HABITAT SELECTION OF NORTHERN BOBWHITE IN THE RIO GRANDE PLAINS OF TEXAS

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ABSTRACT

From June 1987 through September 1988, we determined habitat selection by northern bobwhites (*Colinus virginianus*) in the Rio Grande Plains of south Texas. Habitat components were evaluated at a large scale (100-m circular plots) and fine scale (8-m circular plots) levels of resolution at radiomarked bobwhite locations and at random sites. Data was collected during summer 1987, fall-winter 1987–88, and spring-early summer 1988. On both scales of resolution, during each season, bobwhites were found in more patchier areas than were available. Distance to roads was the only important large scale habitat variable identified. Forbs appeared to be the most important fine scale habitat variable. Grass, shrubs, and bare ground were also identified as important habitat variables. Important fine-scale and large-scale habitat variables were not correlated with one another. Therefore, it is important to examine habitat variables at different scales when studying habitat use by northern bobwhites.

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Key words: northern bobwhite, *Colinus virginianus*, habitat, habitat interspersion, scale, Texas

INTRODUCTION

Northern bobwhites are an important natural resource in the Rio Grande Plains of Texas (Lehmann 1984:5), and numerous landowners are interested in optimizing the economic return on quail hunting (Guthery 1986: 212). Understanding the specific habitat requirements of bobwhites, and how various brush management techniques and grazing systems affect vegetative succession, bobwhite habitat selection and population dynamics are important in implementing a successful bobwhite management plan.

Habitat variables such as nesting and brooding cover (native bunchgrasses), thermal cover (shrubs) and food (forbs and mast) are important to bobwhites (Stoddard 1931:132, Rosene 1969:165, Lehmann 1984:212, Guthery 1986:78, and Wilkins 1987). Reid (1977) and Reid et al. (1979) found a relationship between northern bobwhite abundance and habitat interspersion on a large scale of resolution. Often overlooked, however, is the interspersion of habitat variables at a finer scale of resolution. For example, Beecher (1942:40) noted that abundance of forbs in a meadow together with grass, and sedges must be considered an interspersion of habitat types. Since northern bobwhites are terrestrial and have low mobility, the interspersion of fine scale habitat variables would be important to northern bobwhites.

The primary objective of our study was to determine which large scale and fine scale habitat variables were important to bobwhites. A second objective was to determine if there was a relationship between large scale and fine scale habitat variables selected by northern bobwhites. We consider the results of this study a preliminary analysis of spatial data collected for the senior author's Ph.D. dissertation. Many of the spatial analysis techniques currently used to quantify the spatial relationships of habitat variables on large and fine scales of resolution did not exist when the analyses was conducted for these data over a decade ago. Consequently, we anticipate applying some of the new spatial statistical techniques to the data to better quantify the preliminary results reported in this paper.

METHODS

Study Area

The study was conducted from May 1987–September 1988 at the La Copita Research Area, a 1,093-ha ranch, owned and operated by the Texas Cooperative Extension Service, in Jim Wells County, Texas. The ranch is located between the South Texas Plains

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and Gulf Prairies and Marshes ecological regions (Gould 1975).

The climate at La Copita is subtropical with a mean annual temperature of 22.2° C and a growing season of about 300 days/year (Loomis 1989). Mean annual precipitation was 71.5 cm (Loomis 1989), and was bimodally distributed with peaks occurring during April–June and August–September. Predominant upland range sites were sandy loams and gray sandy loams, while drainages were primarily claypan prairie and clay loam range sites (Walsh 1985).

Walsh (1985) classified the overall vegetation type at La Copita as Tamaulipan thorn-scrub woodland and Scanlan (1988) described the landscape as consisting of shrub clusters dispersed with grassy interstitial areas. The dominant woody species was mesquite (*Prosopis glandulosa*). Dominant herbaceous species were panicums (*Panicum* spp.), tridens (*Tridens* spp.), grama grasses (*Bouteloua* spp.), Texas bristlegrass (*Setaria texana*) and orange zexmenia (*Zexmenia hispida*) (Scanlan 1988).

Procedures

The study was not replicated on other property in the surrounding area nor were replicates established on La Copita. The research should therefore be consider a descriptive study of bobwhite habitat use on a large and fine scale of resolution.

Radio Telemetry

Telemetry was used to determine areas used by northern bobwhites in the field. Bobwhites were captured with funnel traps (Stoddard 1931:443) baited with grain sorghum at permanent trap locations, established at an approximate density of 1/9 ha (Wilkins 1987:12). All bobwhites captured were aged (Petrides and Nestler 1943), sexed, banded, and radiomarked with poncho transmitters. Trap location, date, and climatic conditions for each capture incident were recorded. An effort was made to maintain 10–12 bobwhites (equal sex ratio) fitted with transmitters at all times. Radiomarked birds were located once each day for 3 consecutive days. Monitoring sessions were conducted during mornings, afternoons, and evenings during the 3-day period to minimize temporal biases. Directional bearings were taken from permanently established stations and these data were entered into a computer program (D. Martin, unpublished manuscript) to calculate the geometric center of an error polygon, which represented a bobwhite's location (Mech 1983). Date, time, and climatological data were recorded for each telemetry location.

Landscape-scale Measurements

Large-scale measurements from randomly selected bobwhite telemetry locations were sampled during spring, summer and fall-winter seasons. Large-scale patch measurements were obtained from a 1987 aerial photo (2.5 cm: 230 m) of the research area (United States Department of Agriculture, Natural Resource Conservation Service). To qualify for sampling, a location had to have an error polygon $<$0.5 ha (Wilkins 1987). The geometric centers of the error polygons representing bobwhite locations were plotted on the photo and served as the mid-point of an imaginary circle. Patch measurements were then estimated along 4 sampling transects extending 100-m in cardinal directions originating from the mid-point. For comparative purposes, a 1,000 $\times$ 1,000-m grid overlay was placed on the photo of the research area and 25 random points (center of grid) were located. Patches at random points were measured in a manner identical to bobwhite locations.

From the aerial photo, patch types were classified as brushy areas, openings, or roads. The patch encompassing the mid-point of the circle was designated as the origin patch from which patch measurements for each sampling transect began. The length of each consecutive discrete patch type starting with the length of the origin patch, was then measured along the entire length of each sampling transect (Fig. 1). However, because our objective was to quantify habitat interspersion we believed we needed information regarding the spatial relationships of discrete patch types. Consequently, in addition to measuring the length of each patch type along a sampling line, we also noted the type of patch that immediately followed the origin patch, was defined as the boundary patch. The measured patch was then labeled according to its classification and the identity of its boundary patch (Fig. 1). For example, if a bobwhite or random point was located in an opening on the aerial photo, this opening would represent the first patch type to be linearly measured on the sampling line. The opening would be the origin patch. If the next consecutive patch that immediately followed the opening was a brushy patch, then it would be referred to as the boundary patch. The origin patch would then be labeled an opening-brush patch (OB) based on the classification of the patch measured (opening) and the identity of the boundary patch next encountered along the sampling line (brushy patch) (Fig. 1). The boundary patch (brushy patch) would then become the next patch measured until another boundary patch type, which might have been a road, ended the brushy patch. The second patch would then be labeled a brush-road patch (BR).

Six discrete large scale patch combinations could theoretically be measured (m) along a sampling transect; opening-brush (OB), opening-road (the width of a road) (OR), brush-opening (BO), brush-road (BR), road-opening (RO), and road-brush (RB) (Table 1). In addition to measuring the linear extent (m) of a patch and knowing the identity of its boundary patch, we believed that knowing the distance between patches of the same class, would help quantify patch interspersion. Therefore, we also calculated the nearest neighbor distance between patches of the same classification (Fig. 1). For example, we calculated the distance from an opening (OB patch) to the next nearest consecutive opening (OR) patch on the sampling transect. We started this process with the first opening patch (OB), and then repeated the process for every opening patch en-

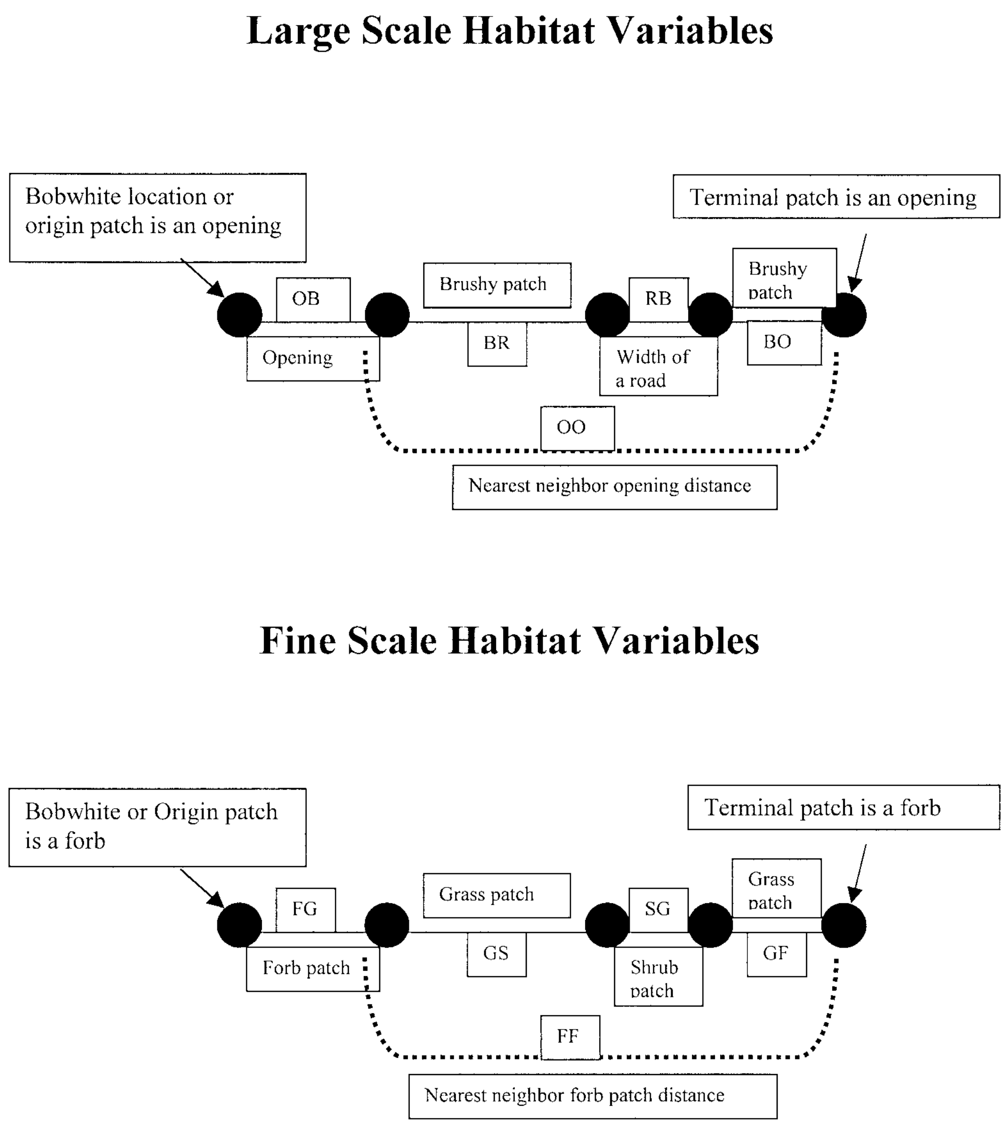

Fig. 1. Methodology used to label patches, measure length of patches and distance between a patch and the next consecutive patch of the same type along sampling line at the La Copita Research Area, 1987–88. (OB = opening ended by a brusy patch, BR = brushy patch ended by the width of a road, RB = road ended by a brushy patch, OO = distance from one opening to the nearest consecutive opening on sampling transect, FG = forb patch ended by a grass patch, GS = grass patch ended by a shrub patch, SG = shrub patch ended by a grass patch, GF = grass patch ended by a forb patch, FF = distance from one forb patch to the nearest consecutive forb patch on sampling transect).

countered along the sampling transect. Measurements were calculated for the distance between nearest neighbor open-open (OO), brush-brush (BB), and road-road (RR) patches.

Fine-scale Measurements

Fine scale measurements were also obtained from bobwhite telemetry sites located in the field. Locations were categorized as spring, summer, or fall-winter periods. Random points were chosen from a 100 × 100-m grid of the research area. Each telemetry location or random point represented the geometric center of an error polygon or selected random grid, respectively. At each telemetry point, a circular area of about 0.2 ha was established. Fine scale cover type distances were estimated in 1-cm increments using a range pole extended to 8 m (radius of a 0.2-ha circle) in the cardinal directions from the center of the plot.

Fine scale patch classes were forb, grass, shrub and bare ground. Patch classes were divided into 12 discrete patch type combinations following the same protocol described for the large scale patches (Fig. 1). Individual patch types measured were: bare ground-shrub (BS), bare ground-forb (BF), bare ground-grass (BG), shrub-bare ground (SB), shrub-forb (SF), shrub-grass (SG), forb-bare ground (FB), forb-shrub (FS), forb-grass (FG), grass-forb (GF), grass-shrub (GF), and grass-bare ground (GB) (Table 1). Telemetry and random points were located in the field, and an origin patch representing the telemetry or random location, was designated from which sampling transects were marked in the cardinal directions. Like the large scale

Table 1. Patch classification protocol for landscape-scale and fine-scale habitat variables from summer 1987–summer 1988, La Copita Research Area, Jim Wells County, Texas.

Patch classification	Boundary patch	Patch acronym
	Large-scale	
Opening	Brush patch	OB
Opening	Road*	OR
Opening**	Opening	OO
Brush patch	Opening	BO
Brush patch	Road	BR
Brush patch**	Brush patch	BB
Road	Opening	RO
Road	Brush patch	RB
Road**	Road	RR
	Fine-scale	
Forb	Grass	FG
Forb	Bare ground	BG
Forb	Shrub	FS
Forb**	Forb	FF
Bare ground	Shrub	BS
Bare ground	Forb	BF
Bare ground	Grass	BG
Bare ground**	Bare ground	BB
Shrub	Bare ground	SB
Shrub	Forb	SF
Shrub	Grass	SG
Shrub**	Shrub	SS
Grass	Forb	GF
Grass	Bare ground	GB
Grass	Shrub	GS
Grass**	Grass	GG

* Width of road is considered the patch.
** Distance from a patch class to the nearest consecutive identical patch class along sampling transect.

patches, fine scale patches were labeled based on the patch class (forb, grass, etc.) measured and the boundary patch, which represented a different patch class, that immediately proceeded it (Fig. 1). Therefore, if the origin patch was a forb and the next consecutive patch along the sampling transect was a grass patch, then the origin patch would labeled a forb-grass (FG) patch. The length of the grass boundary patch was then measured to where the next different patch class (its boundary patch) terminated it, and this second patch was perhaps labeled a grass-bare ground patch (GB). This process was repeated until the end of the sampling transect was reached. Moreover, for all shrub patches measured on the sampling line, the height (cm) for the respective shrub were recorded.

We also calculated the nearest neighbor distance between patches of the same classification (Fig. 1). For example, we calculated the distance from a forb patch (FG) to the next nearest consecutive forb patch (FG, FB, FS) patch on the sampling transect. We started this process with the first forb patch, and then repeated the process for every forb patch encountered along the sampling transect. Measurements were calculated for the distance between nearest neighbor forb-forb (FF), grass-grass (GG), bare ground-bare ground (BB) and shrub-shrub (SS) patches.

Linear canopy coverage (cm) and shrub height (cm) were recorded for all woody species occurring in a plot that had at least a portion of the canopy covering a line. In addition, percent coverage of forbs, grass, bare ground, and litter were determined for each plot, as were forb and grass heights (cm). The number of forb and grass species occurring within a plot were estimated providing an index of species diversity. A total of 28 fine scale habitat variables were measured.

Statistical Analyses

Large-scale data collected for individual habitat variables measured from transects radiating in the 4 cardinal directions from each point were pooled and considered 1 sample. For both telemetry locations and random points, all samples were summed and a mean was calculated on a seasonal basis for each variable. Telemetry and random variable means were subjected to a one-way analysis of variance to determine seasonal differences. Variables were considered significantly different at $P < 0.05$. The Student-Newman-Kuels multiple comparison procedure was used to isolate specific seasonal differences if ANOVA indicated that significant seasonal differences existed. Since cover percentages and herbaceous height and diversity were estimated for the entire plot and were not sampled, these components were excluded from the analysis of variance.

Chi-square analyses were used to determine if habitat variables at telemetry locations differed from random locations each season (Ott 1988:219). Mann-Whitney tests (Conover 1980) were used to determine differences in mean percentages of bare ground, forbs, grass, and litter between telemetry and random locations. Herbaceous diversity and height data did not represent number of patches and were excluded from Chi-square analysis. Data from bobwhite locations were considered ‘‘observed’’ values, while those from random points were considered ‘‘expected’’ values.

Fine-scale and large scale habitat variables that differed between telemetry and random locations were selected based on the seasonal consistency of their significance. Spearman rank-order-correlation coefficients were then calculated to determine the strength of the relationship between the fine-scale components (dependent variable) and the large scale components (independent variable).

RESULTS

Large-Scale

Analysis from the aerial photo revealed seasonal differences in the distance between habitat variables at telemetry sites (Table 2). Brush-opening patches were largest and distances between openings were longest during the first summer and then decreased from season to season thereafter. A similar pattern was evident for road-opening patches and distances between brush-brush patches, although the decreases were not significant from fall-winter 1987–88 to spring-early summer 1988.

The number of opening-brush and brush-opening patches were lowest during summer 1987, then in-

Table 2. Mean distance between patches (m) of landscape-scale habitat variables from summer 1987–summer 1988, La Copita Research Area, Jim Wells County, Texas.

Habitat variable Season	Telemetry locations		Random locations	
	x̄	*n*	x̄	*n*
Brush-brush				
Summer 1987	19.3 A[a]	44	12.8 A	23
Fall-winter 1987–88	14.7 B	55	10.8 A	28
Summer 1988	12.5 B	56	12.6 A	22
Brush-opening				
Summer 1987	9.3 A	44	5.4 A	23
Fall-winter 1987–88	7.6 B	55	5.3 A	28
Summer 1988	5.3 C	56	6.1 A	22
Brush-road				
Summer 1987	7.2 A	17	7.2 A	9
Fall-winter 1987–88	5.9 A	24	6.5 A	12
Summer 1988	7.0 A	29	10.1 A	11
Opening-opening				
Summer 1987	24.0 A	45	25.6 A	26
Fall-winter 1987–88	14.4 B	55	16.9 A	30
Summer 1988	11.9 C	56	20.2 A	24
Opening-brush				
Summer 1987	6.4 A	44	6.3 A	23
Fall-winter 1987–88	6.9 A	55	5.6 A	28
Summer 1988	6.2 A	56	6.2 A	22
Opening-road				
Summer 1987	5.8 A	22	7.5 A	8
Fall-winter 1987–88	7.1 A	25	5.7 A	9
Summer 1988	6.7 A	28	5.3 A	6
Road-road				
Summer 1987	41.9 A	37	56.2 A	13
Fall-winter 1987–88	50.0 A	40	48.1 A	17
Summer 1988	44.7 A	41	56.5 A	15
Road-brush				
Summer 1987	3.3 A	46	2.2 A	26
Fall-winter 1987–88	2.1 A	55	1.7 A	30
Summer 1988	2.1 A	56	4.3 A	24
Road-opening				
Summer 1987	20.5 A	22	16.7 A	6
Fall-winter 1987–88	5.9[b] B	29	17.4[b] A	12
Summer 1988	4.5 B	32	10.2 A	8

[a] Means within a column sharing a letter are not significantly ($P > 0.05$) different.
[b] Means within rows are significantly ($P < 0.05$) different.

Table 3. Mean number of patches of landscape-scale habitat variables observed from summer 1987–summer 1988, La Copita Research Area, Jim Wells County, Texas.

Habitat variable Season	Telemetry locations		Random locations	
	x̄	*n*	x̄	*n*
Brush-brush				
Summer 1987	22.6 A[a]	46	27.9 A	26
Fall-winter 1987–88	27.0 B	55	33.5 A	30
Summer 1988	34.1 C	56	31.7 A	24
Brush-opening				
Summer 1987	20.5 A	46	28.9 A	26
Fall-winter 1987–88	24.5 B	55	30.9 A	30
Summer 1988	31.2 C	56	26.2 A	24
Brush-road				
Summer 1987	0.4 A	46	0.4 A	26
Fall-winter 1987–88	0.6 A	55	0.7 A	30
Summer 1988	0.7 A	56	0.8 A	24
Opening-opening				
Summer 1987	24.0 A	46	39.9 A	26
Fall-winter 1987–88	27.9 B	55	39.9 A	30
Summer 1988	35.6 C	56	39.0 A	24
Opening-brush				
Summer 1987	20.9 A	46	25.8 A	26
Fall-winter 1987–88	25.0 B	55	30.9 A	30
Summer 1988	32.8 C	56	28.7 A	24
Opening-road				
Summer 1987	0.9 A	46	0.4 A	26
Fall-winter 1987–88	0.7 A	55	0.3 A	30
Summer 1988	1.0 A	56	0.3 A	24
Road-road				
Summer 1987	1.1 A	46	0.8 A	26
Fall-winter 1987–88	1.4 A	55	1.3 A	30
Summer 1988	1.7 A	56	1.1 A	24
Road-brush				
Summer 1987	0.4 A	46	0.4 A	26
Fall-winter 1987–88	0.5 A	55	0.7 A	30
Summer 1988	0.6 A	56	0.6 A	24
Road-opening				
Summer 1987	0.7 A	46	0.3 A	26
Fall-winter 1987–88	0.8 A	55	0.5 A	30
Summer 1988	1.1 A	56	0.4 A	24

[a] Means within a column sharing a letter are not significantly ($P > 0.05$) different.

creased each season throughout the study (Table 3). The number of opening-opening and brush-brush patches exhibited an identical pattern. The general pattern as the study progressed revealed patch sizes decreased, while the number of patches increased.

Fine Scale

Telemetry Locations.—At telemetry locations, the distance between habitat variables had significant seasonal differences (Table 4). Patch dimensions were larger for bare ground-shrub, bare ground-forb, bare ground-grass, forb-shrub, forb-grass, and grass-bare ground, patches during summer 1987 than in fall-winter 1987–88 and spring-early summer 1988. Grass-forb patches during summer 1987 were larger than fall-winter patches and these were larger than grass-forb patches in spring-early summer 1988. Similarly, summer 1987 shrub-grass patches were larger than those of fall-winter 1987–88 and spring–early summer 1988. During spring-early summer 1988, forb-bare ground and grass-bare ground patches were larger than during the previous 2 seasons. Distances between bare ground patches were greater during summer 1987 than the following fall-winter 1987–88 and spring-early summer 1988. However, forb patches were farther apart during spring-early summer 1988 than the previous summer, which were farther apart than fall-winter 1987–88.

Beginning in the summer 1988, percent bare ground, and forb coverage declined from season to season, while percent grass coverage declined from summer to fall and then remained unchanged. The reverse was true for percent litter coverage, which increased every season over the course of the study. Grass heights remained similar from summer 1987 through fall-winter 1987–88 then, decreased during

Table 4. Mean distance between patches (cm), linear canopy coverage (cm), height (cm), and diversity (# species) for fine-scale habitat variables from summer 1987–summer 1988, La Copita Research Area, Jim Wells County, Texas.

Habitat variable Season	Telemetry locations		Random locations	
	$\bar{x}$	*n*	$\bar{x}$	*n*
Bare ground-bare ground				
Summer 1987	54.6 A[a]	45	48.4 A	27
Fall-winter 1987–88	40.5[b] B	57	57.9[b] A	30
Summer 1988	46.0 B	61	47.3 A	24
Bare ground-forb				
Summer 1987	15.3 A	44	7.7 A	30
Fall-winter 1987–88	9.3 B	57	6.2 B	22
Summer 1988	6.3 B	59	17.7 B	27
Bare ground-grass				
Summer 1987	25.8 A	45	17.7 A	27
Fall-winter 1987–88	12.1 B	57	12.0 B	30
Summer 1988	7.2 B	61	6.9 B	24
Bare ground-shrub				
Summer 1987	13.4 A	35	20.6 A	20
Fall-winter 1987–88	8.1 B	46	8.0 B	25
Summer 1988	8.0 B	58	8.4 B	19
Forb-bare ground				
Summer 1987	27.0 A	45	35.7 A	25
Fall-winter 1987–88	24.9[b] A	57	40.3[b] A	30
Summer 1988	38.2[b] B	59	54.7[b] A	24
Forb-forb				
Summer 1987	100.9[b] A	45	135.5[b] A	8
Fall-winter 1987–88	62.7[b] B	57	125.1[b] A	9
Summer 1988	145.4[b] C	59	178.7[b] A	6
Forb-grass				
Summer 1987	23.9 A	44	16.1 A	21
Fall-winter 1987–88	14.9 B	55	17.8 A	26
Summer 1988	10.3 B	43	11.9 A	13
Forb-shrub				
Summer 1987	21.1[b] A	12	41.6[b] A	7
Fall-winter 1987–88	6.8 B	13	6.9 A	7
Summer 1988	6.0 B	8	5.0 A	1
Grass-bare ground				
Summer 1987	27.3 A	45	26.7 A	27
Fall-winter 1987–88	24.4[b] A	57	37.4[b] A	30
Summer 1988	34.4 B	61	36.9 A	24
Grass-forb				
Summer 1987	16.9 A	43	11.7 A	23
Fall-winter 1987–88	10.2 B	56	8.8 A	25
Summer 1988	7.6 C	46	8.8 A	18
Grass-grass				
Summer 1987	78.0 A	45	71.8 A	27
Fall-winter 1987–88	63.3 A	57	71.0 A	30
Summer 1988	71.1[b] A	61	94.6[b] A	24
Grass-shrub				
Summer 1987	38.2[b] A	18	25.2[b] A	12
Fall-winter 1987–88	7.8 A	18	9.6 A	9
Summer 1988	17.5 A	14	12.2 A	6
Shrub-bare ground				
Summer 1987	41.7 A	35	48.1 A	20
Fall-winter 1987–88	43.2[b] A	45	70.6[b] A	27
Summer 1988	59.6 A	56	49.8 A	19
Shrub-forb				
Summer 1987	18.5[b] A	10	31.0[b] A	8
Fall-winter 1987–88	13.6[b] A	16	39.5[b] A	8
Summer 1988	21.2 A	9	26.7 A	3
Shrub-grass				
Summer 1987	21.9 A	18	21.1 A	9
Fall-winter 1987–88	16.3 AB	16	18.6 A	9
Summer 1988	10.9 B	15	10.8 A	6
Shrub-shrub				
Summer 1987	310.7 A	36	308.3 A	20
Fall-winter 1987–88	340.5[b] A	49	245.5[b] A	27
Summer 1988	278.1[b] A	59	339.4[b] A	19
Percent bare ground				
Summer 1987	23.9 A	45	19.9 A	25
Fall-winter 1987–88	32.0[b] B	57	24.2[b] A	30
Summer 1988	39.9[b] C	61	46.9[b] B	23
Percent forbs				
Summer 1987	30.6 A	43	30.3 A	23
Fall-winter 1987–88	25.2[b] B	57	12.3[b] B	30
Summer 1988	15.5 C	59	14.5 B	22
Percent grass				
Summer 1987	40.2 A	45	44.4 A	26
Fall-winter 1987–88	31.1 B	57	38.5 A	30
Summer 1988	29.2 B	61	23.1 B	23
Percent litter				
Summer 1987	6.9 A	41	10.4 A	20
Fall-winter 1987–88	12.0[b] B	55	25.2[b] B	30
Summer 1988	16.2 C	60	16.3 AB	22
Forb diversity				
Summer 1987	6.0 A	42	5.6 A	21
Fall-winter 1987–88	8.6 B	57	5.1 A	30
Summer 1988	7.7 B	61	5.7 A	23
Grass diversity				
Summer 1987	3.2 A	42	3.8 A	22
Fall-winter 1987–88	2.7 A	57	2.8 A	30
Summer 1988	2.7 A	61	2.9 A	23
Forb height				
Summer 1987	26.5 A	44	32.7 A	25
Fall-winter 1987–88	8.5 B	56	10.4 B	30
Summer 1988	9.0 B	59	13.2 B	21
Grass height				
Summer 1987	23.8 A	45	33.5 A	26
Fall-winter 1987–88	22.5[b] A	57	36.4[b] A	30
Summer 1988	13.9 B	60	21.7 B	21
Woody height line				
Summer 1987	118.6 A	36	118.9 A	21
Fall-winter 1987–88	104.9 A	49	115.4 A	27
Summer 1988	89.7[b] A	59	60.6[b] A	19
Woody height plot				
Summer 1987	126.6[b] A	21	226.0[b] A	22
Fall-winter 1987–88	163.3[b] B	49	202.5[b] A	27
Summer 1988	152.7 B	60	156.0 A	19
Woody canopy line				
Summer 1987	98.3 A	18	98.9 A	22
Fall-winter 1987–88	24.0[b] B	16	10.6[b] B	27
Summer 1988	12.2 B	15	17.0 B	19
Woody canopy plot				
Summer 1987	292.3[b] A	30	229.6[b] A	18
Fall-winter 1987–88	204.5[b] B	49	341.1[b] B	27
Summer 1988	199.7 B	60	175.6 A	19

[a] Means within a column sharing a letter are not significantly ($P > 0.05$) different.
[b] Means within rows are significantly ($P < 0.05$) different.

Table 5. Mean number of patches of fine-scale habitat variables observed from summer 1987–summer 1988, La Copita Research Area, Jim Wells County, Texas.

Habitat variable Season	Telemetry locations			Random locations		
	$\bar{x}$		n	$\bar{x}$		n
Bare ground-bare ground						
Summer 1987	62.3	A[a]	45	72.2	A	27
Fall-winter 1987–88	84.3[b]	B	57	63.2	A	30
Summer 1988	76.0	C	62	77.5	A	24
Bare ground-forb						
Summer 1987	23.0	A	45	21.0	A	27
Fall-winter 1987–88	39.5[b]	B	57	18.1	A	30
Summer 1988	21.1	A	62	16.9	A	24
Bare ground-grass						
Summer 1987	34.7	A	45	44.6	A	27
Fall-winter 1987–88	39.4	A	57	38.5	A	30
Summer 1988	50.3	B	62	52.3	A	24
Bare ground-shrub						
Summer 1987	2.2	A	45	3.9	A	27
Fall-winter 1987–88	3.0	A	57	4.9	A	30
Summer 1988	4.7	B	62	4.0	A	24
Forb-bare ground						
Summer 1987	22.9	A	45	21.4	A	27
Fall-winter 1987–88	40.0[b]	B	57	18.7	A	30
Summer 1988	21.4	A	62	18.6	A	24
Forb-forb						
Summer 1987	35.4[b]	A	45	27.44	A	27
Fall-winter 1987–88	54.6[b]	B	57	24.9	A	30
Summer 1988	25.1	C	62	178.7	A	24
Forb-grass						
Summer 1987	10.7[b]	A	45	5.3	A	27
Fall-winter 1987–88	12.8[b]	A	57	6.5	A	30
Summer 1988	2.28	B	62	1.83	B	24
Forb-shrub						
Summer 1987	0.24[b]	A	45	0.26	A	27
Fall-winter 1987–88	0.32	A	57	0.27	A	30
Summer 1988	0.15	A	62	0.04	A	24
Grass-bare ground						
Summer 1987	34.2	A	45	44.0	A	27
Fall-winter 1987–88	39.5	A	57	37.5	A	30
Summer 1988	50.0	B	62	51.8	A	24
Grass-forb						
Summer 1987	11.1[b]	A	45	5.2	A	27
Fall-winter 1987–88	13.6[b]	A	57	6.4	A	30
Summer 1988	2.5	B	62	2.2	B	24
Grass-shrub						
Summer 1987	0.50	A	45	0.52	A	27
Fall-winter 1987–88	0.42	A	57	0.40	A	30
Summer 1988	0.30	A	62	0.38	A	24
Grass-grass						
Summer 1987	47.8	A	45	51.6	A	27
Fall-winter 1987–88	53.6	A	57	47.7	A	30
Summer 1988	51.8	A	62	54.9	A	24
Shrub-bare ground						
Summer 1987	2.0	A	45	4.0	A	27
Fall-winter 1987–88	3.1[b]	A	57	4.9	A	30
Summer 1988	4.4	B	62	4.0	A	24
Shrub-forb						
Summer 1987	2.9[b]	A	45	0.30	A	27
Fall-winter 1987–88	0.30	A	57	0.37	A	30
Summer 1988	0.16	A	62	0.13	A	24

Table 5. Continued.

Habitat variable Season	Telemetry locations			Random locations		
	$\bar{x}$		n	$\bar{x}$		n
Shrub-grass						
Summer 1987	0.58	A	45	0.37	A	27
Fall-winter 1987–88	0.39	A	57	0.43	A	30
Summer 1988	0.29	A	62	0.29	A	24
Shrub-shrub						
Summer 1987	3.1	A	45	4.7	A	27
Fall-winter 1987–88	3.8	A	57	5.8	A	30
Summer 1988	4.9	B	62	3.9	A	24

[a] Means within a column sharing a letter are not significantly ($P > 0.05$) different.
[b] Means within rows are significantly ($P < 0.05$) different.

spring-early summer 1988, whereas forb heights decreased between summer 1987 and fall-winter 1987–88 remaining unchanged thereafter. Forb diversity increased from summer 1987 to fall-winter 1987–88 where it remained the same for the rest of the study.

Shrub heights within the plots increased between the first summer and the following fall-winter season. Woody canopy cover along sampling lines and those within plots decreased over the same period. Woody height and canopy cover then remained unchanged through spring-early summer 1988.

At telemetry locations, the number of patches differed by season (Table 5). Numbers of bare ground-shrub, bare ground-grass, shrub-bare ground, and grass-bare ground patches were comparable during summer 1987 and fall-winter 1988, but increased during spring-early summer 1988. Similarly, the mean number of patches for all woody species variables were higher in spring-early summer, than the previous 2 seasons. In addition, more shrubs with greater heights were recorded within plots during fall-winter 1987–88 than in summer 1987. Quantities of bare ground-forb, forb-bare ground, forb-grass and grass-forb patches, were higher during fall-winter 1988–89 than in either of the other 2 seasons, which were similar.

Random Locations.—At random points, distance between patches had significant seasonal differences (Table 4). Distance between bare ground-shrub, bare ground-forb, and brush-grass patches were larger during summer 1987 than during fall-winter 1987–88 and spring-early summer 1988. The percent of bare ground did not change significantly from summer 1987 through winter 1988, but increased during spring-early summer 1988. However, percent forb cover and height were highest during the first summer, then declined during fall-winter 1987–88. Grass cover and height followed the same pattern, except decreases in coverage were not significant until spring-early summer 1988. Less ground litter was encountered during summer 1987 than what was found the following fall-winter. Woody canopy cover along the sampling lines decreased between summer 1987 and fall-winter 1987–88, although woody canopy within plots displayed the reverse pattern.

At random points, the number of forb-grass and grass-forb patches were similar between summer 1987 and fall-winter 1987–88, but declined during spring-early summer 1988 (Table 5). The number and height of shrubs within plots increased noticeably from season to season throughout the term of study. Seasonal differences in fine-scale mean patch sizes and numbers followed a pattern similar to that exhibited at the landscape scale. Patch sizes tended to decrease seasonally, while patch numbers correspondingly increased.

Telemetry vs. Random Locations

Large Scale.—Large scale patch dimensions did not differ significantly between telemetry and random points during summer 1987 and spring-early summer 1988 (Table 2). However, road-opening distance at telemetry sites were smaller than at random sites during fall-winter 1987–88. Similarly, there were no differences in patch numbers at telemetry locations and random points during fall-winter 1987–88 and spring-early summer 1988 (Table 3). Fewer opening-opening distances were recorded at telemetry locations than at random sites during summer 1987.

Fine scale.—During summer 1987, fine-scale habitat variables at 45 telemetry locations and 27 random points were sampled and differences were found for 8 habitat variables (Table 4). Telemetry locations contained smaller shrub-forb and forb-shrub patches, as well as shorter distances between forb-forb patches. Conversely, grass-shrub patches were larger. The heights of woody species within telemetry plots were shorter than those in random plots, but had more extensive canopies. More forb-grass and grass-forb patches were found in telemetry plots than were in random plots, as were the number of woody species (Table 5). Percent coverage of bare ground, forbs, grass, and litter were similar for both telemetry and random plots (Table 4).

During fall and winter 1987–88, 11 habitat variables differed between telemetry and random locations (Table 4). Telemetry plots had smaller shrub-bare ground, shrub-forb, forb-bare ground, and grass-bare ground patches, shorter grass heights, as well as shorter distances between bare ground-bare ground, and forb-forb patches. The distance between shrub patches was greater at telemetry locations than at random locations. Also, shrubs were smaller within telemetry plots, had more extensive canopies along the sampling lines, but had less extensive canopies within the sampling plots than shrubs found in random plots. Patch numbers were greater for bare ground-forb, forb-bare ground, forb-grass, and grass-forb patches at bobwhite locations than at randomly sampled plots (Table 5). In addition, more shrub-shrub and forb-forb patch distances were recorded at telemetry plots. A significant lack of cover and a higher percentage of forbs occurred in telemetry plots than in random plots, but less litter was found in telemetry plots (Table 4).

During spring and early summer 1988, 5 habitat variables differed between telemetry and random locations (Table 4). Patches of forb-bare ground were smaller and the distance between forb-forb, grass-grass, and shrub-shrub patches, was shorter at telemetry locations. Shrubs occurring along the sampling lines were taller, while shrub canopies in the plots were more extensive at telemetry plots than at random plots. No significant differences in patch numbers were apparent between telemetry and random sites (Table 5). However, fewer bare ground-grass patches occurred at telemetry sites than at random sites. Forb, grass, and litter coverage were similar at both sites.

Field/Aerial Photo Relationships

The only habitat variable measured in the field that differed substantially between telemetry and random sites during all 3 seasons was forb-forb distance (Table 4). A smaller road-opening distance at telemetry locations during fall-winter was the only significant habitat variable measured on the aerial photo (Table 2). Correlation analysis revealed no relationship ($r = -0.23$, $P = 0.2301$, $n = 16$) between forb-forb and road-opening distances.

Patch numbers of forb-forb and grass-forb patches at telemetry sites were larger than at random sites during summer 1987 and fall-winter 1987–88 (Table 5). Fewer opening-opening measurements at telemetry locations during summer 1987 was the only significant habitat variable from analysis of the aerial photo (Table 3). No correlation was found between forb-grass and opening-opening ($r = 0.02$, $P = 0.8939$, $n = 16$) and grass-forb and opening-opening patch numbers ($r = 0.10$, $P = 0.5299$, $n = 16$). The results of these correlation analyses indicated there was essentially no relationship between important habitat variables measured from the aerial photo and from the field.

DISCUSSION

Results of this study indicated habitat interspersion was an important variable associated with areas preferred by northern bobwhites. Patterns of interspersion were evident in habitats used by northern bobwhites during each of the 3 seasons.

Seasonal differences in patch size and abundance were apparent for a number of habitat variables. Some of these differences were evident solely at telemetry locations, while others were similar at telemetry and random locations. Differences that occurred only at telemetry locations presumably reflect habitat preference.

Large-Scale Measurements

Since the only seasonal differences were at telemetry locations and no seasonal differences were evident at random sites, it is likely that changes in habitat variables represented shifts in quail habitat preferences. Northern bobwhites exhibited a tendency to select habitats that were composed of increasingly smaller, though more numerous patches, that were closer together from one season to the next.

From summer 1987 through fall-winter and into spring-early summer 1998, brush-opening and road-opening distances decreased, while the number of brush-opening patches increased. Similarly, opening-brush patch size remained unchanged throughout the year, while patch numbers increased to their highest level during spring-early summer. In addition, distances between open patches and distances between brush patches decreased, while the number of opening-opening and brush-brush patches increased during the same period. Northern bobwhites, thus exhibited a tendency to select habitats that were composed of smaller, more numerous patches that were closer together as the study progressed.

Bobwhites seemed to prefer roads near openings during fall and winter. However, it would be inappropriate to conclude that this variable was more important than others on an annual basis. What appeared to be important were the number and the spatial distribution of openings, brush, and roads.

Fine-Scale Measurements

Several-habitat variables measured followed similar seasonal patterns of change at both telemetry and random locations indicating that whatever external factor(s) was responsible, it influenced the study area similarly. After 2 years of above average precipitation, a drought began during late summer 1987, and with the exception of a few centimeters of rain in November, persisted through the duration of the study (D. McKown, unpublished data). The significant seasonal disparities observed were at least partially attributable to this lack of rainfall.

Habitat variables that differed seasonally at telemetry locations were probably seasonally preferred by northern bobwhites. Bobwhites apparently selected habitats where forb patches were clumped and had higher forb coverage than found at random locations, indicating bobwhites were selecting habitat partially on the basis of percent-forb coverage. Wilkins (1987:53) also noted that bobwhites sought areas with high-forb coverage and diversity when herbaceous cover and diversity were limited during fall and winter.

Bobwhites selected areas with more grass in summer than during fall and winter. This was probably in response to nest-site selection. Wilkins (1987:51) also reported less grass use by bobwhites during fall and winter.

Percent bare ground and litter increased throughout the study at both telemetry and random locations indicating that these variables were probably not being selected by bobwhites. However, despite the increase in litter, there was less dead plant material at telemetry locations than at random sites, suggesting quail selected for areas with less litter. In addition, the distance between patches of bare ground decreased at telemetry sites from summer to fall-winter. These trends indicated that, although bare ground cover and litter accumulations increased, bobwhites selected areas with smaller, more numerous bare ground patches with lower percent litter cover during fall and winter. In addition to high forb and low grass coverage, areas with a substantial number of small bare ground patches resulting in high bare ground coverage were preferred by bobwhites during fall-winter. Wilkins (1987:50) also reported that bobwhites were associated with habitats with higher percentages of bare-ground coverage during this same period.

Bobwhites also preferred taller shrubs with less extensive canopies during fall/winter than during spring and summer. In addition, the number of shrubs at telemetry locations increased from summer to fall-winter, offering coveys more shrubs in which they could take refuge. This suggested that as the herbaceous habitat conditions continued to deteriorate in response to the drought, bobwhites moved into areas with higher shrub densities.

Habitat Interspersion

Few large scale variables appeared to be important to bobwhites. Areas with more roads and fewer openings were apparent in bobwhite habitat during fall-winter 1987–88 and summer 1987, respectively.

During each season of this study, habitat interspersion at the fine-scale of resolution was greater at telemetry locations than at random sites as determined from field aerial photograph data. Generally, patch sizes were smaller and more numerous, and patches were closer together in habitats at telemetry locations than at random sites. Patterns of habitat interspersion influenced bobwhite habitat selection.

Seasonal differences in numbers of habitat variables comprising the interspersion matrix were evident throughout the study. During fall-winter 1988–89, 10 patch dimension and 6 patch number variables were important to bobwhites. During summer 1987, 6 dimension and 3 patch number variables were important. Only four patch dimension variables differed significantly from random locations during spring-early summer 1988. Bobwhites were grouped in coveys during the fall and winter, making it possible that a greater diversity of habitats were necessary to fulfill the daily needs of a covey. This would seem to be particularly important during stressful periods, such as when bobwhites were experiencing food shortages and had to compete for a scarce resource. Such an event may have been occurring over winter. However, as the drought increased in severity through winter and into spring, food should have become even more limiting. Yet the number of important variables within the interspersion matrix decreased. The most plausible explanation is that coveys were breaking up and pairs were beginning to select reproductive areas.

Although each individual habitat variable may have served a useful purpose, what seemed most important in determining bobwhite use of habitats was the interspersion of roads, brush, and openings at the large scale. Interspersion of forbs, grass, shrubs, and bare ground at the fine scale of resolution seemed more important to bobwhites than a specific patch size or number of patches. In bobwhite habitat, patches were smaller, numbers of patches were greater, and patches were in closer proximity to one another than at random sites. As the year progressed and the drought increased in severity, patch sizes decreased, patch numbers increased, and patches were closer together. Selecting patchy habitats provides bobwhites with certain obvious advantages. For example, areas where essential habitat patches are in close proximity to one another minimizes the amount of movement required for a bird to fulfill its daily and seasonal requirements. Scott and Klimstra (1954:261) noted that by moving less, bobwhites reduced risks of exposure to predators. Another advantage of minimizing movement is that bobwhites are able to conserve more energy. Roseberry and Klimstra (1984:33) believed that during severe winter weather, the proximity of food and cover required less movement of bobwhites and resulted in a more favorable net energy balance. Also, south Texas summers are hot and as a result quail often expend a significant amount of energy in an attempt to maintain cooler body temperatures. Consequently, the reduction in movement afforded by patchy habitats may provide bobwhites with bioenergetic advantages.

CONCLUSIONS

The results of this study suggested that interspersion of fine scale habitats used by bobwhites consisted of patches that were smaller, more numerous, and closer together than those of random locations. Bobwhite habitats had more patches, at both the large and fine scales during each of the 3 seasons studied. In addition, as the study progressed and the drought increased in severity, patches in bobwhite habitats grew smaller, more numerous and closer to one another.

Distance to roads seemed to be the most important large scale habitat variable associated with bobwhite habitat. Roads might have served as foraging areas as well as a means for bobwhites to move to various areas of their range.

Forb, grass, bare ground and shrub patches were identified as important fine scale habitat components. Distance between forb patches was the most important fine scale variable at telemetry locations each season Forbs, along with grasses and shrubs provided food and cover for bobwhites while bare ground enhanced foraging activity and movement.

Relationships between significant large scale and fine scale variables were not apparent. As a result, it would be inadvisable to examine an aerial photo and conclude the area had adequate bobwhite habitat without conducting field studies.

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