large island tract of state-managed prairie was exploited frequently by nesting hens. The kinds of covertypes available at the prairie mosaic are available within a 1.6 km radius of the island habitat. But these

other covertypes were not used to any extent. The island tract is exploited apparently because it has an acceptable combination of qualitative and quantitative habitat.

Robel (1970) proposed that females nested within the first available adequate nesting cover. Drobney and Sparrowe (1977) presented data to support this contention. The short lek-to-nest distances at the prairie island are a function of the immediate proximity of nesting cover within the confines of the island preserve. Data from the prairie island showed that nest dispersion tracked changes in the availability of suitable nesting cover as a response to haying treatments between years.

This hypothesis is not entirely adequate to explain nest distribution at the prairie-agricultural mosaic. We documented 6 individual prairie-mosaic hens that moved distances greater than 3.2 km from their capture lek for nesting, seemingly passing up adequate nesting cover.

Previous radio-telemetry research lends comparisons to our nest dispersion data. The mean distances from capture lek reported by Svedarsky (1979) in Minnesota (1.3 km) were less than those at the prairie mosaic (2.1 km) but similar to the distances recorded at the prairie

island (1.2 km). Mean distances from nearest lek at the prairie mosaic (1.6 km) were greater than the mean of 1.2 km reported by Watt (1969) in the extensive prairies of the Kansas Flinthills. However, those at the prairie island (0.8 km) were less.

Research that did not use radio-telemetry reported a tendency of nests to be clumped around the leks at distances comparable to the pattern of nest dispersion at the prairie-island study area. In Missouri, prairie-chickens nested an average of 0.3 km from nearest lek (Drobney and Sparrowe 1979). In Illinois, hens tended to nest within 0.4 km and in Wisconsin "most" nests were found between 0.8 to 1.6 km from the nearest lek (Silvy 1968).

Mayfield nest success calculations for prairie-chickens have not been reported in the literature. However, comparisons to previous research can be made for simple nest success. Percent nest success at the prairie mosaic during 1986 (23%) and in the pooled data (32%) was lower than the typical range of 42-80% reported in the literature (Baker 1953, Svedarsky 1979, Horak 1985). However, Silvy (1968) reported 20% nest success for prairie-chickens in the Kansas Flinthills. Nest success at the prairie island (1986 = 50%, 1987 = 39%) was comparable to previously reported rates.

Westemeier and Vance (1975) believed that nest success of prairie-chickens must average 50% to maintain viable populations in Illinois. Our data indicated that average nest success was below 50% in both areas. However, average nest success at the prairie island (44%) is apparently sufficient for maintaining population levels based on spring population surveys. Average nest success at the prairie mosaic (32%) was much less than 50%. Surveys of spring booming grounds at the prairie mosaic show a decline in the number of booming males since 1972 (Missouri Dept. of Conservation, unpubl. data).

The lower nest success at the prairie-mosaic was related to patterns of nest-site use and cause of nest loss. Fifty-nine % of the prairie-mosaic nests, compared to 5% of prairie-island nests, were located in agricultural habitats. Nests in agricultural habitats were vulnerable to agriculture-related destruction. Of the 19 nests located in agricultural habitats at the prairie mosaic, 23% were destroyed by agricultural operations. An important aspect of these data was that hen mortality occurred concurrent with nest loss. Landowners in the area have reported that hen mortality is not uncommon during mowing of haycrops. Agricultural nest-loss occurred during mechanized operations.

Schwartz (1945) previously documented that spring plowing was a cause of nest loss in Missouri.

Differences between years in the extent of agricultural-related nest loss at the prairie mosaic could be attributed to changes in agricultural practices. Data from 1987 show that only one agricultural nest-loss was sustained. Fewer losses compared to 1986 could reflect an area-wide delay in combining fescue (approximately 2-3 weeks) and in the implementation of the Conservation Reserve Program.

There was no difference between study areas in nest loss due to predation. Nest predation might be expected to be greater at the prairie-agriculture mosaic because the habitat configuration had more edge relative to area and created small tracts of nesting habitats. These 2 habitat characteristics have been correlated to increased vulnerability of nests of ground-nesting game birds (Roseberry and Klimstra 1975, Silvy 1978). We explain the lack of effect because only 25% (n=8) of the prairie mosaic nests were located along edges or within tracts of nesting habitat less than 15 ha.

CONCLUSION

Our research has shown that greater prairie-chickens exploited different habitat patterns that were comparable to applied management strategies. These data

should reflect the reproductive costs and benefits associated with each habitat pattern. The implementation of a management strategy should be compatible with specific objectives that take into account these costs and benefits.

The reproductive cost associated with the mosaic study area was nest-loss due to agricultural practices. Hen mortality that occurs concurrent with this nest loss could be an important cost. At the prairie island, the reproductive benefit was that a majority of nesting occurred within the confines of the refuge where nests were not vulnerable to agriculture.

One of the rationales to the "ecologically patterned" strategy is that local populations are managed on a region-wide basis. Our nest dispersion data at the prairie mosaic support this contention that prairie-chickens can be managed as a network of local populations. Consequently, populations inhabiting a prairie mosaic may garner reproductive benefits from genetic mixing. In contrast, nest dispersion data at the prairie island suggest that this may be an insular population with little outbreeding.

We suggest that the "ideal" is to combine the two management approaches to attain the benefits of each strategy. Large tracts could be linked using smaller,

scattered tracts as corridors for genetic exchange. The large tracts would function as refuges to attract nesting hens and would be less influenced by management of the surrounding private lands.

Large tracts may not be available for acquisition. Consequently, management may be forced to accept "ecological patterning". Along this line, we offer certain considerations for effective implementation of this strategy. Tracts of native prairie larger than 65 ha may be more effective in attracting nesting hens than smaller parcels. Acquisition of at least 20% native prairie within a management region should be a strategic goal.

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Appendix I. Number of greater prairie-chicken females radio-collared at the prairie mosaic and at the island prairie, Missouri, 1986-1987.

Year	Prairie mosaic	Prairie island
1986	24	26
1987	23	29
TOTAL	47	55

Appendix II. Nest-site utilization (%) by year of greater prairie-chicken females at the prairie mosaic, Missouri, 1986-1987.

Covertypes	1986 N = 17	1987 N = 15	TOTAL N = 32
Native prairie	5 (28)	4 (27)	9 (28)
Exotic grass	3 (18)	2 (13)	5 (16)
Wheat	3 (18)	1 (9)	4 (13)
Brush /			
Field Edge	1 (6)	2 (12)	3 (9)
Mixed grass			
pasture ^a	2 (12)	3 (20)	5 (16)
Fallow cropland	1 (6)	2 (12)	3 (9)
Sweet clover	1 (6)	1 (7)	2 (6)
Disked field	1 (6)	0 (0)	1 (3)

^a Mixed exotic and native prairie grass pasture.

CHAPTER III
GREATER PRAIRIE-CHICKEN HABITAT USE
IN SOUTHWESTERN MISSOURI

Native prairie habitats of the greater prairie-chicken (Tympanuchus cupido) have been fragmented into disjoint remnants throughout much of its range. Consequently, the interspersion pattern of habitats is an important consideration in the implementation of management strategies (Hamerstrom et al. 1957, Kirsch 1974, Cannon and Christisen 1984). Hamerstrom et al. (1957) developed a management strategy using scattered tracts of native prairie among agricultural blocks that they called "ecological patterning."

The basis of "ecological patterning" is that a regional mosaic of habitat-types will be exploited by local populations of prairie chickens to meet annual biological requirements (Hamerstrom et. al 1957, Cannon and Christisen 1984). Small, scattered tracts of native prairie are managed as nesting and brood-rearing cover. The surrounding agricultural tracts provide space for large home ranges, lek-sites, winter food, and escape and roosting cover. Implementation of this strategy in Wisconsin has been successful in maintaining viable populations (Hamerstrom and Hamerstrom 1973).

An alternative approach is to preserve large, isolated blocks of native prairie as a refuge system. Large blocks of prairie provide the biological requirements of an insular population within the confines of the preserve. This strategy has been used in the management of the Attwater's prairie-chicken (T. c. attwateri) in Texas and has been successfully applied in Missouri (Christisen 1985).

Although each management strategy has been implemented, there is an absence of research that explicitly compares habitat use and preference relative to these 2 habitat patterns. Our research compared a population of greater prairie-chickens that inhabited a prairie-agricultural mosaic to one that occupied an isolated block of native prairie habitat.

STUDY AREA

The prairie-agricultural mosaic was located in northwest Dade County, Missouri (Fig. 3-1). The area was 112 km² with 15 km² (12%) in native grass cover. The prairie-island study area was located in southwest St. Clair County, Missouri (Fig. 3-2). This study area was 52.5 km² with 6.5 km² (12.5 %) of native grass cover contained in a single block. The boundary of each study area was defined by prairie-chicken telemetry locations

Figure 3-1. The prairie mosaic study area. Scattered tracts of native prairie are represented. State-managed prairies are designated by cross-hatching.

Prairie-Agriculture Mosaic

Study Area

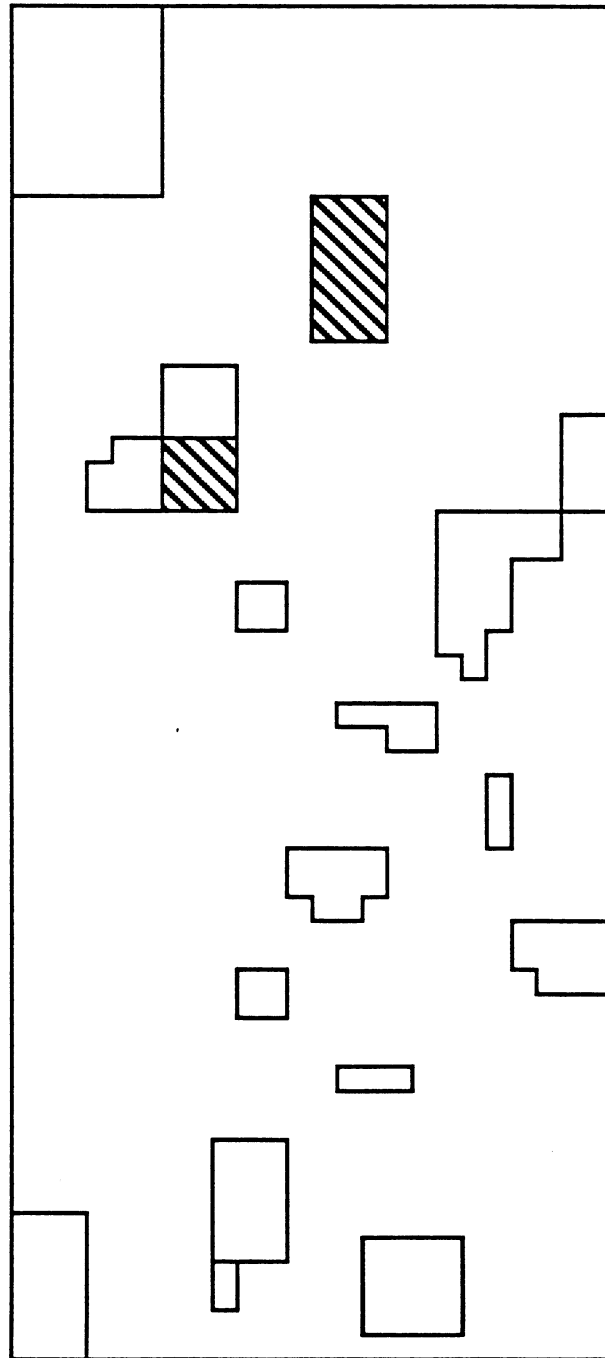
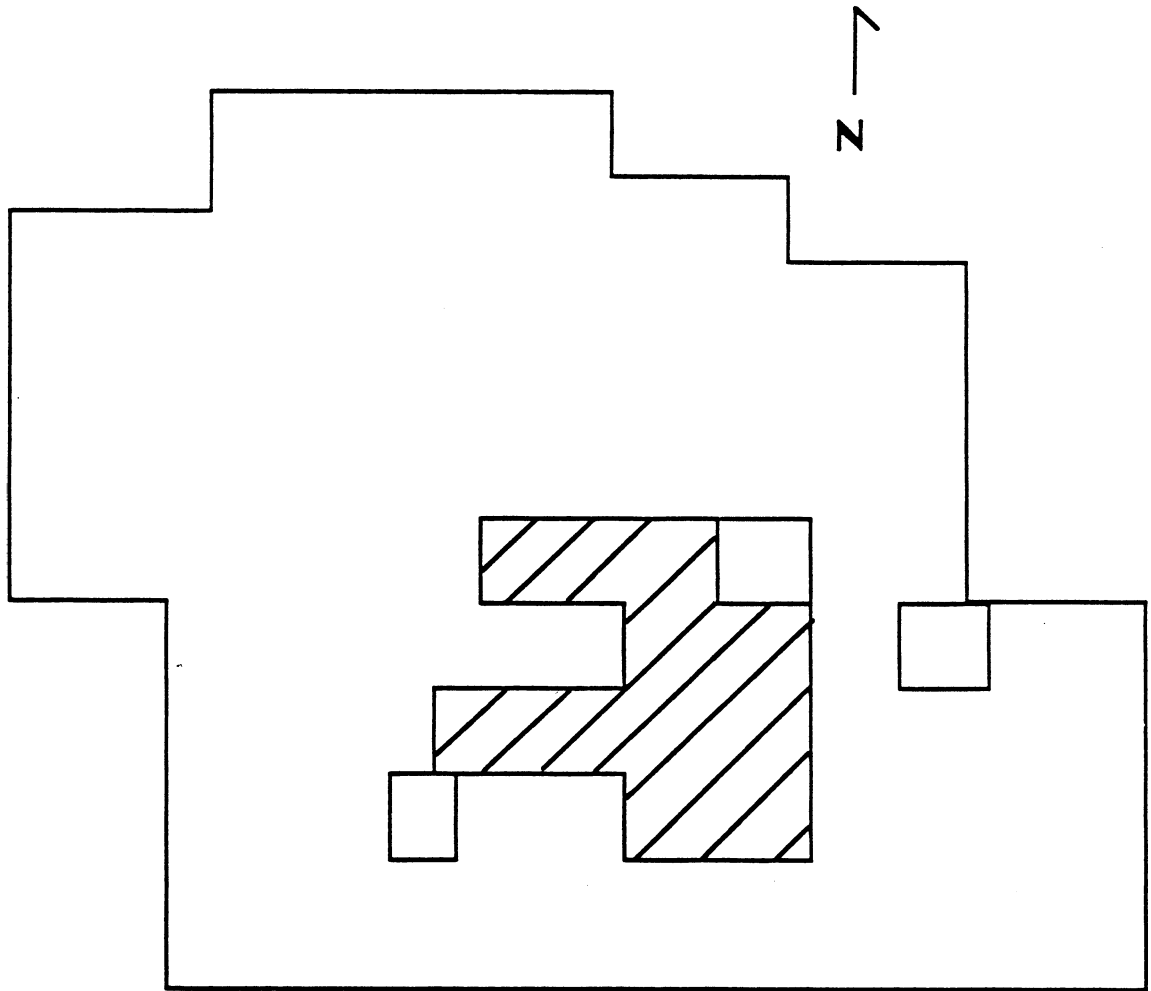


Figure 3-2. The prairie island study area. Native prairie is represented. The large tract of state-managed prairie is designated by the cross-hatching.

PRAIRIE ISLAND
STUDY AREA



and homeranges. Distance between the 2 study areas was 88 km. Annual precipitation at both areas averages 40 - 45 cm and annual average temperature was 12°C.

The prairie mosaic was characterized by a scatter pattern of native prairie, row and grain crops, exotic-grass pasture and hayland (primarily Festuca sp.), mixed grass pasture (mixed exotic and native prairie grass) and woodland. The primary land-use on the prairie-mosaic study area was agriculture. Eighty-seven % of the native prairie was privately owned. The privately-owned prairies were managed as pastures or for annual hay crops. The remainder (194 ha) was managed by the state to provide prairie-chicken habitat. Tract size of the prairies ranged from approximately 10 ha to 269 ha. Distance between the tracts varied from 0.8 to 3.2 km.

The prairie-island study area was comprised of the the same habitats as the prairie mosaic but most of the native prairie (75%) was contained in a single, large block. This block of native prairie habitat was managed to provide prairie-chicken nesting and brood-rearing cover. Management practices included haying and prescribed burning. Approximately one-half of the prairie island was hayed, in treatment units averaging 32 ha, on an annual basis. Haying occurred during July. The hayed tracts were interspersed among the unhayed

units. Burning of various sized tracts was prescribed on a 3-year rotational basis. Approximately 120 ha were burned during 1986 by a spring arson fire. Twenty-four ha were maintained in cropland.

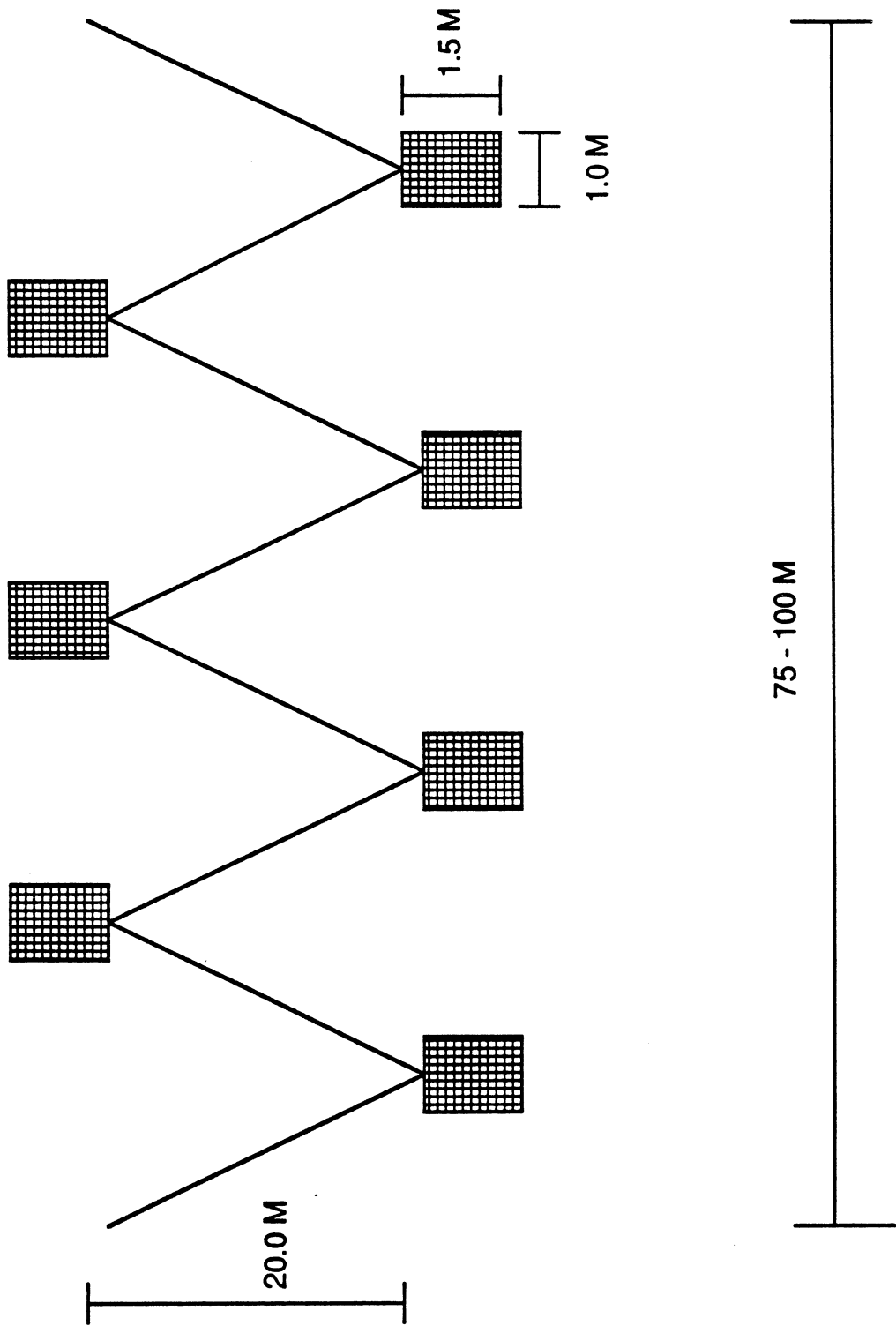
The principal grasses on the prairie island included big bluestem (Andropogon gerardi), little bluestem (Andropogon scoparius), indian grass (Sorghastrum nutans), switchgrass (Panicum virgatum), wild rye (Elymus canadensis), June grass (Koeleria cristata), prairie dropseed (Sporobolus heterolepis), and sloughgrass (Spartina pectinata).

METHODS

We captured female prairie-chickens on leks using walk-in funnel traps during spring 1986 and 1987 (Fig. 3-3). Supplemental capture techniques were used during the summer and the fall. These included modified cloverleaf traps and nightlighting from an All Terrain Vehicle.

The traps were constructed of wire fencing with a mesh of 2.5 cm x 5 cm. Dimensions of the trap were 1.5 m x 1 m x 1 m. Funnel entrances were made of chicken wire and were approximately 15-20 cm at the highest point and approximately 12 cm at the narrowest. Funnel lengths were 25-30 cm. Sixty cm high chicken wire was used as drift fencing to connect the traps.

Figure 3-3. Schematic diagram of a typical string of walk-in funnel traps.



OVERVIEW OF A TYPICAL TRAPLINE

Poncho-mounted (Ampstrup 1980) flatpack solar/NiCd radio transmitters were fitted onto captured hens. Ponchos were made of herculite. These packages weighed 16-20 g (2 to 2.5 % body weight). An oblong neck-hole was cut to fit tightly over the head of the female. The transmitters emitted a signal at 164-165 MHz. We used a programmable, scanning receiver and a hand-held 4-element yagi antenna to locate birds on a daily basis. Females were located using 2 or 3 intersecting bearings. Data collection alternated between the two study areas on a 3 (1986) or 4-day rotational basis.

Habitat-use data were derived by overlaying radio locations (expressed as UTM coordinates) on covertype maps of the two study areas using the Map Overlay and Statistical System (MOSS) geographical information system. Covertype maps were produced from aerial photographs and ground-truthing. The accuracy of the mapping was within 100 m and was within the accuracy of the radio-telemetry system. Bearing standard deviation was ± 2.5 degrees and was determined from transmitters placed at known locations.

Habitat preference was determined with the Johnson (1980) method using the software program PREFER (Frank 1980). Habitats are ranked from most to least preferred based on the magnitude of the average difference in the

ranks of habitat usage and availability. The PREFER program uses Fisher's F-statistic to test if the usage ranks are the same as the availability ranks. If equal preference among habitats is rejected, then the Waller-Duncan multiple comparison procedure is used to test which pairs of habitats are significantly different. This method was chosen because our sample size and number of habitats result in acceptable Type I and II errors (Alldredge and Ratti 1986).

Habitat preference was determined for 3 intervals based on reproductive status and season. The first encompassed breeding and nesting and began at the time of capture on booming grounds. The second interval was the summer period, beginning after nest hatch or loss and ending on 31 September. Brood-rearing and non-brood hens were analyzed separately. Habitat preference could not be determined for females with broods and without broods at the prairie mosaic due to inadequate sample size. The fall/winter period began on 1 October and ended when females began visiting leks. The beginning date of the fall/winter period was based on observations of brood break-up and changes in weather. March first was chosen as a common end date for this interval.

Habitat preference was evaluated at two levels. Percent availability of habitats within the study area

was compared to percent use to express preference at the study area level. Secondly, habitat availability within homeranges, as measured by the 100 % minimum convex polygon method, was compared to usage.

Our results were derived from 48 females (1,230 daily radio-locations) at the prairie-agricultural mosaic and 55 females (1,699 daily radio-locations) at the prairie-island. Each radio-collared hen was treated as a pseudo-replicate. Treatment effects can not be replicated. Therefore, results and conclusions of this research are applicable only to these specific study areas.

RESULTS

Greater prairie-chicken habitat use was proportional to availability within homeranges except at the prairie island during the fall/winter season (Table 3-1). However, use was strongly disproportionate to availability at the study area level at both study sites. During the fall and winter season at the prairie mosaic, habitat preference at the study area level was not significant ($P = 0.10$), probably because of small sample size ($N = 9$).

Table 3-1. Probability values associated with the hypothesis of equal habitat preference by female prairie-chickens at the prairie mosaic and prairie island, Missouri, 1986-1987.

Season	Study Area	Use vs. Homorange Availability	Use vs. Study Area Availability
Breeding / nesting	Prairie mosaic	P = 0.1	P < 0.001
	Prairie island	P = 0.3	P < 0.001
Summer ^a	Prairie mosaic	P = 0.25	P < 0.005
	Prairie island	P = 0.3	P < 0.001
Fall / winter	Prairie mosaic	P = 0.45	P = 0.1
	Prairie island	P = 0.06	P < 0.001

^a Females with broods and without broods.

Breeding/Nesting Season

A contrast in habitat-use existed between the two study areas during the breeding/nesting period (Table 3-2). At the prairie-agriculture mosaic, 5 of 7 habitats each received more than 15 % use, with privately-owned prairies and grain crops receiving the most use. Managed native prairie accounted for less than 3 % of the radio-locations. In contrast, at the prairie island, nearly 75 % of habitat-use occurred in managed native prairie. Mixed grass was the only other habitat to receive more than 10 % use.

Four habitats at the prairie mosaic were used more than predicted by study area availability. Use of mixed grass pastures and grain crops was 2 - 3 times greater than availability. Fallow areas and privately-owned prairies also were used disproportionately compared to study area availability. Use-availability comparisons ranked exotic grass and row crops as significantly avoided habitats at both areas.

Post-nesting season

During the summer period at the prairie mosaic, female prairie-chickens with and without broods increased their use of cropland (i.e. grain and row crops) (Table 3-3). These habitats accounted for 53 % of the use by brood hens.

Table 3-2. Mean percent habitat use, mean percent homerange habitat availability and study area habitat availability, and preference rankings of habitats by breeding/nesting female prairie-chicken at the prairie mosaic and prairie island, Missouri, 1986-1987.

Habitat	\bar{X} % Use ^b	<u>Availability</u>		<u>Preference Ranks^a</u>	
		\bar{X} % Homerange	Study Area	Home- range	Study Area
Prairie Mosaic					
Mixed					
grass ^c	7.0	2.4	2.0	1 A ^d	1 A
Grain					
crops	19.7	16.0	7.1	2 AB	2 AB
Managed					
prairie	2.9	5.6	2.1	4 B	3 BC
Fallow	15.1	11.2	8.2	5 AB	4 CD
Private					
prairie ^e	21.8	20.2	11.2	3 AB	5 D
Row					
crops	16.3	21.5	27.3	7 B	6 D
Exotic					
grass ^f	17.1	22.4	41.7	6 B	7 E

Table 3-2. Con't

Prairie Island

Managed					
prairie	73.8	59.5	12.5	1 A	1 A
Private					
prairie	0.8	2.7	4.3	5 A	2 B
Mixed					
grass	11.8	16.7	6.5	6 A	3 C
Grain					
crops	0.4	1.1	4.4	3 A	4 C
Row					
crops	4.6	8.3	25.2	4 A	5 D
Exotic					
grasses	8.3	11.1	45.0	2 A	6 E

^a Johnson 1980.

^b Prairie mosaic N = 24 females; Prairie island N = 23 females.

^c Mixed introduced cool season and native prairie grasses.

^d Ranks with the same capital letter are not significantly ($P > 0.05$) different from each other.

^e Annually hayed or livestock grazing.

^f Introduced cool season grasses (primarily Festuca sp.).

Table 3-3. Mean percent use, mean percent homerange habitat availability, and study area habitat availability of female prairie-chickens with broods and females without broods at the prairie mosaic, Missouri, 1986-1987.

Habitat	\bar{X} % Use ^a		\bar{X} % Homerange		
	Brood	Nonbrood	Availability		Study Area Availability
Row crops	28.1	39.3	26.3	38.2	27.3
Grain					
crops	24.7	9.5	19.9	10.8	7.1
Exotic					
grass ^b	16.7	2.1	21.1	5.3	41.7
Private					
prairie ^c	10.8	13.3	20.2	6.3	11.2
Fallow	10.3	33.8	7.6	35.8	8.2
Managed					
prairie	4.7	0.0	2.7	0.0	2.1
Mixed					
grass ^d	3.4	1.4	2.2	3.7	2.0
	$\chi^2 = 38.4$		$\chi^2 = 43.4$		
	P < 0.001		P < 0.001		

Table 3-3. Con't.

- a With broods N = 7; Without broods N = 7.
- b Introduced cool season grasses (primarily Festuca sp.).
- c Annually hayed or pasture.
- d Mixed introduced cool season and native prairie grasses.

Females with and without broods at the prairie mosaic exhibited important differences in habitat use ($X^2 = 38.44$, $P < 0.001$) and in the availability of habitats within homeranges ($X^2 = 43.43$, $P < 0.001$). Females with broods used 5 habitats frequently ($> 10\%$), whereas, only 3 habitats received more than 10% use by nonbrood hens.

Differences also were evident in the kinds of habitats used. Grain crops and exotic grasses were used more frequently by brood hens (24.7% and 16.7% , respectively) than by nonbrood hens (9.5% and 2.1% , respectively). Nonbrood hens concentrated use in row crops and fallow areas. Managed native prairie seemingly was not an important habitat for females with or without broods.

Use of grain crops by females with broods (24.7%) was greater than predicted by study area availability (7.1%). Brood hens used row crops frequently (28.1%), but use was proportional to availability (27.3%). Nonbrood hens used fallow areas and row crops disproportionately to availability. Females with and without broods appeared to avoid exotic grass habitats.

At the prairie island, brood hens exhibited a seasonal shift toward increased use of row crops and mixed grass habitats (Table 3-4). Consequently, managed

Table 3-4. Mean percent habitat use, mean percent homerange habitat availability and study area habitat availability, and preference rankings of habitats by female prairie-chickens with broods and without broods prairie island, Missouri, 1986-1987.

Habitat	\bar{X} % Use ^b	<u>Availability</u>		<u>Preference Ranks^a</u>	
		\bar{X} % Homerange	Study Area	Home- range	Study Area
Brood Hens					
Private					
prairie ^c	4.7	5.5	4.3	4 A ^d	1 A
Managed					
prairie	42.9	44.5	12.5	6 A	2 A
Mixed					
grass ^e	16.0	20.6	6.5	5 A	3 AB
Grain					
crops	0.0	0.6	4.4	2 A	4 BC
Row					
crops	18.5	11.2	25.2	1 A	5 C
Exotic					
grass ^f	18.0	16.6	45.0	3 A	6 D

Table 3-4. Con't.

Non-brood Hens

Private

prairie	3.4	3.1	4.3	1 A	1 A
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Managed

prairie	58.2	50.6	12.5	4 A	2 AB
---------	------	------	------	-----	------

Mixed

grass	6.4	4.6	6.5	2 A	3 BC
-------	-----	-----	-----	-----	------

Grain

crops	0.0	0.4	4.4	3 A	4 C
-------	-----	-----	-----	-----	-----

Row

crops	11.1	12.3	25.2	6 A	5 D
-------	------	------	------	-----	-----

Exotic

grass	20.8	28.1	45.0	5 A	6 D
-------	------	------	------	-----	-----

^a Johnson 1980.

^b With broods N = 14; Without broods N = 10.

^c Annually hayed or pasture.

^d Ranks with the same capital letter are not significantly ($P > 0.05$) different from each other.

^e Mixed introduced cool season and native prairie grasses.

^f Introduced cool season grasses (primarily Festuca sp.).

native prairie was used less by females with broods (42.9 %) than by females without broods (58.2 %).

Females with broods used a greater variety of habitats than females without broods at the prairie island. Brood hens used 4 habitats, each more than 15 % of the time, whereas, only 2 habitats received more than 15 % use by nonbrood females. Managed native prairie was the predominant component of the habitat-use patterns of both brood hens and nonbrood hens. Exotic grass also was used frequently by females with broods (18 %) and without broods (20.8 %). However, in both cases use was substantially less than predicted by availability.

Managed native prairie was ranked as a highly preferred habitat by females with and without broods. This was the only habitat at the prairie island to be used disproportionately to availability by nonbrood hens. However, females with broods also used mixed grass more than predicted by study area availability.

Fall and Winter Season

During the fall and winter, a diversity of habitats was used by female prairie-chickens at the prairie mosaic (Table 3-5). Row crops, private prairie, and exotic grass pastures each accounted for more than 20 % of the radio-locations at the prairie mosaic. Mixed

Table 3-5. Mean percent habitat use, mean percent homerange habitat availability and study area habitat availability, and preference rankings of habitats by female prairie-chickens during the fall and winter at the prairie mosaic and prairie island, Missouri, 1986-1987.

Habitat	\bar{X} % Use ^b	Availability		Preference Ranks ^a	
		\bar{X} % Homerange	Study Area	Home- range	Study Area
Prairie Mosaic					
Mixed					
grass ^c	12.5	4.9	2.0	2 A ^d	1 A
Fallow	14.5	8.7	8.2	1 AB	2 A
Managed					
prairie	1.2	4.4	2.1	6 AB	3 A
Grain					
crops	5.3	5.9	7.1	4 AB	4 AB
Row					
crops	23.1	22.3	27.3	5 B	5 AB
Private					
prairie ^e	20.5	19.2	11.2	3 AB	6 AB
Exotic					
grass ^f	22.9	34.1	41.7	7 B	7 B

Table 3-5. Con't.

Prairie Island

Managed

prairie	45.2	39.8	12.5	2 A	1 A
---------	------	------	------	-----	-----

Private

prairie	2.5	2.6	4.3	4 A	2 A
---------	-----	-----	-----	-----	-----

Grain

crops	3.4	1.6	4.4	1 A	3 B
-------	-----	-----	-----	-----	-----

Row

crops	29.0	21.2	25.2	3 A	4 C
-------	------	------	------	-----	-----

Mixed

grass	4.9	6.3	6.5	5 AB	5 C
-------	-----	-----	-----	------	-----

Exotic

grass	14.8	27.1	45.0	6 B	6 D
-------	------	------	------	-----	-----

^a Johnson 1980.

^b Prairie mosaic N = 9; Prairie island N = 18.

^c Mixed introduced cool season and native prairie grasses.

^d Ranks with the same capital letter are not significantly ($P > 0.05$) different from each other.

^e Annually hayed or pasture.

^f Introduced cool season grasses (primarily Festuca sp.).

grass and fallow areas were of secondary importance, both having been used more than 10 % of the time.

Private prairies, mixed grass, and fallow habitats at the prairie mosaic were used more than expected relative to study area availability. Row crops were used in proportion to availability. Exotic grass continued to be used less than predicted.

At the prairie island, managed native prairie received the greatest use (45.2 %) and was the most highly preferred habitat by female prairie-chickens during the fall and winter period (Table 3-5). Row crops were the second most frequently used (29 %) habitat but use was proportional to availability (25.2 %). Exotic grass was significantly avoided despite it being the third most frequently used habitat.

DISCUSSION

We compared two levels of habitat availability to use to evaluate preference by female prairie-chickens. These levels are comparable to Johnson's (1980) orders of selection. The highest level measures availability of habitats within the study area (i.e. second-order selection). This level determines the placement of homeranges within a geographical region. At both study areas, during all seasons, habitat preference was exhibited at the study area level. The second level

expresses preference of habitats within a homerange (i.e. third-order selection). Our data showed proportional use of habitats within homeranges.

This level of selection appears to represent an attempt by female prairie-chickens to meet different seasonal requirements simultaneously within a homerange. At the prairie mosaic, homeranges were comprised of an array of habitats. In contrast, managed native prairie was the predominant component of homeranges at the prairie island.

In contradiction to predicted use (Hamerstrom et al. 1957, Cannon and Christisen 1985) of managed native prairie for nesting and brood-rearing, hens at the prairie mosaic seemingly were not attracted to small managed tracts. The strategy of "ecological patterning" is based on the assumptions that nesting and brood-rearing activities drive the habitat-use patterns of prairie-chickens and that scattered tracts will be used disproportionately to their availability for nesting and brood-rearing (Hamerstrom 1957, Cannon and Christisen 1984). Our data showed that a diversity of habitats was used to meet all annual biological requirements. Seemingly, no one life-history facet takes precedence in the selection of homeranges. Secondly, managed prairie was not a highly preferred habitat for nesting or brood-

rearing.

At the prairie-agriculture mosaic, an array of habitats was used for nesting and brood-rearing because females use habitats in proportion to availability within homeranges. These results suggest that reproductive activities may have been forced into marginal-quality habitats because high-quality habitats were limited in availability or habitat juxtaposition was poor. Further evidence of the use of sub-optimal habitats was that 56 % of nests (18 of 32) at the prairie mosaic were in exotic grass or cultivated areas (Jones 1988).

At the prairie island, managed native prairie was strongly preferred for nesting and brood-rearing. This large tract of native prairie provided botanical and structural diversity that apparently met the biological requirements of female prairie-chickens for both reproductive activities.

We detected shifts toward the use of habitats disturbed by agriculture at both areas during brood-rearing. Increased use of cropland was particularly evident, with frequent use of grain crops at the prairie mosaic. At the prairie island, much of the use of row crops was immediately adjacent to the large tract. We hypothesize that grain crops were not used at this

latter study area because this habitat was not closely juxtaposed to the large prairie tract.

Grassland habitats disturbed by haying or grazing were used at both areas. Jones (1988, unpubl. data) observed broods using recently hayed units on the prairie island. Brood-rearing also occurred in mixed-grass pastures adjacent to the large tract. At the prairie mosaic, brood hens frequently used exotic grass pastures that were either grazed or recently hayed.

"Preference" by prairie-chicken broods for disturbed habitats has been previously documented (Jones 1963, Svedarsky 1979, Horak 1985). Presumably, this disturbance creates an attractive combination of insect abundance, ease of foraging and mobility, and concealment cover. Cropland, especially wheat, provides overhead, concealment cover with openness at ground level. Haying may make insects more readily accessible for foraging, as well as, facilitating brood mobility. Drobney and Sparrowe (1977) and Horak (1985) reported that light to moderate grazing increased structural diversity that was seemingly advantageous to broods.

Conventional prairie-chicken management considers "nest-brood habitat" to be a single component (Kirsch 1974). However, Svedarsky (1979) suggested this definition may not be entirely correct. Our data from

both areas support Svedarsky's contention that nesting habitats may not provide all of the requirements for brood-rearing. This reinforces our hypothesis that different seasonal requirements must be met simultaneously within a homerange.

During the fall and winter, females at both areas increased their use of row crops. The importance of cultivated crops as a winter food resource has been documented throughout the range of the greater prairie-chicken (Schwartz 1945, Baker 1953, Hamerstrom et al. 1957). At the prairie mosaic, fallow areas also became important habitats (as reflected by greater use than expected). Baker (1953) documented that "weed" seeds were important food items during the fall and Korschgen (1962) reported that Ragweed (Ambrosia sp.) seeds occurred frequently in prairie-chicken droppings during this season.

The importance of winter cover in the ecology of the greater prairie-chicken has not been documented conclusively. Drobney and Sparrowe (1977) considered winter cover to be critical in Missouri. However, neither Hamerstrom et al. (1957) nor Kirsch (1974) emphasized this component. At the prairie mosaic, females used a variety of habitats for roosting, including covertypes (such as milo stubble) that

seemingly provided little residual cover. At both areas, exotic grasses were avoided habitats. Exotic grasses are considered poor winter cover because the grasses do not stand up to snow (S. Clubine, Missouri Dept. of Conservation, pers. comm.).

Habitat-use patterns at the two areas may be the result of evolutionary strategies to minimize predation. Burger (1988) reported that at both areas, higher predation rates and lower nest success were associated with females making longer daily movements. Limited daily movements may have been adaptive in presettlement native prairies. These prairies provided the botanical and structural heterogeneity that permitted prairie-chickens to meet annual requirements within a limited homerange.

Habitat juxtaposition becomes critical because of constraints on the length of daily movements and homerange size. At the prairie mosaic, use of managed prairie may be lower than expected unless managed prairies are near other required habitats. Our data suggests that female prairie-chickens will not increase their daily movements or seasonal homerange size in order to frequently use managed prairie.

Reproductive costs may be associated with this evolutionary strategy at the prairie mosaic. Given

limited movements and homeranges, nesting and brood-rearing may occur in sub-optimal habitats such as agricultural covertypes. Jones (1988) documented that 23 % of nests at the prairie mosaic were destroyed by agricultural practices. Farmers at the prairie mosaic reported that broods were frequently killed during wheat harvesting and mowing of clover (Jones, unpubl. data).

Social interactions between females also may play a role in these contrasting habitat-use patterns. Robel (1970) suggested that female aggression may be acting as a mechanism that regulates prairie-chicken populations. Nesting homeranges at the prairie mosaic showed little overlap (Burger 1988). The exclusion of females from small tracts of native prairie may result in nesting in poorer-quality habitats.

CONCLUSION

Our data have shown that contrasting habitat-use existed between two populations of greater prairie-chickens relative to the dispersion pattern of managed native prairie. At both study areas, prairie-chickens selected homeranges that fulfilled annual biological requirements simultaneously and resources were used in proportion to availability within those homeranges. At the prairie-agricultural mosaic, homeranges were

comprised of an array of habitats and managed native prairie was never strongly preferred. In contrast, managed native prairie was the predominant component of homeranges at the prairie island in all seasons.

Our data indicate that large tracts of prairie are more effective than smaller, scattered tracts at attracting female prairie-chickens. These results suggest that nesting females can not be "packed" onto small prairie tracts and these parcels will not become intensive prairie-chicken production areas. Also, the habitat-use data indicate that a significant proportion of reproduction at the prairie mosaic occurred in agricultural habitats in which nests and broods may be vulnerable to agricultural practices. As a result, population densities of prairie-chickens inhabiting a prairie mosaic may be lower than a population inhabiting a large refuge.

Large prairies may not exist in Missouri for prairie-chicken management. Consequently, the strategy of ecological patterning may be the only viable management option. Effective implementation of "ecological patterning" is dependent on habitat juxtaposition because prairie-chickens establish homeranges that encompass annual biological requirements. Scattered tracts of native prairie, of and

by themselves, seemingly will not attract frequent use by female prairie-chickens. These parcels must be "packaged" together in complement with brood habitats and winter food resources. Also, the usefulness of individual tracts will be influenced by the surrounding land-use.

It is important to recognize that the management strategy of "ecological patterning" is affected by the dynamics of surrounding land use. Flexibility will be a necessary component of this management approach.

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CHAPTER IV
MANAGEMENT IMPLICATIONS

This section will address general implications for the strategies of prairie-chicken management and some specific aspects of the species management plan developed by the Missouri Department of Conservation. Our data reflect ecological costs and benefits associated with both the "large" refuge and "ecological patterning" strategies. Additionally, management advantages and disadvantages exist with each approach. The implementation of either management strategy should be compatible with specific objectives that take into account these aspects.

At the prairie mosaic, a significant proportion of the reproductive activities occurred in agricultural habitats (Jones 1988). Consequently, the ecological debit associated with the scatter-pattern study area was nest loss due to agricultural practices. Hen mortality that occurred concurrent with this nest loss could be an important cost. Additionally, there was strong anecdotal evidence that broods may be killed during some agricultural operations (Jones 1988, unpubl data). Mortality rates may be higher at the prairie mosaic (Burger 1988).

Our habitat-use data suggest that nesting females can not be "packed" onto small tracts and these small parcels will not become intensive prairie-chicken production areas. Additionally, Jones (1988, unpubl. data) reported that of 12 nesting females captured within approximately 1/2 mile of managed prairie, only 2 of these females nested on state-managed tracts. These results indicate that "ecological patterning" may not produce high population densities of prairie-chickens. Limited quota hunts may not be a compatible objective with this strategy.

An ecological benefit of ecological patterning is that several local sub-populations are preserved rather than just one population. Our nest dispersion and movement data support the contention that scattered tracts of prairie can be effective in linking regional sub-populations of greater prairie-chickens. Consequently, populations inhabiting a prairie mosaic may garner reproductive benefits from genetic mixing.

At the prairie island, the reproductive benefit was that a preponderance of the nesting occurred within the confines of the refuge where nests were not vulnerable to agriculture. Ninety % of the hens at the prairie island nested within the refuge and no nests were lost to agricultural practices (Jones 1988).

A potential ecological cost associated with the prairie island is that, quite literally, the entire reproductive effort is in one basket. A natural catastrophe could decimate an entire population. In 1967, Hurricane Beulah hit an Attwater's prairie-chicken management area in Texas and killed an estimated 80 % of the population (Lehmann 1968). In October 1983, a severe hailstorm hit the northern portion of the prairie mosaic study area. Tom Toney, prairie wildlife biologist, estimated that the storm had a significant impact on the local population (Toney, Missouri Dept. of Conservation, pers comm.).

There are also management advantages and disadvantages associated with each strategy. One of the management rationales to "ecological patterning" is that this approach will allow for the management of 2 to 5 times the area as the same number of acres in a solid block (Hamerstrom et al. 1957). A corollary to this advantage is that a scatter pattern will cover more area per dollar spent. Additionally, some flexibility exists in acquiring land because no one particular tract is absolutely indispensable to the whole scheme. A disadvantage is the administrative and logistical difficulty associated with managing several smaller tracts rather than one large block.

The relative ease of managing a large tract is the advantage of the prairie island. However, large tracts of prairie rarely exist for acquisition. Also, if a large tract is identified, there is less flexibility in acquiring a large tract at any one time.

We suggest that the "ideal" would be to combine the two management approaches to attain the benefits of each. Large tracts could be linked together using smaller, scattered parcels of managed prairie as corridors to facilitate genetic exchange. The large prairies would attract nesting hens and reproduction would not be vulnerable to agriculture. Also, large tracts would be influenced less by management of the surrounding private lands.

Large prairies may not exist for acquisition. Ecological patterning may be the only viable management option. Thus, we offer certain recommendations for the species management plan developed by the Missouri Department of Conservation.

The acquisition goal of 6 to 8 % native prairie within each management zone should be increased to at least 20 %. Kirsch (1974) recommended that management units be comprised of at least 25 % native prairie. Successful application of "ecological patterning" in Wisconsin used more than 20 % prairie (Hamerstrom and

Hamerstrom 1973). "Ecological patterning" in Illinois employs approximately 15 % permanent grassland. However, it should be noted that these populations are currently unstable (Westemeir 1986). Our data suggest that 12 % native prairie (includes both state-managed and privately-owned praires) at this particular mosaic may not be sufficient for preserving this population.

We recommend that the 80 - 160 acre "preferred" tract size proposed by the restoration plan be modified. Our data indicate that larger blocks of prairie are more efficient in attracting prairie-chicken use. Fifty-six % of nests at the prairie mosaic were in blocks of nesting habitat of at least 160 acres (Jones 1988). Kirsch (1974) suggested a minimum tract size of 160 acres. An important modification of the acquisition criteria would be to eliminate the upper limit of 240 acres.

Recommendations on minimum tract size are more difficult to establish and are dependent on juxtaposition to larger tracts of prairie. Eighty acres would be acceptable if the tract was adjacent to or within one-half mile of a large tract of prairie.

Because female prairie-chickens establish homeranges that encompass annual requirements, habitat juxtaposition is critical to attract use by prairie chickens of scattered tracts of prairie. Our data showed

that scattered tracts, of and by themselves, will not attract frequent use by female prairie-chickens. Native prairie habitats should be clustered within one-half mile of one another and in association with winter food resources and brood habitats. Kirsch (1974) recommended that a minimum of 2 square miles of prairie be contained within no more than 8 square miles. The restriction against purchasing prairie tracts adjacent to previously acquired tracts should be eliminated.

The usefulness of individual prairie tracts is influenced by the surrounding land-use. The effectiveness of a prairie could be affected by changes in haying or grazing practices on adjacent grasslands. The Conservation Reserve Program may be a positive influence if these set-aside lands are contiguous with a prairie tract. Conversely, prairie adjacent to a woodland may not be desirable because of the raptors associated with the woodland.

It is important to recognize that "ecological patterning" is a dynamic system, affected by changing agricultural practices on the surrounding private lands. Flexibility will be a necessary component of this management approach. Tracts of cropland may even be considered for purchase. We recommend that field personnel be given latitude in the acquisition protocol.

The expanded private lands program is an integral component to managing this species. The biological efficacy of state-managed prairies will be enhanced by compatible management on private lands. We fully support this objective in the species restoration plan.

A "triage" approach to the management of prairie-chickens in Missouri may be necessary. Greater investment in fewer management zones (as identified in the species management plan) should be considered in order to attain the recommended goal of 20 % native prairie. The restoration plan identifies 6 management zones in Group A (Table 2, p. 21) as priorities. The total acreage in these 6 zones is approximately 70,000 acres. Thus, nearly 14,000 acres would be necessary to attain the minimum acquisition goal. However, the species management plan proposes only 10,900 acres for the entire program (10 management zones).

The current management of nesting habitat on managed prairies is a useful approach. Jones (1988) documented that 72 % of nesting at Taberville occurred in second year's growth after haying. The pattern of nest dispersion tracked changes in the availability of suitable cover as a response to haying treatments between years. However, it should be noted that haying on the smaller, scattered prairies may reduce the

effective size of a tract by one-half. Kirsch (1974) recommended that only 1/3 to 1/4 of a management area should be hayed during any one year.

Management of brood habitat at Taberville prairie could be given greater consideration. Our data showed that some broods moved off Taberville to use disturbed habitats. The current mowing treatments on Taberville are useful in managing brood habitat but grain crops (particularly wheat) could be of some additional value. Livestock grazing should be considered as a tool for creating brood habitat.

The species restoration plan for the greater prairie-chicken is an important beginning for managing this species in Missouri. An aggressive habitat acquisition program must be followed to achieve success. We recommend a combination of "ecological patterning" and the acquisition of large tracts to conserve prairie-chickens in Missouri. This approach will yield a prairie complex that links disjointed grassland habitats and also provides nesting refuges.

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