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Abstract

Previous authors have described nesting habitat of the northern bobwhite (*Colinus virginianus*) throughout its range, but few have compared structural or compositional differences of vegetation between nest sites and random non-use sites, and successful and non-successful nests. From 1996–1998, we compared cover and structure of 85 plant species from 80 nest sites of northern bobwhite in western Oklahoma. Nest sites were consistently associated with greater structural complexity than what was available at random. Bobwhites selected nest sites with a greater coverage of grass (ca. 50%) and woody (ca. 20–30%) vegetation with a relatively low percentage of bare ground, presumably because these attributes maximize their chance for successful reproduction by providing protection against weather and predators. Successful nests were more concealed during 1996 and 1997 (12.37 and 10.74% visibility, respectively) than non-successful nest sites (21.6 and 27.65% visibility), but levels of concealment did not differ during 1998. We found no significant differences in vegetation composition or structure between successful and non-successful nest sites.

Key Words: bobwhite, *Colinus virginianus*, gallinaceous, habitat, northern, quail, upland game.

Resumen

Anteriormente otros autores han descrito el hábitat de anidamiento del "Northern bobwhite" (*Colinus virginianus*) a través de su rango de adaptación, pero pocos han comaprado las diferencias estructurales y de composición de la vegetación entre sitios de anidamiento y sitios aleatorios de no- uso y el éxito y fracaso de los nidos. De 1996 a 1998 comparamos la cobertura y estructura de 85 especies de plantas de 80 sitios de anidamiento del "Northern bobwhite" en el oeste de Oklahoma. Los sitios de anidamiento fueron consistentemente asociados con una mayor complejidad estructural que la que estuvo disponible al azar. Los "Bobwhite" seleccionaron sitios de anidamiento con una mayor cobertura de zacate (50%) y vegetación leñosa (20–30%) y con un porcentaje relativamente bajo de suelo desnudo, presumiblemente porque estos atributos maximizan sus probabilidades de una reproducción exitosa al proveer protección contra el clima y los predadores. Durante 1996 y 1997 los nidos exitosos estuvieron más ocultos (12.37 y 10.74% de visibilidad respectivamente) que los nidos no exitosos (21.6 y 27.65% de visibilidad), pero los niveles de ocultamiento no difireiron en 1998. No encontramos diferencias significativas en la composición o estructura de la vegetación entre sitios de anidamiento exitosos y no exitosos.

Ground-nesting birds in shrub and grassland habitats suffer greater nesting mortality than other species, and many are documented to be in long-term population declines (Martin 1993a). Declining populations of northern bobwhite (*Colinus virginianus*) are no exception and have been well documented (Klimstra 1982, Church et al. 1993). Oklahoma experienced a 16% decrease from 1961 to 1988 (Brennan 1991). Although reasons for these declines remain unknown, successful reproduction is an important factor of bobwhite ecology that depends on adequate nesting and brood rearing habitat (Berner and Gysel 1969). Previous studies have described the macrohabitat of bobwhite nest sites throughout their range (Klimstra and Roseberry 1975, Lehmann 1984, Roseberry and Klimstra 1984, Taylor 1991), but few have compared structure and composition of vegetation between nest sites vs. random non-use sites and successful vs. non-successful nest sites. Our study was designed to determine whether nest-site selection by bobwhites is related to specific site characteristics and whether such characteristics influence likelihood of nest success.

Study Area

Research was conducted at the Packsaddle Wildlife Management Area (35° 52' N 99° 40' W) in western Oklahoma. This 6,475-ha area of mixed-prairie habitat is located 40 km north

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of Cheyenne, Okla., where elevation ranged from 579 to 762 m above mean sea level. The area was season long grazed (April 15–September 15) with stocker cattle at a rate of 6.5 ha/AU (light-moderate based on NRCS recommendations). Mean precipitation throughout the breeding season (April–September) was 11.3 cm in 1996, 9.4 cm in 1997 and 4.3 cm in 1998. Precipitation was greater than normal in 1996 (4.4 cm) and 1997 (3.5 cm), but was below normal in 1998 (–2.7 cm). Ambient temperatures averaged 2.1°C during winter and 27.0°C in summer (Cole et al. 1966). Soils consisted of sandy Nobscot (Loamy, mixed, superactive, thermic Arenic Paleustalfs)–Delwin (Fine-loamy, mixed, active, thermic Typic Paleustalfs) and Eda (Mixed, thermic Lamellic Ustipsamments)-Tivoli (Mixed, thermic Typic Ustipsamments), moderately sandy Hardeman (Coarse-loamy, mixed, superactive, thermic Typic Haplustepts)-Likes (Mixed, thermic Aridic Ustipsamments)-Devol (Coarse-loamy, mixed, superactive, thermic Typic Haplustalfs) and Eda (Mixed, thermic Lamellic Ustipsamments)-Carwile (Fine, mixed, superactive, thermic Typic Argiaquolls), and loamy Quinlan (Loamy, mixed, superactive, thermic, shallow Typic Haplustepts)-Woodward (Coarse-silty, mixed, superactive, thermic Typic Haplustepts (Cole et al. 1966, USDA-NRCS Official Soil Series Descriptions 2000). Dominant species of grasses included sand bluestem (*Andropogon hallii* Hack), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), indiangrass (*Sorghastrum nutans* (L.) Nash), switchgrass (*Panicum virgatum* L.), sand paspalum (*Paspalum stramineum* Nash), blue grama (*Bouteloua gracilis* (Kunth in H.B.K.) Lag.), hairy grama (*B. hirsuta* Lag.), and sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray). Common forbs on the area included western ragweed (*Ambrosia psilostachaya* DC.), croton (*Croton sp.* L.), and prairie sunflower (*Helianthus petiolaris* Nutt.). Woody vegetation included shinnery oak (*Quercus harvardii* Rydb.), sand sage (*Artemisia filifolia* Torr.), and sand plum (*Prunus angustifolia* Marsh.) (Cole et al. 1966).

Methods

Radio-telemetry

We trapped bobwhite using modified Stoddard funnel traps (Wilbur 1967) baited with sorghum throughout the year, and by nightlighting (Huempfner et al. 1975) sessions prior to the nesting season (March–April). Captured birds were marked with radio transmitters (Holohill Systems Limited, Ontario, Canada and Wildlife Materials, Incorporated, Carbondale, Ill.) weighing < 7 g, sexed, aged and banded with aluminum leg bands (Webb and Guthery 1982). Birds were monitored at least once daily throughout the nesting and brood rearing season (May–October).

Nesting Cover

Nest sites were marked and microhabitats characterized after parents permanently left the nests. Successful nests were defined by a hatch of ≥ 1 chick from each nest. Lost nests were characterized as either: (1) predated (mammal or snake) or (2) abandoned. We took additional habitat measurements at each of 2 plots: a plot centered directly over the nest and a plot 20 m from the nest selected at a random direction (Badyaev 1995). Ten, 0.10 m quadrats were used to characterize plant cover (Daubenmire 1959) in a 1-m^2 plot positioned directly over each nest site. Estimates of percent cover by plant species and bare ground were recorded using Daubenmire's coverage classes (Daubenmire 1959).

Nesting Habitat Characteristics

Physiographic variables such as aspect (degree), slope (%) (Sieg and Becker 1990), distance to nearest shinnery oak stand, or any other noticeable abrupt change in macro-habitat cover type (edge), or major disturbance (roads, burns, food plots, etc.) were recorded. Diameter of the nest at the top, and depth and thickness of the nest lining were recorded (Lehmann 1984). Tradeoffs associated with nest-site selection between visibility (a bobwhite's view of its surrounding while incubating eggs) and concealment from predators were evaluated (Gotmark et al. 1995). Visual obstruction (simulating a bobwhite's view while sitting on the nest) was evaluated using a vertical profile board placed 3 m from each nest or non-use site (Nudds 1977) and measurements were taken in 4 different directions (Angelstam 1986): the first direction was random and subsequent directions were taken at 90° intervals. Obstruction was recorded at 4 heights: <0.25 m, 0.25–0.50 m, >0.50–1.00 m, and >1.00–2.00 m and percentage of vegetation cover was differentiated into 6 categories; <2.5%, 2.5–25%, >25–50%, >50–75%, >75–95%, and >95% (Schmutz et al. 1989).

Nest concealment from outside the nest (predator's view) was quantified by 9 points; 8 at 45° compass intervals 1 m from the nest and 1 overhead view taken at 0.5 m from the nest (Keppie and Herzog 1978, Martin and Roper 1988, Holway 1991, Gotmark et al. 1995). Concealment was quantified by placing a 10-cm disc

Table 1. Nest-site selection by northern bobwhites based on percent ground cover of nest and random sites on PWMA, Ellis County Okla., 1996–1998.

Year	Nest Site			Random Site			
Coverage	n	x̄	SE	n	x̄	SE	P
1996							
Bare ground	41	22.79	2.88	41	37.40	4.50	0.003
Leaf Litter	41	11.06	2.22	41	12.66	3.43	0.679
Grasses	41	49.72	2.95	41	32.82	3.35	0.001
Forbs	41	6.36	1.45	41	8.88	2.06	0.365
Woody plants	41	19.58	3.05	41	9.55	2.12	0.015
Sedges	41	0.13	0.05	41	0.26	0.10	0.585
Legumes	41	1.15	0.57	41	0.64	0.23	0.294
1997							
Bare ground	21	5.64	2.34	21	28.00	5.12	0.001
Leaf Litter	21	15.03	2.22	21	12.36	3.55	0.623
Grasses	21	49.47	5.15	21	36.33	5.32	0.056
Forbs	21	9.65	2.92	21	13.60	3.08	0.310
Woody plants	21	28.63	5.14	21	15.62	3.90	0.023
Sedges	21	0.68	0.63	21	0.01	0.01	0.052
Legumes	21	0.54	0.37	21	0.71	0.34	0.792
1998							
Bare ground	18	14.35	3.22	18	18.44	5.79	0.575
Leaf Litter	18	19.26	4.77	18	15.88	4.24	0.563
Grasses	18	49.78	4.78	18	46.42	6.34	0.648
Forbs	18	6.83	1.41	18	12.10	4.32	0.211
Woody plants	18	29.78	4.78	18	15.04	4.00	0.017
Sedges	18	0	0	18	0	0	
Legumes	18	0.04	0.03	18	0.10	0.08	0.939

divided into 5 equivalent sections and each section was assigned a visibility percentage as follows: 0 = 0%; 1 = 20%, 2 = 40%, 3 = 60%, 4 = 80%, 5 = 100% (Holway 1991). Because bobwhites in western Oklahoma primarily nest in old growth little bluestem, we quantified little bluestem patch density around the nest and non-use site within 1 m^2 and at 1 m, 2 m, and 5 m radii (Martin and Roper 1988). This density was compared with nest success in relation to predation.

We measured shrub densities at 1 m, 2 m, and 5 m radii around each nest and non-use site. Shrubs were defined as woody vegetation >0.50 m in height and with a stem diameter <2 cm (Holway 1991). Effective plant height directly over the nest was measured using a meter tape (Higgins et al. 1994).

Statistical Analyses

We compared percent plant cover and nest characteristics between nest sites vs. random non-use sites, and successful and non-successful nests with analysis of variance (SAS Institute, Incorporated 1996). Sources of variation were distributed among main factor effects (site and year) and the interaction terms (site by year). If there were significant interaction terms ($P \leq 0.05$), main effects were compared separately by each year.

Results

Vegetative Cover

Our analysis of plant species composition associated with 80 bobwhite nest sites yielded few differences. As a result, we summarized vegetation cover in the following categories: bare ground, leaf litter, grasses, forbs, woody plants, sedges and legumes. Bobwhites selected nest sites associated with greater coverage of woody and grass vegetation and less coverage of bare ground than what was available at random. During 1996 and 1997, cover of grass and woody vegetation, respectively, was greater at nest sites than at random non-use sites (Table 1). During 1998, woody vegetation was also greater at nest sites than at random non-use sites. Coverage of bare ground was 1.6-fold greater in 1996 ($P = 0.003$) and 5-fold greater in 1997 ($P = 0.001$) at random non-use sites than at nest sites. Coverage of plant species did not differ between successful and non-successful nest sites (Table 2).

Table 2. Percent ground cover of successful and non-successful nests sites on PWMA, Ellis County Okla., 1996–1998.

Year	Successful			Non-Successful			
Coverage		$\bar{x}$	SE	n	$\bar{x}$	SE	P
1996		(%)			(%)		
Bare ground	23	15.53	2.83	18	32.06	4.72	0.001
Leaf Litter	23	13.23	3.14	18	8.29	3.06	0.288
Grasses	23	53.36	4.62	18	45.07	3.01	0.206
Forbs	23	8.03	2.22	18	4.22	1.62	0.227
Woody plants	23	22.76	4.41	18	15.51	3.97	0.274
Sedges	23	0.12	0.05	18	0.14	0.09	0.968
Legumes	23	1.71	0.99	18	0.43	0.23	0.149
1997							
Bare ground	12	8.29	3.94	9	2.11	0.87	0.346
Leaf Litter	12	11.54	2.83	9	19.67	3.07	0.212
Grasses	12	49.33	7.44	9	49.67	7.23	0.971
Forbs	12	12.05	4.94	9	6.44	1.63	0.204
Woody plants	12	24.56	6.93	9	34.06	7.72	0.306
Sedges	12	1.11	1.11	9	0.11	0.08	0.136
Legumes	12	0.90	0.64	9	0.06	0.06	0.494
1998							
Bare ground	7	14.18	5.77	11	14.45	4.01	0.969
Leaf Litter	7	27.00	8.99	11	14.34	5.11	0.078
Grasses	7	46.04	8.57	11	52.16	5.84	0.542
Forbs	7	5.54	1.95	11	7.66	1.97	0.660
Woody plants	7	30.11	9.12	11	29.57	5.64	0.958
Sedges	7	0	0	11	0	0	
Legumes	7	0.04	0.04	11	0.05	0.05	0.994

Nesting Characteristics

Bobwhites selected nest sites associated with dense vegetation cover and greater densities of little bluestem. Density of little bluestem at 1 m and visual obstruction estimates (0–1 m high) were consistently greater at nest sites than at random non-use sites (Table 3). During 1996, little bluestem density within 1 m^2 of nest sites ($\bar{x} = 7.07$, $SE = 0.47$) was greater than that of random non-use sites ($\bar{x} = 4.07$, $SE = 0.47$; $P < 0.001$), but it did not differ during 1997 or 1998.

We found no differences in structure of vegetation characteristics between successful and non-successful nest sites (Table 4). However, nest concealment was related to nest success. Successful bobwhite nests were less visible than non-successful nests in 1996 ($P = 0.026$) and 1997 ($P = 0.012$) but did not differ in 1998 ($P = 0.536$; Fig. 1), presumably because of below average rain fall and poor plant growth.

Discussion

Nest-site selection can be a critical factor in determining reproductive success of bobwhites. Individuals that select nest sites in more favorable environments are likely to increase successful reproduction (Martin 1993b). Bobwhites selected nest sites that consisted primarily of old growth little bluestem at a height of 84 cm, slight-

Table 3. Nest site selection based on a comparison of vegetation characteristics of bobwhite nest sites and their respective random sites on PWMA, Ellis County Okla., 1996–1998.

	Nest Site			Random Site			
Characteristic	n	$\bar{x}$	SE	n	$\bar{x}$	SE	P
Shrub Stem Count, 1 m	80	39.53	4.01	80	34.43	3.85	0.336
Shrub Stem Count, 2 m	80	93.59	10.14	80	71.45	7.13	0.142
Shrub Stem Count, 5 m	80	228.98	22.80	80	172.16	17.20	0.064
Little Bluestem Patch, 1 m	80	12.06	0.62	80	9.83	0.64	0.036
Little Bluestem Patch, 2 m	80	22.43	1.18	80	19.24	1.12	0.140
Little Bluestem Patch, 5 m	80	46.25	2.47	80	43.61	2.78	0.828
Visual Obstruction, 0-0.25 m	80	65.90	1.11	80	58.15	2.01	0.005
Visual Obstruction, 0.25-0.50 m	80	46.51	2.26	80	34.23	2.21	0.001
Visual Obstruction 0.50-1.00 m	80	29.99	2.57	80	17.59	1.77	0.001
Visual Obstruction, .00-2.00 m	80	8.06	1.74	80	4.84	1.13	0.285

ly taller than vegetation heights reported by Klimstra and Roseberry (1975) in Illinois (50 cm) and Taylor et al. (1999) in Kansas (52 cm).

Microhabitat selection is best described by a nonrandom distribution of nest sites within dense vegetation (Gloutney and Clark 1997). Bobwhite nests were consistently associated with greater structural complexity than what was available at random. Meseke (1992) documented that nest site selection by bobwhites on Conservation Reserve Program (CRP) fields in Illinois did not differ from random sites. In contrast, our data was collected on native rangeland where landscape composition tends to be more heterogenous (Patten and Ellis 1995, Fuhlendorf and Smeins 1999) than grassland monocultures typically found in CRP fields. As a result, bobwhites in western Oklahoma apparently select nest sites that have a greater coverage of grass and woody vegetation with a relatively low percentage of bare ground.

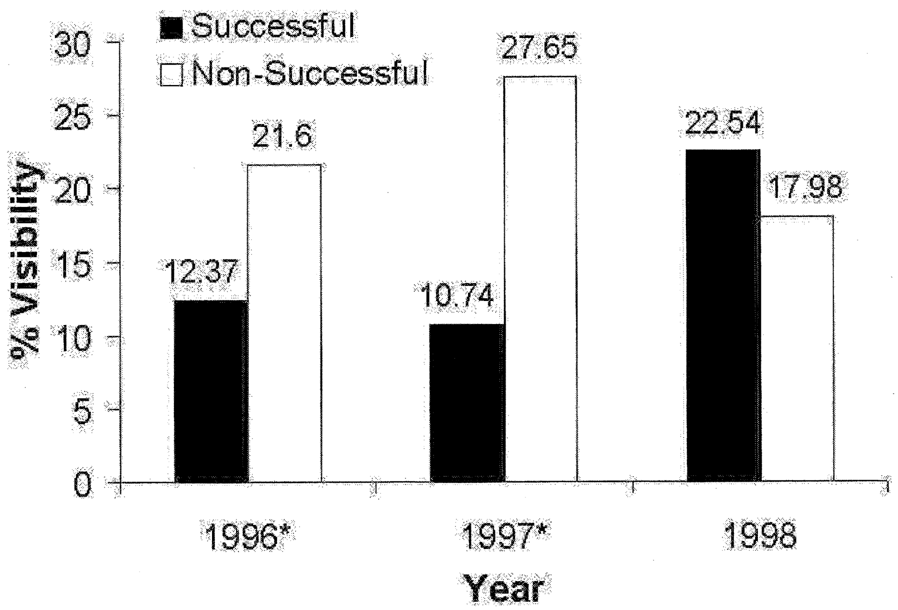

Fig. 1. Mean estimates of nest concealment for successful and non-successful bobwhite nest sites at PWMA, Ellis County, Okla. 1996–1998 (* = P < 0.05).

Taylor et al. (1999) documented that bobwhite nest sites, in Kansas, were associated with taller vegetation, greater visual obstruction and more litter cover than what was available at random. Nest sites associated with 20–30% woody and 50% grass vegetation may provide bobwhites greater protection from predators throughout the breeding season in western Oklahoma. Sites associated with dense vegetation are thought to be less vulnerable to predation (Rands 1988, Filliater et al. 1994) because these sites presumably offer superior cover that helps prevent predation by inhibiting chemical, auditory, or visual clues (Martin and Roper 1988) and protects incubating bobwhites from weather and other disturbances (Colwell 1992, Riley et al. 1992). McKee et al. (1998) reported similar results in nest site selection of greater-prairie chicken (*Tympanuchus cupido pinnatus*). They documented litter and woody cover or forb and grass cover to be the best predictors of nest success of greater-prairie chickens.

Unlike McKee et al. (1998), plant cover around bobwhite nest sites was not a predictor of nest success. Martin and Roper (1988) hypothesized that increased density of nest-site foliage (within a habitat patch surrounding the nest) decreases a predators chance of finding the nest. Bobwhite nest sites in western Oklahoma primarily were constructed within patches of little bluestem, but we found that the mean density of little bluestem patches at successful nest sites did not differ from non-successful nest sites. In addition, coverage of vegetation did not differ between successful and non-successful nest sites. Several studies on artificial ground-nest predation have supported our conclusions and have found that neither vegetation type nor coverage was associated with nest success (Byers 1974, Horkel et al. 1978, Yahner and Piergallini 1998).

Estimates of concealment have been documented to be another important component of nest success (Keppie and Herzog 1978, Riley et al. 1992). Bowman and Harris (1980) found spatial heterogeneity to be more important than concealment in reducing nest predation. Angelstam (1986) also documented greater predation rates on less concealed artificial ground nests. Similarly, we believe that bobwhites are primarily cuing on structural complexity associated with visual obstruction and coverage of woody vegetation, because we assume these attributes provide greater concealment from predators.

Table 4. Comparison of vegetation characteristics between successful and non-successful bobwhite nest sites at PWMA, Ellis County Okla., 1996–1998.

	Successful			Non-Successful			
Characteristic	n	$\bar{x}$	SE	n	$\bar{x}$	SE	P
Shrub Stem Count, 1 m	42	36.52	5.39	38	42.84	6.00	0.575
Shrub Stem Count, 2 m	42	102.81	15.72	38	83.39	12.41	0.467
Shrub Stem Count, 5 m	42	244.74	34.51	38	211.55	29.34	0.662
Little Bluestem Patch, 1 m	42	12.98	0.91	38	11.05	0.82	0.298
Little Bluestem Patch, 2 m	42	23.98	1.70	38	20.71	1.61	0.286
Little Bluestem Patch, 5 m	42	48.62	3.65	38	43.63	3.28	0.494
Visual Obstruction, 0-0.25 m	42	66.96	1.43	38	64.74	1.73	0.657
Visual Obstruction, 0.25-0.50 m	42	49.77	2.79	38	42.91	3.57	0.227
Visual Obstruction, 0.50-1.00 m	42	32.39	3.27	38	27.34	4.04	0.453
Visual Obstruction, 1.00-2.00 m	42	7.43	2.55	38	8.75	2.38	0.816
Total Height (cm)	41	85.01	4.06	37	83.19	2.51	0.737
Clump Width (cm)	41	80.30	5.29	37	79.00	4.72	0.815
Clump Length (cm)	41	67.75	4.94	37	66.70	3.42	0.847
Bowl Width (cm)	42	14.51	1.49	38	12.17	0.18	0.337
Bowl Length (cm)	42	14.32	1.25	38	12.36	0.25	0.372
Depth Dome (cm)	40	8.92	0.54	35	8.56	0.73	0.542
Depth Bowl (cm)	33	5.45	0.36	32	4.97	0.38	0.368
Lining Thickness (cm)	42	4.89	0.22	37	4.82	0.18	0.550

Management Recommendations

Because nest predation is the primary cause of reproductive failure in many species of birds (Ricklefs 1969, Martin 1992), management practices should be designed to help maximize fitness by providing optimal nesting habitat. It is well established that bobwhites require highly variable habitats that are very patchy in productivity and composition (Ellis et al. 1969, Burger et al. 1990, Roseberry and Sudkamp 1998). Rangeland management practices that provide 50% grass and 20–30% woody vegetation will produce adequate bobwhite nesting habitat on western Oklahoma rangelands. Consequently, light to moderate stocking rates usually provide the proper proportions of bare ground, herbaceous quail foods, and woody cover that is required to sustain bobwhite populations on western Oklahoma rangelands.

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