

Characteristics of nest sites of northern bobwhites in western Oklahoma

DARRELL E. TOWNSEND II, RONALD E. MASTERS, ROBERT L. LOCHMILLER, DAVID M. LESLIE, JR.,
STEPHEN J. DEMASO AND ALAN D. PEOPLES

Authors are Ph.D. candidate in the Department of Plant and Soil Sciences, Oklahoma State University, Stillwater, Okla. 74078; State extension wildlife specialist, Oklahoma State University, Stillwater, Okla. 74078; professor, Department of Zoology, Oklahoma State University, Stillwater, Okla. 74078; unit leader, USGS Biological Resources Division, Oklahoma Cooperative Fish and Wildlife Research Unit, Oklahoma State University, Stillwater, Okla. 74078; Upland wildlife program coordinator, Wildlife Division, Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Tex. 78744; and chief of game, Department of Wildlife Conservation, Oklahoma City, Okla. 73152.

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.

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

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 comparado 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 difirieron en 1998. No encontramos diferencias significativas en la composición o estructura de la vegetación entre sitios de anidamiento exitosos y no exitosos.

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

Financial support for this research was provided by the Oklahoma Department of Wildlife and Oklahoma State University through the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, Oklahoma State University, United States Geological Service Biological Resource Division, and Wildlife Management Institute, cooperating).

Manuscript accepted 29 Jun. 2000.

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), indiagrass (*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 psilostachya* 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 (Huempfer 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-m² 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			P	
	Coverage	n	\bar{x}	SE	n	\bar{x}		SE
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 m² 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 Coverage	Successful			Non-Successful			P
	\bar{x}	SE	n	\bar{x}	SE		
	(%)			(%)			
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 m² 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 bob-

white 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.

Characteristic	Nest Site			Random Site			P
	n	\bar{x}	SE	n	\bar{x}	SE	
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 heterogeneous (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.

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 pre-

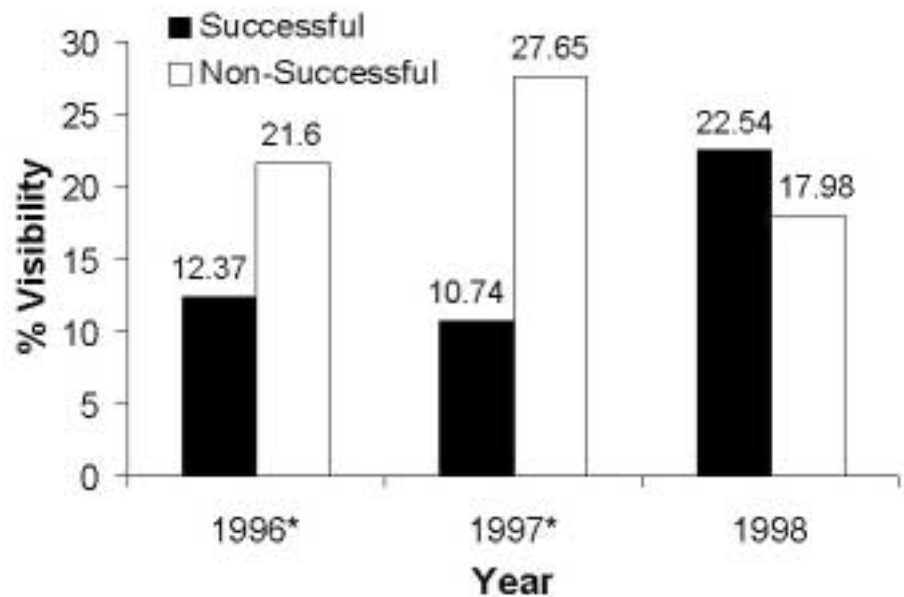


Fig. 1. Mean estimates of nest concealment for successful and non-successful bobwhite nest sites at PWMA, Ellis County, Okla. 1996–1998 (* = $P < 0.05$).

dation 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 pre-

dictor of nest success. Martin and Roper (1988) hypothesized that increased density of nest-site foliage (within a habitat patch surrounding the nest) decreases a predator's 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.

Characteristic	Successful			Non-Successful			P
	n	\bar{x}	SE	n	\bar{x}	SE	
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.

Literature Cited

- Angelstam, P. 1986. Predation on ground-nesting birds' nests in relation to predator densities and habitat edge. *Oikos* 47:365–373.
- Badyaev, A.V. 1995. Nesting habitat and nesting success of eastern wild turkeys in the Arkansas Ozark highlands. *Condor* 97:221–232.
- Berner, A. and L.W. Gysel. 1969. Habitat analysis and management considerations for ruffed grouse for a multiple use area in Michigan. *J. Wildl. Manage.* 33:769–778.
- Bowman, G.B. and L.D. Harris. 1980. Effect of spatial heterogeneity on ground-nest predation. *J. Wildl. Manage.* 44:806–813.
- Brennan, L.A. 1991. How can we reverse the northern bobwhite population decline. *Wildl. Soc. Bull.* 19:544–555.
- Burger, L.W., Jr., E.W. Kurzejeski, T.V. Dailey, and M.R. Ryan. 1990. Structural characteristics of vegetation in CRP fields in northern Missouri and their suitability as bobwhite habitat. *Trans. N. Amer. Wildl. Nat. Res. Conf.* 55:74–83.
- Byers, S.M. 1974. Predator-prey relationships on an Iowa waterfowl nesting area. *Trans. N. Amer. Wildl. Nat. Res. Conf.* 39:223–229.
- Church, K.E., J.R. Sauer, and S. Droege. 1993. Population trends of quails in North America. pp 44–54 *In* K. E. Church and T. V. Dailey, editors. Quail III: national quail symposium. Kan. Dept. Wildl. and Parks, Pratt, Kansas, USA.
- Cole, E.L., A.J. Conradi, and C.E. Rhoades. 1966. Soil survey of Ellis county, Oklahoma. U.S. Dept. Agr., Soil Conserv. Serv., Washington, D.C. 136pp.
- Colwell, M.A. 1992. Phalarope nesting success is not influenced by vegetation concealment. *Condor* 94:767–772.
- Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. *Northwest Sci.* 33:43–64.
- Ellis, J. A., W.R. Edwards, and K.P. Thomas. 1969. Responses of bobwhites to management in Illinois. *J. Wildl. Manage.* 33:749–762.
- Filliater, T.S., R. Breitwisch, and P.M. Nealen. 1994. Predation on Northern cardinal nests: does choice of nest site matter? *Condor* 96:761–768.
- Fuhlendorf, S.D. and F.E. Smeins. 1999. Scaling effects of grazing in a semi-arid grassland. *J. Veg. Sci.* 10:731–738.
- Gloutney, M. L. and R.G. Clark. 1997. Nest-site selection by mallards and blue-winged teal in relation to microclimate. *Auk* 114:381–395.
- Gotmark, F., D. Blomqvist, O.C. Johansson, and J. Bergkvist. 1995. Nest site selection: a trade-off between concealment and view of the surroundings. *J. Avian Biol.* 26:305–312.
- Higgins, K.F., J.L. Oldemeyer, K.J. Jenkins, G.K. Clambey, and R.F. Harlow. 1994. Vegetation sampling and measurement. pp. 567–591 *In*: T.A. Bookhout, ed. Research and management techniques for wildlife and habitats. *Wildl. Soc. Bethesda, Md.* 740pp.
- Holway, D.A. 1991. Nest-site selection and the importance of nest concealment in the black-throated blue warbler. *Condor* 93:575–581.
- Horkel, J.D., R.S. Lutz, and N.J. Silvy. 1978. The influence of environmental parameters on nesting success of upland game birds. *Proc. Southeastern Assoc. Fish and Wildl. Agencies* 32:234–241.
- Huempferner, R.A., S.J. Maxson, G.J. Erickson, and R. Schuster. 1975. Recapturing radio-tagged ruffed grouse by nightlighting and snow-burrow netting. *J. Wildl. Manage.* 39:821–823.
- Keppie, D.M., and P.W. Herzog. 1978. Nest site characteristics and nest success of spruce grouse. *J. Wildl. Manage.* 42:628–632.
- Klimstra, W.D. 1982. Bobwhite quail and changing land use. pp. 1–5 *In*: F. Schitoskey, Jr., E. C. Schitoskey, and L. G. Talent, eds. *Proc. Second Nat. Bobwhite Quail Symp.*, Oklahoma State Univ., Stillwater, Okla.
- Klimstra, W.D., and J.L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. *Wildl. Monogr.* 41:1–37.
- Lehmann, V.W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A & M University Press 371pp.
- Martin, T.E. 1992. Breeding productivity considerations: what are the appropriate habitat features for management? pp. 455–473 *In*: J. M. Hagan and D. W. Johnston, eds. *Ecology and Conservation of Neotropical Migrant Land Birds.* Smithsonian Institution Press, Washington, D.C.
- Martin, T.E. 1993a. Nest predation among vegetation layers and habitat types: revising the dogmas. *Amer. Nat.* 141:897–913.
- Martin, T.E. 1993b. Nest predation and nest sites: new perspectives on old patterns. *Biosci.* 43:523–532.
- Martin, T.E. and J.J. Roper. 1988. Nest predation and nest-site selection of a western population of the hermit thrush. *Condor* 90:51–57.
- McKee, G., M.R. Ryan, L.M. Mechlin. 1998. Predicting greater prairie-chicken nest success from vegetation and landscape characteristics. *J. Wildl. Manage.* 62:314–321.
- Meseke, C.A. 1992. Nest-site selection of the northern bobwhite on central illinois grasslands. *Amer. Zool.* 32(5):101A.
- Nudds, T.D. 1977. Quantifying the vegetative structure of wildlife cover. *Wildl. Soc. Bull.* 5:113–117.
- Patten, R.S. and J.E. Ellis. 1995. Patterns of species and community distributions related to environmental gradients in an arid tropical ecosystem. *Vegetatio* 117:69–79.
- Rands, M.R.W. 1988. The effect of nest site selection on nest predation in Grey Partridge *Perdix perdix* and Red-legged Partridge *Alectoris rufa*. *Ornis Scandinavica* 19:35–40.
- Ricklefs, R.E. 1969. An analysis of nesting mortality in birds. *Smithsonian Contributions to Zool.* 9:1–48.
- Riley, T.Z., C.A. Davis, M. Ortiz, and M.J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of lesser prairie chickens. *J. Wildl. Manage.* 56:383–387.
- Roseberry, J.L. and W.D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press. 259pp.
- Roseberry, J.L. and S.D. Sudkamp. 1998. Assessing the suitability of landscapes for northern bobwhite. *J. Wildl. Manage.* 62:895–902.
- SAS. 1996. Proprietary Software Release 6.08 ts407. SAS Institute Incorporated, Cary, N.C.
- Schmutz, J.A., C.E. Braun, and W.F. Andelt. 1989. Nesting habitat use of Rio Grande Wild Turkeys. *Wilson Bull.* 101:591–598.
- Sieg, C.H. and D.M. Becker. 1990. Nest-site habitat selected by merlins in southeastern Montana. *Condor* 92:688–694.
- Taylor, J.S. 1991. Aspects of northern bobwhite reproductive biology in south Texas. Thesis, Texas A&I University, Canyon, Tex.
- Taylor, J.S., K.E. Church, and D.H. Rusch. 1999. Microhabitat selection by nesting and brood-rearing northern bobwhite in Kansas. *J. Wildl. Manage.* 63:686–694.
- United States Department of Agriculture-Natural Resource Conservation Service. 2000. Official Soil Series Descriptions (<http://www.statlab.iastate.edu/cgi-bin/osd/>).
- Webb, W.M. and F.S. Guthery. 1982. Response of bobwhite to habitat management in northwest Texas. *Wildl. Soc. Bull.* 10:142–146.
- Wilbur, S.R. 1967. Live-trapping North American upland game birds. U.S. Fish and Wildlife Service Special Scientific Report, Wildlife No. 106. 37pp.
- Yahner, R.H. and N.H. Piergallini. 1998. Effects of microsite selection on predation of artificial ground nests. *Wilson Bull.* 110:439–442.