Research Article

Nesting Ecology and Survival of Scaled Quail in the Southern High Plains of Texas

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Abstract

*Scaled quail (*Callipepla squamata*) populations have been declining since the early 1960s, and there is no clear understanding of what is causing this decline. It has been suggested that reproductive failure is a probable cause of this decline. We used radiotelemetry to evaluate nesting ecology and survival of scaled quail in the Southern High Plains of Texas in 1999 and 2000. We radio-marked 138 hens (66 in 1999 and 72 in 2000) and reported nesting activity on 106 nests. In 1999, 50 nests were detected with a nesting success of 44%. In 2000, 56 nests were detected with a nesting success of 64%. Chick survival was recorded at 21 days posthatch and was analyzed as present or absent, as exact numbers were difficult to determine. Two hens had chicks present at 21 days in 1999, but 16 hens had chicks present at 21 days in 2000. Chick presence with the hen at 21 days was negatively associated with cool and wet weather. Logistic regression revealed predictive relationships for models describing vegetation characteristics at and around nest sites as predictors of nesting success and nest sites. Variables in the models included percentage of bare ground, forb diversity, and amount of visual obstruction at different heights. Hen survival, nesting success, and chick survival were higher in 2000 than in 1999. Differences in vegetation composition and structure were likely responses to differences in precipitation between years. Drought and overgrazing by livestock increase the percentage of bare ground and reduce visual obstruction; these are likely contributors to the reduced scaled quail populations in the Southern High Plains.* (JOURNAL OF WILDLIFE MANAGEMENT 70(3): 632–639; 2006)

Key words

Callipepla squamata, *chicks, nesting habitat, nest success, scaled quail, Southern High Plains, survival, Texas.*

Scaled quail population abundance has declined significantly throughout the range of this species since the early 1960s (Church et al. 1993). Populations declined 1.5% per year between 1966 and 2003 (Sauer et al. 2004). Disease, habitat degradation, weather patterns, and increases in predator populations have all been suggested as possible influences, but the cause of the decline is unknown (Schemnitz 1994, Rollins 2000).

Quail population size is believed to be maintained through high reproductive output (Schemnitz 1994). Thus, reproductive failure is a likely mechanism for negative population changes. Unfortunately, an incomplete understanding of scaled quail demographics, especially reproduction, hampers the ability to evaluate the impacts of environmental factors on population growth. Reproductive output could be affected by 4 factors: 1) hen survival, 2) nest success, 3) egg hatchability, and 4) chick survival. We initiated a study to examine the influence of these factors on scaled quail reproductive success. Our objectives were to 1) determine hen survival from late winter through the breeding season; 2) estimate nesting success, clutch size, egg hatchability, and chick survival; 3) identify habitat features selected by scaled quail for nest sites; and 4) identify habitat features associated with successful nests. Evans and Schemnitz (2000) hypothesized that high chick mortality during their study was caused by high ambient temperature. Thus, our final objective was 5) to identify relationships between chick survival and weather conditions.

Study Area

We conducted this study on roughly 12,140 ha in southern Cochran County (33°43′N, 102°46′W) in the Southern High Plains of Texas, USA. Most of the study area consisted of rangeland, with portions adjoining farmlands and new and old fields in the Conservation Reserve Program (Dabbert et al. in press). The primary range sites in the county are sandy land and deep sand sites, both of which can contain dunes and are highly susceptible to wind erosion (Newman 1964). Blowouts form quickly where vegetation is sparse. The other predominant range site is the mixed land site that consists of gently sloping plains that slope toward playas or shallow draws. Four soil types dominated most of our study area within these range sites: 1) Amarillo fine sand; 2) Brownfield fine sand, thick surface; 3) Brownfield fine sand, thin surface; and 4) Tivoli fine sand. The climate is semiarid, warm, and continental (Newman 1964). Low annual precipitation, high wind velocities, high summer temperatures, low humidity, and rapid changes characterize the region, with extremes in temperature and amount of rainfall (Newman 1964). More than 80% of the average annual rainfall occurs during May through October. The long-term average annual rainfall is 46.5 cm (National Weather Service, www.weather.gov/climate/xmacis.php?wfo=lub). Continuous strong winds occur from February through April. Sustained velocities of 35 km/h for 24 hr are common (Newman 1964).

Methods

We captured scaled quail from late February through mid-April in 1999 and 2000 in walk-in funnel traps (Smith et al. 1981) baited with millet and cracked corn, and we banded quail with

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sequentially numbered aluminum tarsus bands National Band and Tag Company, Newport, Kentucky. After banding, we aged (subadult or adult) and sexed the quail, using plumage characteristics described by Wallmo (1956), and then fitted each hen with a 6.5-g necklace-style transmitter (American Wildlife Enterprises, Monticello, Florida) without a body loop. We collected $\leq$0.25 ml of blood from the brachial vein of each bird for an ancillary study.

We located radio-marked hens at least once every other day to find nests from mid-April until mid-July. During this period, we approached each bird on foot until it flushed or moved away; we observed it, or we circled it, and we determined whether it was on a nest. We tied flagging tape to tall vegetation at a distance of 10 m on opposite sides of the nest and determined nest position on subsequent visits by sighting between the flags. Using this method prevented our marks from drawing predators or livestock directly to the nest. We did not intentionally flush hens from nests and rarely did so inadvertently. To confirm the nest location and clutch size, we returned to the site at times when the hen was feeding away from the nest. We determined hen presence or absence on the nest using radiotelemetry and recorded the clutch size during hen absence. We estimated the date the hen began incubation by averaging the last date the hen was found not on the nest and the first date she was found incubating eggs. Successful nests had at least 1 egg hatch. We calculated percentage of hatchability as the number of eggs that hatched divided by the clutch size.

We measured chick survival at 21 days posthatch by using flush counts. Because of the difficulty in obtaining definite counts of chicks, even when using multiple observers, we recorded chick survival as a brood being present or absent from the hen at 21 days posthatch. In the case of absent chicks, we monitored the hen on 2 successive days to validate that absence.

Vegetation Measurements

We evaluated characteristics of vegetation at the nest site after the eggs hatched, the nests were depredated, or the hen abandoned a nest. Nest site measurements included visual obstruction and species composition. We quantified visual obstruction by the horizontal component of foliage using a vegetation profile or cover-board as described by Nudds (1977). Alternating black and white bands marked 25-cm intervals on the 2-m-high, 25-cm-wide board. We recorded the proportion of each 0.25-m interval covered by vegetation as a single digit that corresponded to the percentage of the interval obscured by vegetation (i.e., 1 corresponded to the range from 0 to 20%, 2 to the range from 21 to 40%, and so forth). We evaluated visual obstruction from a distance of 2 m and a height of 1 m. We estimated percentage of bare ground and plant species composition in a 1-m^2 quadrat, along with visual obstruction scores at the nest and at 4 random locations 10 m from the nest. We obtained random locations by measuring 10 m down a random bearing from the center of the nest. Random bearings were generated using a spinner held over the center of the nest. We estimated available habitat characteristics by calculating the mean of variables measured in the 4 random locations.

Data Analysis

We used Cox's regression analysis to test for differences in survival between age classes within years (SPSS 2002), and the Kaplan–Meier staggered-entry method and a log-rank test to compare survival between years (Pollock et al. 1989). We used Mann–Whitney tests to compare clutch size and percent hatchability between years (SPSS 2002), and binomial-proportions tests to compare nest success between age classes and years and the proportion of hens with chicks present 21 days posthatch between years (Ott 1988). We used logistic regression to examine the relationships among the proportion of hens with chicks present 21 days posthatch and weather conditions occurring during the same period posthatch. A central weather station at Morton, Texas (33°43′N, 102°46′W), which was located <20 km from all nests provided weather data. It is possible, however, that weather events recorded at the central station might not impact all nests because weather events in this region can be localized. We used weather data from 2 secondary weather stations that exceed the northern (Muleshoe, Texas; 33°57′N, 102°47′W) and southern (Plains, Texas; 3°11′N, 102°50′W) boundaries of the study area to address this problem. We calculated precipitation and temperature variables as the mean value detected at the 3 (central, northern, and southern) weather stations during the same 24-h period. In a few instances, data were not available from the Plains, Texas, station. We calculated variables using Morton and Muleshoe, Texas, sites in these instances. The maximum temperature, minimum temperature, number of days with precipitation, and total centimeters of precipitation recorded during the first 7 days posthatch and during the entire 21-day period posthatch were considered for inclusion in the logistic regression analysis. We used an approach similar to that of Brennan et al. (1986) to select predictor variables to include in the logistic regression analysis. First, we used separate variance *t*-tests to determine which variables were different ($P < 0.05$) among groups (SPSS 2002). Second, we determined Spearman rank-correlation coefficients between all pair-wise combinations of the variables that were different between groups and eliminated 1 of a pair if $r_s \geq 0.4$. The variable having the least among-group significance was eliminated from further analysis. We fitted a full logistic regression model using all variables selected by the previously described 2-step approach. We then selected variables to include in a reduced model using a sequential procedure of individually excluding variables from the full model and testing their significance with likelihood-ratio tests (Tabachnick and Fidell 2001). We also evaluated variables based upon change in predictive ability when variables were excluded from the full model. We interpreted logistic regression coefficients by stating odds ratios. Logistic regression analysis and separate variance *t*-tests were used in the same way to identify habitat characteristics associated with successful versus depredated nests and to identify habitat characteristics selected by scaled quail for nest sites. Species richness, number of shrub species, number of grass species, number of forb species, percentage of bare ground, and cover board score for 6 separate heights (from 0–0.25 m, 0.25–0.5 m, 0.5–0.75 m, 0.75–1 m, 1–1.25 m, and 1.25–1.50 m) recorded at the nest site and in the available habitat surrounding the nest site composed 22 of 23 predictor variables used in the analysis to identify habitat characteristics associated with successful nests. Canopy coverage of the nest was the last variable. The regression was set to solve for a successful nest. Criterion for predictor-

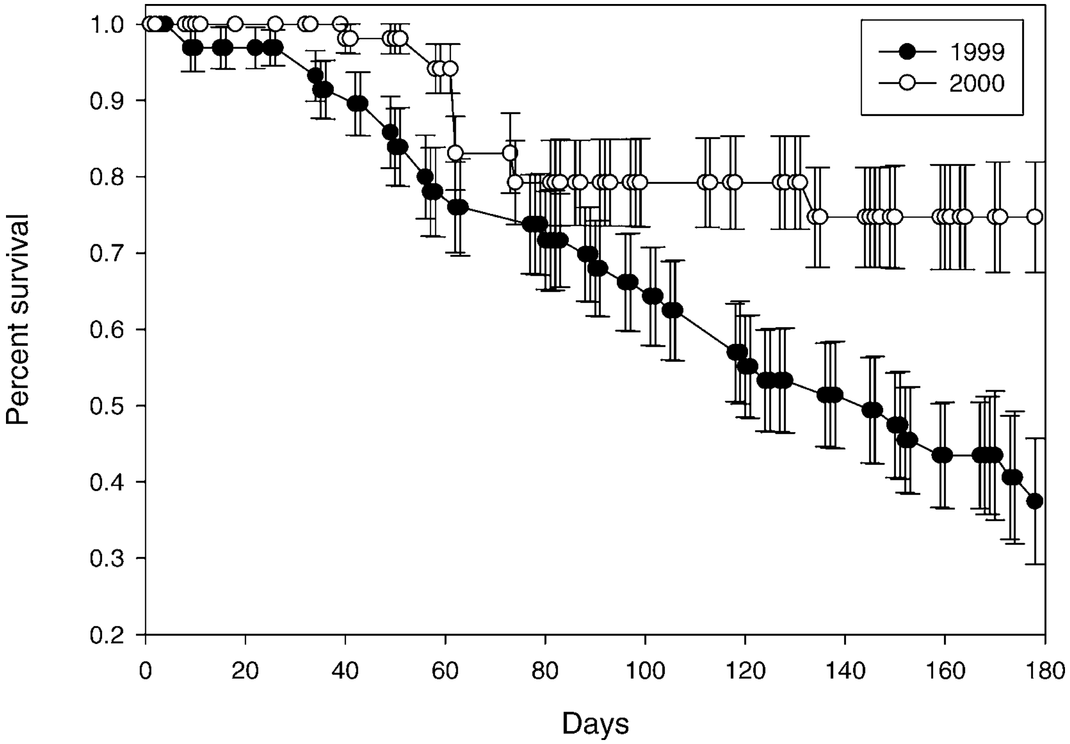

Figure 1. Survival of female scaled quail in the Southern High Plains of Tex., USA, from 18 February until 15 August during 1999 and 2000.

variable inclusion into the full model, likelihood-ratio tests, and interpretation of coefficients were conducted as previously described.

Species richness, number of shrub species, number of grass species, number of forb species, percentage of bare ground, and cover board score for 6 separate heights (from 0–0.25 m, 0.25–0.50 m, 0.5–0.75 m, 0.75–1 m, 1–1.25 m, and 1.25–1.50 m) were used as predictor variables for the logistic regression analysis to identify habitat characteristics selected by scaled quail for nest sites versus the available habitat. The regression was set to solve for the nest site. Criterion for predictor-variable inclusion into the full model, likelihood-ratio tests, and interpretation of coefficients were conducted as previously described.

Results

We radiomarked 66 hens (20 subadults, 43 adults, and 3 unknown) in 1999 and 72 hens (60 subadults, 12 adults) in 2000. Survival was not different between age classes during 1999 (adult $S = 0.38$, subadult $S = 0.38$, $\chi^2 = 0.00$, $P = 0.99$) and 2000 (adult $S = 0.30$, subadult $S = 0.43$, $\chi^2 = 2.61$, $P = 0.11$), so age classes were pooled for comparison by year. Hen survival from 18 February until 15 August was almost 40% greater ($P < 0.005$) in 2000 than in 1999 (Fig. 1). In 1999, 31 hens produced 50 nests; 11 hens produced 2 nests each, and 4 hens produced 3 nests each. In 2000, 38 hens produced 56 nests; 14 hens produced 2 nests each, and 2 hens produced 3 nests each. During both years, all renesting occurred after loss of a previous nest or loss of young before 21 days of age. Nest success was greater ($P = 0.02$) in 2000 (64%, $n = 55$) than in 1999 (44%, $n = 50$). Nest success of subadults (15%) was less ($P = 0.006$) than nest success of adults (56%) during 1999, but not different ($P = 0.41$) between ages (subadult = 67%, adult = 63%) during 2000. Hatchability ($n = 51$, $\nu = 0.95$, SE = 0.01, $P = 0.342$) and clutch size ($n = 51$, $\nu = 12.62$, SE = 0.38, $P = 0.793$) were not different between years.

A greater ($P < 0.003$) percentage of hens (48%, $n = 33$) had chicks present with them 21 days after hatch during 2000 than during 1999 (10%, $n = 21$). Maximum temperatures during the first 21 days of the life of broods recorded in 1999 and 2000 were 39°C. Minimum temperatures were 12°C and 13°C during 1999 and 2000, respectively. Weather conditions were colder and wetter (during the first 7 days after hatch and during the entire 21 day monitoring period) for broods that were absent from the hen at 21 days of age than for broods that were present with the hen at 21 days of age (Table 1). The 2-step procedure for selecting predictor variables indicated that maximum temperature, number of days with precipitation, and total centimeters of precipitation recorded during the first 7 days posthatch should be included in the initial (full) logistic regression analysis to predict chick presence with the hen at 21 days of age (Table 1). This full model ($\chi^2 = 27.50$, $P < 0.001$) accurately predicted 83.3% of the cases. Examination of individual covariates revealed that minimum temperature recorded during the first 21 days posthatch was not a significant predictor of chick presence with the hen, and the predictive ability of the reduced logistic regression equation increased when this variable was removed from the model (Table 2). The final model included maximum temperature and number of days with precipitation during the first 7 days posthatch as significant predictors of chick presence with the hen at 21 days of age (Table 2). The final model was $g(x) = -44.22 + 1.28$ (maximum temperature) $-$ 0.847 (days with rain). Chicks were 3.39 times more likely to be present with the hen at 21 days of age with each 1°C increase in maximum temperature during week 1 (Fig. 2a). However, chicks were 57%

Table 1. Comparison of weather conditions occurring during the first 21 days posthatch of scaled quail broods, which were present ($n = 17$) with the hen at 21 days posthatch, with conditions occurring during the same time period of broods that were absent ($n = 37$) at 21 days posthatch. Broods were monitored from 18 May to 29 August 1999 ($n = 21$) and from 19 May to 27 August 2000 ($n = 33$) in the Southern High Plains of Tex., USA. Parameter estimates for environmental variables are presented along with their corresponding *P* values for separate variance *t*-tests.

	Present		**Absent**		
Variable	**Mean**	**SE**	**Mean**	**SE**	***P***
Recorded during 3 weeks					
Maximum temperature[a]	37.91	0.13	37.54	0.15	0.066
Minimum temperature[a]	15.23	0.21	14.09	0.28	0.002
Days with precipitation	3.87	0.56	5.38	0.35	0.030
Total precipitation[b]	3.83	0.68	6.61	0.46	0.002
Recorded during week 1					
Maximum temperature[a]	37.48	0.20	35.57	0.29	<0.001
Minimum temperature[a]	16.05	0.25	15.14	0.29	0.020
Days with precipitation	1.29	0.21	2.17	0.15	0.002
Total precipitation[b]	1.35	0.36	2.53	0.25	0.012

[a] In °C.

[b] Centimeters of precipitation.

less likely to be present with the hen at 21 days of age with each 1-day increase in the number of days of precipitation during week 1 (Fig. 2b). This model correctly classified 85% of the cases.

Habitat and weather conditions were different between 1999 and 2000. Almost 60 cm of precipitation fell during 1999, but only 39 cm fell during 2000. Because we wanted to obtain an average estimate of habitat use by scaled quail across a range of environmental conditions, we pooled data concerning nest location and success between years. Data were sufficiently complete to analyze 98 nests ($n = 45$ nests during 1999, and $n = 53$ nests during 2000).

The initial 2-step predictor variable-selection procedure indicated that cover board score from 0.5–0.75 m in available habitat and number of forb species in available habitat should be included in the initial (full) logistic regression analysis to predict nest success (Table 3). This full model ($\chi^2 = 15.09$, $P < 0.001$) accurately predicted 67.3% of the cases. Examination of the individual variables revealed that all were significant predictors of nest success (Table 4). Thus, in this case the full model [$g(x) = 0.274 - 0.340$ (forb species) $+ 1.45$ (cover board score at 0.5–0.75 m)] was not reduced. Nests were 4.34 times more likely to be successful with each 1-unit increase in the cover board score at the 0.5–0.75-m height of habitat surrounding nest sites (Fig. 2c), and 39% less likely to be successful with each additional forb species present in habitat surrounding nest sites (Fig. 2d).

The 2-step variable-selection procedure indicated that cover board scores of 0–0.25 m, 0.25–0.50 m, and 0.5–0.75 m; number of shrub, forb, and grass species; and percentage of bare ground should be included in the initial (full) logistic regression analysis to predict nest site location (Table 5). This full model ($\chi^2 = 166.24$, $P < 0.001$) accurately predicted 89.3% of the cases. Examination of individual covariates revealed that cover board score of 0.25–0.50 m and 0.5–0.75 m and number of grasses were not significant predictors of nest success (Table 6). The final model included cover board score from 0–0.25 m, number of shrubs and forbs, and percentage of bare ground as significant predictors of nest location (Table 6). The final model was $g(x) = -5.36 + 0.828$ (shrub species) $- 0.325$ (forb species) $+ 2.185$ (visual obstruction score at 0.0–0.25 m) $- 0.153$ (bare ground) and correctly classified 89.3% of the cases. Potential sites were 8.89 times more likely to be nest sites with each 1-unit increase in the cover board score at the 0.0–0.25 m height (Fig. 2e) and 2.29 times more likely to be a nest site with each additional shrub species present (Fig. 2f). Potential sites were 28% less likely to be nest sites with each additional forb species present (Fig. 2g), and 14% less likely to be nest sites with each 1% increase in bare ground (Fig. 2h).

Scaled quail appeared to nest in a variety of vegetative structure types depending on the ability of the available vegetation to provide visual obstruction. With the possible exception of yucca (*Yucca* spp.), scaled quail did not appear to select any particular plant species with which to associate their nests. Yucca was used as all or at least as a component of 33% of nests in 1999 and 35% in 2000. In addition to yucca, nests were associated with honey mesquite, shinoak (*Quercus havardii*), sand sagebrush, and catclaw acacia (*Acacia gregii*). Grasses that composed a large portion of nest sites included threeawns (*Aristida spp.*) and weeping lovegrass (*Eragrostis curvula*). It appears that scaled quail will use a variety of plant species for their nest sites if the appropriate visual obstruction is provided

Discussion

Hen Survival

Hen survival from mid-February through mid-August in our study is similar to reports from the other scaled quail telemetry studies in Texas (Rollins 2000, Lerich 2002). The greatest

Table 2. Relationships between weather conditions during the first 21 days posthatch of scaled quail broods and their survival to 21 days of age. Broods were monitored from 18 May to 29 August 1999 ($n = 21$) and from 19 May to 27 August 2000 ($n = 33$) in the Southern High Plains of Tex., USA.

Independent variable	***B*[a]**	**SE**	**χ^{2}[b]**	***P***	**Exp (*B*)[a]**	**Changes in correct classification[c]**
Recorded during 3 weeks						
Minimum temperature	0.143	0.19	0.602	0.438	1.15	1.9
Recorded during week 1						
Maximum temperature	1.247	0.45	14.83	<0.001	3.48	−16.6
Days with precipitation	−0.706	0.45	2.83	0.092	0.49	−9.2

[a] B = logicstic regression coefficient; Exp (B) = odds ratio.

[b] Value for likelihood-ratio test when variable was excluded from the full model containing all 3 variables.

[c] Percentage change in correct classification of cases when variable was excluded from the full model containing all 3 variables (full model correct classification = 83.3%).

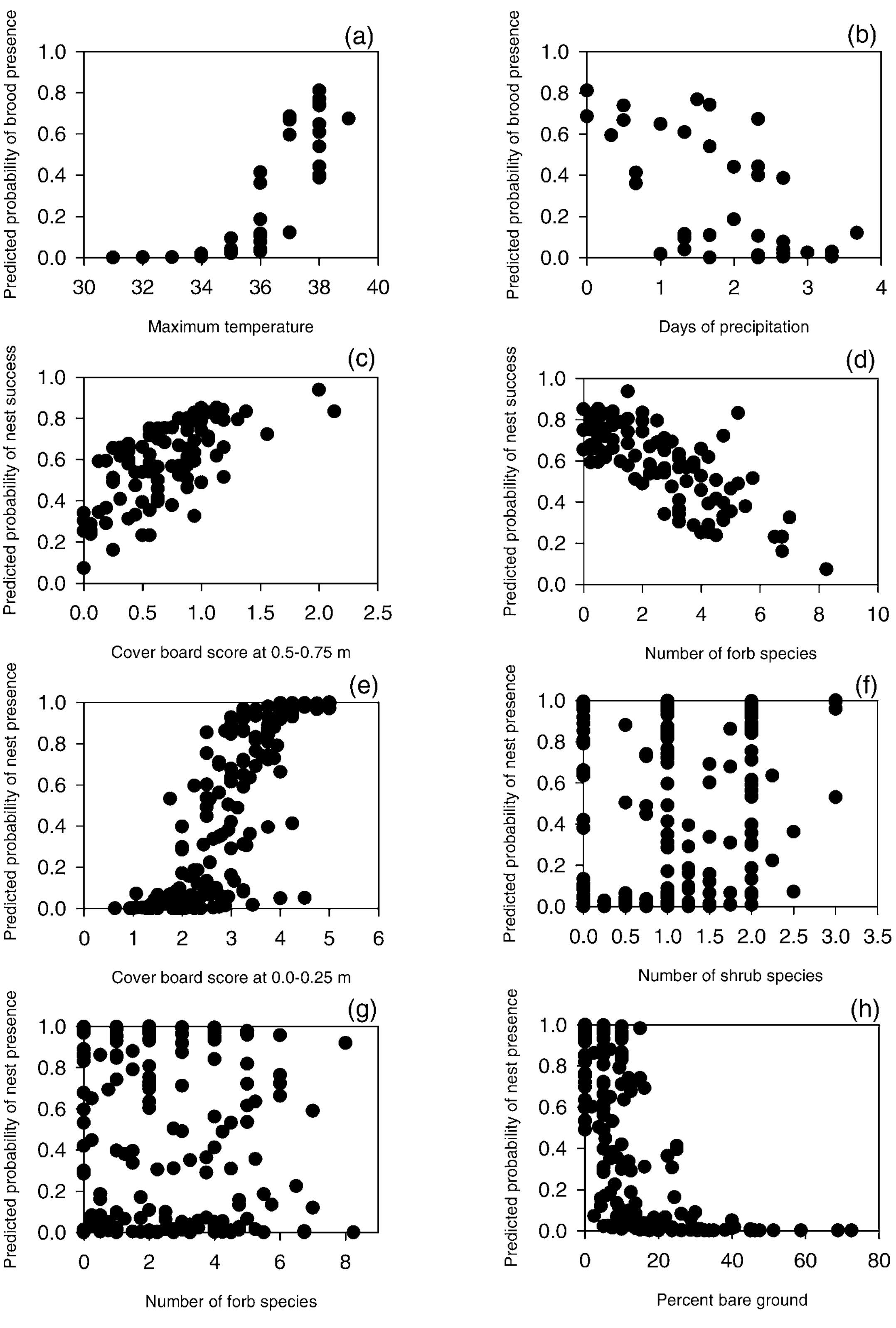

Figure 2. Scatter plots of weather and habitat characteristics in relation to the predicted probability of scaled quail brood presence, nest success, and nest location in the Southern High Plains of Tex., USA. (a) Maximum temperature and (b) number of days of precipitation during the first 7 days posthatch were significant predictors of the presence of scaled quail broods with the hen at 21 days posthatch. Broods were monitored from 18 May to 29 August 1999 and 19 May to 27 August 2000. (c) Visual obstruction and (d) the number of forb species present in the available habitat surrounding nests were significant predictors of scaled quail nest success. (e) Visual obstruction, (f) the number of shrub species, (g) the number of forb species, and (h) percentage of bare ground in the square meter centered on the nest were significant predictors of nest location. Nests were monitored from 18 May to 29 August 1999 and 19 May to 27 August 2000.</fig

difference in survival of scaled quail hens between years of the current study occurred during the nesting and brooding period. We believe differences in vegetative structure and composition between years provided more cover and food. This difference increased the number of potential nest sites and the quality of their concealment in 2000, leading to greater survival of incubating and brooding hens. Differences in vegetative structure were the result of substantial changes from the year before our study began through the end of the study. At the onset of this study, range conditions were poor. The study area only received 23.3 cm (63% of normal) of precipitation during 1998 (National Weather Service; www.weather.gov/climate/xmacis.pho?wfo=lub). Low precipitation combined with overuse by livestock had minimized available vegetative cover on much of

Table 3. Comparison of habitat characteristics measured in the square meter centered on the nest and in the available habitat surrounding nest sites that were associated with depredated nests ($n = 42$) vs. successful nests ($n = 56$) monitored from 18 May to 29 August 1999 and 19 May to 27 August 2000 in the Southern High Plains of Tex., USA. Available habitat characteristics were estimated by calculating the mean of variables measured in 4 1-m^2 quadrats located 10 m from the nest site in 4 different random directions. Parameter estimates for habitat characteristics are presented along with their corresponding P values for separate variance t-tests.

	Successful nests		**Depredated nests**		
Variable	**Mean**	**SE**	**Mean**	**SE**	***P***
Nest site					
Species richness[a]	6.78	0.38	7.02	0.53	0.717
Shrub species[b]	1.30	0.11	1.31	0.12	0.971
Grass species[b]	3.73	0.23	3.33	0.30	0.296
Forb species[b]	1.75	0.22	2.40	0.33	0.105
Canopy coverage[c]	89.64	2.53	93.69	2.01	0.214
Bare ground[d]	4.02	1.01	4.29	1.11	0.859
Cover board[e]					
0–0.25 m	3.75	0.11	3.81	0.13	0.710
0.25–0.5 m	2.29	0.11	2.32	0.15	0.530
0.5–0.75 m	1.11	0.06	1.09	0.14	0.885
0.75–1 m	0.59	0.06	0.44	0.09	0.165
1–1.25 m	0.19	0.05	0.11	0.04	0.190
1.25–1.5 m	0.05	0.03	0.01	0.01	0.132
Area around nest					
Species richness[a]	6.74	0.34	7.38	0.33	0.181
Shrub species[b]	0.96	0.09	1.05	0.11	0.527
Grass species[b]	4.19	0.22	4.03	0.24	0.629
Forb species[b]	2.30	0.24	3.39	0.29	0.005
Bare ground[d]	18.85	1.98	20.65	2.21	0.545
Cover board[e]					
0–0.25 m	2.35	0.10	2.15	0.13	0.207
0.25–0.5 m	1.34	0.06	1.17	0.09	0.123
0.5–0.75 m	0.77	0.06	0.56	0.06	0.009
0.75–1 m	0.38	0.05	0.25	0.05	0.063
1–1.25 m	0.13	0.03	0.08	0.03	0.234
1.25–1.5 m	0.07	0.03	0.03	0.02	0.311

[a] Number of all species present.
[b] Number of species for this specific grouping.
[c] Measured as a percentage of coverage of the actual nest only.
[d] Percentage.
[e] Score (range is 1–5) for intervals on the cover board.

our study site by 1999. Above-average rainfall (59.6 cm) in 1999 produced a tremendous forb response and increase in grasses. After a second season of adequate rainfall in 2000, vegetation was thicker, grasses were more abundant, and forb diversity had decreased from its high in 1999. These contrasts were apparent in vegetation characteristics measured in the area around each nest site and reflected in the rate of hen survival between years. Variations in scaled quail hen survival rates of 40% between years reported in this study suggest hen survival is one path by which the environment influences scaled quail population growth.

Nesting Success, Clutch Size, and Egg Hatchability

Nesting success was different between years of this study and could potentially affect population growth. The increases in cover and food, induced by 2 growing seasons with ample precipitation, produced a more favorable plant composition and structure and is likely responsible for the 20% difference in nesting success between years. Assuming a 13-egg clutch size, 95% egg hatchability, and 50% chick survival to 21 days of age, a 20% decrease in nest success would result in approximately 124 fewer chicks surviving to 21 days of age for every 100 nests that are initiated. Variations in scaled quail nesting success rates between years reported in this study suggest that, like hen survival, nesting success is also a path by which the environment influences scaled quail population growth.

In contrast to hen survival and nest success, clutch size and egg hatchability were highly stable. The mean clutch size and egg hatchability in our study are consistent with other published studies (Leopold 1959, Schemnitz 1961). It appears that, although changes in climatic conditions influenced available cover, and possibly food, scaled quail hens were not sufficiently physiologically affected to hamper egg laying or to alter egg composition. We assume that as long as a hen's body condition remains above some level of nutritional fitness these variables remain near constant. With no variation in these variables between years, it appears that clutch size and egg hatchability are unlikely pathways by which the environment could modulate the population growth of scaled quail.

Chick Survival

Greater chick survival in 2000 than in 1999 is consistent with the variations reported in hen survival and nest success in this study. Just as with hen survival and nest success, vegetative conditions appear to have been more favorable during the second year of this study for survival of chicks. Assuming a 13-egg clutch size and a 95% egg hatchability, a reduction from 50 to 10% chick survival to 21 days of age, as seen in our study, would result in approximately 494 fewer chicks surviving to 21 days of age per 100 successful nests. The dramatic variations in scaled quail chick survival rates reported between years in this study suggest chick survival is also a path by which the environment influences scaled quail population growth.

Table 4. Relationships between habitat characteristics measured in the square meter centered on the nest and in the available habitat surrounding nest sites and the nest success. Nests were monitored from 18 May to 29 August 1999 and 19 May to 27 August 2000 in the Southern High Plains of Tex., USA.

Independent variable	***B*[a]**	**SE**	**χ^{2b}**	***P***	**Exp(*B*)[a]**	**Changes in correct classification[c]**
Area around the nest						
Forb species	–0.340	0.12	8.322	0.004	0.72	–9.1
Cover board score						
0.5–0.75	1.467	0.60	6.929	0.009	4.34	–5.1

[a] B = Logicstic Regression Coefficient; Exp (B) = odds ratio..
[b] Value for likelihood-ratio test when variable was excluded from the full model containing all 3 variables.
[c] Percentage change in correct classification of cases when variable was excluded from the full model containing all 3 variables (full model correct classification = 67.3%).

Table 5. Comparison of habitat characteristics measured in the square meter centered on the nest, with characteristics of the available habitat surrounding nest sites. Nests were monitored from 18 May to 29 August 1999 ($n = 45$) and from 19 May to 27 August 2000 ($n = 53$) in the Southern High Plains of Tex., USA. Available habitat characteristics were estimated by calculating the mean of variables measured in 4 1-m^2 quadrats located 10 m from the nest site in 4 different random directions. Parameter estimates for habitat characteristics are presented along with their corresponding P values for separate variance t-tests.

Variable	Nest site		Available		P
	Mean	SE	Mean	SE	
Species richness[a]	6.89	0.31	7.02	0.24	0.748
Shrub species[b]	1.31	0.08	0.99	0.07	0.004
Grass species[b]	3.56	0.18	4.12	0.16	0.024
Forb species[b]	2.03	0.19	2.77	0.19	0.007
Bare ground[c]	4.13	0.74	19.62	1.47	<0.001
Cover board[d]					
0–0.25 m	3.77	0.08	2.27	0.08	<0.001
0.25–0.5 m	2.26	0.09	1.27	0.05	<0.001
0.5–0.7 5m	1.10	0.07	0.68	0.04	<0.001
0.75–1 m	0.53	0.05	0.32	0.03	0.001
1–1.25 m	0.15	0.03	0.11	0.02	0.236
1.25–1.5 m	0.04	0.02	0.05	0.02	0.445

[a] Number of all species present.
[b] Number of species for this specific grouping.
[c] Percentage.
[d] Score (range is 1–5) for intervals on the cover board.

Evans and Schemnitz (2000) believed that multiple days of elevated temperature (>38°C) was the probable cause for chick mortality observed in their study during 1994. In contrast, higher temperatures during the first week posthatch and survival of scaled quail chicks were positively related in this study. This relationship is intuitive as the maximum temperature recorded while chicks were present (38.89°C) is within a degree of the temperature at which artificial brooders are maintained for the first week of life of captive-raised quail (Dozier et al. 2002). Differences in the relationship between survival and maximum temperature between this study and that of Evans and Schemnitz (2000) are unclear but are likely related to higher maximum temperature during week 1 in southern New Mexico. Multiple days of precipitation during week 1 suggest a negative influence on the likelihood that chicks would be present with the hen at 21 days. This relationship combined with the influence of maximum temperature could imply that cool wet periods during week 1 caused mortality of scaled quail chicks.

Cool wet periods have been linked with mortality of California quail (*Lophortyx californicus*) chicks. Savage (1974) reported a negative relationship between subadult birds in autumn and the amount of precipitation occurring during the previous June. Sumner (1935) suggested chicks become chilled when rainfall occurs during their early development. Raitt and Genelly (1964) reported a negative relationship between June and July precipitation and a measure of chick production. However, these relationships and the relationship described in our study have not been experimentally tested. An alternative hypothesis is that cool, wet periods delay plant and insect growth, which reduces chick survival. Clearly, chick survival can be highly variable among years and is affected by weather patterns. Future research efforts should be designed to delineate the effects of weather on chick survival.

Successful Versus Depredated Nests

The fact that no nest site characteristics differed between depredated and successful nests suggests that scaled quail nests that are depredated and those that are successful are structured the same. Factors other than nest site structure may influence nest success. Patch size, which predators must search for nests within, appears to influence nest success (Burhans and Thompson 1999, Hoover et al. 1995). Larger patches lead to greater nest success because predators have a larger area to search through than in smaller patches. The area around nest sites must be related to nest success for patch size to be of influence on scaled quail in our setting. Although they were not highly predictive, 2 such variables were related to nest success. The positive relationship between visual obstruction at the 0.5–0.75-m height in areas around the nest and nest success illustrate the importance of having sufficient cover in areas surrounding the nest. The negative relationship between the number of forb species at the nest and nest success is not likely a cause-and-effect relationship but is a result of a negative correlation between dense grass cover and the number of forb species present.

Nest-Site Selection

Scaled quail selected nest sites with greater visual obstruction, less bare ground, the presence of more shrub species, and fewer forb

Table 6. Relationships among habitat characteristics of the nest site and nest site location. Nests were monitored from 18 May to 29 August 1999 and 19 May to 27 August 2000 in the Southern High Plains of Tex., USA.

Independent variable	B[a]	SE	χ^{2b}	P	Exp(B)[a]	Changes in correct classification[c]
Shrub species	0.835	0.39	4.99	0.026	2.31	−1.5
Grass species	−0.310	0.17	0.03	0.854	0.97	−0.5
Forb species	−0.300	0.14	4.83	0.028	0.74	−1.0
Bare ground	−0.160	0.04	38.01	<0.001	0.85	−7.7
Cover board score						
0.0–0.25 m	2.231	0.50	31.06	<0.001	9.31	−2.0
0.25–0.5 m	0.246	0.65	0.15	0.703	1.28	0.0
0.5–0.75 m	−0.683	0.73	0.88	0.348	0.51	−0.5

[a] B = Logicstic Regression Coefficient; Exp (B) = odds ratio..
[b] Value for likelihood-ratio test when variable was excluded from the full model containing all 3 variables.
[c] Percentage change in correct classification of cases when variable was excluded from the full model containing all 3 variables (full model correct classification = 89.8%).

species relative to the available habitat surrounding nest sites. Visual obstruction greater than 1 m in height did not influence scaled quail nest site selection. It is intuitive that scaled quail would seek areas of high visual obstruction and a low percentage of bare ground within which to place their nest sites. As before, we believe the negative relationship between the number of forb species at the nest and nest location is not likely a cause-and-effect relationship but a result of a negative correlation between dense grass cover and the number of forb species present.

The importance of shrubs is less clear. Shrubs could be important because they function to protect grasses from grazing. Morphological characteristics of shrubs, cacti, and half-shrubs (i.e., thorns, spines, and dense or low-growing branches) may provide a protective mechanism that reduces the probability of defoliation of associated herbaceous plants (Vallentine 1990). Thus, scaled quail may not actually be selecting for shrub presence directly, but for the protection from grazing pressure that several shrubs together in a square meter would offer to grasses. Alternatively, some shrubs offer significant visual obstruction. It is possible that shrubs are related to scaled quail nest sites for some attribute other than protection of grass cover. For instance, scaled quail hens may select shrub presence because shrubs provide some important microclimate feature, such as reduced temperature due to increased shade.

Management Implications

Vegetation composition and diversity identified as significant in this study could be used for setting management goals and strategies. Management strategies to provide sufficient nesting cover 0.75-m high would be the most economical and practical tool a landowner could use. Vegetation structure, plant-species composition, and spatial arrangement of these habitat components seem to have a profound effect on the reproductive success and survival of scaled quail populations. Finally, individual land managers interested in scaled quail populations should consider reducing stocking rates early in the drought cycle, especially if the rangeland has a history of overuse. Amount and timing of precipitation ultimately influences overall nesting success and annual production. However, without optimum range conditions existing when timely rainfall occurs, maximum benefits to this species cannot be realized in terms of annual scaled quail numbers.

More research is needed concerning the reproductive ecology of this species. A cause-specific investigation into chick mortality is needed, including availability of foods. Continued investigation of characteristics of successful versus unsuccessful nests might help identify more specific habitat-management strategies.

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