NEST-SITE SELECTION AND NEST SURVIVAL OF NORTHERN BOBWHITE IN SOUTHERN TEXAS

Author(s) :MICHAEL J. RADER, LEONARD A. BRENNAN, FIDEL HERNÁNDEZ, NOVA J. SILVY, and BEN WU

Source: The Wilson Journal of Ornithology, 119(3):392-399. 2007.
Published By: The Wilson Ornithological Society
DOI:
URL: http://www.bioone.org/doi/full/10.1676/06-069.1

The Wilson Journal of Ornithology 119(3):392–399, 2007

NEST-SITE SELECTION AND NEST SURVIVAL OF NORTHERN BOBWHITE IN SOUTHERN TEXAS

MICHAEL J. RADER,[1,4,5] LEONARD A. BRENNAN,[1] FIDEL HERNÁNDEZ,[1] NOVA J. SILVY,[2] AND BEN WU[3]

ABSTRACT.—We examined abiotic and biotic variables potentially associated with Northern Bobwhite (*Colinus virginianus*) nest-site selection and nest success in southern Texas, USA during 2002–2005. These data were used to characterize bobwhite nest-site selection, and to develop and evaluate models of daily nest survival in Program MARK. Nest sites (n = 123) had greater visual obscurity (3.50 vs. 2.60 dm) and vegetation height (64 vs. 47 cm), and less bare ground (11 vs. 25%) compared to random locations (n = 123). The two best models indicated daily nest survival increased with increasing mean maximum temperature and increasing cumulative precipitation. The model-averaged (± SE) estimate for bobwhite daily nest survival was 0.9593 ± 0.0060. These results suggest that bobwhites selected for a specific range of nest-site microhabitat attributes, but that nest predation was largely random. Bobwhite nest survival and productivity in semiarid, subtropical, southern Texas may be largely dependent on weather factors (e.g., temperature and precipitation). *Received 22 May 2006. Accepted 29 December 2006.*

Nest success is key to avian production and recruitment. Ground-nesting gamebirds in particular, including the Northern Bobwhite (*Colinus virginianus*) (hereafter, bobwhite), have high nest-loss rates (Reynolds et al. 1988, Newton 1993, Rollins and Carroll 2001). An understanding of the principal factors influencing nest success is necessary to effectively understand the population dynamics of the bobwhite.

Evolutionary theory suggests birds should select nest sites that maximize reproductive success (Wiens 1989, Martin 1993). Nest-site availability and habitat characteristics affecting nest fate are potentially valuable information for understanding population fluctuations of bobwhites in regions where nesting habitat is subject to periodic alteration by severe weather (e.g., drought and heat) (Lehmann 1984, Guthery et al. 2000, Rollins 2002) and anthropogenic influences such as grazing (Cantu and Everett 1982, Brown et al. 1993, Rollins 2002). Numerous studies have documented microhabitat (i.e., site-level) characteristics at bobwhite nests (Klimstra and Roseberry 1975, Simpson 1976, Lehmann 1984). None of the three studies that examined microhabitat characteristics of both nest sites and random sites, and between failed and successful nests (Taylor et al. 1999, Townsend et al. 2001, Lusk et al. 2006) was conducted in semiarid, subtropical, rangeland habitat of southern Texas.

Bobwhite productivity also may be influenced by weather. Drought is a recurrent feature in southern Texas and may be the driving mechanism of the characteristic boom-bust phenomenon exhibited by bobwhite populations in the region (Lehmann 1984; Hernández et al. 2002, 2007). It is becoming more apparent that reduced precipitation (Kiel 1976, Bridges et al. 2001, Hernández et al. 2005) and high temperatures (Guthery et al. 1988; Forrester et al. 1998; Guthery et al. 2001, 2005) at nest level associated with drought have significant potential to negatively impact bobwhite productivity in southern Texas.

We conducted a 4-year study of Northern Bobwhites in southern Texas to gain a better understanding of the biotic and abiotic factors influencing nest success (Rader 2006). The objectives of this paper are to: (1) describe microhabitat characteristics of nest sites versus random locations, (2) describe abiotic and biotic factors associated with successful and

[1] Caesar Kleberg Wildlife Research Institute, Texas A&M University–Kingsville, Kingsville, TX 78363, USA.

[2] Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA.

[3] Department of Ecosystem Science and Management, Texas A&M University, 2138 TAMU, College Station, TX 77843, USA.

[4] Current address: 8143 Kahilan Dr., Fair Oaks Ranch, TX 78015, USA.

[5] Corresponding author; e-mail: searader@hotmail.com

failed nests, and (3) develop and evaluate competing models of daily nest survival.

METHODS

Study Area.—The study was conducted on the San Tomas Hunting Camp (~15,000 ha) on the Encino Division of the King Ranch in Brooks County, ~32 km south of Falfurrias, Texas (26° 58′ N to 26° 50′ N, 98° 02′ W to 98° 00′ W). The area is dominated by honey mesquite (*Prosopis glandulosa*)–live oak (*Quercus virginiana*) savannah and Tamaulipan thornscrub (McLendon 1991, Fulbright and Bryant 2002, Rader 2006). Other characteristic vegetation included huisache (*Acacia smallii*), granjeno (*Celtis pallida*), prickly pear (*Opuntia lindheimeri*), tasajillo (*O. leptocaulis*), seacoast bluestem (*Schizachyrium scoparium*), gulf cordgrass (*Spartina spartinae*), purple threeawn (*Aristida purpurea*), doveweed (*Croton* spp.), sunflower (*Helianthus* spp.), and sandbur (*Cenchrus incertus*). The climate is semiarid and subtropical with periodic drought. Annual rainfall averages 56–66 cm; the annual mean temperature is ~23° C with a mean January temperature of ~9° C and a mean maximum July temperature of ~35° C (Lehmann 1984). Data collection occurred during an unusually wet period. The mean annual precipitation was 76 cm for 2002–2004 at the National Oceanic and Atmospheric Administration (NOAA) weather station in Falfurrias (U.S. Department of Commerce 2005). Major land uses included cattle grazing, petroleum extraction, and hunting, primarily for bobwhites and white-tailed deer (*Odocoileus virginianus*) (Fulbright and Bryant 2002).

The study was conducted on three distinct study sites (North Viboras, Loba, Cuates), each ~1,200–2,000 ha and separated by ≥5 km. Study sites were arranged north to south with a decreasing percentage of woody cover present at each study site (North Viboras = 32%, Loba = 11%, Cuates = 5%). Sites were representative of the range of woody cover and landscape habitat variability present on the study area.

Nest-site Selection.—We quantified bobwhite nest-site selection by comparing actual nest sites with random locations. We captured bobwhites throughout 2002–2005 at each study site using funnel traps baited with milo (Stoddard 1931) as needed to maintain ≥20 radio-marked bobwhites per site. We radio-marked a sample of bobwhites using 6–7 g, neck-loop, radio transmitters (American Wildlife Enterprises, Tallahassee, FL, USA). We used three-element, directional, hand-held, yagi antennas and portable receivers to track bobwhites approximately three times/week. We assumed bobwhites were incubating when found in the same location on two consecutive tracking attempts. Once nests were located, they were monitored every 1–2 days to ascertain nest fate. We examined the nest bowl to record fate if no bird was present at the nest.

We quantified vegetation height, visual obscurity, and canopy cover (i.e., grass, herbaceous, woody, and bare ground) at each nest site and at four random locations for each nest site once nesting had ceased. We measured vegetation height at the nest from the bottom-center of the nest bowl. We measured visual obscurity from the mean of four observations from the four cardinal directions using a Robel pole (Robel et al. 1970) placed at the center of the nest bowl or at a random location. Observations were taken at a distance of 4 m and height of 1 m. We estimated percent canopy cover at each nest and random site using a modified 1-m^2 Daubenmire frame (Daubenmire 1959). We selected random locations in each of the four quadrants of a circle within a 200-m radius of each nest-centered location. We used a random number generator to assign compass azimuth and distance to the random point in each quadrant. We took the mean of the vegetation measurements for the four random sites and used that value for comparison with each nest site. We tested for differences in vegetation height, visual obscurity, and canopy cover between nest and random sites using a Mann-Whitney test (Bradley 1968), because the data were not normally distributed.

Nest Success.—We used the Mann-Whitney test to examine differences between successful and failed nests in visual obscurity, vegetation height, bare ground, forb, grass, mean maximum temperature, and cumulative precipitation. We calculated mean maximum temperature as the mean of the maximum temperatures recorded for each day the nest was under observation. We calculated cumulative precipitation as the cumulative precipitation recorded 30 days prior to the nest being located and for each day the nest was under observation. Temperature and precipitation data were obtained from the nearest NOAA weather station in Falfurrias, Texas, ~30 km northwest of the study area. These data were intended as a coarse index of conditions in the region within the specified period and were not nest-site specific. We considered a nest was successful if ≥1 egg hatched. Failed nests included those lost to predation and abandonment. We considered a nest depredated if ≥1 egg was removed or destroyed, and the adult did not return to incubate the remainder of the clutch. A nest was considered abandoned if eggs remained intact, but incubation was not completed.

Daily Nest Survival Models.—We used the nest survival model in Program MARK (White and Burnham 1999) to evaluate competing models of bobwhite daily nest survival. Models were ranked based on Akaike's Information Criterion (AIC) (Burnham and Anderson 2002).We developed 10 *a priori* hypotheses to explain variation in nest survival. The model set incorporated constant daily nest survival (i.e., Mayfield 1961, 1975) in addition to models incorporating variation in relation to two classes of biotic covariates and four classes of abiotic covariates.

1. Microhabitat (i.e., vegetation height, visual obscurity, and percent grass). We hypothesized that increased vegetation height, visual obscurity, and percent grass would result in increased daily nest survival due to increased nest concealment from predators. Increased nest concealment should enhance nest success and bobwhites would be expected to select nest sites with greater nest concealment if this behavior maximized fitness (Martin 1993, Alcock 2001).
2. Macrohabitat (i.e., percent woody cover on the landscape). Lehmann (1984) suggested bobwhite nests may be more vulnerable to predation when placed near woody patches as many bobwhite nest predators (e.g., badger [*Taxidea taxus*], common raccoon [*Procyon lotor*], bobcat [*Felis rufus*], and gray fox [*Urocyon cinereoargenteus*]) have higher densities in wooded versus open landscapes. We predicted that increased woody cover on the landscape associated with the different study sites would result in decreased daily nest survival.
3. Temperature. We hypothesized that increased temperature during the nesting period would result in decreased daily nest survival due to nest abandonment since bobwhites would more likely experience hyperthermia when nesting during these conditions (Forrester et al. 1998; Guthery et al. 2001, 2005).
4. Precipitation. We hypothesized that increased cumulative precipitation 30 days prior to and during the nesting period would increase daily nest survival as bobwhite productivity has been linked to increased rainfall during the nesting season in southern Texas (Kiel 1976, Bridges et al. 2001, Hernández et al. 2005).
5. Date. We predicted that variation in daily nest survival would be related to temporal variation within seasons. Lehmann (1946, 1984) suggested that increased availability of alternate foods to predators as mast abundance improves later in the summer may result in increased daily nest survival.
6. Year. We predicted that year-to-year variation would explain variation in daily nest survival rates due to changing weather patterns, predator population fluctuations, etc. associated with different nesting seasons (Dinsmore et al. 2002).

RESULTS

Nest-site Selection.—We quantified microhabitat attributes at 123 bobwhite nests during 2002 (37), 2003 (44), 2004 (36), and 2005 (6). Nest sites differed from random locations for five of six microhabitat variables measured (Table 1). Nest sites had greater visual obscurity (+35%), vegetation height (+36%), and grass cover (+13%), and decreased bare ground (−56%) and forb cover (−12%) compared to random locations (Table 1). The absolute differences between nest and random locations for the forb and grass variables were small and their biological significance is questionable. Nest sites consisted largely of grass, followed by relatively even proportions of bare ground, forb, and woody cover.

Nest Success.—We found only one difference between successful and failed bobwhite nests for the variables tested (n = 109) (Table 2). The mean maximum temperature recorded

TABLE 1. Microhabitat characteristics of nest-centered (n = 123) and random locations (n = 123) for Northern Bobwhites in southern Texas, USA, 2002–2005.

Variable	Nest-centered Mean	SE	Range	Random Mean	SE	Range	U[a]	P
Visual obscurity (dm)	3.50	0.100	1.3–7.8	2.60	0.097	0.0–5.5	3,824	<0.001
Vegetation height (cm)	64.00	2.550	14–200	47.00	1.765	5–90	4,711	<0.001
Bare ground[b]	0.11	0.010	0.03–0.38	0.25	0.016	0.03–0.86	3,749	<0.001
Forb[b]	0.15	0.016	0.03–0.86	0.17	0.013	0.03–0.63	6,066	0.004
Grass[b]	0.70	0.023	0.03–0.98	0.62	0.021	0.03–0.98	5,982	0.003
Woody[b]	0.11	0.018	0.03–0.98	0.06	0.006	0.03–0.38	7,129	0.258

[a] Mann-Whitney U statistic.
[b] Proportion of total cover for this cover type.

during nest observation was 0.6° C lower for failed nests compared to successful nests. This difference is small and we cannot conclude that statistical significance equals biological significance in this case.

Daily Nest Survival Models.—The best models identified indicated that bobwhite daily nest survival increased with increasing mean maximum temperature and increasing cumulative precipitation during the nesting period (n = 109) (Table 3). These models were virtually indistinguishable, differing by <2 ΔAIC_c units and having Akaike weights of 0.398 and 0.349, respectively. Models that held daily nest survival constant (i.e., Mayfield method) or contained covariates for microhabitat, macrohabitat, date, and year had virtually no support (i.e., ΔAIC_c >4 and Akaike weights <0.05).

We plotted daily nest survival versus mean maximum temperature and cumulative precipitation, respectively for the two best models (Fig. 1). Bobwhite daily nest survival modeled as a function of mean maximum temperature alone increased from 30° to 37.6° C (Fig. 1A). Daily nest survival modeled as a function of both mean maximum temperature and cumulative precipitation showed different patterns when examined at three different levels of mean maximum temperature and cumulative precipitation, respectively. Daily nest survival versus mean maximum temperature at three levels of precipitation had the same pattern (Fig. 1A) with daily nest survival increasing with the level of cumulative precipitation (Fig. 1B). Daily nest survival versus cumulative precipitation at three levels of mean maximum temperature indicated a negligible precipitation effect at mean maximum temperature levels of 34° and 37.6° C (Fig. 1C). The model-averaged (± SE) estimate for bobwhite daily nest survival from the two best models was 0.9593 ± 0.0060.

DISCUSSION

Nest-site Selection.—Increased visual obscurity and vegetation height, and decreased

TABLE 2. Biotic and abiotic variables for successful (n = 61) and failed (n = 48) Northern Bobwhite nests in southern Texas, USA, 2002–2004.

Variable	Successful Mean	SE	Range	Failed Mean	SE	Range	U[a]	P
Visual obscurity (dm)	3.50	0.144	2.1–7.8	3.50	0.121	2.0–6.1	1,419	0.781
Vegetation height (cm)	67.00	2.831	23–116	63.00	4.125	14–138	1,242	0.175
Bare ground[b]	0.10	0.012	0.03–0.38	0.12	0.016	0.03–0.38	1,301	0.271
Forb[b]	0.17	0.024	0.03–0.86	0.14	0.025	0.03–0.63	1,305	0.292
Grass[b]	0.70	0.031	0.16–0.98	0.69	0.034	0.03–0.98	1,420	0.780
Temperature[c]	35.30	0.182	31.8–37.6	34.70	0.235	31.6–37.5	1,098	0.025
Precipitation[d]	7.80	0.650	0.70–17.5	8.00	0.830	0.80–33.0	1,461	0.985

[a] Mann-Whitney U statistic.
[b] Proportion of total cover for this cover type.
[c] Mean maximum daily temperature (°C) recorded during period nests were under observation.
[d] Cumulative precipitation (cm) recorded 30 days prior-to and during the period nests were under observation.

TABLE 3. Selection results for models of daily nest survival rate for Northern Bobwhite nests in southern Texas, USA, 2002–2004 (n = 109). Rankings were based on Akaike's Information Criterion (AIC) values.

Model[a]	K[b]	AIC_c[c]	ΔAIC	Weight
$\beta_0 + \beta_1 *Temp$	2	331.40	0.00	0.398
$\beta_0 + \beta_1 *Temp + \beta_2 *Precip$	3	331.66	0.26	0.349
$\beta_0 + \beta_1 *Precip$	2	335.26	3.86	0.058
β_0[d]	1	335.61	4.20	0.049
$\beta_0 + \beta_1 *VegHeight$	2	336.02	4.62	0.04
$\beta_0 + \beta_1 *VisObscurity$	2	336.64	5.24	0.029
$\beta_0 + \beta_1 *Cuates + \beta_2 *Loba + \beta_3 *Viboras$	4	336.68	5.27	0.028
$\beta_0 + \beta_1 *Date$	2	337.58	6.17	0.018
$\beta_0 + \beta_1 *Grass$	2	337.61	6.21	0.018
$\beta_0 + \beta_1 *2002 + \beta_2 *2003 + \beta_3 *2004$	4	338.12	6.72	0.014

[a] *Temp* is the covariate mean maximum temperature; *Precip* is the covariate cumulative precipitation; *VegHeight* is the covariate vegetation height at nest; *VisObscurity* is the covariate nest visual obscurity; *Cuates*, *Loba* , and *Viboras* are covariates of study sites; *Date* is the covariate describing nesting period; *Grass* is the covariate describing grass cover at nest-sites; and *2002*, *2003*, and *2004* are the covariates for year of study.
[b] Number of model parameters.
[c] Akaike's Information Criterion corrected for small samples.
[d] Intercept-only model of constant daily nest survival rate.

bare ground appear to be consistently important features of bobwhite nest sites. We did not find that woody cover significantly influenced nest-site selection and note the nature of woody cover (e.g., species composition) in Oklahoma (Townsend et al. 2001) and in the Texas Panhandle (Lusk et al. 2006) differs from that found in our study area in southern Texas. Bobwhites in Kansas preferred nest sites with taller vegetation, greater visual obscurity, and less bare ground than random sites (Taylor et al. 1999), while those in Oklahoma selected nest sites with greater structural complexity, grass and woody cover, and less bare ground compared to random sites (Townsend et al. 2001). Bobwhite nest sites in the Texas Panhandle became more suitable with increasing nest-canopy height and shrub cover, and decreasing bare ground (Lusk et al. 2006).

Nest Success.—Bobwhite nest success was not affected by the microhabitat characteristics or weather variables measured with the possible exception of mean maximum temperature. Research on bobwhite nest success has produced ambiguous results with respect to correlations with measures of nest-site vegetation. Most studies have indicated no significant differences between successful and unsuccessful nests in terms of nest concealment (Lehmann 1946, 1984; Klimstra and Roseberry 1975; Simpson 1976; Townsend et al. 2001). However, Taylor et al. (1999) reported that successful bobwhite nest sites had less litter cover and were in habitat patches with taller grass cover. Lusk et al. (2006) established that successful bobwhite nests had higher vegetation canopies, more shrub cover, and more bare ground than unsuccessful nests. Lehmann (1984) reported nest sites that were more homogeneous (i.e., in terms of height and type of vegetation) relative to immediate surrounding vegetation had a higher probability of success.

Daily Nest Survival Models.—Models that estimated daily nest survival as a function of abiotic variables (i.e., temperature and precipitation) were best supported. This is consistent with our descriptive data (Table 2) for mean maximum temperature. Increasing precipitation during the nesting season has been shown to be positively correlated with bobwhite productivity in southern Texas (Kiel 1976, Bridges et al. 2001, Hernández et al. 2005). Our model that incorporated both temperature and precipitation covariates indicated that temperature had a constant influence on daily nest survival, but that precipitation did not (Fig. 1B, C). The lack of influence from precipitation at temperatures of $\geq 34°$ C indicates that temperature has the greatest influence on daily nest survival, which is substantiated by our descriptive data (Table 2). Lusk et al. (2002) also found that an index of bobwhite abundance increased with July and August temperature.

We found little support for models that assumed constant daily nest survival or that es-

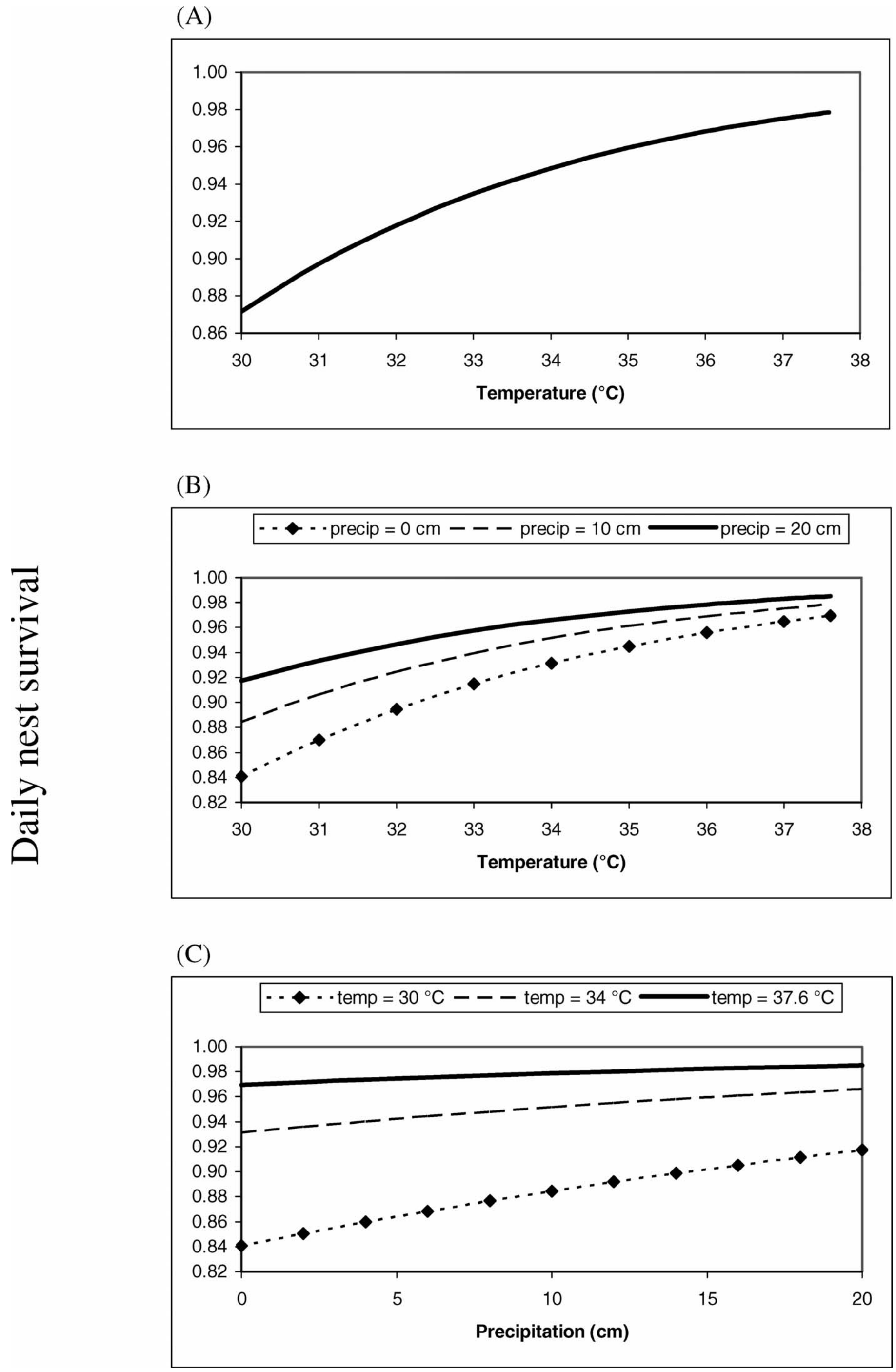

FIG. 1. Daily nest survival probabilities for Northern Bobwhites as a function of (A) mean maximum temperature, (B) mean maximum temperature at three levels of cumulative precipitation, and (C) cumulative precipitation at three levels of mean maximum temperature in southern Texas, USA, 2002–2004.

timated nest survival as a function of microhabitat, macrohabitat, date, or year. Most previous bobwhite nesting studies used apparent nesting success or Mayfield estimator derivatives to estimate nest survival and suggested that habitat (both site- and landscape-level) may have a role in nest survival (e.g., Lehmann 1946, 1984; Klimstra and Roseberry 1975; Twedt et al. 2002). Our study area was comprised of largely contiguous rangeland habitat at the landscape level and relatively high-quality nesting cover due to above-average precipitation. This may partially explain the inability of habitat covariates to show significant variation in daily nest survival. We believe habitat conditions were optimal for bobwhites during the study period and prevented measurement of the potential negative impacts of poorer habitat on daily nest survival.

ACKNOWLEDGMENTS

Funding was provided by the Caesar Kleberg Wildlife Research Institute, Quail Unlimited, Houston Safari Club, and video camera donors. We especially thank King Ranch, Inc., Ronnie Howard and the San Tomas Hunting Camp, South Texas Quail Research Project, Froylan Hernández, Johnny Arredondo, Trent Teinert, Jason Hardin, Russell Bradley, and many others. We thank W. P. Kuvlesky and Bart Ballard for their constructive comments on previous drafts of this manuscript. This is publication 06-118 from the Caesar Kleberg Wildlife Research Institute and the Richard M. Kleberg Jr., Center for Quail Research.

LITERATURE CITED

ALCOCK, J. 2001. Animal behavior: an evolutionary approach. Seventh Edition. Sinauer Associates, Inc., Sunderland, Massachusetts, USA.

BRADLEY, J. V. 1968. Distribution-free statistical tests. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, USA.

BRIDGES, A. S., M. J. PETERSON, N. J. SILVY, F. E. SMEINS, AND X. B. WU. 2001. Differential influence of weather on regional quail abundance in Texas. Journal of Wildlife Management 65:10–18.

BROWN, D. E., A. SANDS, S. CLUBINE, AND C. E. BRAUN. 1993. Strategic plan for quail management and research in the United States: issues and strategies- grazing and range management. Proceedings of the National Quail Symposium 3:176–177.

BURNHAM, K. P. AND D. R. ANDERSON. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second Edition. Springer, New York, USA.

CANTU, R. AND D. D. EVERETT. 1982. Reproductive success and brood survival of Bobwhite Quail as affected by grazing practices. Proceedings of the National Quail Symposium 2:79–83.

DAUBENMIRE, R. F. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33: 43–64.

DINSMORE, S. J., G. C. WHITE, AND F. L. KNOPF. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

FORRESTER, N. D., F. S. GUTHERY, S. D. KOPP, AND W. E. COHEN. 1998. Operative temperature reduces habitat space for Northern Bobwhites. Journal of Wildlife Management 62:1506–1511.

FULBRIGHT, T. AND F. BRYANT. 2002. The last great habitat. Special Publication 1. Caesar Kleberg Wildlife Research Institute, Texas A&M University–Kingsville, Kingsville, USA.

GUTHERY, F. S., N. E. KOERTH, AND D. S. SMITH. 1988. Reproduction of Northern Bobwhites in semiarid environments. Journal of Wildlife Management 52:144–149.

GUTHERY, F. S., C. L. LAND, AND B. W. HALL. 2001. Heat loads on reproducing bobwhites in the semiarid subtropics. Journal of Wildlife Management 65:111–117.

GUTHERY, F. S., N. D. FORRESTER, K. R. NOLTE, W. E. COHEN, AND W. P. KUVLESKY JR. 2000. Potential effects of global warming on quail populations. Proceedings of the National Quail Symposium 4: 198–204.

GUTHERY, F. S., A. R. RYBAK, S. D. FUHLENDORF, T. L. HILLER, S. G. SMITH, W. H. PUCKETT JR., AND R. A. BAKER. 2005. Aspects of the thermal ecology of bobwhites in north Texas. Wildlife Monographs 159.

HERNÁNDEZ, F., F. S. GUTHERY, AND W. P. KUVLESKY. 2002. The legacy of bobwhite research in south Texas. Journal of Wildlife Management 66:1–18.

HERNÁNDEZ, F., R. PEREZ, AND F. S. GUTHERY. 2007. Quail management on the south Texas plains. Pages 273–298 *in* Ecology and management of Texas quails (L. A. Brennan, Editor). Texas A&M University Press, College Station, USA.

HERNÁNDEZ, F., F. HERNÁNDEZ, J. A. ARREDONDO, F. C. BRYANT, L. A. BRENNAN, AND R. L. BINGHAM. 2005. Influence of precipitation on demographics of Northern Bobwhites in southern Texas. Wildlife Society Bulletin 33:1071–1079.

KIEL, W. H. 1976. Bobwhite quail population characteristics and management implications in south Texas. Transactions of the North American Wildlife and Natural Resources Conference 41:407–420.

KLIMSTRA, W. D. AND J. L. ROSEBERRY. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

LEHMANN, V. W. 1946. Bobwhite Quail reproduction in southwestern Texas. Journal of Wildlife Management 10:111–123.

LEHMANN, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, USA.

LUSK, J. J., S. G. SMITH, S. D. FUHLENDORF, AND F. S. GUTHERY. 2006. Factors influencing Northern Bobwhite nest-site selection and fate. Journal of Wildlife Management 70:564–571.

LUSK, J. J., F. S. GUTHERY, R. R. GEORGE, M. J. PETERSON, AND S. J. DEMASO. 2002. Relative abundance of bobwhites in relation to weather and land use. Journal of Wildlife Management 66:1040–1051.

MARTIN, T. E. 1993. Nest predation and nest sites: new perspectives on old patterns. Bioscience 43:523–532.

MAYFIELD, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

MAYFIELD, H. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456–466.

MCLENDON, T. 1991. Preliminary description of the vegetation of south Texas exclusive of coastal saline zones. Texas Journal of Science 43:13–32.

NEWTON, I. 1993. Predation and limitation of bird numbers. Current Ornithology 11:143–198.

RADER, M. J. 2006. Factors influencing nest success of Northern Bobwhites in southern Texas. Dissertation. Texas A&M University, College Station and Kingsville, USA.

REYNOLDS, J. C., P. ANGELSTAM, AND S. REDPATH. 1988. Predators, their ecology and impact on gamebird populations. Pages 72–97 *in* Ecology and management of gamebirds (P. J. Hudson and M. R. W. Rands, Editors). BSP Professional Books, Oxford, United Kingdom.

ROBEL, R. J., J. N. BRIGGS, A. D. DAYTON, AND L. C. HULBERT. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

ROLLINS, D. 2002. Sustaining the 'quail wave' in the southern Great Plains. Proceedings of the National Quail Symposium 5:48–56.

ROLLINS, D. AND J. P. CARROLL. 2001. Impacts of predation on Northern Bobwhite and Scaled Quail. Wildlife Society Bulletin 29:39–51.

SIMPSON, R. C. 1976. Certain aspects of the Bobwhite Quail's life history and population dynamics in southwest Georgia. Technical Bulletin WL1. Georgia Department of Natural Resources, Game and Fish Division, Atlanta, USA.

STODDARD, H. L. 1931. The Bobwhite Quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

TAYLOR, J. S., K. E. CHURCH, AND D. H. RUSCH. 1999. Microhabitat selection by nesting and brood- rearing Northern Bobwhite in Kansas. Journal of Wildlife Management 63:686–694.

TOWNSEND, D. E., R. E. MASTERS, R. L. LOCHMILLER, D. M. LESLIE, S. J. DEMASO, AND A. D. PEOPLES. 2001. Characteristics of nest sites of Northern Bobwhites in western Oklahoma. Journal of Range Management 54:260–264.

TWEDT, D. J., R. R. WILSON, J. L. HENNE-KERR, AND D. A. GROSSHEUSCH. 2002. Avian response to bottomland hardwood reforestation: the first 10 years. Restoration Ecology 10:645–655.

U.S. DEPARTMENT OF COMMERCE. 2005. National climatic data. U.S. Department of Commerce, National Climatic Data Center. http://www.ncdc.noaa.gov/oa/ncdc.html (accessed June 2005).

WHITE, G. C. AND K. P. BURNHAM. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:120–139.

WIENS, J. A. 1989. The ecology of bird communities. Volume 2. Processes and variations. Cambridge University Press, Cambridge, United Kingdom.