Summer Habitat Relationships of Northern Bobwhite in Piedmont Virginia

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Abstract: We examined the relationships of northern bobwhite (*Colinus virginianus*) to agricultural land uses in the Virginia Piedmont during 1986–1987. Bobwhite were censused and the associated habitat components quantified at 121 roadside census stations. Relative quail densities decreased ($P < 0.05$) from 1986 to 1987. A multiple regression model ($R^2 = 0.43$) relating relative density of quail at stations to adjacent habitat found positive ($P < 0.10$) relationships for fallow croplands and other miscellaneous, uncommon cover types, and negative ($P < 0.10$) relationships for mown lawns and 3 variables describing dense, woody canopies. Management recommendations are to emphasize maximizing the number of different edges present and number of fallow fields in early successional stages. Cultivation of field borders and corners, waterways, and other idle areas should be discouraged.

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The northern bobwhite is an important game species throughout the Southeast. However, the quail population in the Piedmont has declined for several years. Quail call counts conducted by the Virginia Department of Game and Inland Fisheries (VDGIF) indicate a 55% reduction in the number of males heard calling during the period 1982 to 1986 (from 59.4 per transect to 26.8 per transect). Over the same period, the number of quail bagged per hunter hour also decreased by approximately 35% (0.61 quail bagged per hunter hour to 0.40 quail bagged per hunter hour) (VDGIF 1986).

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Agricultural land-use patterns also have changed. For example, land standing idle or in soil improvement programs declined by 75% from 1940 to 1982 (Virginia Crop Reporting Service 1982). Changes in agricultural practices, including an increase in "clean" farming which has a detrimental effect on the wildlife resource, are not a recent phenomenon. Goodrum (1949) found "clean" farming to be the main cause of a nationwide decline in bobwhite populations during the period 1939 to 1948. Vance (1976) compared changes in land use in a predominantly agricultural region of southeastern Illinois between 1939 and 1974 and found an 84% reduction in brushy fencerows and a 100% loss of grasslands. Coupled with this habitat loss, bobwhite populations in the same region of Illinois declined 71% over the 25-year period (Ill. Wildl. Habitat Comm. Rep. 1984–1985).

The decline in farmland habitat and the reduction in quail numbers has generated a need for research exploring the current habitat use patterns of bobwhite to provide information useful in guiding future management. Thus, our objectives were to describe and relate current land-use patterns on farmland in Piedmont Virginia to relative abundances of bobwhite and to develop management recommendations to enhance habitat on farmlands for bobwhite.

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Methods

Study Area

The study was conducted on a 23,000-ha area in southwestern Halifax County, Virginia. The topography consists of a gently rolling plateau dissected by many small streams, with elevations ranging from approximately 90 to 180 m. Mean daily temperatures range from 3C in January to 26C in July. Annual precipitation averages 107 cm and is evenly distributed throughout the year (Va. Crop Rep. Serv. 1982).

Typical woodland trees found on the study area include oak (*Quercus spp.*), yellow poplar (*Liriodendron tulipifera*), hickory (*Carya spp.*), ash (*Fraxinus spp.*), sweetgum (*Liquidambar styraciflua*), loblolly pine (*Pinus taeda*), Virginia pine (*P. virginiana*), dogwood (*Cornus spp.*), black cherry (*Prunus serotina*), and sassafras (*Sassafras albidum*).

Halifax County is one of the most intensely farmed counties in Virginia. The 1982 agricultural census reported 1,652 farms, encompassing 103,742 ha of the county's total area of 207,465 ha. The majority of the remaining area was composed primarily of commercial woodlands. Pasture of all types totalled 15,852 ha. Cropland encompassed 27,733 ha, with corn (3,784 ha), wheat (3,507 ha), tobacco (3,824 ha), soybeans (3,750 ha), and hay (3,936 ha) occurring in relatively even proportions.

Woodlands, including those pastured, account for 51,797 ha (U.S. Dep. Comm. 1984). Pastures and crop fields ranged in size from <2 to >40 ha, and were cultivated using conventional, minimum-till, and no-till methods. Cultivated areas were interspersed among numerous woodlots, ponds, and other nonfarmed areas.

Censusing

We established 10 census routes along roads, each 8 to 10 km in length (totalling 96.8 km) distributed so that the habitat diversity encountered was maximized. Ten to 13 listening stations (121 total) were established at 0.8 km intervals along each transect (Rosene 1969). Using 400 m as the estimated maximum distance the bobwhite call can be detected under most conditions (Rosene 1969), this interval sampled a 50.2 ha area at each station. The number of individual birds heard calling at least once during a 10-minute listening period at each station was recorded.

Censuses were conducted from mid-April through July 1986 and 1987. Censuses began at sunrise and were completed within 2.5 hours. Direction of travel along the routes was alternated on consecutive visits. No censusing was conducted in rain or when the wind velocity exceeded 10 km/hour.

We calculated the mean number of quail recorded per station for each census run (1986 runs = 9, 1987 runs = 7). After inspecting the variance in index values for each run, we eliminated runs 1, 2, and 9 from the 1986 data and runs 1 and 2 from 1987, for which variance was high. This eliminated the periods when quail were only beginning to call and the time after the peak calling season when vocalizations were declining. The mean number of quail per station was transformed using natural logarithms to normalize distributions. We used paired *t*-tests to compare the mean number of birds per station between 1986 and 1987.

Habitat Analysis

The 50.2-ha area surrounding each road transect listening station was cover mapped each of the 2 field seasons. Cover types were classified broadly as crop, pasture, wooded pasture, road, pond, hedge, yard, forest, or other. The crop category was further subdivided into specific crop types. Forests were categorized based on their stocking densities for 3 size classes (saplings, trees <10 cm dbh; poles, trees 10-25 cm dbh; and logs, trees >25 cm dbh). Broad forest categories based on canopy densities also were identified: forests containing only saplings (locan); forests with saplings and poles (medcan); and stands with a sapling, pole, and log size trees represented (hican). The area of each cover type within each sampling unit was measured using a computerized planimeter program.

Lengths of all edges, defined as the junction of 2 or more different cover types, were determined and classified based on the components composing the individual edge. Only those edge combinations occurring ≥20 times over the study area were analyzed as separate edge variables. All edge variables occurring <20 times were classified as edge variable "other."

We first categorized habitat variables as crop, forest, and edge variables for model development (Table 1). We used a stepwise multiple linear regression proce-

Table 1. Descriptions of cover variables measured for 50.2-ha plots to which relative quail densities showed significant relationships in Halifax County, Virginia, 1987–87.

Variable	Description
Crop	
Grain	% of area in primarily wheat, oats, and barley
Fallow	% of area in uncultivated crop field
Other crops	% of area in other crops (broccoli, sorghum, and sudan grass)
Yard1	% of area in mown lawns
Other	% of area in utility rights-of-way, cemetaries, etc.
Forest types	
S25	% of area forested with medium stocked saplings; light, medium, or densely stocked pole size trees
S5	% of area forested with light, medium, or densely stocked pole size trees
S147	% of area forested with lightly stocked saplings, light or medium stocked poles, lightly stocked log size trees
S257	% of area forested with medium stocked saplings, light or medium stocked poles, and lightly stocked log size trees

dure (SAS Inst. 1985) to determine which variables within each class explained a significant ($P < 0.1$) amount of the variation in the mean quail index for the 2 years combined. Variables from the 3 categories exhibiting a correlation $>|0.1|$ with relative quail abundance were combined and analyzed with stepwise multiple linear regression to develop a model relating relative quail abundance to habitat characteristics.

The models were evaluated by assessing the R^2 value adjusted for the number of parameters in the model, which indicates the fit of the model to the data used for development. We also evaluated the R^2_{PRESS}, which indicates the predictive ability of the model. When R^2_{PRESS} is substantially lower than R^2, the predictive ability of the model would be low.

A model also was developed for broad cover categories. The 3 major classes for forests (locan, medcan, and hican) were analyzed along with the category crop and the proportion of area identified by the variables ponds, pastures, wooded pastures, roads, short grass yards (mown or bush hogged), tall grass yards, and "others."

Results

Call Count Census

In 1987, we recorded fewer quail per census station per run ($\bar{x} = 0.82$) than in 1986 ($\bar{x} = 1.31$, $P < 0.001$). We believe drought conditions in 1986 may have had a detrimental effect on quail production and cover composition on the study area, reducing quail numbers in 1987 (Cline 1988).

Habitat Models

Crop Variables.—Grain was the only agricultural crop that had a significant relationship to bobwhite densities (Table 2). The adjusted R^2 for this class of variables was low, but significant.

Forest Variables.—Relative densities of quail had a negative relationship with 4 forest variables: S5, S25, S147, and S257 (Table 2). The model of forest variables produced a relatively high adjusted R^2 value (0.25), although the R^2_{PRESS} (0.09) was relatively low.

Edge Variables.—Relative densities of bobwhites were related to 6 variables describing specific edge combinations (Table 2). An additional significant variable, "other edges," was a composite variable composed of all edges that did not occur >20 times in either of the 2 field seasons. This category is composed of about 13% (N = 995) of all edges measured.

Relative quail densities were positively related to the amount of road/pasture edge, road/fallow field edge, crop/crop edge, and the total amount of miscellaneous "other" edges (Table 2). Road/tall yard edge and short yard/crop edge appeared to have a negative effect on relative quail densities. Compared to the other 3 classes

Table 2. Significant predictor variables resulting from a stepwise multiple linear regression relating relative quail densities (N of birds/run) at 121 sampling stations to crop, forest, and edge variables in Halifax County, Virginia, 1986–1987.

Variable set	Predictor variable	Regression coefficient[a]	SE	Contribution to R^2	t	P[b]
Crop	Grain	4.522	1.357	0.085	3.33	0.001
	Adjusted R^2 = 0.078		$F_{1,119}$ = 11.10		P = 0.001	
	R^2_{PRESS} = 0.055					
Forest	S5	−6.114	1.372	0.113	−4.48	<0.001
	S147	−1.744	0.411	0.073	−4.24	<0.001
	S257	−1.188	0.372	0.065	−3.20	0.002
	S25	−2.575	1.334	0.023	−1.93	0.056
	Adjusted R^2 = 0.250		$F_{4,116}$ = 10.98		P = 0.001	
	R^2_{PRESS} = 0.094					
Edge	Road/pasture	4.8	1.0	0.081	4.96	<0.001
	Road/fallow	5.4	1.7	0.056	3.24	0.002
	Road/tall yard	−12.0	5.3	0.034	−2.28	0.025
	Crop/crop	4.2	1.3	0.072	3.17	0.002
	Crop/forest	1.2	0.5	0.031	2.51	0.014
	Short yard/crop	−3.4	2.0	0.017	−1.67	0.097
	Other edges	1.0	0.6	0.019	1.76	0.080
	Adjusted R^2 = 0.26		$F_{7,113}$ = 7.20		$P \leq 0.001$	
	R^2_{PRESS} = 0.20					

[a]Regression coefficient and SE values are X 10^4.
[b]Represents significance of the variable as a predictor in the model.
[c]Represents the porportion of variation in relative quail densities explained by the predictor variables, adjusted for sample size and number of factors in the model.
[d]F-statistic and associated significance for the model.
[e]R^2 of prediction derived from PRESS statistic for each model.

of variables examined, edge factors accounted for the highest amount of variation in relative quail abundance (adjusted $R^2 = 0.27$, $P < 0.001$). The R^2_{PRESS} statistic of 0.201 indicates this model had good predictive power relative to the other models.

Combination of Crop, Forest, and Edge Variables.—When variables with a correlation coefficient of $>|0.1|$ were analyzed using stepwise regression (Table 3), 5 cover type variables contributed significantly to the model. The fit of this model, as indicated by the adjusted R^2 (0.43), was higher than that of any of the individual variable-class models, and predictive power was relatively good ($R^2_{PRESS} = 0.37$).

General Classes of Cover Variables.—In a model developed from broad categories of cover, woodlands with dense overstory had a negative ($P < 0.001$) effect on the number of birds recorded (Table 4), as did the amount of mown lawns present ($P = 0.01$). Conversely, the proportion of land composed of miscellaneous "other" covers had a positive influence on bird densities ($P = 0.07$). A comparison of the adjusted R^2 (0.28) and the R^2_{PRESS} (0.25) indicates that this model possessed relatively good predictive power.

Discussion

A basic assumption when using relative quail abundance as the response variable in regressions is that population densities are linked to measurable habitat characteristics that reflect habitat quality. This approach is not without peril. Van Horne (1983) emphasized the need to consider factors that may result in high densities of individuals in low-quality habitats, or low densities in high-quality habitats. In this study, low rainfall in April through July 1986 (33% below normal, (Va. Agric. Stat. Serv. 1987) may have exerted an influence on habitat use by quail. This drought

Table 3. Significant predictor variables resulting from a stepwise multiple linear regression of relative quail densities (*N* birds/run) at 121 sampling stations on variables representing specific crop and forest types and lengths of specific edge types combined in Halifax County, Virginia, 1986–1987.

Predictor variable	Regression coefficient	SE	Contribution to R^2	t	P[a]
S5	−5.31341	1.19130	0.114	−4.46	<0.001
S147	−1.28753	0.20576	0.137	−6.26	<0.001
S257	−0.88034	0.19462	0.098	−4.52	<0.001
Yard1	−2.77635	0.96676	0.036	−2.87	0.005
Fallow	1.54902	0.43738	0.039	3.53	0.001
Other	3.65960	1.46649	0.030	2.50	0.014
Adjusted $R^2 = 0.43$[b]		$F_{6,114} = 15.80$[c]		$P \leq 0.001$	
$R^2_{PRESS} = 0.371$[d]					

[a]Represents significance of the variable as a predictor in the model.
[b]Represents the proportion of variation in relative quail densities explained by the predictor variables, adjusted for sample size and number of factors in the model.
[c]F-statistic and associated significance for the model.
[d]R^2 of prediction derived from PRESS statistic for each model.

Table 4. Significant predictor variables resulting from a stepwise multiple linear regression relating relative quail densities (*N* birds/run) at 121 sampling stations to percent cover of general classes of cover type variables in Halifax County, Virginia, 1986–1987.

Predictor variable	Regression coefficient	SE	Contribution to R^2	t	P[a]
Forest with 3 canopy layers	−1.1389	0.1815	0.239	−6.27	<0.001
Yard1	−2.6882	1.0544	0.037	−2.55	0.012
Other cover	2.9686	1.6418	0.020	1.81	0.073
Adjusted R^2 = 0.278[b]		$F_{3,117}$ = 16.41[c]		$P \leq 0.001$	
R^2_{PRESS} = 0.246[d]					

[a]Represents significance of the variable as a predictor in the model.
[b]Represents the proportion of variation in relative quail densities explained by the predictor variables, adjusted for sample size and number of factors in the model.
[c]F-statistic and associated significance for the model.
[d]R^2 of prediction derived from PRESS statistic for each model.

may have reduced survival of quail that summer, reducing the number of birds heard in 1987 (Stoddard 1931, Rosene 1969 and others). Further, the paucity of precipitation may have affected vegetation detrimentally, influencing habitat use (Stoddard 1931, Reid and Goodrum 1960). Thus, these models represent habitat use patterns by bobwhite under drought conditions during the spring and summer. Extrapolation of our results to other seasons would not be warranted.

The appearance of the variable grain in the crop model may be a result of temporal relationships. Much of the wheat was harvested in June, coinciding with the period when the greatest number of quail were heard calling. Thus, an abundance of waste grain may have been temporarily attracting the birds.

Forest variables accounted for approximately 25% of the variation in relative quail density. All 4 of the variables identified in this analysis displayed a strong negative influence on bird numbers. The forest cover represented by S5 was composed almost exclusively of loblolly pine >10 years old. These sites were densely planted (standard rate is 1606 trees/ha, Landers and Mueller 1986) and were about 5–10 m in height with little understory vegetation. These artificial plantings of pines provide little food or ground cover for quail (Rosene 1969).

The S147 and S257 forest types were very common on the study area, together composing 83% of the wooded cover types and 16% of the total censused area. Because of the 3 canopy layers characteristic of these forests, scant sunlight penetrates to the forest floor. We observed little or no herbaceous vegetation on the forest floor, providing minimal food for bobwhite. A similar lack of ground vegetation also occurred on the S25 cover type.

Edges composed of either short yards (lawns) or tall yards (>15-cm height) were avoided by the birds. An avoidance of these "developed" areas is likely not the result of the bird's aversion to the physical and floristic properties of the yards per se, but to the presence of predators and frequent disturbance associated with developed areas.

Road-to-pasture edges typically were characterized by fences grown up with brush, small trees, and species of herbaceous vegetation not found in the pasture. These narrow edges may provide quail with food and possibly nesting locations (Landers and Mueller 1986) as well as perches for whistling males. Road/fallow field edges are probably important because of the fallow field component. These fallow areas, depending on their age, and therefore their floral composition, may be providing food, roosting, and nesting sites.

The proximity of roads to cover already attractive to quail may have had an effect on the significance of variables representing combinations of road edges. Stoddard (1931) noted that bobwhite show a marked partiality for nesting near roads, paths, edges of fields, and similar open situations. Rosene (1969) observed a similar situation, stating that "nest coverts most used are those alongside openings such as fields, disked strips, roadways, or paths." In addition, the locations of calling cocks have been positively related to the locations of nesting sites (Klimstra 1950, Johnsgard 1973). Thus, the relationship of road/fallow field and road/pasture edges with relative quail density may be indicative of the birds' use of these cover types juxtaposed with roadways as nesting habitat. An increase in crop/crop edge is indicative of increasing crop heterogeneity and small field size within a delineated area. The narrow strips between crops may have been attractive to bobwhite, contributing to the significance of this variable.

Rosene (1969) discussed in depth what he termed "the transition band," a narrow strip of land between a cultivated field and a woodland containing annual and perennial plants beneficial to bobwhite as food and cover. The positive relationship between bird densities and crop/forest edge may be the result of the bobwhite's affinity for these transition bands. The herbaceous vegetation that occurs in these strips likely provides nesting habitat, and the diverse vegetation found around and within these strips creates an environment conducive to a wide variety of insects and seed-producing plants (Rosene 1969).

We have observed that situations where crops have been planted to the edge of the trees are more common than cases where a transition band separated the cultivated field from the woodland. There often is a flush of herbaceous growth along the forest edge just inside the trees. Perhaps the presence of even a limited amount of this transitory cover has a significant effect on bobwhite utilization of the area.

Hanson and Miller (1961) found that an increase in the amount of general edge did not necessarily lead to an increase in quail numbers. They postulated that edge types attractive to bobwhite were in the minority. This supposition was reinforced when our analysis of indices did not find an increase in total edge to be significantly related to quail numbers. It is possible that the composite of edges contained in the "other" variable may contain specific edges having a strong effect on the number of birds associated with these areas.

The model developed using all the crop, forest, and edge variables showed that cover variables had a substantial effect on the relative density of bobwhite (Table 3). A strong negative relationship existed between relative quail density and the proportion of cover composed of S5, S147, and S257 type forests. This reaffirms the contention that these densely wooded areas are of limited value to the bobwhite during spring and summer. Mown yards again appeared as a cover type having little to offer quail as habitat.

Although fallow areas were not found to be significant in the analysis of crop variables, they were significant when combined with variables from the other 2 classes. All the fallow fields we encountered had been out of cultivation <2 years, thus providing nearly ideal ground cover for bobwhite (Rosene 1969). Apparently, the interaction of fallow cover with the forest variables S5, S147, and S257 contributed to its value as quail habitat.

The cover variable "other" consisted primarily of small family cemeteries and utility rights-of-way. These coverts form islands and corridors of grasses, forbs, and honeysuckle, providing additional bobwhite habitat, especially in wooded areas.

With the exception of the fallow cover type, the analysis of the general cover classes reflected the previous combined analysis (Table 4). The 3 canopy layer forest variable is an amalgamation that included the S5, S147, and S257 cover types. The adjusted R^2 (0.28) of the cover-only model, when compared to that produced by the combination model (0.43), indicated that cover composition is an important factor influencing relative densities of quail in spring and summer. The proportion of mature forest is by far the most influential habitat characteristic.

Abiotic factors comprise a significant part of the habitat of wildlife (Giles 1978). The effects of soil type and moisture regime, microclimate, agricultural chemical use, hunting pressure, and other abiotic variables may be having a profound effect on bobwhite distribution. An analysis of these variables might be useful in accounting for portions of the variance associated with quail densities.

A portion of the unexplained variance in quail numbers may be the result of our use of spring whistle counts as a means of indexing population levels. Because a host of factors can potentially influence whistle counts as well as other auditory indices, researchers often have questioned their utility (Norton et al. 1961, Rappole and Waggerman 1986, Demaso 1991). In addition to limits to accuracy imposed by differences in the density of vegetation across sites sampled, successful application of this index requires that several assumptions be met. First, the rate at which males whistle must be constant both on a temporal, as well as a spatial scale. Additionally, one must also assume that calling intensity is constant for a given whistling bout. Finally, problems with distinguishing individual males are also likely as the number of males calling approaches the point where calling is nearly continuous.

Although some unexplained variance may be attributable to problems associated with sampling various habitat types, we feel our large sample size (N = 121) may help to minimize these effects. Temporal and spatial effects should be minimal; counts made prior to and after the peak of breeding were not used. Because of the relatively small size of the study area, any spatial effects that may have influenced calling should have been constant across the study area. Because no more than 4–5 quail were ever recorded at a given station, double counting and under counting probably were not a big problem.

Recognizing these limitations, and considering that we were sampling only a portion of the population, we feel that the manner in which our counts were used was reasonable. Improvements in R^2 values may come not by abandoning whistle counts for alternative estimates, but by altering the analytical approach.

Grouping of certain variables to simplify analysis may have masked some of the important habitat components. Because of the specific level of cover mapping we used, a large number of variables with very low frequencies of occurrence were produced. To produce a smaller, more analytically useful set of variables, the cover types and edge compositions exhibiting minimal differences were lumped together into more general classes. This was based on grouping cover types with closely related structural characteristics. The hazard is that these structural characteristics were those that appeared similar from a human perspective. It is possible that we failed to classify the habitat in a way analogous to how the quail perceived it.

Management Implications

Good bobwhite range can be identified by the presence of 3 distinct habitat characteristics. First, the vegetation will be in an early stage of plant succession. Secondly, the area's vegetation will be highly diverse, with a large amount of edge present. Finally, cover found on good quail range will be open at ground level, affording the birds protection while allowing them easy walking, feeding, and escape (McInteer 1986). All management recommendations are aimed at providing or enhancing these 3 factors.

The value of early successional vegetation to bobwhite was illustrated in our results in 2 ways. First, we found a negative relationship between the relative density of quail and the proportion of cover composed of mature woodlands. Unless the canopy of these forests is opened by drastic thinning or a timber harvest, little more than the edge of these woodlands will be used by bobwhite (Rosene 1969, Landers and Mueller 1986). Management resources would be better spent on lands with greater suitability for bobwhite.

The importance of early successional vegetation also was illustrated by the significance of fallow cover in the models. Fields left fallow are important sources of food and nesting cover for bobwhite. These areas are of optimal value with respect to food and cover when they are between 3 and 10 years post-cultivation (Schroeder 1985). It is during this time period that leguminous plants may dominate these fields and 30%–60% of the ground remains bare, allowing the birds to use the area efficiently. Managers should strive to maintain these and other idle areas in about this stage of succession through the judicious use of mowing, disking, and burning.

An abundance of suitable edge is an important ingredient of good quail habitat. We found a number of particular edge combinations contributing significantly to the variation in quail densities we encountered on our sampling areas. Efforts should be made to maximize the number of preferred edges available to bobwhite; this is best accomplished by maximizing cover diversity. One way to do this on agricultural lands is to minimize the acreage of individual fields. A large number of small fields, each with a fallow or brushy border, is better than the same acreage encompassed in only a few fields. The disadvantage of increased time spent transporting equipment between fields can be partially overcome by linking smaller fields together with strips of the same crop (Landers and Mueller 1986). Landowners should be discouraged from cultivating field corners, waterways, and other idle areas. These odd areas add needed habitat diversity.

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