Habitat Relationships Of Bobwhite Quail And Cottontail Rabbits

On Agricultural Lands In Halifax County, Virginia

by

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(ABSTRACT)

I examined the relationships of quail and rabbits to agricultural landuses in the Virginia Piedmont during 1986-1987. Bobwhites and cottontails were censused and the associated habitat components quantified at 2 scales: macro-scale at 121 road transect stations, and a micro-scale at 87 foot transect stations. Additionally, the quail's immediate habitat was measured using variables found in the HSI model for northern bobwhite.

The paucity of rabbit sightings prevented an analysis of habitat relationships for this species. Relative quail densities decreased from 1986 to 1987 along both road and foot transects ($P<0.05$).

A model ($R^2 = 0.374$) relating relative density of quail at stations to adjacent habitat found positive ($P<0.10$) relationships for crop/crop, road/pasture, road/fallow, and "other" edges and negative ($P<0.10$) relationships for road/tall grass yard edge and 3 variables describing dense overstory canopies. The presence/absence of quail at foot transect stations was related to habitat characteristics using logistic regression. Wooded fallow fields, the length (m) of pasture/fallow and forest/forest edges, and the total number of all edges present were positively related to quail presence ($P<0.001$). Analysis of quail-centered plots indicated quail preferred areas with more woody cover, less grass composing the herbaceous canopy, more bare ground or light litter (<2 cm deep), and more honeysuckle canopy than was randomly available ($P<0.05$).

Management recommendations are to emphasize maximizing the number of different edges present, especially the combinations highlighted by this analysis. Efforts should be

made to maximize the number of fallow fields in early successional stages. Cultivation of field borders and corners, waterways, and other idle areas should be discouraged.

Acknowledgements

It is impossible to succeed in graduate school without the help of other graduate students. I owe a debt of gratitude to all the fisheries and wildlife graduate students at Virginia Tech, both those here now and those that left before me, for all the advice, encouragement, and positive distraction they have provided. I owe a special thanks to the people with whom I shared an office during the months I spent writing my thesis. So to Steve Martin, Sue Bruenderman, Betsy Stinson, Becky Wajda, Fay Cotton, and Scott Smith: "Thanks ya'll!".

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All the landowners I encountered during the course of my work in Halifax County were, without exception, friendly and cooperative. Without their help this project could not have succeeded. A very special thanks to the Bane, Geisinger, and Owen clans for making me feel a part of their extended family.

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Finally, the people to whom I owe the most thanks are my family. A heartfelt thanks to my mother and father, who no longer have to endure the question: "When is that boy of yours going to finish school?". A very special thanks to my wife Dolores and my children Jessie and Mike. Without their sacrifice, encouragement, and love I could never have earned this degree.

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Introduction

Bobwhite quail (*Colinus virginianus*) and cottontail rabbits (*Silvilagus floridanus*) are 2 important small game species endemic to the Piedmont region of Virginia. Both animals have long been a subject of ardent interest to Virginia sportsmen. Mention "birds" to nearly any hunter or landowner in southern Virginia, and it's understood that you're discussing bobwhite, Birds with a capital "B". The popularity of "Bob White" is manifested by the number of sportsmen pursuing him each autumn. An estimated 12,000 quail hunters harvested over 124,000 birds in Virginia's Piedmont during the 1984-85 season (Virginia Commission of Game and Inland Fisheries 1986). Although often more "low profile" than the quail hunting fraternity, preferring the stoic trailing of their baying beagles to the statuesque pointing of setters, the ranks of Piedmont rabbit hunters contain almost 37,000 outdoorsmen. These houndsmen and their dogs teamed up to harvest more than 186,000 cottontails in 1984-85 (Virginia Commission of Game and Inland Fisheries). Clearly, these 2 species provide a wealth of recreation for a large number of southern Virginia sportsmen.

Both bobwhite and cottontails thrive in areas containing a diverse environment of mixed pasture, small grain and hay fields, thickets and small woodlots, and brushy fencerows and other idle areas; this is the type of habitat found in abundance on the small farms once common in the Piedmont. Unfortunately, the small farm, with its proportionally small fields and diverse crops, is disappearing rapidly from Virginia's Piedmont, following a trend seen throughout the nation. With the increasingly wide-spread availability of tractors in the early half of this century, many farmers gradually abandoned the traditional farming regime in which crops such as oats and hay were grown in small fields surrounded by brushy borders. The economics of this new agricultural regimen encouraged the consolidation of small farms into fewer large ones, resulting in larger, more open fields and a monocultural system better suited to modern, large-scale agribusiness.

The total number of farms in the Piedmont region of Virginia has dropped from about 71,000 in 1940 to approximately 18,500 in 1982 (U. S. Department of Commerce 1984), while the total land in farms decreased from about 2.7 million hectares in 1940 to 1.35 million hectares by 1982. The portion of cropland left unharvested, i.e. land standing idle or in soil improvement programs, has been reduced by 75% over the same period (Virginia Crop Reporting Service 1982). Thus, less land is being farmed, reducing the suitability of agricultural lands for farm-loving wildlife; the remaining land is being farmed much more intensively, further reducing the available habitat.

These changes in agricultural practices, and their detrimental effects to the wildlife resource, are not a recent phenomena. Goodrum (1949) found "clean" farming to be the main cause of a nationwide decline in bobwhite populations during the period from 1939 to 1948. A study comparing changes in land use in a predominantly agricultural region of southeastern Illinois between 1939 and 1974 found an 84% reduction in brushy fencerows and a 100% loss of grasslands in the study area (Vance 1976). Coupled with this habitat loss, bobwhite quail and cottontail rabbit populations in the same region of Illinois declined 71% and 75-90% respectively over the last 25 years (Illinois Wildlife Habitat Commission Report 1984-1985).

The quail population in the Piedmont has been on the decline for several years; the rate of this decline has become steeper since the beginning of the 1980's. Quail call counts conducted each July by Virginia Department of Game and Inland Fisheries personnel reflect a 55% reduction in the number of males heard calling in this region during the period 1982 - 1986 (from 59.4 per transect to 26.8 per transect). Over this same period, the number of quail bagged per hunter hour also has decreased by approximately 35% (from 0.61 quail bagged per hunter hour to 0.40 quail bagged per hunter hour) (Virginia Commission of Game and Inland Fisheries 1986).

The first step in finding a solution is to understand the problem. Land use practices in this agriculturally dynamic region are constantly in a state of flux. The broad objective of this study was to determine the characteristics of the habitat the bobwhite and cottontails currently are utilizing. More specifically I wished to describe current land use patterns on farmland in the Piedmont region, estimate relative abundances of quail and rabbits on areas representing a variety of farmland types, relate relative abundances of quail and rabbits to characteristics of existing agricultural habitats, and develop recommendations for habitat management to enhance habitat on farmlands for quail and rabbits.

This fundamental baseline data will allow future investigators to track changes in habitat composition on these farmlands and with it the changing habitat use patterns of quail and rabbits. I regard this study as the first step on our long road to understanding and managing the forces affecting wildlife on our perpetually changing farmlands.

Literature Review

Description and Distribution

The bobwhite is a small, brown-mottled, plump quail without a topknot. Both males and females average 240-275 mm in length, and weigh 140-200 grams (Rosene 1969). Males are recognizable by their white throat; the female has a buffy throat (Peterson 1947).

Bobwhite quail inhabit most of the eastern half of the United States. Their range extends from southern Maine west to southern Minnesota and across to southeastern Wyoming, southward to eastern New Mexico and eastward again to Florida (American Ornitholigists Union 1983). Range expansion is limited to the west by insufficient rainfall over all seasons in most years, and to the north by excessive cold, ice and snow (Rosene 1969).

Reproduction

The bobwhite's breeding season can extend from March through September, with the majority of the mating occurring in April and May (Rosene 1969). Breeding begins with the dissolution of the winter coveys, when the males establish territories that they actively defend from other males. Females are attracted by males issuing the "bobwhite" call, and a monogamous bond is formed that will endure through the breeding season (Stoddard 1931).

A nest is constructed on the ground in a small depression approximately 9-13 cm across and 3-6 cm deep, usually in low standing vegetation on fairly open ground. Both sexes participate in site selection and nest construction (Rosene 1969). Nests are constructed of nearby grass, plant stems, and pine needles. A clutch of 14-15 eggs is incubated 23 days primarily by the female, but also occasionally by the male (Stoddard 1931). Young quail are precocial, receive parental care from both parents, and mature in about 120 days. Nesting success averages 30-40 %, with predation, abandonment, and human disturbance being the main causes of nesting failure (Rosene 1969).

A pair of bobwhite quail strive to raise 1 brood each breeding season. Renesting regularly occurs, and persistent attempts by females usually result in about half of the adult females in a population successfully raising a brood (Johnsgard 1973).

Population Dynamics

Except during the breeding season, the social unit among bobwhite quail is the covey (Johnsgard 1973). Late summer coveys are composed of adults and their brood, with shuffling and redistribution of a covey's approximately 14 members with other nearby coveys occurring in fall (Rosene 1969). Approximately 80% of the fall population is composed of juvenile birds, and about 60% of the total fall population is male (Rosene 1969). Adult quail experience a 70% mortality rate annually. Primary causes of mortality are weather, predation, and, indirectly, habitat loss (Rosene 1969).

General Habits

Bobwhite roost on the ground, forming a disk with tails in and heads pointing out (Stoddard 1931). Primary activity occurs in the early morning and late afternoon, with the mid-day period spent resting and loafing. Daily movements usually do not exceed 500 m (Rosene 1969). There is no seasonal migration (Rosene 1969, Stoddard 1931).

Habitat Requirements

Food

The bobwhite quail is primarily a granivore (Edminster 1954). Plants provide 97 to 99% of quail diets except during summer when insects compose one-fourth of the total (Schroeder 1985). Bobwhite foods can be categorized into 8 major groups: wild seeds (mainly of forbs), legume seeds, grass seeds, cultivated grains, mast, fruit, greens, and insects (Edminster 1954). The relative importance of specific foods varies among geographic locations and depends on food availability (Reid and Goodrum 1979).

Fall and winter studies provide most of the information on bobwhite food habits (Schroeder 1985). Landers and Johnson (1979) compiled results of 27 food habits studies conducted in the southeast. They found over 650 different types of seeds to be utilized by quail, with 78% of these types comprising 1% or more of the food volume in one or more of the studies. Bobwhite crops contained both a high percent frequency and a high percent volume of beggarweeds (*Desmodium spp.*), ragweeds (*Ambrosia spp.*), lespedezas (*Lespedeza* *spp.*), corn (*Zea mays*), soybeans (*Glycine max*), cowpeas (*Vigna spp.*), partridge peas (*Cassia spp.*) oaks (*Quercus spp.*), sumacs (*Rhus spp.*), and pines (*Pinus spp.*). Baldwin and Handley (1946) found common ragweed to be the single most important winter food in Virginia, comprising 21% of the food volume. Other major foods eaten by Virginia quail were as follows: native and naturalized legumes (29%), cultivated legumes (14%), cultivated grains (11%), mast (10%), miscellaneous seeds (7%), fruits (4%), forage and grasses (2%), and animal matter (2%).

Low availability of seed and fruit crops make spring the most difficult time for bobwhites (Reid and Goodrum 1979). Quail survival depends on the early seed and fruit crop, and the availability of residual crops from the previous growing season (Schroeder 1985). Deterioration rates and preference of seeds from 35 species of food plants was studied in South Carolina (Preacher 1978). Six of the 10 most preferred fresh seeds were also among the 10 most preferred seeds after 120 days of being on the ground. These 6 seeds were from sorghum, poison ivy (*Toxicodendron radicans*), chiwapa millet (*Echiochloa framentacea*), pearl millet (*Pennisetum glaucum*), browntop millet (*Panicum ramosum*) and Japanese millet (*E. crusgalli*). Additionally, Eubanks and Dimmick (1974) found soybeans accounted for 71% of the volume of food eaten in winter and 40% of the volume eaten in spring in western Tennessee.

Insects are the most important food of quail chicks less than 14 days old (Hurst 1972, Eubanks and Dimmick 1974); insects tend to be most abundant in habitats containing mixed forbs and legumes. Adult feeding habits are adopted when young quail reach 7 to 9 weeks of age (Schroeder 1985).

Stoddard (1931) regarded ideal foraging habitat to consist of open vegetation composed of primarily leguminous plants interspersed with some bare ground or a light litter, with protective cover nearby. Bobwhites forage primarily on the ground or in a light litter layer (Rosene 1969); they cannot feed in thick mats of vegetation and snow > 7.6 cm deep forces the birds to confine their foraging to seeds within reach that haven't fallen yet (Schroeder 1985). Early seral stage communities such as found in abandoned fields provide the best foods and vegetative structure. Very little food is found in climax plants communities

(Baumgartner et al. 1952, Robinson 1957). As plant succession progresses, vegetation density increases, reducing the amount of bare ground, which reduces the number of shade-tolerant quail food plants (Ellis et al. 1969).

Old fields 3 to 5 years past cultivation produced the greatest abundance of legumes. Fields < 3 years post cultivation were predominately covered by grasses and composites, while fields exceeding 5 years old exhibit a steady decrease in legumes and a concurrent decrease in quail utilization (Schroeder 1985). Croplands containing rough stubble with annual weeds provide good feeding areas for bobwhite over the winter, while lands with little residue remaining or that were fall plowed are of little value (Edminster 1954).

Robel et al. (1979) stated that habitat improvements should include considerations of food quality and palatability. They found sorghum (*Sorghum vulgare*) and corn to have high metabolizable energy and acceptability to quail. Shrub lespedeza (*L. japonica*) and hemp (*Cannabis sativa*) were mediocre in these respects, with red oak (*Q. rubra*) acorns poor and panicum (*P. virgatum*) extremely poor.

Baumgartner (1945) found that quail were eliminated from pastures in Oklahoma that were persistently overgrazed, but noted that overgrazing seemed to increase several important quail foods on another site (Baumgartner et al. 1952). Apparently, selective grazing by livestock may facilitate the increase of bobwhite foods, but the overall reduction in cover makes the area inhospitable for quail.

Until they are about 2 years old, loblolly pine (*P. taeda*) plantations provide ample annual vegetation preferred by bobwhite, but 3 and 4 year old plantations contain fewer annual food plants and consequently are used little by quail (Sweeney et al. 1981). Excess herbaceous vegetation and litter can be removed from southern forests by controlled burning, thereby setting back succession. this results in an increase in the leguminous food supply (Stoddard 1931, Goodrum and Reid 1952, Rosene 1969, Cushwa et al 1971). Mechanical removal by disking or chopping is also effective in rejuvenating berbaceous vegetation (Rosene

1969).

Water

Bobwhites require water; it may be obtained as free water, from dew or from food (Rosene 1969). Bobwhite populations fluctuate dramatically in the arid western part of its range depending on the annual rainfall (Edminster 1954).

Cover

Optimal bobwhite cover has approximately an equal mix of bare ground and cover of upright stems of herbaceous and woody vegetation (Rosene 1969). Bobwhites typically forage during the early morning and late afternoon hours, spending the middle of the day in dense woody vegetation known as "headquarters" areas (Robinson 1957, Roseberry and Klimstra 1984). The dense understory cover provided by Japanese honeysuckle (*Lonicera japonica*) makes excellent "headquarters areas" (Roseberry and Klimstra 1984). Eubanks and Dimmick (1974) found that naturally occurring vegetation found in undisturbed areas provided the best protective cover.

Scarcity of food and poor quality protective cover often make late winter the critical season for bobwhites (Edminster 1954). This situation is especially acute in the northern parts of the bird's range where winter cover is relatively scarce, and the need greater (Rosene 1969). Woody hedgerows provide the majority of winter cover on farmlands in Wisconsin where bobwhite populations were eliminated as the amount of hedgerows was reduced (Kabat and Thompson 1963).

The physical characteristics of vegetation are more important than the species of vegetation found at roost sites (Klimstra and Ziccardi 1963). The majority of roosts examined in

Illinois were on bare ground or light duff in herbaceous vegetation (Klimstra and Ziccardi 1963, Ellis et al. 1969). Klimstra and Ziccardi (1963) described areas providing an open canopy; sparse, short vegetation; and a ground surface with little dead vegetation as being preferred roosting habitat. Similarly, Stoddard (1931) found bobwhite avoided roosting in dense vegetation, preferring relatively open areas in herbaceous vegetation. Rosene (1969) stated that cold, snow, or wind will cause roost sites to be established in denser cover. Klimstra and Ziccardi (1963) postulated that suitable roosting cover, both open roosting cover and, to a lesser extent, the denser cover needed during severe winter conditions, may be a limiting factor is some situations.

Reproductive Cover

Bobwhite select areas to nest in that are open, with the ground partly bare to allow easy movement (Stoddard 1931, Rosene 1969). Bobwhite seem to favor areas with scattered shrubs and briars mixed with herbaceous vegetation. Old fields maturing from the perennial weed stage into the shrub stage often provide these conditions (Roseberry and Klimstra 1984).

Bobwhite nests generally are built on the ground, placed in grass and constructed of dead grass stems (Klimstra and Roseberry 1975). Locations dominated by annual weeds are poor nest sites due to a paucity of dead grass stems (Roseberry and Klimstra 1984).

Rosene (1969) often found bobwhite nests placed along an edge between grass and bare soil areas. Stoddard (1931) also found most nests near open ground such as paths or roads. Klimstra and Roseberry (1975), working in Illinois, report nests frequently located near a change in cover pattern. Fields dominated by broomsedge (*Andropogon viginicus*) or similar grasses were preferred nest sites (Stoddard 1931). Preferred nesting habitat is created most efficiently through natural succession. Intermediate secondary successional stages (5-10 years old) allow the establishment of the grasses required for nesting (Klimstra and Roseberry 1975). Hay fields, particularly fields of alfalfa (*Medicago sativa*), offer poor nesting cover

(Rosene 1969). Klimstra and Roseberry's (1975) work in Illinois found nesting success lowest in hayfields and highest in idle fields, with farming operations causing 18% of the failures and predators contributing to 55% of of the losses. Heights of vegetation in nesting areas should be between 7.6 and 51 cm (Rosene 1969, Lehman 1984). An herbaceous canopy cover of approximately 50% can be considered optimal (Harshburger and Simpson 1970).

Composition and Interspersion of Habitat

Management of bobwhite habitat must take into account the type of cover needed, the amount of each needed, and the arrangement of these needs (Edminster 1954). Those resources required on a daily basis, such as food and cover, need to be in close proximity, while seasonally required resources, for example nesting habitat, may be more distant (Roseberry and Klimstra 1984).

High bobwhite populations are common in areas containing a large variety of plants (Rosene 1969). Areas containing a mix of woodlands and open fields, separated by transition bands, provide these conditions (Schroeder 1985). Hanson and Miller (1961) found a positive correlation between bobwhite populations and the amount of edge between brushy pastures and cultivated fields, but could establish no correlation between quail numbers and the total amount of all edges, mainly because many edges were not used. It seems that an abundance of woody protective cover adjacent to foraging areas is more important than total amount of all edges (Burger and Linduska 1967, Eubanks and Dimmick 1974). Edminster (1954) estimated the proportion of several cover types required for good bobwhite quail range. Grasslands should compose 30 to 40% of the total cover, in 2 to 4 ha units. Crop fields should comprise 40 to 60% of the total cover, in 0.4 to 2 ha units. Brushy cover should make up 5 to 20% of the habitat, in units between 0.1 and 0.4 ha in size. Woodlands should compose 5 to 40% of the total cover, with units 2 to 8 ha in size being ideal. While the amount of these habitat components is important, the interspersion of these covers, allowing them to be fully utilized, is more so (Eubanks and Dimmick 1974).

A wide range of home range sizes has been reported in the literature. Home ranges of coveys in Oklahoma averaged 4.4 ha, were centered along streams, and did not vary from fall through spring (Wiseman and Lewis 1981). Rosene (1969) reported winter range in Alabama and South Carolina to vary from 1.6 to 31.2 ha. Late winter ranges in southern Illinois averaged 15 ha, with average range size reduced to 9 ha during a year with protracted periods of snow cover (Roseberry and Klimstra 1984). Robinson (1957) estimated 4.9 ha to be the minimum area needed to support a covey in the critical season. Stoddard (1931) found bobwhite in the Southeast to be essentially sedentary, usually not undertaking large movements. About one-half of the bobwhite studied by Murphy and Baskett (1954) in Missouri had a lifetime cruising radius of < 0.8 km. However, coveys may move several kilometers in the fall to reach habitats that will provide food and cover throughout the winter (Rosene 1969).

Habitat Models

I currently am aware of three models that attempt to asses bobwhite habitat quality using habitat characteristics.

Baxter and Wolfe (1972) formulated an index relating a measure of interspersion to habitat quality. Their method involved counting the incidence of edges, or the junction of 2 different cover types. The assumption was that greater interspersion of covertypes, as measured by the number of edges formed, indicated greater habitat value for quail. Their model produced an index value significantly correlated ($r = 0.976$) with bobwhite numbers.

While the output of their model produced an impressive correlation, I feel the model may be too simplistic. The presence of edges was the only parameter measured. All edges are assumed to have equal value as quail habitat. However, there is evidence that certain edges receive greater utilization by bobwhite than do others (Eubanks and Dimmick 1974).

Another habitat model was developed to evaluate bobwhite habitat in Missouri (Urich et al. 1983). A numerical value representing overall quality was determined for each of several cover types such as pasture and haylands, old fields, croplands, upland hardwoods,and bottomland hardwoods. A single value cannot be determined when describing a mix of several different covertypes when using this model.

The final model is the Habitat Suitability Index Model for northern bobwhite (Schroeder 1985). This model attempts to describe quantitative relationships between important environmental variables and habitat suitability. Based upon the biological and habitat information available in the literature, it relies on the use of 11 key habitat variables describing bobwhite life requisites such as winter food, cover, nesting habitat, and the interspersion of the covers supplying these requisites. The value of these habitat variables are scored and the area being examined is given an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat) (Schroeder 1985).

The habitat suitability index model is the most comprehensive of the models reviewed. It incorporates the many components comprising a habitat while attempting to produce a single value describing the habitat quality. It's weakness lies in attempting to be broadly applicable in all situations. While some flexibility in evaluating certain variables exists, e.g. determining primary bobwhite foods in specific regions, the broad brush approach may be too generalized for all areas within the bobwhite's range. With this problem in mind, a criteria for describing habitat suitability for northern bobwhites in the southeastern United States is currently being developed.

Study Area

The study was conducted on a 23,000 ha area in southwestern Halifax County, Virginia (Figure 1). The topography consists of a gently rolling plateau dissected by many small streams, with elevations ranging from approximately 90 to 180 m above sea level (Virginia Crop Reporting Service 1982). Mean daily temperatures range from 3 $^{\circ}$ C in January to 26 $^{\circ}$ C in July. Annual precipitation averages 107 cm and is evenly distributed throughout the year (Virginia Crop Reporting Service 1982).

Halifax County is underlain by ancient igneous and metamorphic rocks and sediments of the Triassic Age. Most rock is mixed gneiss consisting of either granite gneiss or hornblende gneiss (Legrand 1960). Appling and Cecil series soils dominate this part of the county. Both soils are sandy loams with good drainage, low fertility and medium to high erosion potential. These soils have medium potential for crop production, being best suited for raising tobacco, corn, grain, soybeans, hay and truck crops (U.S. Department of Agriculture 1934, U.S. Department of Agriculture 1956, U.S. Department of Agriculture 1977).

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

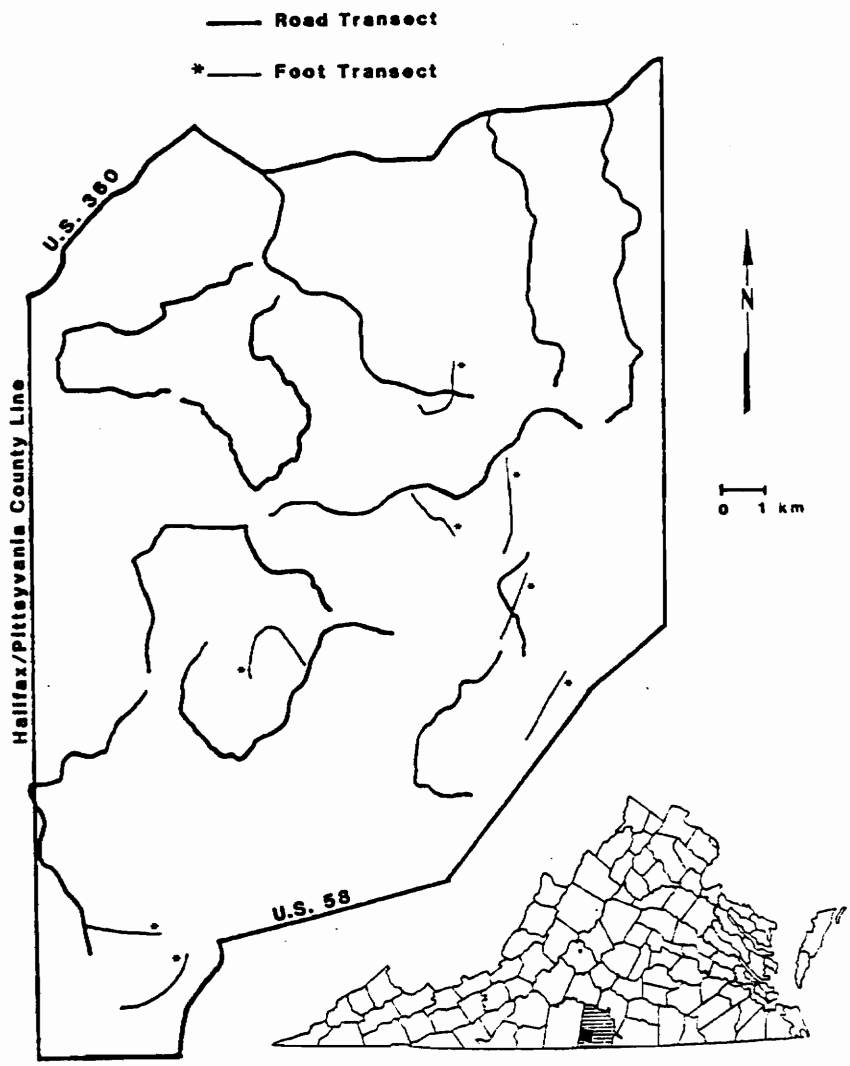

Figure 1. Location of study area and transects in Halifax Co., Virginia, 1986-87.

Wildlife habitat potentials on these soils are classified as good for grain and seed crops, grasses and legumes, wild herbaceous plants, hardwood trees and coniferous plants. Potential for open land and woodland wildlife also is considered good (U.S. Department of Agriculture 1934, U.S. Department of Agriculture 1956, U.S. Department of Agriculture 1977).

Halifax County is one of the most intensely farmed counties in the Virginia Piedmont. The 1982 agricultural census reported 1,652 farms, encompassing 103,742 ha of the county's total area of 207,465 ha. Thus, approximately 50 % of Halifax County is considered active farmland, with the remaining 50% of the land area 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. The remaining 8,360 ha of agricultural land is composed of houselots, ponds, roads, wastelands, etc (U. S. Department of Commerce 1984). Pastures and crop fields range in size from <2 to >40 ha, and are cultivated using conventional, minimum-till, and no-till methods. Cultivated areas are interspersed among numerous woodlots, ponds, and other nonfarmed areas.

Methods

The focus of this study was to investigate bobwhite quail and cottontail rabbit utilization of various farmland habitats. Relationships between animals and habitats can be examined over a wide range of specificity. For this investigation, the relationship between the species and its use of available habitats was examined at 2 levels. At the macro level I sought to understand which general land uses were being preferentially exploited by quail and rabbits. These general characteristics, such as proportion of various crops, size of fields, and length of edges, could then be used to determine habitat suitability for these species over large tracts of land.

A micro level of investigation was used to examine the structural characteristics of specific habitats used by quail and rabbits. This information yielded an understanding of which particular characteristics of various cover types were influencing their use.

Bobwhite quail and cottontail rabbits were censused and habitat characteristics measured at both scales. Many techniques were similar for both levels of investigation, with modifications developed to tailor the technique to the particular scale.

Macro-scale censusing

Quail

Numerous methods have been used by earlier researchers to determine population densities of bobwhites. The use of trained bird dogs was an early method of detecting quail (Bennett and Hendrickson 1938). Capture - recapture methods are described by Davis and Winstead (1980). Direct counts of bobwhites have been accomplished by workers systematically traversing an area counting coveys or individuals (Dimmick and Yoho 1972). Often, trained pointing dogs have been used in conjunction with this method (Steen 1950, Robinson 1957, Roseberry and Klimstra 1984). The disadvantage shared by these methods is the limited area that can be sampled efficiently. My study area was too large to census adequately using these methods. Because I required only an index of relative quail densities, an accurate estimate of population density was not necessary. For these reasons I chose a modification of the call-count technique (Rosene 1969). This method allowed myself and 1 other worker to sample the entire study area several times over the course of the field season, yielding an index of relative quail density.

I established 10 census routes, each 8 to 10 km in length (totalling 96.8 km) throughout the study area so the habitat diversity encountered was maximized. Ten to 13 listening stations (121 total) were established at 0.8 km intervals along each of the transects. Quail call counts were conducted along these transects. Assuming that 400 m is the maximum distance a quail emitting the "bobwhite" call can be detected under most conditions, this interval sampled a 50.23 ha area surrounding the listening post with no overlap between stations (Rosene 1969). To facilitate counting, I divided the area surrounding the sampling point into 4 quadrants, with the road forming one axis, and an imaginary line at a right angle to the roadway forming the other axis (Figure 2). Calling birds were recorded as being in 1 of these 4 quadrants, which reduced confusion when many birds were calling simultaneously.

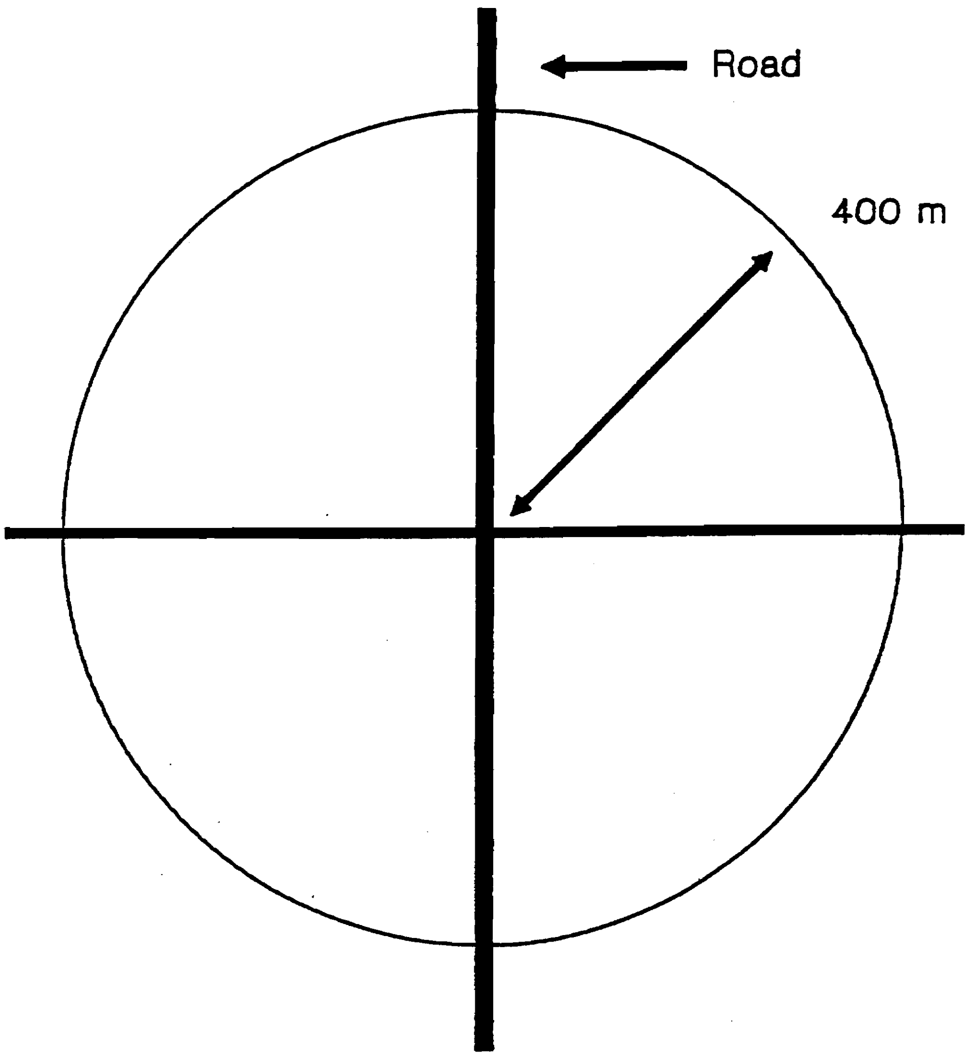

Figure 2. Layout of sampling stations used for quail call-count censuses along roads in Halifax Co., Virginia, 1986-87.

Individual birds heard calling at least once during a 10 minute listening period at each station were recorded. I tried not to double-count birds that moved or ceased calling and then resumed during the 10 minute census period.

Censusing began in mid-April and continued daily through July in both 1986 and 1987. Routes were run sequentially so each transect was censused repeatedly throughout the season. Direction of travel along the routes was alternated so stations at the beginning and end of the transect were censused at different times of the morning to avoid temporal bias in the results. No censusing was conducted in the rain or when the wind velocity exceeded 10 km/hr.

Rabbits

Relative densities of cottontail rabbits were determined by recording the location of all rabbits encountered along the quail call count routes and noting the cover type the animal was occupying. This method is compatible with the early morning quail census because most rabbit activity during the summer months occurs shortly after sunrise (Lord 1963).

Additional rabbit censusing was conducted in fall and winter of 1986-87. Each of the 10 road transects were traversed by automobile between 1800 and 2300 hours on the nights of January 9, 1987, January 29, 1987, and between 0100 and 0400 hours on March 21, 1987. The location and adjacent cover type of each rabbit spotted was noted. These censuses were each conducted at different times of the night to coincide with the variations in seasonal peak activity times of the animal (Lord 1963). A handheld spotlight was used to aid in locating the animals.

Micro-scale censusing

Quail and Rabbits

Eight foot-transects, each 1 to 2 km long, were established in areas away from public roads. These transects were routed in an effort to sample the breadth of land use practices found on the study area. Nine to 14 call count stations were established at 200 m intervals along each transect. All quail heard calling from within a 100 m radius of the station during censuses were recorded along with the type of cover the bird was occupying using techniques analogous to those used on the road transects (Figure 3). Censuses were conducted from mid-April through July of 1986 and 1987. Direction of travel along the routes was alternated and no censusing was conducted in rain or when the wind velocity exceeded 10 km/hr. The perpendicular distance from the transect line to the location of all rabbits and quail flushed also was recorded (Burnham and Anderson 1984).

Macro-habitat Sampling

The 50.23 ha area surrounding each of the road transect listening stations was cover mapped each of the 2 field seasons. A system for classifying the various land uses encountered within the study area was developed to facilitate cover mapping. Cover types were classified broadly as crop, pasture, wooded pasture, road, pond, hedge, yard, forest or other

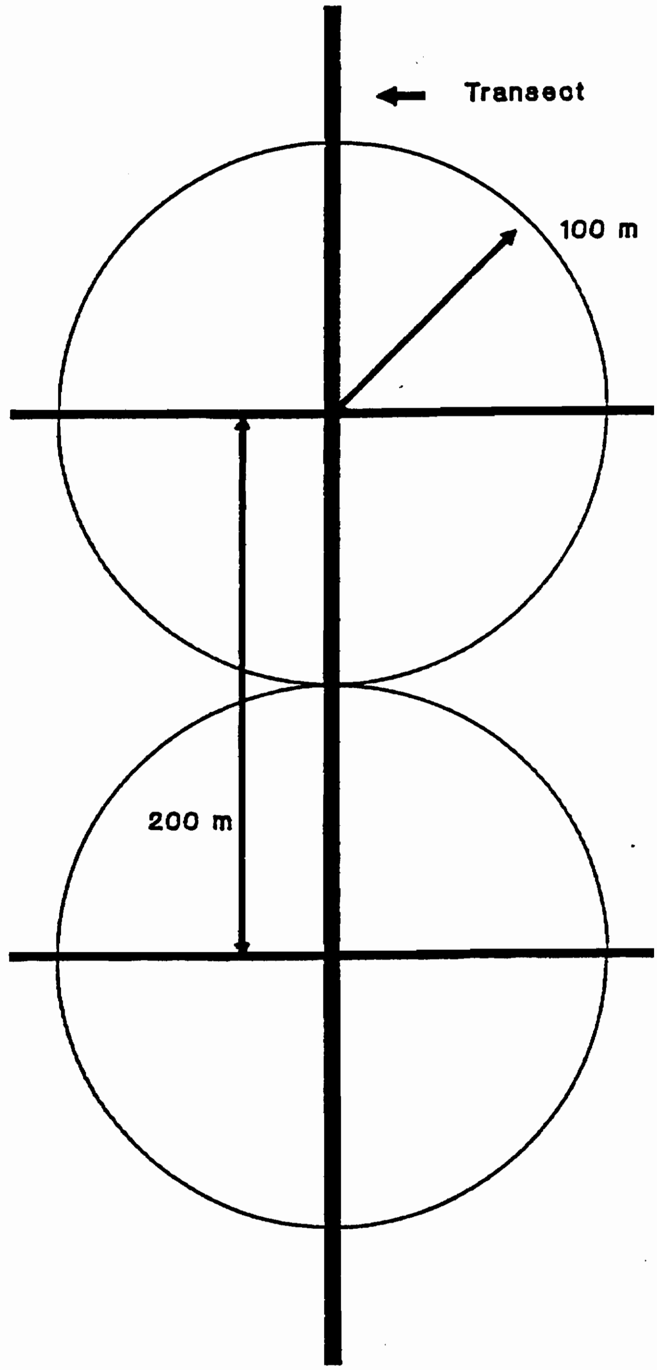

Figure 3. Layout of sampling stations used for quail call-count censuses along foot-transects in Halifax Co., Virginia, 1986-87.

(Table 1). The crop category was further subdivided into the specific crops currently growing on the individual fields. Forests were categorized based on their stocking densities for 3 size classes of trees. These size categories were: saplings, trees <3 cm dbh; poles, trees 3-25 cm dbh; and logs, trees > 25 cm dbh. This method resulted in several stand classifications occurring relatively few times. These infrequently occurring forest types were grouped with more common stand classes that were closely related. This reduced the total number of variables while retaining the important characteristics of each variable. Finally, the 13 specific stand classes were placed into 1 of 3 broad classes based on canopy densities: forests containing sapling canopies; forests with canopies comprised of saplings and poles; and stands with a sapling, pole, and log size tree composing the canopy. These categories were labeled locan, medcan, and hican, respectively.

The location of each station and its associated censused area was drawn on USDA-ASCS black and white aerial photos (scale 1:660). This circle and the cover types discernible from the photo were traced and photostat copies of the tracings produced. Using these copies and the associated photos, cover maps depicting the various cover types found at each station were made. These maps were updated the second field season to reflect any changes in size or composition of the cover types.

The area of the various cover types was measured using a planimeter program (PLANIMTR, Environmental Systems Management, Inc.) and a Numonics model 2300-1 digitizing board with an IBM PC directly from the aerial photos. Information from the cover maps was used to label the contents of the polygon.

Additionally, 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. Because of the many permutations possible when combining 2 or more covertypes to form an edge combination, 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" .

Table 1. Descriptions of variables used to describe cover composition of habitats used by quail in Halifax County, Virginia, 1986-87.

Variable	Description
Crop	
corn	field corn
grain	primarily wheat, oats, barley
grain hay	usually barley cut green for hay
hay	alfalfa, orchard grass, or fescue harvested for hay
soybean	primarily harvested for beans
tobacco	
melons	cantaloupe and watermelon
garden	household gardens
fallow	uncultivated crop field
wooded fallow	uncultivated crop field with successional trees and shrubs
bare ground	cultivated field without vegetation
unknown	
other	
Pasture	open, grazed pasture
Wooded pasture	pastured forest
Road	paved and gravel roadways
Pond	primarily irrigation and livestock ponds
Yard 1	mown lawns
Yard 2 & 3	grassy nonagricultural areas
Hedge	shrubs and herbs growning in an isolated, linear covert

Table 1. Continued.

Variable	Description
Lowcan	forested cover consisting of only saplings (< 3cm dbh)
S1	light and medium stocking
S1_Sl	light and medium stocking with slash
S3	dense stocking
Medcan	forested cover consisting of saplings and poles (3 - 25 cm dbh)
S15	lightly stocked saplings; light, medium or densely stocked poles
S25	medium stocked saplings; light, medium, or densely stocked poles
S5	light, medium or densely stocked poles
S24 _Sl	medium stocked saplings; light, medium or densely stocked poles with slash
S34	dense saplings with light or medium stocked poles
Hican	forested cover consisting of saplings, poles, and/or logs (> 25cm dbh)
S47	light or medium stocked poles, lightly stocked logs
S147	lightly stocked saplings, light or medium stocked poles, lightly stocked logs
S257	medium stocked saplings, light or medium stocked poles, and lightly stocked logs
S247_Sl	medium stocked saplings, light or medium stocked poles, and lightly stocked logs, with slash
S347	densely stocked saplings, light or medium stocked poles, and lightly stocked logs

Micro-habitat Sampling

The same procedure used to measure cover types and edges at the road censusing stations was applied to the 3.14 ha areas surrounding each of the foot transect listening stations.

Quail-centered Plots

A more intense evaluation of quail habitat use was conducted based on the specific locations of quail found during censusing the foot transects. These bird locations were used as sample plots for measuring habitat occupied by quail in relation to the habitat available to the birds.

During the 1986 field season the sampling plots were determined based on quail detected along the foot transects. All quarters in which birds were found (n=48) during censusing were used to represent habitat used by quail. Also, several quarters (n=16) were chosen randomly from stations at which I recorded no quail. These functioned as plots to evaluate the total available habitat.

Measurements were made in each sampled quarter along a line starting 25 m from the sample station and extending for 50 m along a randomly chosen vector. This line effectively sampled the middle 50 m of the total 100 m radius quadrant (Figure 4). The parameters measured at the specific bird site were based on those discussed in the Habitat Suitability Index Model developed for northern bobwhite quail (Schroeder 1985) and are outlined in Table 2. Habitat measured along this transect was assumed to reflect conditions within the quarters.

Many of the cover types in which quail were located occurred as small, relatively isolated patches. Using the random vector technique we often found ourselves measuring a cover type located near to but very different in composition from the cover in which the bird

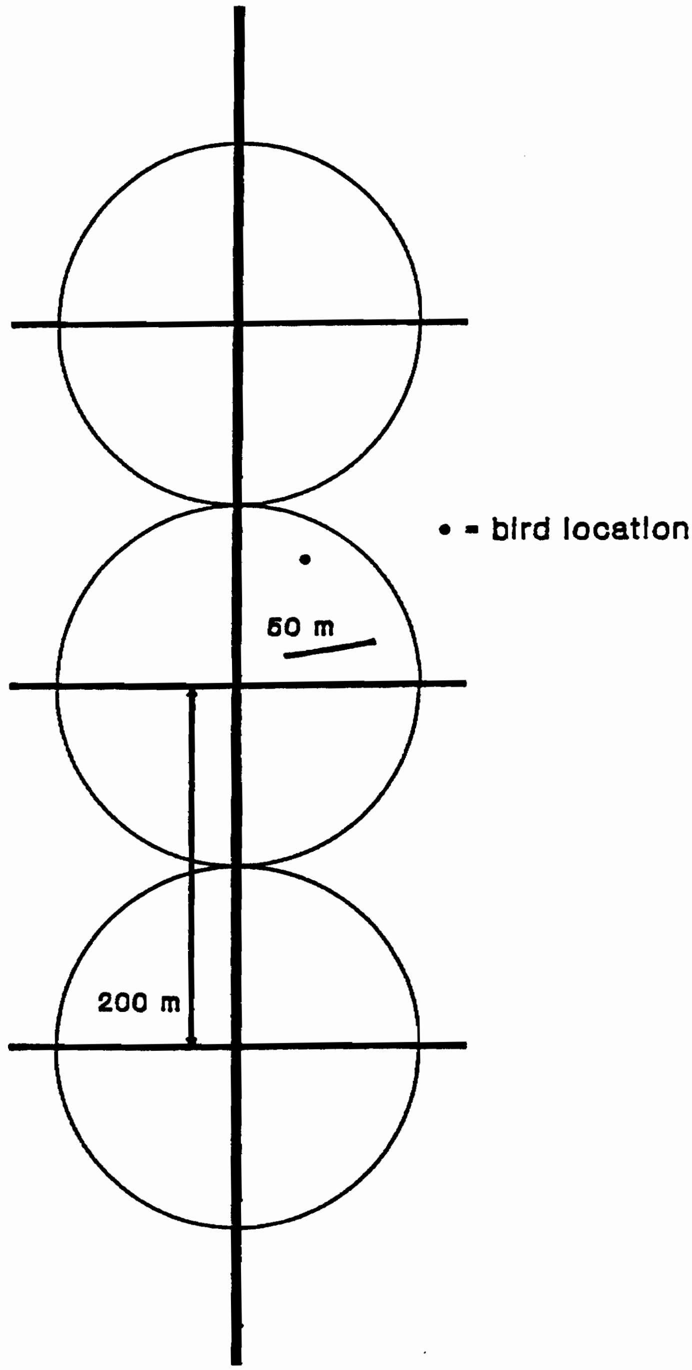

Figure 4. Layout of sampling plot used for quail-centered plot measurements along foot-transects in Halifax Co., Virginia, 1986.

Table 2. Descriptions of variables used to describe habitat on quail-centered plots in Halifax County, Virginia, 1986-87.

Variable (units)	Definition	Method
High canopy (%)	woody canopy > 5m high	line intercept
Medium canopy (%)	woody canopy 2 - 5 m high	line intercept
Low canopy (%)	woody canopy < 2 m high	line intercept
Herbaceous cover (%)	canopy composed of herbaceous vegetation	line intercept
Grass cover(%)	portion of herbaceous canopy composed of grass	line intercept
Quail food (%)	portion of herbaceous canopy composed of locally preferred quail foods	line intercept
Bare ground/light litter (%)	portion of ground bare or covered by litter less than 2 cm deep	line intercept
Honeysuckle (%)	portion of canopy <2 m high composed of honeysuckle	line intercept
Height of herbs (cm)	mean height of herbaceous vegetation	meter stick

had actually been located (Figure 4). To insure that only the cover the bird was occupying was measured, the sampling method was modified for the 1987 field season.

Exact locations of quail detected while traversing the foot transects were marked. These locations were not limited to the 100 m radius area surrounding sampling stations, and included both aurally detected and flushed birds. An adjacent plot (paired plot) where no quail were located was also sampled to provide information on habitat availability versus habitat utilization. These plots were established by randomly choosing either the station preceding or succeeding the station nearest the bird location. Using a randomly chosen quarter of that station, a point 50 m from the center of the station, on a 45^0 vector from the center, served as the center of the plot (Figure. 5). This technique resulted in 31 quail-centered plots and 31 associated random plots.

Quail-centered plots and their paired plots were sampled along 4 12.5 m lines radiating from the center in the 4 cardinal directions using the line intercept method (Hays et al. 1981). The same habitat variables measured using the old method were also measured here.

Analytical methods

Macro-scale census

The individual stations (n=121) formed the basic sampling unit for analysis in this study. I calculated the mean number of quail recorded per station over all runs (1986 runs = 9, 1987 runs = 7). After examining the coefficient of variation (CV) statistic associated with this mean, I decided to eliminate runs 1, 2, and 9 from the 1986 data and runs 1 and 2 from 1987 for which CV was high. This eliminated the periods of the census when birds were only beginning to call and the point after the peak calling season when vocalizations were tailing off for that year. The mean number of quail per station for the remaining runs was transformed using

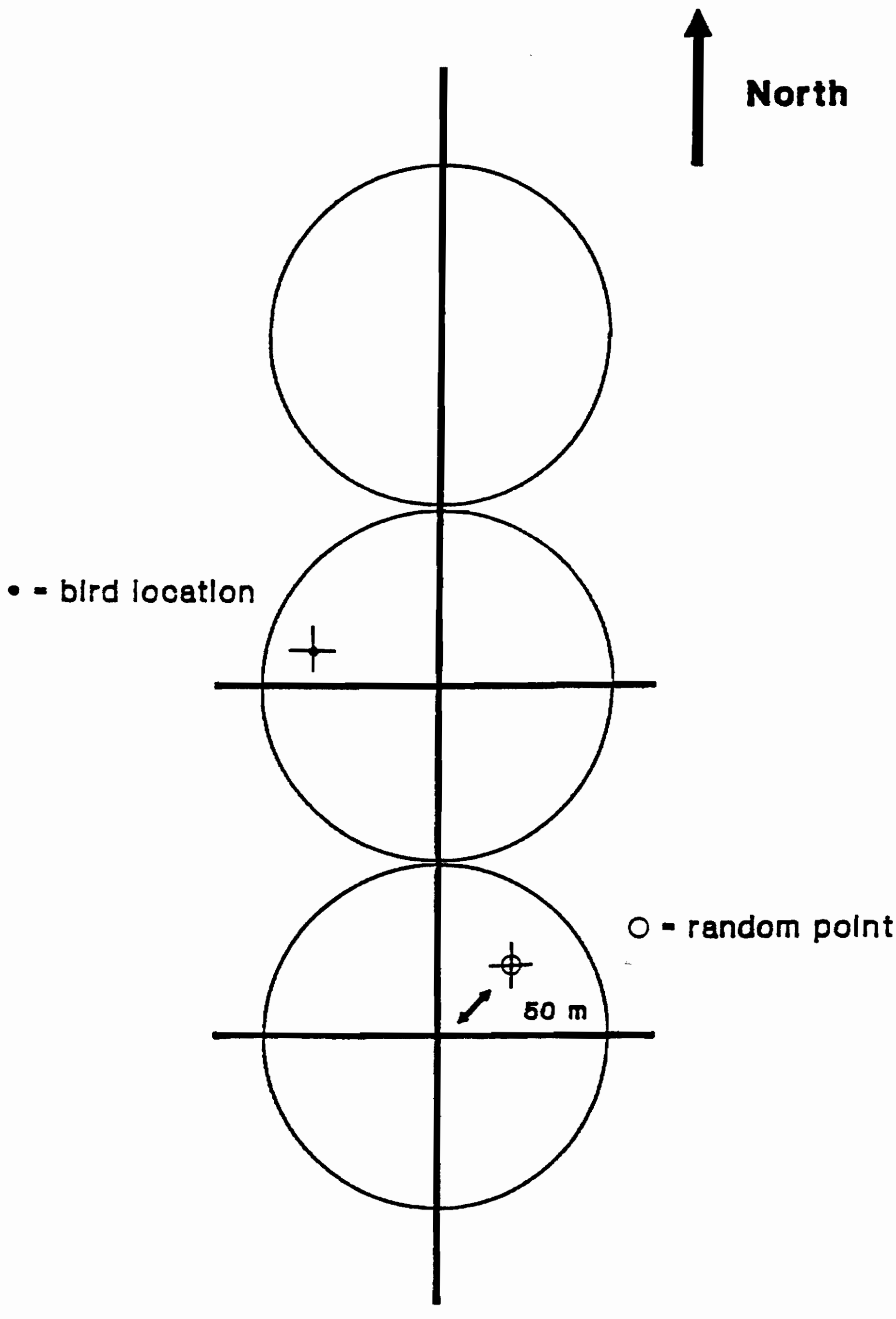

Figure 5. Layout of sampling plot used for quail-centered plot measurements along foot-transects in Halifax Co., Virginia, 1987.

natural logarithms, normalizing their distributions. Paired t-tests then were used to compare the mean number of birds per station between 1986 and 1987, for each of the 10 transects.

Macro-habitat Analysis

Cover variables used in analysis were the proportion of each cover type around each station. For example, if there were 3 individual ponds encompassed in the area around a station, each with an area of 1 ha, the total area of the ponds equaled 3 ha. Thus, the proportion of the station covered by ponds was 3/50.23 or 0.06.

For the analysis of the edges, I used the total length of each specific edge combination found on a station. If a specific edge combination occurred more than once on a station, the total length of all those edges combined was the value used. Additionally, 8 indices of habitat heterogeneity were formulated for each station using ratios of cover values to edge values (Table 3). Cover, edge and index variables were compiled for each year individually, and the variables were averaged to produced values for the 2 years combined.

A logical method was needed to analyze all these variables and produce a model relating relative densities of bobwhite to these habitat variables (Figure 6). The first step was to place all habitat variables into 1 of 4 classes: index variables, crop variables, forest variables, and edge variables. A stepwise multiple linear regression procedure (SAS 1985) was used to determine which of these variables within each class explained a significant ($P < 0.1$) amount of the variation in mean bird numbers between stations within each year and for the 2 years combined. The significant variables identified from each class were then combined and a stepwise multiple linear regression was performed on this combination. The final model incorporated those variables found to be significant.

A model construction procedure analogous to that used in the previous habitat model also was performed using broad categories of cover. In this procedure the three major classes of forests, locan, medcan, and hican, were analyzed. All crops, including fallow fields,

Table 3. Definitions of index variables used to describe habitat used by quail on the bird centered plots in Halifax County, Virginia, 1986-87.

Variable	Definition
Ncvr	total number of cover polygons
Nedge	total number of discrete edge segments
Nindx	number of edges / number of cover polygons
Meancvr	mean size of cover polygons
Meanedge	mean length of edge segments
Mnindx	mean length of edge / mean size of cover polygons
Sumedge	total length of all edges
Sumindx	total length of edge / total area of station

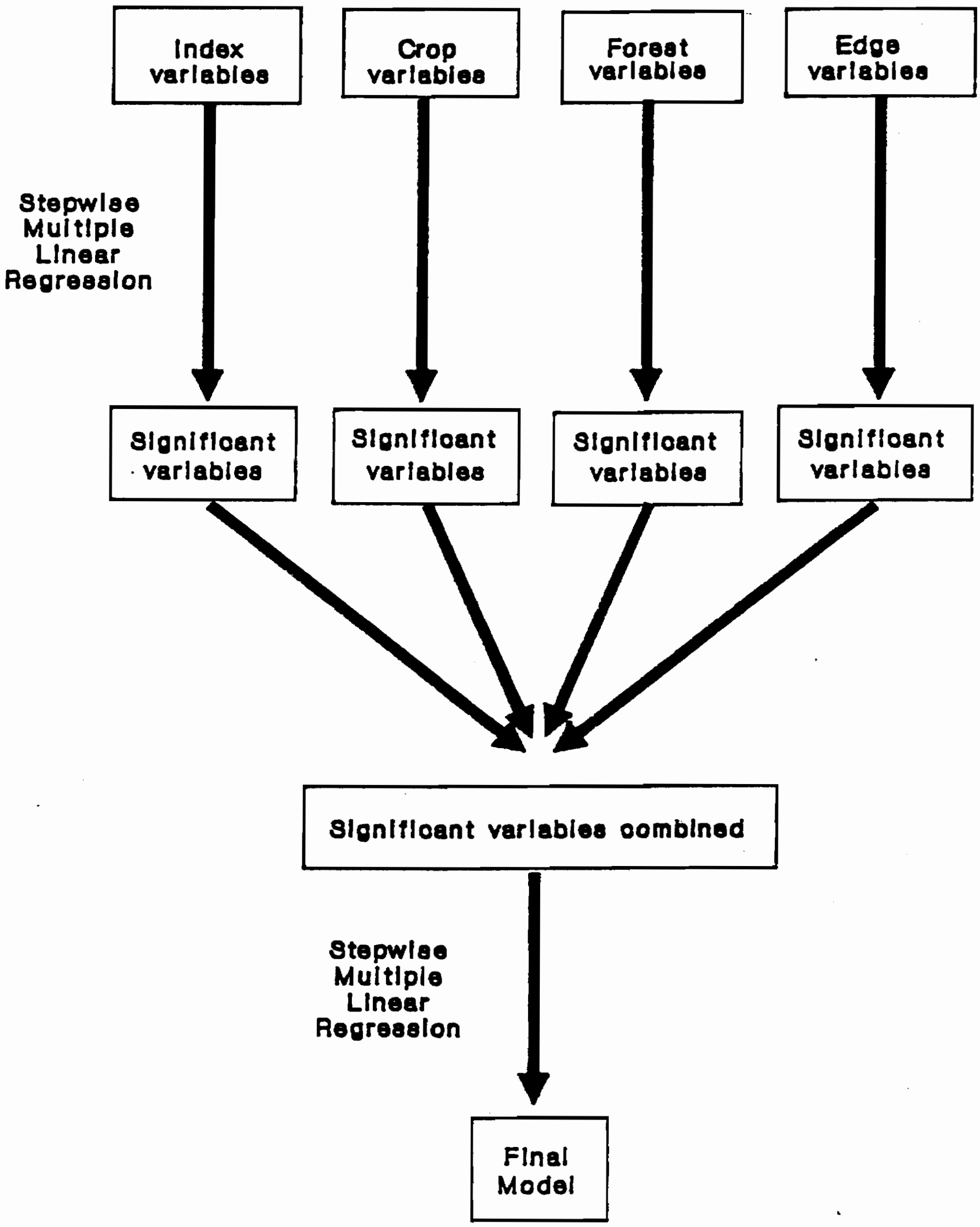

Figure 6. Steps used in constructing a habitat use model for bobwhite using index, crop, forest, and edge variables in Halifax Co., Virginia, 1986-87.

were lumped together. Other variables were the proportion of area made up of ponds, pastures, wooded pastures, roads, short grass yards, and tall grass yards. Additionally, a variable called "other" included cover types occurring in small numbers such as cemeteries and utility right of ways.

Micro-habitat Sampling

Models were developed using a procedure analogous to that for the road transect data (Figure 5). For the 1986 and 1987 data combined, quail were recorded at least once at 44 of the 87 total foot transect stations. Because these data were essentially presence/absence data, I used logistic regression (SAS 1985) rather than multiple linear regression for analysis. The goal of the individual class models and the composite model was to relate the presence or absence of bobwhite with the cover, index and edge variables measured at these sites. These variables were measured in the same manner as for the macro-habitat plots.

Quail-centered Plots

Paired t-tests were used to compare the values for each habitat variable measured on the quail-centered plots and the associated random plot.

Results and Discussion

Rabbits

Road Census

I censused cottontails in conjunction with the roadside quail counts. The 10 transects were each traveled 9 times during 1986, with 23 cottontails observed (0.25 rabbits/transect/census, SE = 0.04). Ten cottontails were seen over the 7 runs conducted in 1987 (0.14 rabbits/transect/census, SE = 0.06) (paired-t test, t = 1.657, df = 9, P = 0.134). These observations all were recorded between 0545 and 0830 hours, which has been described as the peak period of roadside activity by cottontails during the summer months (Lord 1961, Kline 1965).

Since the censuses were conducted during what should have been the periods of optimal efficiency for this technique, rabbit populations apparently were very low during the study. The efficiency of the roadside count method of censusing rabbits is dependent on the animal density. At low density the probability of sighting rabbits along the narrow corridor of the roadway is proportionately lower than if the rabbits were more numerous. A technique sensitive to low densities of cottontails would be much more useful for determining habitat use patterns in the conditions encountered on this study.

One rabbit was observed on each of the first 2 winter census trips. On 21 March, 1987 the census was repeated a third time; this time 9 cottontails were observed. The average number of rabbits observed on the winter road census was 3.67 rabbits/census (SE = 2.67). All 3 censuses were conducted during times of day during which cottontails were reported to be most active for the respective month (Lord 1961, Kline 1965).

The low productivity of these winter censuses was probably the result of a low population of cottontails. The same causes and possible solutions discussed above for the early morning censuses are applicable here. Because of time and budgetary constraints, the roadside censusing of cottontails was discontinued. Any attempt to evaluate habitat use by cottontails on this area will require a significantly greater dedication of resources than was possible in this study.

Foot Transects

Cottontails flushed while traversing the 8 foot-transects also were recorded. A total of 22 animals was observed in 1986 (0.39 rabbits/transect/census, SE = 0.17); whereas only 5 were seen in 1987 (0.11 rabbits/transect/census, SE = 0.06) (paired t-test, t = 2.286, df = 7, P = 0.0584).

The reduction in rabbits recorded in the 1986 field season versus the 1987 season deserves comment. The most obvious explanation for this drop is that the population of cottontails along the censused areas declined. A second reason is that there may have been a shift in the distribution of the animals. Both explications could be linked to major habitat changes along the sampling transects. For these to be viable explanations, habitat changes would have to occur along much of the total area sampled by transects. Although cover composition within farmlands is continually in a state of flux, I saw no habitat alterations of sufficient magnitude to explain the decline in rabbit numbers I observed. The most likely explanation is that the drop in flushes observed is an artifact of the small sample size, only 8 transects, and the limited number of seasons available to sample. More transects sampled over several seasons would detect a change in rabbit population with greater confidence. Further, a sampling technique with a lower variance on the population estimates would allow tests for differences to have greater statistical power. Live trapping methodology such as that used by Swihart and Yahner (1982), working in Minnesota farmlands, may be more appropriate.

Regardless of the underlying cause for the change in observations recorded, it appears that recording the incidental flushes of cottontails while traversing the foot transect census routes is not an effective means of determining habitat utilization or relative population sizes of this species on farmlands. Regrettably, time intensive techniques such as there were beyond the scope and resources of this study.

Quail

Flush Census

In addition to the call-count census of bobwhite along the 8 foot transects, all quail flushed while traversing those transects were recorded. I noted 24 flushes in 1986, representing a total of 47 birds. Twenty-nine quail from 19 flushes were recorded in 1987. Most flushes consisted of 1 (57%) or 2 (39%) birds; 1 flush in 1986 consisted of 2 adults and 13 young birds. Because this was the only time I flushed more than 3 birds at once, I included only the 2 adult birds in my analysis. This eliminated the outlier's skewing effect, and provided a more representative sample of bobwhite density. Discounting the covey flush of 15 birds to 2 birds produced a density of 0.59 quail/transect/census (SE = 0.12) in 1986. The density of bobwhite in 1987 was 0.65 quail/transect/census (SE = 0.23). Based on 2 years of data, it appears that the quail population in the areas sampled by the foot transects remained fairly constant (paired t-test, t = 0.270, DF = 7, P = 0.880). Unfortunately, I suspect this is not true based on the more complete call-count data (see below), and is only an artifact of the limited sample size (i.e. the number of flushes).

Based on personal observation, the one-man flushing method of censusing quail appears to be an unsatisfactory technique. The perpendicular flushing distances recorded varied markedly, ranging from 0 to 75 m ($\overline{X}$ = 17, SE = 2.8). Interestingly, I found no significant difference in flush distance between birds flushed from wooded edge covers ($\overline{X}$ = 18.4, SE = 3.87, n = 26) and those jumped from nonwooded coverts such as pastures and crop fields ($\overline{X}$ = 14.4, SE = 3.91, n = 17) (t-test, t = 0.713, DF = 43, $P > 0.4$).

This wide range in flush distance leads me to believe that many birds were overlooked by the observer/flusher because the birds "sat tight". Several times I have located male bobwhites calling at points ahead of me on the transect, only to not flush the bird when I stopped nearby for the 10 minute call count census. The quail then resumed calling from the same location after I had proceeded several hundred meters down the transect.

If the flush transect method was used as the primary census method, implementation of modifications such as those described by Dimmick et al. (1982) would be advantageous. This method employs 5 to 10 persons walking abreast at 20 m intervals, recording the number of birds flushed, their location and direction of flight. This technique essentially "traps" the birds between walkers, increasing the probability the quail will flush. This reduces the propensity for the bobwhite to "sit tight" and let the censuser pass that I experienced on this study.

Road Transect Call Count Census

The mean number of birds per station per run in 1987 (0.82, Table 4) was lower ($P < 0.001$) than the 1.31 birds per station per run calculated for the 1986 field season. All 10 road transects showed a reduction in the number of birds from the first to the second field season, although only 5 of these decreases were significant ($P < 0.05$).

Based on only 2 years of census data, it is not possible to determine viable causes for this reduction in quail recorded on the study area. We can speculate on possible explanations for this apparent decrease in density, bearing in mind that the explanations presented are strictly conjectural.

Most of the Southeastern United States endured a drought during the spring and summer of 1986. Precipitation for the period of March 1986 through August 1986 was 21% below normal near (40 km) the study area (Table 5). Average daily temperatures over the same period were above normal (Table 6).

There is general agreement that hot, dry summers are less conducive to bobwhite reproduction than cool, moist summers (Speake and Haugen 1960, Rosene 1969) and many authors have associated summer drought with poor quail reproduction (Stoddard 1931, Robinson and Baker 1955, Reid and Goodrum 1960, Rosene 1969, Stanford 1974a, 1974b). Dry, hot summers may affect reproduction by increasing nest abandonment, reducing hatchability of eggs, and reducing food supplies for chicks in the form of insects, vegetation, and fruit (Stoddard 1931, Murray 1958, Reid and Goodrum 1960).

Roseberry and Klimstra (1985) investigated the effect of weather during the egg-laying and hatching season in Southern Illinois. They found that total precipitation from 22 March through 30 April had a positive linear relationship with the rate of summer population gain. A second weather variable related characteristic, the number of days of snow cover $>= 2.5$ cm multiplied by the ratio of winter density to carrying capacity, was found to have a significant negative, linear affect on rates of summer gain. Because evaluating this variable requires population data unavailable in this study, the effect of that factor is uncertain.

Table 4. Mean number of quail/station/run on each road transect in Halifax Co., Virginia, 1986-87.

Transect	Number of stations	Quail/station/run 1986 $\bar{x}$	1986 SE	1987 $\bar{x}$	1987 SE	t^a	P^b
A	12	2.05	0.42	1.38	0.21	2.46	0.031
B	10	1.30	0.28	0.90	0.14	1.41	0.193
C	13	1.32	0.16	0.93	0.26	1.70	0.114
D	12	1.38	0.21	0.52	0.09	5.93	<0.001
E	13	1.35	0.14	1.13	0.24	1.91	0.257
F	13	1.17	0.17	0.70	0.14	5.46	<0.001
G	11	1.51	0.27	0.81	0.12	2.37	0.039
H	13	1.12	0.14	0.79	0.13	1.98	0.071
I	12	0.62	0.12	0.48	0.11	1.70	0.118
J	12	1.35	0.15	0.52	0.10	5.69	<0.001
Overall	121	1.31	0.07	0.82	0.06	7.79	<0.001

[a] t - statistic from a paired t - test for differences in relative quail numbers between years.
[b] Significance of the paired t - test.

Table 5. Precipitation during spring and summer months at Danville, Virginia, 1986 (Va. Agricultural Statistics Service 1987).

	Precipitation (cm)	Normal (cm)	Percent difference
March	5.66	10.27	-45%
April	2.39	8.76	-73%
May	7.85	9.47	-18%
June	5.51	9.80	-42%
July	9.83	10.31	-5%
August	15.57	10.26	+52%
Total	46.78	58.87	-21%

Table 6. Mean temperatures during spring and summer months at Danville, Virginia, 1986 (Va. Agricultural Statistics Service 1987).

	Temperature (°C)	Normal (°C)	Difference (°C)
March	8	7	+1
April	14	13	+1
May	18	17	+1
June	23	22	+1
July	26	24	+2
August	22	24	-2

Precipitation for the months of March and April (Table 5) were 58% below normal levels. Levels for March through August, including the greater than normal amount of rain in August, still left the area with a 21% deficit in rainfall. Whether the shortage of rain in late March and April had an effect on that summer's recruitment, as described by Roseberry and Klimstra (1985), or if the short-fall of precipitation during the primary nesting and and hatching periods of early summer exerted a negative influence on rearing success, as predicted by earlier researchers, is indeterminable. The case for the drought of 1986 reducing the number of bobwhite in 1987 seems a viable and reasonable possibility.

A second explanation for the decrease in the number of bobwhite recorded in 1987 is related to habitat changes within the area censused. To investigate this alternative, a paired t-test was used to compare the value of certain land use descriptors measured in 1986 with those recorded in 1987. Cover types for the area were categorized into 4 broad categories based on the proportion of the total land area encompassed by each of the following: cropland, pasture, forested areas, and other (which included roads, yards, and ponds). In addition, the length of the 5 most prevalent edge combinations were compared, along with the total length of all edges measured each of the 2 years.

Only 3 of the variables tested were found to have changed significantly over the course of the study (Table 7). The total linear length of edge between areas planted to crops and forested tracts, combined over the entire study area, decreased by slightly over 26,000 m from 1986 to 1987, a reduction of 17%. Conversely, the amount of edge formed when woodlots abut agricultural fields that have lain fallow increased 14% (+15,300 m). Overall, the total length of all edges over the census area decreased by 14,000 m, or about 1 %.

It appears that the values for the crop/forest edge and the fallow/forest are reciprocals. The percentage of crop lands lying fallow increased from 29.8% in 1986 to 33.4% in 1987 (sign rank test T = -459, P = 0.094). Fields that had produced a crop in 1986, but in which no crops were planted in 1987, composed almost all of this change. If fewer crops were planted in 1987, the amount of crop/forest edge would decrease; simultaneously, the total length of fallow/field

Table 7. Change in proportions of major cover types and total lengths (m) of common edge combinations from 1986 to 1987 along road transects in Halifax County, Virginia.

Variable	1986	1987	% change	t^a	P^b
% crop	24.0	24.0	0.0	-0.03	0.979
% pasture	13.7	13.6	0.0	0.29	0.771
% forest	21.9	21.3	- 3.0	1.60	0.112
% other	40.4	41.0	+ 1.5	-1.73	0.086
Crop/forest edge	149718	123677	- 17.4	4.21	<0.001
Forest/forest edge	130497	129788	- 0.5	1.52	0.132
Fallow/forest edge	90557	105850	+ 14.4	-2.63	0.010
Road/forest edge	89083	88380	- 0.8	0.97	0.332
Pasture/forest edge	67301	67245	0.0	0.06	0.955
Total length of edge	989302	975240	- 1.4	2.54	0.012

[a] t - statistic from a paired t - test for differences between years.
[b] Significance of the paired t - test.

edge would increase proportionally. Whether the change in the proportion of these edge combinations contributed to the decrease in quail heard calling is only speculation.

It is impossible to determine with these data if the value of crop/forest edge is of greater value to bobwhite than the fallow/forest edge juxtaposition. The category "crop" encompasses a wide range of vegetation, from well documented quail foods such as corn and wheat, to cover composed of plants of little value to bobwhite, such as tobacco and melons. Also, the value to quail of the crop/forest edge is dependent on the abruptness of the junction of the covers. Fields possessing what Rosene (1969) termed a transition band of volunteer species connecting the cultivated crop with the forest is of great value to bobwhite. Unfortunately, many fields are cultivated to the trees, eliminating this important cover component. Because we don't know if the transition from cultivated crop to uncultivated fallow field eliminated these transition lands, the impact of the crop/forest edge lost from 1986 to 1987 is indeterminate.

The acquisition of additional fallow/forest edge probably did not provide any measurable improvement in habitat quality for bobwhites. Work conducted on old fields in Alabama Piedmont found areas 1 to 2 years post-cultivation contained mostly grasses and composites with few native legumes (Speake 1966). Also, croplands are most useful as bobwhite nesting habitat after 5 to 10 years of natural secondary succession (Klimstra and Roseberry 1975). The young age of these fallow fields (<1 year) probably did not provide much habitat enhancement, and the simultaneous loss of the crop/forest interface may have been detrimental.

Another contributing factor to the diminished number of quail recorded along the road transects may have been the loss of 14,000 m of total edge between 1986 and 1987. The value of edge for wildlife populations is one of the earliest canons of the profession (Leopold 1933). Rosene (1969) stated unequivocally, "The bobwhite is an 'edge' species." From this, it seems that the significant reduction in the total amount of edge found on the study area could be linked to the reduction in the number of cock quail heard calling over the same period. However, evidence exists that the quality of the edge is the factor of importance, not the total amount of all edges. Hanson and Miller (1961) found no correlation between bobwhite numbers and the total length of all edge combinations. "Cover types occurred in many combinations, some attractive to bobwhites and some not. The total of all kinds of edge could not be highly correlated with the number of bobwhites because the attractive edge types were in the minority" (Hanson and Miller 1961). Because it is impossible to quantify the value to bobwhite represented by the lost edge, the significance of the relationship between the reduction in total edge and bird numbers is unclear.

Fewer runs of each of the 10 road transects were accomplished the second year (1986 - 9 runs, 1987 - 7 runs). Although each station along the transects was sampled 2 fewer times in 1987, I do not believe this had an appreciable effect on the census data. The censusing operation was conducted over approximately the same period of time, i.e. mid-April through July, encompassing the period of greatest whistling activity (Robinson 1957). The minimum of 7 runs over each transect during the calling season should have been adequate to develop a reasonable index of bobwhite density.

Two observers were used to census quail each of the 2 years; one of whom was replaced before the second field season. Each observer received approximately 5 days of training in censusing protocol, and was monitored periodically over the duration of that season's work. Using different observers for each of the 2 years should have minimal effect on the accuracy of the census data. Sampling protocol was relatively uncomplicated and easily grasped by both individuals. Also, I participated in censusing for both seasons in addition to training both workers, thus providing sampling continuity over the course of the study.

To summarize, I believe that the combination of the drought effect on quail reproduction and the change in cover composition between the 2 years, combined to reduce quail numbers on the study area in 1987. Unfortunately, testing the relationship between these variables and relative density of bobwhite will require continued monitoring of both variables for a longer period of time than was available.

Foot Transect Call Count Census

The same general trend of decreasing numbers of quail heard calling discussed for the road transect censusing is reflected in the analysis of foot transect census data. The total number of bobwhites recorded dropped from 85 birds in 1986 to only 22 birds in 1987. Seven of the 8 foot-transects registered a decrease in the mean number of birds recorded per station per run from 1986 to 1987 (Table 8), two of which (FD and FE) were significant ($P < 0.05$). Only one transect exhibited an increase from 1986 to 1987, but this increase was not significant. Analysis of the mean number of birds per station per run between the 2 years found the relative number of quail significantly diminished from 1986 to 1987 (sign rank test $T = 271$, $P = 0.002$).

The apparent impacts of the drought of 1986 on the number of bobwhite heard calling, discussed above, apply equally to this data. The same circumstances regarding sampling protocol and field observers discussed for the road transect sampling also applies to the foot transect procedures. Thus, the effect of these variables should be minimal.

Changes in covertype proportions, and composition and lengths of edges may have contributed to the general decline in the number of bobwhite heard along these transects. Only 2 of the cover and edge variables examined were found to be significantly different from 1986 to 1987 (Table 9).

A 5.8% increase in the total length of edge measured, along with a dramatic 210.3% increase in the proportion of covertype "other" are directly attributable to alterations in land use occurring between the 1986 and 1987 field seasons. These habitat modifications also are linked partially to the decrease in bird numbers between the 2 seasonal censuses.

Station 8 on foot transect FB is an example of this relationship. This station was composed of 44% crop cover and 56% forests in 1986. During the fall of 1986, this wooded cover was bulldozed into piles and burned. An irrigation pond was dug on the site, filling with water that winter. In 1987 the cover composition around station 8 was classified as 38% cropland and 62% "other" cover, with the newly constructed irrigation pond and the grass covered

Table 8. Mean number of quail/station/run on each foot transect in Halifax Co., Virginia, 1986-87.

		Quail/station/run						
		1986		1987				
Transect	Number of stations	$\bar{x}$	*SE*	$\bar{x}$	*SE*	t^a	T^b	P^c
FA	10	0.06	0.02	0.03	0.03		2.5	0.572
FB	9	0.38	0.12	0.15	0.06	1.71		0.126
FC	12	0.06	0.04	0.03	0.02		1.0	0.855
FD	10	0.33	0.10	0.0	0.0	3.21		0.011
FE	10	0.19	0.06	0.03	0.02	2.84		0.019
FF	14	0.03	0.03	0.02	0.02		0.0	1.000
FG	13	0.02	0.01	0.04	0.03		-2.0	0.581
FH	9	0.17	0.07	0.06	0.04	1.26		0.244
Overall	87	0.14	0.02	0.04	0.10		271.0	0.002

[a] t - statistic from a paired t - test for differences in relative quail numbers between years, for normally distributed data.
[b] T - statistic from a signed rank test for differences in relative quail numbers between years, for non-normal data.
[c] Significance of the paired t or signed rank test.

Table 9. Change in proportions of major cover types and total lengths (m) of common edge combinations from 1986 to 1987 along foot transects in Halifax County, Virginia.

Variable	1986	1987	% change	T^a	P^b
% crop	41.7	41.3	- 1.0	14	0.681
% pasture	40.4	38.4	- 5.0	7.5	0.059
% forest	15.0	14.2	- 5.3	9	0.234
% other	2.9	6.1	+ 210.3	- 72	0.008
Crop/forest edge	7385	6557	- 11.2	10.5	0.236
Forest/forest edge	447	447	0.0	—	—
Fallow/forest edge	4594	3839	- 16.4	5.5	0.483
Road/forest edge	360	360	0.0	—	—
Pasture/forest edge	2764	2764	0.0	—	—
Total length of edge	35982	38178	+ 5.8	- 33.5	0.021

[a] T - statistic from a sign rank test for differences between years.
[b] Significance of the sign rank test.

and 62% "other" cover, with the newly constructed irrigation pond and the grass covered berms surrounding it constituted the "other" component. Before excavation, the fallow crop field, grain field, and woodlot combination produced records of 6 calling male bobwhites over the 1986 field season, contributing to the 0.38 quail/station/run recorded that year. The barren crop field, pond, grass combination found on the site in 1987 produced no birds, represented by the 61% reduction in birds heard on the FB transect in 1987 (Table 8).

A similar example of the effects of habitat alterations on quail numbers in illustrated by foot transect FD. Hedges, formed by bulldozing slash from forest cutting operations into windrows and allowing vegetation to grow naturally on them, were scattered throughout a lightly grazed pasture along the transect. These islands of woody vegetation and weeds provided ideal whistling posts for bobwhite cocks, and several sightings were recorded. Between the 1986 and 1987 field seasons these hedges were destroyed by bulldozing and burning, and the newly bared soil planted to wheat as supplemental quail food. This resulted in a 100% decrease in the number of quail using this pasture during the censusing period. Similar habitat modifications, although not as dramatic as these examples, likely played a substantial role in the diminished number of bobwhite recorded along other foot transects.

The total size of the sampled area also contributed to the striking change in habitat structure found in the habitat analysis. Each station along the foot transects had a radius of 100 m, forming a sampled area of 3.14 ha. This produces, over 87 stations, a total sampled area of 273.18 ha. The 121 road transect stations, each encompassing 50.2 ha, yielding a sampled area of 6074.2 ha. The effect of almost any habitat alteration within the area encompassed by the foot transects is emphasized by the relatively small total sampled area.

Habitat Selection Patterns

Habitat Modeling

Most habitat model development hinges on the principal assumption that the relative abundance of a species is positively related to the quality of the habitat for that species and that we can measure habitat characteristics indicative of quality. It is an advantageous adaptation for an animal to select one particular site over another if it will increase the animal's probability of surviving and reproducing (Flather and Hoekstra 1985). By favoring individuals that choose better habitats, natural selection should produce a correlation between preference for a given patch type and the animals fitness within it (Pianka 1983), thus relative densities should be higher in habitats that lead to increased fitness.

A goal of this study was to develop a model that uses certain important habitat characteristics of an area to predict the suitability of that area for bobwhite. I constructed this model by linking 2 types of information. First, I determined the relative abundance of quail on 121 individual areas. Then I measured a wide range of habitat characteristics that I believed would serve to describe the area with regard to its suitability for quail. Finally, using the assumption that more quail would be found in areas that contained greater concentrations of those habitat characteristics that quail require, I determined which habitat variables were important, i.e., which factors had a positive influence on quail density, and which habitat characteristics negatively influenced the number of quail present.

This approach is not without its pitfalls. Van Horne (1983) emphasized the need to consider factors that may cause high densities of individuals to occur in lower quality habitats. These factors include seasonal habitat use, social interactions, and variability of environmental factors. Thus a discussion of these possible sources of bias is appropriate.

Quail can exhibit differential use of habitats by season. I censused quail during the spring and summer, a time of the year when quail required appropriate nesting habitat. During the harsher months between nesting seasons, quail form coveys and inhabit ranges providing maximum shelter (Rosene 1969). Stoddard (1931) noted bobwhite in the southeastern United States do not undertake large movements between seasonal ranges. Agee (1957), working in Missouri, found that quail in adequate habitats overwinter within a few hundred yards of where they were hatched. Conversely, Rosene (1969) reports coveys formed in late summer and early fall may move several miles to habitats where adequate food and cover will be available throughout the winter. Because winter food and cover are not in as critically short supply in the southeastern United States as it is along the northern boundary of the bobwhite's range, coveys in southern Virginia probability need not travel far to meet their needs. Hence, habitat used by bobwhite in spring and summer, as determined by the call count surveys, is probably indicative of the habitat used by the birds throughout the year.

Social interaction probably was not a major source of bias. It is true that call surveys detect primarily unmated male bobwhites, and these excess birds may have been forced to inhabit lower quality habitat. But unmated males tend to call very close to nests of established pairs (Johnsgard 1973), therefore, quail counted using this method are likely to be close to well used nesting areas.

It is possible that environmental factors influenced habitat use by the endemic bird population. We received exceptionally low amounts of precipitation both years of the study. Although water is not a limiting factor in most of the quail's range most years, Edminster

(1954) stated that occasional droughts may cause severe losses in quail numbers. Rainfall levels from April through July, 1986 were 33% below normal (Virginia Agricultural Statistics Service 1987). Although unsubstantiated, this drought may have reduced survival of quail that summer, reducing the number of birds in 1987. Further, the paucity of precipitation may have had a detrimental effect on vegetation, influencing habitat use by bobwhite. Only by continued monitoring of quail abundance and habitat use through years with normal precipitation will the effects of the drought be more clearly understood. Except for the possible effects of the drought, I believe the habitat models constructed do not violate the assumption that bobwhite abundance as a valid indicator of habitat quality.

Road Transect Data

Composite Model

Index Variables

Two index variables were found to account for a small, yet significant, amount of the variance in relative quail densities along the road transects (Table 10). A conundrum is raised by this analysis because the 2 variables appear diametrically opposed.

The number of individual cover patches (Ncvr) exhibited a negative relationship with bird numbers in 1986 data analysis and for the analysis of both years combined. An increase in the number of covers is usually associated with an increase in wildlife habitat, and consequently an increase in wildlife density (Giles 1978). This model predicts the opposite effect; as the number of cover polygons increases, relative numbers of bobwhite decrease.

Table 10. Significant predictor variables resulting from a stepwise multiple linear regression relating relative quail densities (# birds/run) at 121 sampling stations to indices of habitat heterogeneity in Halifax Co. Virginia, 1986 and 1987. Regression models were developed from data for each year and from average data for the 2 years.

Data set	Predictor variable	Regression coefficient	*SE*	Contribution to R^2	*t*	P^a
1986	Mnindx	0.011	0.004	0.029	2.66	0.009
	Ncvr	-0.012	0.006	0.028	-1.87	0.064
	Adjusted R^2 = 0.041[b]			$F_{2,118}$ = 3.58[c]	P = 0.031	
	R^2_{PRESS} = 0.0[d]					
1987	Mnindx	0.008	0.003	0.062	2.80	0.006
	Adjusted R^2 = 0.054			$F_{1,119}$ = 7.81	P = 0.006	
	R^2_{PRESS} = 0.022					
Combined	Mnindx	0.011	0.004	0.053	3.00	0.003
	Ncvr	-0.010	0.006	0.024	-1.75	0.082
	Adjusted R^2 = 0.061			$F_{2,118}$ = 4.91	P = 0.009	
	R^2_{PRESS} = 0.017					

[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.

The second variable, Mnindx, represents the ratio of the mean length of edges to the mean size of cover polygons. An increase of this variable would also be indicative of increased habitat heterogeneity. As would be expected, the model predicts an increase in the value of Mnindx will result in an increase in quail density.

The Mnindx variable is the more important variable in this model. Its positive relationship with quail density is in agreement with conventional thought concerning the habitat preferences of bobwhite. In addition, the P - value associated with this variable was much lower that that found for the Ncvr variable and its adjusted R^2 is higher. Based on the analysis of these indices, it appears that quail favor habitat with a high ratio of edge length to cover-patch size.

Unfortunately, an examination of the adjusted R^2 and R^2_{PRESS} statistics suggested that index variables alone are relatively poor predictors of habitat quality for bobwhite. Although significant, the adjusted R^2 for the combined model accounts for only 6% of the variation in relative quail densities. The R^2_{PRESS} statistic, a measure of the predictive ability of the model, drops to slightly less than 2 %, indicating very low predictive power.

Crop Variables

Grain was the only crop that had a consistent significant effect on relative bobwhite densities (Table 11). Winter wheat (*Tritium spp.*) was the primary small grain grown, with scattered fields of oats (*Avena sativa*) and barley (*Hordeum spp.*) also found on the study area. Much of the wheat crop was harvested in June, coinciding with the period when the greatest number of of quail were heard calling. Quail may have been frequenting these fields at this time of year in search of waste grain.

Most wheat fields are replanted to a new crop soon after grain is harvested; thus continued suitability of these fields for quail after harvest is largely a function of the tillage method used by the farmer. Most farmers use conventional tillage equipment that uproots the crop

Table 11. Significant predictor variables resulting from a stepwise multiple linear regression relating relative quail densities (# birds/run) at 121 sampling stations to percent cover of crop variables in Halifax Co. Virginia, 1986 and 1987. Models were developed from data for each year and from average data for the 2 years.

Data set	Predictor variable	Regression coefficient	*SE*	Contribution to R^2	t	P[a]
1986	Melons	4.880	2.289	0.039	2.13	0.035
	Grain	0.951	0.571	0.061	1.67	0.098
	Adjusted R^2 = 0.045[b]			$F_{2,118} = 3.81$[c]	P = 0.025	
	$R^2_{PRESS} = 0.017$[d]					
1987	Grain	1.267	0.589	0.037	2.15	0.034
	Adjusted R^2 = 0.0293			$F_{1,119}$ = 4.63	P = 0.034	
	$R^2_{PRESS} = 0.016$					
Combined	Grain	1.357	0.652	0.045	2.08	0.040
	Garden	-1.158	0.659	0.030	-1.76	0.081
	Fallow, wooded	3.210	1.752	0.024	1.83	0.069
	Adjusted R^2 = 0.075			$F_{3,117} = 4.24$	P = 0.007	
	$R^2_{PRESS} = 0.029$					

[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.

stubble, turns over the soil, and covers the waste grain and vegetation, greatly reducing the amount of food and cover available. However, increasing number of farmers have been using minimum-till methods when replanting their wheat fields. With minimum-till techniques a second crop, often soybeans, is planted directly into the wheat stubble. This leaves the vegetation cover intact, and the waste grain remains available to quail.

Based on the data available, it is impossible to tell if the relationship between quail density and the amount of cropland dedicated to small grains is a year-round phenomenon. It is possible that the coincidence of the grain harvest and the availability of waste grain with the census period of this study produced a relationship that is valid for only that portion of the year.

No information is available on melons being used by quail as food. Melon fields are usually well cultivated, providing little more than low herbaceous cover for bobwhite. I believe the significance of this variable in the model stems from the low frequency of this cover type on the study area. Both watermelons and cantaloups were found growing only in 2 small, localized areas of the study site. Coincidentally, these melon fields were directly adjacent to brushy coverts that consistently produced some of the highest concentrations of bobwhite encountered in 1986. I believe melon fields have little real impact on quail distribution and abundance, and the significance of the variable displayed by this analysis is a product of chance.

Gardens are usually very cleanly cultivated and grow few crops of benefit to quail, thus providing the birds with little food or cover. The negative relationship of this variable to relative bird density illustrates this.

The wooded fallow fields demonstrate a positive relationship to relative bird numbers in the combined analysis. These fields contained a diverse mix of herbaceous species, as well as scattered deciduous and coniferous trees, most $<$ 3 cm dbh. Speake's (1966) work in Alabama Piedmont found old fields 3-5 years past cultivation to have a large component of herbaceous quail food. The size of the trees found in the wooded fallow fields suggests these fields are of an age similar to that in Speake's study. Although the quantity of herbaceous quail food available on these areas was not evaluated, it is probable that these fields provide food and cover components that were attractive to bobwhite.

As in the analysis of the index variables, the adjusted R^2 for this class of variable was low, but significant. Obviously, the analysis of covertype variables alone does not explain much about the distribution of bobwhite on these farmlands.

Forest Variables

Relative densities of quail had a negative relationship with all significant forest variables (Table 12). Three of these variable, PS5, PS147, and PS257, were common to all 3 analyses.

The forest cover represented by PS5 was composed almost exclusively of loblolly pine > 10 y old. These trees were densely planted (standard rate is 650 trees/acre, Landers and Mueller 1986) and were about 5 - 10 m in height. The ground beneath them was covered with a thick layer of pine needles with little understory vegetation. These artificial plantings of pines in thick stands provide no food or cover for quail (Rosene 1969).

The PS147 and PS257 forest types were very common on the study area, together composing 83% of the wooded covertypes and 16% of the total censused area. Because of the 3 canopy layers characteristic of these forests, scant sunlight penetrates to the forest floor. As a result, little or no herbaceous vegetation survives on the forest floor, providing no cover or food for bobwhite. A similar lack of ground vegetation also occurred in the PS257_SL and PS25 cover types.

To have relatively high densities of bobwhite, woodland overstory should be open enough to allow large patches of sunlight to reach 60% of the forest floor. This amount of sunlight allows an understory of low woody shrubs to grow in association with herbaceous annuals and perennials needed for food and cover by quail (Rosene 1969).

Obviously, quail have a strong aversion to most of the woodlands found in the study area. Rosene (1969) observed that thick woodlands also had a depressing effect on quail

Table 12. Significant predictor variables resulting from a stepwise multiple linear regression relating relative quail densities (# birds/run) at 121 sampling stations to percent cover of forest variables in Halifax Co. Virginia, 1986 and 1987. Models were developed from data for each year and from average data for the 2 years.

Data set	Predictor variable	Regression coefficient	*SE*	Contribution to R^2	t	P[a]
1986	PS5	-7.289	1.603	0.123	-4.55	<0.001
	PS147	-1.900	0.477	0.069	-3.98	<0.001
	PS257	-1.367	0.415	0.069	-3.29	0.001
	Adjusted R^2 = 0.242[b]			$F_{3,117}$ = 13.75[c]	P = <0.001	
	R^2_{PRESS} = 0.218[d]					
1987	PS5	-4.412	1.919	0.036	-2.30	0.023
	PS147	-1.429	0.574	0.033	-2.49	0.014
	PS257	-1.066	0.525	0.031	-2.03	0.045
	PS257_SL	-5.724	2.542	0.033	-2.25	0.026
	Adjusted R^2 = 0.102			$F_{4,116}$ = 4.41	P = 0.002	
	R^2_{PRESS} = 0.0					
Combined	PS5	-6.144	1.372	0.113	-4.48	<0.001
	PS147	-1.744	0.411	0.073	-4.24	<0.001
	PS257	-1.188	0.372	0.065	-3.20	0.002
	PS25	-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					

[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.

populations on surrounding open lands. I have no data to support or refute this statement. If it is true that these types of woodlands do depress nearby quail populations, these forests, because they are so widespread throughout the study area, could be having a strong affect on local quail distributions.

The combined model using forest variables produced a relatively high adjusted R^2 value (0.250). Most of this variance was explained using the 1986 data, the model of which explained 24% of the variance, with good predictive power ($R^2_{PRESS} = 0.218$). The 1987 data produced a weaker model than did the 1986 data. Not only did the 1987 model explain less of the variance (adjusted R^2 0.102), it also had no predictive power ($R^2_{PRESS} = 0.0$). This lack of predictive ability carried into the model of the combined data, reducing its value for the R^2_{PRESS} statistic to 0.094.

Edge Variables

Relative densities of bobwhites were found to be related to 6 variables describing specific edge combinations (Table 13). A second significant variable, "other edges", is 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% of all edges measured (n = 995).

Relative bird densities were positively related to the amount of road/pasture edge and road/fallow field edge. Road to pasture edges always were characterized by a fence separating the pasture and the roadway. Often these fences were grown up with brush, small trees, and species of herbaceous vegetation not found in the pasture. These fencelines provide quail with food in the form of seeds and insects, cover, calling sites, and possibly nesting locations. 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 and nesting sites.

Table 13. Significant predictor variables resulting from a stepwise multiple linear regression relating relative quail densities (# birds/run) at 121 sampling stations to edge variables along roads in Halifax Co. Virginia, 1986 and 1987. Models were developed from data for each year and from average data for the 2 years.

Data set	Predictor variable	Regression[a] coefficient	*SE*[a]	Contribution to R^2	*t*	*P*[b]
1986	Road/pasture	4.8	1.1	0.048	4.24	<0.001
	Road/fallow	4.9	1.7	0.037	2.84	0.005
	Road/tall yard	-18.7	6.2	0.037	-3.03	0.003
	Crop/crop	5.3	1.6	0.050	3.34	0.001
	Crop/forest	1.4	0.5	0.041	3.08	0.003
	Short yard/crop	-4.4	2.3	0.024	-1.94	0.055
	Adjusted R^2 = 0.250[c]			$F_{6,114} = 7.68$[d]	P = <0.001	
	$R^2_{PRESS} = 0.199$[e]					
1987	Road/pasture	4.3	1.2	0.030	3.49	0.001
	Road/fallow	3.6	2.1	0.022	1.74	0.084
	Crop/crop	3.4	1.5	0.027	2.31	0.023
	Other	1.6	0.7	0.038	2.18	0.032
	Adjusted R^2 = 0.165			$F_{4,116} = 5.71$	P = <0.001	
	$R^2_{PRESS} = 0.089$					

Table 13. Continued.

Data set	Predictor variable	Regression[a] coefficient	SE[a]	Contribution to R^2	t	P[b]
Combined	Road/pasture	4.8	1.0	0.047	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	0.035	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 $R^2 = 0.266$			$F_{7,113} = 7.20$	$P = <0.001$	
	$R^2_{PRESS} = 0.201$					

[a] x 10^{-4}
[b] Represents significance of the variable as a predictor in the model.
[c] 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.
[d] F-statistic and associated significance for the model.
[e] R^2 of prediction derived from PRESS statistic for each model.

A negative relationship was found between quail and road/tall yard edges. Tall yards were defined as nonagricultural lands vegetated primarily by grass > 15 cm in height. This negative association is probably the result of the bird's aversion to thick sod forming grasses that hamper mobility.

The proximity of the road 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. He found 74% of all nests (n = 602) located within < 15 meters of such openings. Rosene (1969) observed a similar situation, stating that "nest coverts most used are those alongside openings such as fields, disked strips, roadways, or paths." The locations of calling cocks have been positively related to the locations of nesting sites (Klimstra 1950 *in* 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 covertypes juxtaposed with roadways as nesting habitat.

Because all sampling units were centered on censusing stations located along roads, each sampling unit contained at least 800 m of roadway. Because each side of the roadway was measured as a separate edge component, there was at least 1600 m of edge that included road as 1 of its elements in each sampling unit. This omnipresence of road type cover is a potential source of bias. The amount of edge containing road remained constant over all sampling units. The presence of the road (and its associated right of way) had no influence on the type of cover adjoining it. The sole exception was the short yard cover type, which consisted almost exclusively of lawns surrounding residences. The amount of road/short yard edge did not significantly affect the relative abundance of bobwhite. Although I cannot completely discount the possibility of bias being introduced by the constant presence of the roads, I don't believe it adversely influenced the model construction.

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 to forest edge may be the result of the bobwhite's affinity for these transition bands. The herbaceous vegetation that occurs on these strips provides excellent 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).

I 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. Fortunately, 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.

A highly significant, positive relationship was found between bird numbers and the amount of crop to crop edge. An analysis presented later in this thesis will show the proportion of land planted to agricultural crops having a positive relationship with relative quail densities. It is probable that the relationship seen here with crop to crop edge is a manifestation of that association between bird density and the proportion of available land planted to crops. An increase in various different crops planted would increase the crop/crop edge.

Some crop fields are separated by narrow (< 5 m) bands of woody and/or herbaceous vegetation. Strips or areas of this size were too narrow to measure accurately using the aerial photos available. Nevertheless, these narrow strips may have been attractive to bobwhite, contributing to the significance of this variable.

Short yards were defined as nonagricultural lands planted to grass < 15 cm tall (in essence, a lawn). It's no surprise that a negative relationship between short yard/crop edge and bird densities surfaced in the analysis. In my experience, almost all lawns adjoining crop fields were mown to the field edge, leaving no vegetation of benefit to quail.

Relative bird densities showed a positive relationship with the amount of miscellaneous edges, which were categorized under the variable "other". As the total length of these other edges increase, an increase in quail density is highly probable. Hanson and Miller (1961) found an increase in the amount of general edge did not lead to an increase in quail numbers. They postulated that edge types attractive to bobwhite were in the minority. This supposition was reinforced when my analysis of indices did not find an increase in total edge (Sumedge) 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 stepwise procedure used during the construction of this model indicated another variable that, although not significant in the final model, does have some value as a predictor of quail density. The first variable entered by the procedure was the amount of forest/forest edge. As other variables were compared and entered into the model the forest/forest variable was discarded. The entry of this variable into the model first, and its subsequent removal as more variables were entered, means that if only one edge variable could be used to predict the relative abundance of bobwhite, the amount of forest to forest edge would be the most efficient. Its negative relationship (slope = -0.0001, $P = 0.001$) with bird numbers means that as forest/forest edge increases, relative densities of bobwhite decrease. The validity of this effect is reinforced by my earlier analysis of covertypes. I found density of quail decreased with increasing proportions of the census area composed of closed canopy woodlands. Obviously, as the amounts of these forests increased, the amount of forest/forest edge also has the potential to increase, depending on the heterogeneity of different forest types within the forest composition.

Compared to the other 3 classes of variables examined, edge factors account for a substantial amount of variation in relative quail abundance (adjusted ($R^2 = 0.266$, $P = < 0.001$). The ability of the model to predict the relative density of birds based on 121 data points, the R^2_{PRESS} statistic, is 0.201. Although dropping slightly from the adjusted R^2 value, it still is better than that found with the models of the other 3 classes of variables.

Combination of Index, Crop, Forest, and Edge Variables

The significant variables identified in the analyses variables were combined and analyzed using a stepwise regression procedure (Table 14). Only 3 cover type variables contributed significantly to the model (PS5, PS147, PS257). The reasons these woodland variables had such a great effect on relative bird densities was discussed earlier. Based on cover type variables only, it is easier to determine the areas bobwhite don't occur than to predict where they will be found.

There were striking differences in results between the 1986 and 1987 analyses. The 1986 model indicated 3 cover variables and 6 edge variables to be significant. The adjusted R^2 of 0.414 is the highest of any model generated. The R^2_{PRESS} statistic of 0.359 shows relatively good predictive power. Contrasting with this is the 1987 model containing only 3 variables: 2 edge factors and 1 index. This model only accounts for about 13% (adjusted $R^2 = 0.126$) of the variance in relative bird densities, and has low predictive power ($R^2_{PRESS} = 0.076$). The model using data from the 2 years combined retained 7 of the 9 variables from the 1986 model, including the 2 edge variables that the 1986 model shared with the 1987 model. It also included a factor not found to be significant in either of the 2 yearly analyses, the variable "other edges". The adjusted R^2 value ($R^2 = 0.374$) is highly significant ($P = < 0.001$), but the predictive power ($R^2_{PRESS} = 0.170$) is reduced by over 50%.

As discussed in an earlier section on population trends, significantly fewer quail were recorded in 1987 than in 1986. I believe this reduction in birds recorded impeded the regression procedure's ability to distinguish an accurate association between habitat characteristics and habitat use by bobwhites in 1987. It appears that this divergence between 1986 and 1987 models carried into the combined model. This model incorporates both of the variables shared by the 2 yearly models. Its adjusted R^2 is similar to that of the 1986 model, with

Table 14. Significant predictor variables resulting from a stepwise multiple linear regression relating relative quail densities (# birds/run) at 121 sampling stations to variables representing specific crop and forest types, lengths of specific edge types, and indices of heterogeneity in Halifax Co. Virginia, 1986 and 1987. Regression models were developed from data for each year and from average data for the 2 years.

Data set	Predictor variable	Regression coefficient	*SE*	Contribution to R^2	*t*	P^a
1986	PS5	-6.6889	1.42803	0.123	-4.68	<0.001
	PS147	-1.4669	0.43861	0.069	-3.34	0.001
	PS257	-1.1557	0.39685	0.069	-2.91	0.004
	Road/tall yard edge	-0.0020	0.00055	0.046	-3.67	<0.001
	Crop/crop edge	0.0005	0.00014	0.070	3.48	<0.001
	Short yard/crop edge	-0.0005	0.00021	0.024	-2.23	0.028
	Road/pasture edge	0.0003	0.00011	0.021	2.62	0.010
	Road/fallow edge	0.0004	0.00015	0.018	2.43	0.017
	Crop/forest	0.0001	0.00004	0.018	2.47	0.015
	Adjusted R^2 = 0.414[b]			$F_{9,111}$ = 10.43[c]		P = <0.001
	R^2_{PRESS} = 0.359[e]					
1987	Mnindx	0.00720	0.00294	0.062	2.45	0.016
	Crop/crop edge	0.0003	0.00016	0.024	1.80	0.074
	Road/pasture	0.0004	0.00012	0.063	3.15	0.002
	Adjusted R^2 = 0.126			$F_{3,117}$ = 6.79		P = <0.001
	R^2_{PRESS} = 0.076					

Table 14. Continued.

Data set	Predictor variable	Regression coefficient	*SE*	Contribution to R^2	*t*	P^a
Combined	PS5	-5.69796	1.28024	0.113	-4.45	<0.001
	PS147	-1.15281	0.39743	0.073	-2.93	0.004
	PS257	-0.79448	0.35743	0.065	-2.22	0.028
	Road/tall yard edge	-0.00146	0.00048	0.036	-3.03	0.003
	Crop/crop edge	0.00043	0.00012	0.044	3.55	0.001
	Road/pasture edge	0.00031	0.00009	0.026	3.44	0.001
	Road/fallow edge	0.00035	0.00015	0.036	2.37	0.020
	Other edges	0.00012	0.00006	0.023	2.10	0.038
	Adjusted R^2 = 0.374		$F_{9,111} = 9.95$		P = <0.001	
	$R^2_{PRESS} = 0.170$					

[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.

which it shares most of its significant variables. The poor fit and predictive uncertainty of the 1987 model manifest themselves in the low R^2_{PRESS} statistic associated with the combined model.

Because of the similarity in variables between the 1986 model and the combined data model, I am confident that the combined model provides the best fit possible using the available data. The low R^2_{PRESS} statistic in the combined model in an artifact of the uncertainty brought in by the inclusion of the 1987 model. The predictive value of the model could be much higher when applied to only the 1986 data.

The final model developed using the combined 1986 and 1987 data showed 2 major classes of cover variables having a profound effect on the relative density of bobwhite. A strong negative relationship exists between relative quail density and the proportion of cover composed of PS5, PS147, and PS257 type forests. As explained earlier, these forest cover types are characterized by a dense overstory canopy that effectively shades the forest floor. This precludes the existence of the shade intolerant shrub and herbaceous vegetation that could provide food or cover for bobwhite. These 3 forest types compose 83% of all forests and 16% of the total land area incorporated in the censused area. The avoidance of these areas by bobwhite limits the distribution of the species within this and similar areas of the Piedmont.

Edges played a significant role in quail distribution, both in defining areas bobwhite preferred, and those they avoided. In particular, roads played a significant part in determining preferred quail habitat. For road/pasture edge and road/fallow edge, the attraction of these areas as nesting sites probably had the greatest effect on their level of use by the birds. Conversely the occurrence of tall, grassy yards along roads had a significant negative effect on bird distributions. Apparently the effect of the presence of a road is very dependent on the cover adjoining the roadway. The influence of crop/crop edge and all other edges, both indicators of heterogeneity, affirms the bobwhites preference for a mosaic of many preferred habitats.

Although this model explains only 37% of the variance in relative quail abundance, I believe the model is better than it's relatively low adjusted R^2 value indicates. The model resolves a highly significant portion of the variance, thus the variables selected for analysis were meaningful and significant. Unfortunately, the low R^2_{PRESS} value of 0.170 indicates that the model cannot predict the call-count index with a high degree of certainty. However, the overall high significance of the model implies that it is useful for evaluating possible quail habitat on a relative basis. While this model cannot predict the actual density of quail on specific sites, it should indicate the relative values of different sites as quail habitat.

The model requires additional "tuning"; 63% of the variance in relative quail densities remains unresolved. Obviously there are factors in the environment that influence quail abundance that were not measured.

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, and other abiotic variables may be having a profound effect on bobwhite distribution. An analysis of these variables might be useful in accounting for a portion of the variance associated with quail densities.

I also have concerns that the grouping of certain variables to simplify analysis may have masked some of the important habitat components. Because of the extremely 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 most often based on grouping covertypes with closely related structural characteristics. The hazard is that these structural characteristics were those that appeared similar from a human perspective. Humans perceive habitat based on the view from 1.5 to 2 m high. A bobwhite's perception of its world comes from a height of 15 cm, and from inside a body the size of a pint jar. It's possible that habitat variables of importance to bobwhite, and that play significant roles in habitat selection by this species, may have been masked by larger groups of less important variables. In other words, I failed to classify the habitat in a way analogous to how the quail perceived it. However, I know of no other criteria for grouping cover types and edge combinations that is more appropriate.

General Classes of Cover Variables

A model construction technique congruent with that used in the previous habitat model was applied utilizing the broader categories of cover described earlier. Woodlands with a thick overstorys that effectively shaded the forest floor again had a significantly negative effect on the number of birds found (Table 16). The proportion of land planted to crops had a highly significant, positive influence on bird densities. This is primarily the result of the food and cover provided by many of the crop types included in this category, provided mostly by the fallow and wooded fallow fields.

The positive relation with pasture is somewhat puzzling. Most pastures were composed of a thick sod of fescue, with few areas of bare ground. This predominately grassy herbaceous cover is poor habitat for bobwhites. The redeeming value of pastures is that they often are bordered by brushy fencerows, often with sapling size trees intermixed. These fencerows provide cover and travel corridors for quail, as well as calling perches for male bobwhite during the breeding season.

The combination of other types not specifically assigned to another variable also had a positive relationship with relative bird density. The countryside of Halifax County is dotted with many small family cemeteries less than 0.1 ha in size. Many of these plots are overgrown with forbs and honeysuckle vines, and often produce small openings in brushy areas. These openings provide excellent quail habitat. Utility right of ways also are common, and are very distinctive when dissecting wooded areas. These right of ways are bush-hogged every 3-5 years. This treatment results in a corridor of grasses and forbs with a relatively open herbaceous canopy and thin stands of early successional shrubs. In short, these corridors provide good quail habitat.

Table 15. Significant predictor variables resulting from a stepwise multiple linear regression relating relative quail densities (# birds/run) at 121 sampling stations to percent cover of general classes of cover type variables in Halifax Co. Virginia, 1986 and 1987. Models were developed from data for each year and from average data for the 2 years.

Data set	Predictor variable	Regression coefficient	*SE*	Contribution to R^2	*t*	P^a
1986	Forest, 3 canopy layers	-0.8068	0.4040	0.122	-2.00	0.048
	Crop	1.2074	0.3102	0.063	3.89	<0.001
	Pasture	0.0120	0.0055	0.033	2.19	0.030
	Short yard	-2.4685	1.2741	0.022	-1.94	0.055
	Other cover	1.4046	0.8228	0.019	1.71	0.091
	Adjusted R^2 = 0.227[b]			$F_{5,115} = 8.06$[c]	P = <0.001	
	$R^2_{PRESS} = 0.172$[d]					
1987	Forest, 3 canopy layers	-0.7060	0.4681	0.080	-1.51	0.134
	Pasture	1.0108	0.3587	0.022	2.82	0.006
	Crop	0.9545	0.3487	0.054	2.74	0.007
	Adjusted R^2 = 0.134			$F_{3,117}$ = 7.21	P = <0.001	
	$R^2_{PRESS} = 0.100$					
Combined	Forest, 3 canopy layers	-0.7263	0.3465	0.142	-2.10	0.038
	Crop	1.0453	0.2582	0.054	4.05	<0.001
	Pasture	0.7840	0.2834	0.065	3.16	0.002
	Other cover	2.0123	1.1228	0.020	1.79	0.076
	Adjusted R^2 = 0.257			$F_{4,116} = 11.38$	P = <0.001	
	$R^2_{PRESS} = 0.225$					

[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.

The adjusted R^2 of 0.257, when compared to that produced by the model using crop, forest, index, and edge variables (0.314), points out that cover composition is probably one of the most important factor determining relative densities of these birds. Of the type of covers present, the proportion of overcanopy producing forest is by far the most influential. The R^2_{PRESS} associated with this model indicates that it possesses good predictive power.

Foot Transect Models

Models were developed using procedures analogous to those used for the road transect data (Figure 5). For the 1986 and 1987 data combined, quail were recorded at least once at 44 of the 87 total foot transect stations. Because these data were essentially presence/absence data, I used logistic regression (SAS 1985) rather than multiple linear regression. The goal of the individual class models and the composite model was to relate the presence or absence of bobwhite with the cover, index, and edge variables measured at these sites (Table 16).

Index Variables

The number of edges (Nedge) was the only index variable found to be a significant factor for predicting the presence or absence of bobwhite. The positive relationship between the number of edges and the presence of quail indicated the birds preferred a mosaic of cover providing many individual edges. It is puzzling that other indices of heterogeneity, such as the number of covers (Ncvr), were not found to contribute significantly to the model. Since Sumedge and Mnedge were not significant. it also appears that the amount of edge is not as important as the number of discrete edges. Using this single variable the model correctly predicted sites where bobwhite occurred 66% of the time, and sites without birds with 72%

Table 16. Logistic regression models for bobwhite census stations along foot transects in Halifax County, Virginia, 1986 and 1987 combined. Quail were recorded at 44 of 87 sampling stations.

Predictor Variables	Index Variables	Crop Variables	Forest[a] Variables	Edge Variables	Best[b] Variables	Major Cover[c] Variables
Intercept	-1.215	-0.206	0.023	-0.178	-1.318	0.019
Nedge	0.343				0.288	
Other crops		111.424				
Fallow, wooded		198.511			92.954	
Pasture/fallow edge				0.141	0.161	
Forest/forest edge				0.080	0.083	
Pasture						-1.275
Pasture, wooded						5.221
Hedge						20.032
X^2	10.94	13.28		11.70	25.61	10.53
P-value	<0.001	0.001		0.003	<0.001	0.015
Predictions (% correct)						
Sites used	65.9	20.5		18.2	63.6	72.7
Sites not used	72.1	100.0		100.0	81.4	41.9

[a] No forest variables were significant at this scale.
[b] The variables found significant from the anaysis of the 4 classes of variables.
[c] The major catagories of variables: crop; pasture; wooded pasture; ponds; roads; short grass yards; tall grass yards; sapling canopy forests; sapling and pole canopy forests; and sapling, pole and log canopy forests.

accuracy. This suggests that Nedge is a strong predictor of bobwhite habitat preferences at this scale.

Crop Variables

Two crop variables had positive effect on the probability of quail occupying a site: the proportion of an area composed of wooded fallow fields and the proportion of fields planted to minor crops encountered infrequently on the study area, classified as "other crops". The affinity of bobwhite for wooded fallow cover also was found to be significant in the road transect analysis. As discussed earlier, these old fields provide good sources of food and cover for bobwhite.

The value of "other" crops to bobwhite is difficult to explain. Based on my personal observations, 3 crops were the primary contributors to this category: broccoli, sorghum, and sudan grass (*Sorgastum spp.*). I am unable to find any reference to broccoli being a quail food. Broccoli fields are always well cultivated, with little vegetation other than broccoli present. Thus, I don't think broccoli functions as any kind of magnet for quail.

A similar situation exists with sudan grass. I could find no references to its value as a quail food. Most sudan grass is "green chopped" for cattle feed in July and August, never maturing sufficiently to produce seeds. Although it may be used by quail for cover, it is doubtful that they gain much benefit from its presence.

There are a plethora of references listing sorghum as a preferred food of bobwhite (Martin 1935, Baldwin and Handley 1946, Korschgen 1948, Baumgartner 1952, Rosene 1969). Rosene (1969) described the existence of many different types of sorghum; some varieties have tall stalks for use as silage while others have shorter stalks and larger heads for seed production. I don't know for what purpose the sorghum on this area was grown. However, because the census was conducted before the period when sorghum matures, it is unlikely that quail were benefiting from these fields as food sources.

The significance of the variable "other" crop is likely an artifact of its low frequency of occurrence. Only 4 of the 87 stations contained this crop type. With such a low frequency, a relative few bobwhite recorded in these stations would be sufficient to make this variable appear significant.

The crop model predicts sites not used by quail with 100% accuracy. Its accuracy when choosing sites used by birds drops to only 20.5%, pointing to the fact that these variables don't contribute much to the predictive power of the model.

Forest Variables

None of the forest variables were found to have any significant effect on the presence or absence of quail at a site. This is contrary to the analysis of forest variables associated with the road transects. That analysis found a highly significant, negative relationship between the relative density of quail and the proportion of the cover composed of woodlands with dense canopies. The negative relationships seen in the road transect data is probably a result of the woodlands shading out herbaceous growth on the forest floor, making the area unsuitable for quail. This effect is most pronounced in the interior of the woodland, where sunlight no longer penetrates to edge of the woods, and can only reach the forest floor through the overhead canopy.

The mean size of forest patches recorded on the cover maps of the foot transect stations was only 0.04 ha (SE = 0.02, range 0 to 2.39 ha). Thus, the woodlands encountered along these stations either were very small or were the edge of larger forests. Because sunlight probably can reach the floor of these stands, the effect of canopy shading was not great and a negative relationship was not seen. Basically, at this scale of sampling the effects of the forest were not detected.

Edge Variables

Two edge variables, pasture/fallow edge and forest/forest edge, were found to be significant predictors of quail use of specific sites. Neither of these variables contributed significantly to the edge variable models constructed from the road transect data.

Each of these edge types was found infrequently on the sample sites (pasture/fallow edge n = 5, forest/forest edge n = 3). In addition, at least 1 quail was recorded at each of the stations where at least one of these edge types occurred. With quail present at each site these edges occurred, it's obvious that a positive relationship between these edges and the occurrence of quail would be found. Although these edges could have had a significant effect on quail distribution, the occurrence of both quail and these edges at a station could just as easily be a chance event.

An examination of the predictive power of the model lends credence to this idea. Although the model predicted unused sites with complete accuracy (100%), it correctly predicted which sites were used by quail only 18.2% of the time. These 2 variables are probably not good predictors of preferred quail habitat.

Combination of Index, Crop, Forest and Edge Variables

Four of the 5 variables found significant in the analyses of variables by class also were significant in this combined model. The variable describing the proportion of "other" crops was not retained.

This model, including the variables Nedge, wooded fallow cover, pasture/fallow edge, and forest/forest edge, had good predictive power, identifying 63.6% of the used sites and 81.4% of the unused sites correctly.

The index variable Nedge seems to have the greatest influence on which sites are chosen by quail. The predictive power of the edge model in approximately equal to that of the combined model. The variables contributed to the combination model by the crop and edge classes confer little power to the final model.

General Classes of Cover Variables

A model also was constructed for foot transects using only the general classes of cover variables, using a method congruent with that described for the road transect data. The presence of quail was related negatively to the proportion of cover composed of pasture. Quail probably avoided these pastures for several reasons. Most pastures in this area were seeded to fescue and the heavy grazing pressure received by these lands kept the grass short, affording little cover for bobwhite. The dense sod formed in these pastures left little bare ground for foraging by the birds, and foods of value to quail were very scarce.

Although the wooded pasture shares many of the same characteristics of the open pasture, the presence of trees often attracts quail. This was reflected in the positive slope associated with this variable. When some brushy understory is present, the wooded pastures provide screening and traveling cover for the birds and the trees also provide calling perches for the males during the nesting season.

The presence of hedges also had a positive influence on the occurrence of bobwhite. Based on personal observation, it appeared that these hedges provided excellent sources of cover and food for bobwhite. These covers often were located in pastures and provided thick, woody cover for the birds in an otherwise open area. The vegetation these hedges support, such as ragweed, brambles (*Rubus spp.*), and sumacs provide food, cover, and calling sites. The power of this model to predict which sites were used by quail is the highest of all models evaluated (72.7%). The model is less adept at choosing sites without quail (41.9).

Comparison of Models

There was very little agreement concerning which habitat variables were significant between the foot transect and the road transect models. I believe this disagreement was a function of the different scales associated with each model. Foot transect census data was limited to records of birds calling within 100 m of the station. I believe my close proximity to the birds during censusing inhibited their propensity to call. This may have introduced bias into the data on quail presence or absence by preventing some birds occupying a station from being detected. Because birds recorded on road stations included all quail that were aurally detected within 400 m, little disturbance bias was introduced.

Secondly, I believe the limitation of mapping only the habitat within a 100 m radius surrounding the foot transect stations prevented me from accurately describing the habitat used by quail. Many of the different cover types of importance to bobwhite existed in very small, scattered patches. The 3.14 ha area around each station probably did not encompass the total home range of the birds. Thus my descriptions of habitat around these stations were incomplete, and may not be an accurate reflection of bobwhite habitat utilization. For these reasons, I am more confidant in the accuracy of model constructed using the road transect data than I am in the foot transect generated habitat model.

Quail-centered Plots

The micro-habitat needs of the bobwhite are provided chiefly by low, dense woody vegetation. Based on information compiled in the Habitat Suitability Index (HSI) model for the Northern Bobwhite (Schroeder 1985), woody vegetation < 2 m tall with a canopy density between 40 and 80% should be considered ideal. I found the density of this low woody canopy to be greater in the quail-centered plots than in the random plots (27.7 % vs. 3.7 % respectively, $P < 0.001$ $n = 31$, Table 17). Although a canopy cover of approximately 28% is less than optimal, it still produced a suitability index score of 0.75, much greater than the value of 0.05 associated with 4% canopy density (Schroeder 1985). The highly significant difference in canopy density between quail-centered plots and the randomly available habitat is a strong indication of how important shrubby cover is as quail habitat. These brushy areas act as refuges of protective cover, providing an island for birds in a sea of open habitat (Robinson 1957, Roseberry 1964, Yoho and Dimmick 1972). The presence of this cover type probably is a key to maintaining stable bobwhite populations (Casey 1965).

Because it required little extra effort, I also measured the canopy density from 2 - 5 m and > 5 m above the ground. Although these 2 variables were not used in the HSI model, I believed the additional information made the effort worthwhile. My analysis revealed a result similar to that found with canopy density at the lower height; the plots containing quail had a canopy density of about 36 - 38%, significantly greater than the 5 - 7 % canopy density found on the random plots ($P < 0.001$).

Bobwhite were strongly attracted to wooded cover of moderate density. Mast producing tree species such as oaks, ashes, and pines often populate these wooded covers, providing food in addition to protective cover. When sunlight reaches > 60% of the forest floor, herbaceous growth beneficial to bobwhite flourishes. Hence, wooded areas, and particularly brushy coverts, provide an important ingredient for good bobwhite habitat on these lands.

The density of the herbaceous canopy cover was lower on the plots where quail were found than it was on randomly selected plots (52.4% vs. 68.6%, $P = 0.071$, Table 17). The density of herbaceous vegetation is related to the suitability of the site for nesting (Schroeder 1985). Optimal densities of herbaceous vegetation for nesting purposes range from 40 - 60% canopy cover (Schroeder 1985). Although the result of this analysis is not definitive, there appears to be a tendency for quail to frequent areas with slightly less dense herbaceous vegetation than is randomly available.

Table 17. Comparison of habitat characteristics measured at 31 quail-centered and randomly selected paired habitat plots in Halifax Co., Virginia, 1987.

	Quail plots		Random plots				
Variable	$\bar{X}$	*SE*	$\bar{X}$	*SE*	*t*[a]	*T*[b]	*P*[c]
% woody canopy cover > 5 m high	38.2	6.3	6.9	4.4		121	<0.001
% woody canopy cover 2 - 5 m high	36.2	5.2	5.4	3.1	5.00		<0.001
% woody canopy cover <2 m high	27.7	4.3	3.7	1.6	4.94		<0.001
% herbaceous canopy cover	53.5	5.4	68.6	6.5	-1.88		0.071
% herb. cover composed of grass	36.8	6.0	58.1	7.6	-2.71		0.011
% herb. canopy composed of quail foods	3.0	1.8	2.3	0.9		-20.5	0.516
% bare ground or light litter	67.6	5.2	49.2	7.3	2.28		0.030
Mean height herb. veg.	49.1	6.2	49.0	5.9	0.03		0.978
% honeysuckle canopy cover	11.9	3.6	2.8	1.4		66	0.014

[a] t - statistic from a paired t - test for differences in the mean value of each habitat variable between quail plots and random plots based on normal data.
[b] T - statistic from a signed rank test for differences in the mean value of each habitat variable between quail plots and random plots for non-normal data.
[c] Significance of the paired t or signed rank test.

Two components of the total herbaceous canopy also were measured. These were the percent of the herbaceous canopy composed of grass, and the percent of the canopy composed of regionally preferred herbaceous quail foods. A moderate amount of grass is an important ingredient of good bobwhite nesting habitat (Schroeder 1985). Significantly less grass was found on the sites where quail were encountered than was found on the random plots ($P = 0.011$). The HSI model awards it's maximum index values for this variable to habitats with 40 - 60% of the herbaceous canopy cover composed of grass. It appears that both the plots containing quail and the randomly selected plots contained optimal densities of grass for the nesting requirements of bobwhite. The preference of quail for areas with less cover than is generally available may be linked to a preference for the greater herbaceous diversity of these areas. More likely, this association may be only an artifact of the correlation with characteristics such as the amount of woody canopy, which can influence the proportion of grass occurring in the herbaceous canopy.

No difference in the proportion of the canopy cover composed of preferred quail foods was found between the quail-centered plots and the random plots (3.0% vs. 2.3% respectively, $P = 0.516$, Table 17). Habitats with 25 to 75% canopy cover composed of preferred quail foods are considered best. Thirty-five genera or species of herbaceous plants (as determined using Landers and Johnson 1976) were listed as being preferred by bobwhite in this region of the Virginia Piedmont. By far the most common food plant I found was ragweed. This species is common in waste places, along roadsides, and in harvested fields of small grains. Although frequently encountered, ragweed plants found at this time of year (spring - summer) were widely dispersed, resulting in low canopy cover values. Other plants that were occasionally encountered included the various lespedezas; nightshades (*Solanum spp.*), primarily horse nettles; paspalums (*Paspalum spp.*); and crops such as corn, wheat, and soybean. With the exception of the cultivated crops, the frequency of these food plants was relatively low.

It should be noted that the presence or absence of preferred herbaceous quail food is probably not a valid indicator of bobwhite habitat quality in the spring and summer. This variable is included in the HSI model as a way of ascertaining the amount of food available to quail in the winter. Therefore preferred herbaceous quail food consisted of species known to constitute an important part of the bird's diet during this season. Very little information is available on the food habits of bobwhite in the spring and summer. A study by McRae et al. (1979) found acorns, panic grass seeds, blackberries, black cherry fruit, and unspecified leafy greens to be the preferred quail foods during the warmer seasons in Florida. Of these, only the canopy produced by panic grass was recorded when I evaluated the plots. Thus, by basing the evaluation of quail habitat on the locations of bobwhite in spring and summer, but measuring that habitat based on the availability of winter and not spring and summer food sources, it should come as no surprise that I found no evidence of habitat selection by bobwhite based on this parameter.

A factor related to the availability of food for bobwhites is the proportion of the habitat in which the ground was bare or covered by a litter layer < 5.1 cm deep (light litter). "Access to seeds is very important for bobwhites, and it is estimated that the best habitats have bare ground or light litter over 30 to 60% of the area." (Schroeder 1985). Although the values of 67.6% bare ground or light litter on the quail-centered plots, and 49.2% bare ground or light litter on the random plots, are both within the range of values considered optimum for bobwhite, quail were found in areas with a greater percentage of the ground in this condition (P = 0.030, Table 17). Because both the quail-centered plots and the randomly selected plots were at optimal levels for this variable, I do not believe this was an influential factor in the birds' habitat selection. Bare ground or light litter is more prevalent in the wooded areas where the effects of shading prevent the total colonization of an area by herbaceous vegetation. As illustrated earlier, the birds show a marked preference for these wooded coverts. Thus the apparent affinity for areas with more bare ground or light litter is probably an artifact of the vegetation conditions in these wooded covers. Optimal nesting conditions are assumed to be provided when herbaceous vegetation is 40 to 60 cm tall (Schroeder 1985). No significant difference in the mean height of herbaceous vegetation was found between the quail-centered and the random plots (49.1 cm vs. 49.0 cm respectively, P = 0.978, Table 17). Both of these values fell within the range considered ideal for this variable. Because herbaceous vegetation of a height favorable to quail nesting was almost universally available, it is not surprising that a habitat preference based on this variable was not detected.

The cover component composed of honeysuckle (*Lonicera spp.*) was not addressed in the HSI model. Honeysuckle provides both food and cover for bobwhite (Rosene 1969:264), and is common along fencerows, woodland edges, and waste areas in Virginia. Because it is a woody plant, but forms a low canopy in a way similar to herbaceous vegetation, it was difficult to decide if it should be included as part of the woody canopy or the herbaceous canopy. Therefore, it was evaluated as an individual variable.

Although honeysuckle composed a small percentage of the canopy (11.9% in quail plots, 2.8% in random plots), significantly greater amounts of it were found in plots used by bobwhites (P = 0.014, Table 17). Hence, honeysuckle appears to be of some importance to quail in regards to habitat selection. The value of this species as a source of cover and food during adverse winter weather is well documented (Davison 1942, Handley 1945, Roseberry 1964, Yoho and Dimmick 1972, Roseberry and Klimstra 1984). Because this study was conducted during spring and summer, and the value of honeysuckle as thermal cover and a food source was negated, its effect, as evidenced by this analysis, was probably an artifact of it's association with woody covers.

In summary, I believe the presence of woody cover, in the form of fencerows, brushy waterways, small woodlots, and shrubby areas has the greatest effect on the choice of micro-habitat by bobwhite. Other variables found to be significantly different on the quail plots than on the random plots probably are related to the presence of the woody habitat type. Although the presence of these other conditions increases the value of a specific site for bobwhite, the structure provided by the trees and shrubs provides the foundation of the covert's desirability.

I was able to effectively evaluate 3 of the 6 variables contained in the HSI model. These 3, the percent woody cover < 2 m high, the percent of the herbaceous cover composed of grass, and the percent of the ground that was bare or covered by litter < 5.1 cm deep, all showed significant differences between the plots containing quail and those without birds, and all were consistent with the predictions made by the model. Two variables, the percent of the herbaceous canopy composed of preferred quail foods, and the mean height of herbaceous vegetation, exhibited no significant differences in value between quail-centered and random plots. Problems associated with evaluating the preferred food variable were discussed earlier. The lack of predictive power shown by the model when using this variable should not be interpreted as a fault in the model. Since the mean height of the herbaceous vegetation was uniformly optimal for bobwhite, I was not afforded an opportunity to verify the accuracy of the model in interpreting this variable.

I believe HSI model, if it is to apply to the Mid-Atlantic Region, should more explicitly address the value of honeysuckle as a component of good quail habitat. Although the author of the model may have assumed that honeysuckle was included in the variable describing the percent canopy cover < 2 m high, I believe its documented value to bobwhite warrants its inclusion in the model as an independent variable.

Conclusions

1. A combination of low cottontail densities and inefficient censusing techniques contributed to low numbers of rabbits recorded during the course of the study. Census techniques more sensitive to low rabbit densities would be more appropriate.

2. Fewer bobwhites were heard calling in 1987 than in 1986 along both the road and the foot transects. There were significant changes in certain habitat characteristics of lands included in the censused areas. Unfortunately, the actual effect of these habitat alterations can not be determined. The drought of 1986 also may have affected the number of birds available in 1987. There is considerable information in the literature describing the negative effects of drought on bobwhite recruitment. While changes in the frequency of certain habitat characteristics found in the censusing area may have contributed to the decline in quail from 1986 to 1987, I believe that the very dry conditions experienced in the study area from April through July of 1986 had the greatest impact on 1987's quail population.

3. Bobwhite do not use woodlots with dense overstory canopies. The shading effect of these canopies may have inhibited the establishment of shrub and herbaceous vegetation on the forest floor needed by the birds.

4. Edges had a strong relationship to relative quail density. Edges classified as road/pasture, road/fallow, crop/crop, and "other" were positively related to quail density, as was the total number of all edges. Road/tall grass yard edge was negatively related to quail density.

5. When modeled separately, the specific crops "grain" and "wooded fallow" demonstrated positive relationships with bobwhite densities. Although the identity of the specific crops was lost in the analysis of larger variable groups, the general category "crop" was still a significant component of the models. Crops are important parts of quail habitat and are positively related to relative numbers of birds.

6. The relationship of pasture to relative quail density is inconclusive. Analysis of road transect data found pastures to have a positive relationship to bird density, while along the foot transects, pastures, with the exception of wooded pastures, were negatively related to the presence of bobwhite. Because of the wide diversity in height, density, and composition of the pastures found on the study area, dividing the broad variable "pasture" into specific variables more descriptive of the characteristics of that covertype may be needed.

7. The best model produced by this analysis accounts for slightly less than 40% of the variance observed in relative quail densities. Other factors, unmeasured in this study, are exerting a marked influence on bird numbers. Factors that may be important include weather,soil type, soil moisture regime, and the use of agricultural chemicals.

8. While quail seem to avoid forests with dense overstory canopies, the results of the quail-centered plot analysis indicated bobwhite chose wooded cover with 30-40% canopy closure over wooded cover with 4-7% canopy density. Canopies with approximately 40% closure provide protective cover while allowing sufficient sunlight to reach the forest floor for the establishment of shrubs and herbaceous plants.

9. Bobwhite preferred herbaceous canopy cover density of around 50%, with less of the herbaceous canopy composed of grass than was randomly available. In conjunction with this, quail were found in areas where more of the ground surface was bare or covered with a light litter than was randomly available.

10. Preferred herbaceous quail foods are in short supply during the summer months. Because much of the food consumed by quail in this season consists of fruits, insects, and green leafy vegetation, this paucity of seed producing species is probably not important. It may be imprudent to try to measure the availability of preferred fall and winter quail food during the early summer months.

11. Based on the limited number of HSI Model variables I examined, the model can correctly predict which habitats are preferred by bobwhite.

Management Implications

Numerous articles, pamphlets, and books have been written describing techniques for managing quail habitat. Most sources agree that 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 important factors. In this section I will integrate the factors I found to be significant from my investigation of habitat use by bobwhite on Virginia's Piedmont region, and relate them to these 3 required characteristics of bobwhite habitat.

The value of early successional vegetation to bobwhite was illustrated in my results in 2 ways. First, I found a significant negative relationship between the relative density of quail and the proportion of cover composed of mature woodlands. These forests are characterized by dense overstory canopies that shade the forest floor, discouraging the establishment of the herbaceous vegetation and shrubby undergrowth required by quail. Unless the canopy of these forests in opened by drastic thinning or a timber harvest, little more than the edge of these woodlands will be used by bobwhite. Management resources would be better spent on lands with greater inherent suitability for bobwhite.

The second example illustrating the importance of early successional vegetation involves the significance of fallow or wooded fallow cover in the models. Fields left fallow are important sources of food and nesting cover for bobwhite. These areas are of optimal value when they are between 3 and 10 years post-cultivation (Schroeder 1985). It's during this time period that leguminous plants 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 edge is an important ingredient of good quail habitat. My analysis found the number of quail to be positively related to the number of discrete edges present. Additionally, I found a number of particular edge combinations contributing significantly to the variation in quail densities I encountered on my sampling areas. Efforts should be made to maximize the number of different 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 main disadvantage of small fields is the increased time spent transporting equipment between fields. This disadvantage can be partially overcome by linking smaller fields together with strips of the same crop (Landers and Mueller 1986). Also, landowners should be discouraged from cultivating field corners, waterways, and other idle areas. These odd areas add needed habitat diversity.

Evidence of the birds preference for cover that was open at ground level was illustrated a number of times in the analysis. Bobwhite showed a significant proclivity for cover where less of the herbaceous canopy cover was composed of sod forming grass, and where more bare ground or light litter was present, than was randomly available. This type of cover was often found in the fallow fields described earlier. This is additional proof of the importance of these idle agricultural areas in good quail range.

Lastly, I feel these model variables illustrate the importance of providing protective cover for quail. This type of cover generally consists of brushy vegetation < 2 m high with a canopy density of 40 - 80%. The effectiveness of this cover is directly related to its distance from other types of habitat required by quail, such as nesting cover and food sources; protective cover is most valuable when it's located less the 100 m from these other habitat requirements (Schroeder 1985). The significance of hedges in the foot transect model indicates they are excellent providers of protective cover, in addition to also being good sources of food for the birds. Finally, honeysuckle should be encouraged where ever practical. It is an excellent source of food and cover for quail, especially in the winter. The retention of these types of cover should be considered a prerequisite to maintaining bobwhite populations.

Literature Cited

Agee, C. P. 1957. The fall shuffle in central Missouri. J. Wildl. Manage. 21:329-335.

American Ornithologist's Union. 1983. Checklist of North American birds. Sixth ed. Am. Ornith. Union. 877pp.

Balwin, W. P., and C. O. Handley. 1946. Winter food of bobwhite quail in Virginia. J. Wildl. Manage. 10:142-149.

Baumgartner, F. M. 1945. Management of bobwhite on oak - tall grass prairie, north central Oklahoma. Trans. North Am. Wildl. Conf. 10:185-190.

_____, M. J. Morris, J. L. Steele, and J. E. Williams. 1952. Oklahoma bobwhite food relations. Trans. North Am. Wildl. Conf. 17:338-359.

Baxter, W. L., and C. W. Wolfe. 1972. The interspersion index for evaluation of bobwhite quail habitat. Proc. Natl. Bobwhite Quail Symp. 1:158-165.

Bennett, L. J., and G. O. Hendrickson. 1938. Censusing quail in early fall. J. Wildl. Manage. 2:169-171.

Burger, G. V., and J. P. Linduska. 1967. Habitat management related to bobwhite populations at Remington Farms. J. Wildl. Manage. 31:1-12.

Burnham, K. P., and D. R. Anderson. 1984. The need for distance data in transect counts. J. Wildl. Manage. 48:1248-1254.

Casey, W. H. 1965. Some speculations on the minimum habitat requirements of bobwhite quail. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 19:30-39.

Cushwa, C. T., R. E. Martin, and M. L. Hopkins. 1971. Management of bobwhite quail habitat in pine forests of the Atlantic Piedmont. Ga. For. Res. Pap. 65. 5pp.

Davis, D.E., and R. L. Winstead. 1980. Estimating the numbers of wildlife populations. Pages 221-246 *in* S. E. Schemnitz, ed. Wildlife management techniques manual. The Wildl. Soc., Washington, D. C.

Davison, V.E. 1942. Bobwhite food and conservation farming. J. Wildl. Manage. 6:97-109.

Dimmick, R. W. and N. S. Yoho. 1972. The response of bobwhite coveys to disturbance during field trials. Pages 82-90 *in* J. A. Morrison and J. C. Lewis, eds. Proc. First Natl. Bobwhite Quail Symp. Okla. State Univ., Stillwater.

_____, F. E. Kellog, and G. L. Doster. 1982. The Lincoln Index and flush census as population estimates for bobwhites. Pages 13-18 *in* F. Schitoskey Jr., E.C. Schitoskey, and L. G. Talent, eds. Proc. Second Bobwhite Quail Symp. Okla. State Univ., Stillwater.

Edminster, F. C. 1954. American game birds of field and forest. Charles Scribner's Sons, New York. 490pp.

Ellis, J. A., W. R. Edwards, and K. P. Thomas. 1969. Responses of bobwhites to management in Illinois. J. Wildl. Manage. 33:749-761.

Eubanks, T. R., and R. W. Dimmick. 1974. Dietary patterns of bobwhite quail on Ames Plantation. Univ. Tenn. Agric. Exp. Stn. Bull. 534. 38pp.

Flather, C. H. and T. W. Hoekstra. 1985. Evaluating population-habitat models using ecological theory. Wildl. Soc. Bull. 13:121-130.

Giles, R. H. Jr. 1978. Wildlife management. Freeman, San Fransisco, Calif. 416pp.

Goodrum, P. 1949. Status of bobwhite quail in the United States. Trans. North Amer. Wildl. Conf. 14:359-369.

_____, and V. H. Reid. 1952. Quail management of forested land. Proc. Southeast. Assoc. Game and Fish Comm. 6:1-4.

Handley, C. O. 1945. Japanese honeysuckle in wildlife management. J. Wildl. Manage. 9:261-264.

Hanson, W. R., and R. J. Miller. 1961. Edge types and abundance of bobwhites in southern Illinois. J. Wildl. Manage. 25:71-76.

Harshburger, T. J., and R. C. Simpson. 1970. Late-summer nesting sites of quail in south Georgia. U. S. For. Serv. Res. note SE-131. 4pp.

Hays, R. L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U. S. Dept. Inter. Fish and Wildl. Serv. FWS/OBS-81/47. 111pp.

Hurst, G. A. 1972. Insects and bobwhite quail brood habitat management. Proc. First Natl. Bobwhite Quail Symp. 1:65-82.

Illinois Wildlife Commission Report 1984-85. 1985. The crisis of wildlife habitat in Illinois. Ill. Dept. Conserv., Springfield. 26pp.

Johnsgard, P. A. 1973. Grouse and quails of North America. Univ. Nebr. Press, Lincoln, Nebr. 553pp.

Kabat, C. and D. R. Thompson. 1963. Wisconsin quail, 1934-1962 population dynamics and habitat management. Wis. Conserv. Dept. Tech. Bull. 30. 136pp.

Klimstra, W. D. 1950. Notes on bobwhite nesting behavior. Iowa Bird Life. 20:2-7.

_____, and V. C. Ziccardi. 1963. Night-roosting habitat of bobwhites. J. Wildl. Manage. 27:202-214.

_____, and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildl. Monogr. 41. 37pp.

Kline, P. D. 1965. Factors influencing roadside counts of cottontails. J. Wildl. Manage. 29:665-671.

Korschgen, L. J. 1948. Late-fall and early-winter food habitats of bobwhite quail in Missouri. J. Wildl. Manage. 12:46-57.

Landers, J. L., and A. S. Johnson. 1976. Bobwhite quail food habitats in the Southeastern United States with a seed key to important foods. Tall Timbers Res. Stn., Tallahassee, Fla. Misc. Publ. 4. 90pp.

_____, and B. S. Mueller. 1986. Bobwhite quail management: a habitat approach. Tall Timbers Res. Stn. Tallahassee, Fla. Misc. Publ. 6. 90pp.

Legrand, H. E. 1960. Geology and groundwater resources of Pittsylvania and Halifax Counties. Va. Div. Mineral Res., Charlottesville, Va. 85pp.

Lehman, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M Univ. Press, College Station. 371pp.

Leopold, A. 1933. Game management. Charles Scribner's Sons, N. Y. 481pp.

Lord, R. D. Jr. 1961. Seasonal changes in roadside activity of cottontails. J. Wildl. Manage. 25:206-209.

_____. 1963. The cottontail rabbit in Illinois. Ill. Dept. Conserv. Tech. Bull. 3. 94pp.

Martin, A. C. 1935. Quail-food plants of the Southeastern States. U. S. Dept. Agric. Cric. no. 348. 15pp.

McInteer, J. F. Jr., editor. 1986. Virginia's bobhwite quail. Virginia Comm. Game and Inland Fish., Richmond. 36pp.

McRae, W. A., J. L. Landers, J. L. Buckner, and R. C. Simpson. 1979. Importance of habitat diversity in bobwhite management. Proc. Southeast. Assoc. Fish and Wildl. Agencies. 33:127-135.

Murphy, D. A., and T. S. Baskett. 1952. Bobwhite mobility in central Missouri. J. Wildl. Manage. 16:498-510.

Murray, R. W. 1958. The effect of food plantings, climatic conditions, and land use practices upon the quail population on an experimental area in northwest Florida. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 12:269-274.

Peterson, R. T. 1947. A field guide to birds. Second ed. Houghton Mifflin Co., Boston, Mass. 230pp.

Pianka, E. R. 1983. Evolutionary ecology. Third ed. Harper & Row Publ., New York, N. Y. 416pp.

Preacher, J. W. 1978. Deterioration rates of 35 bobwhite quail foods and their preferential use. Proc. Southeast. Assoc. Fish and Wildl. Agencies. 32:356-363.

Reid, V. H., and P. D. Goodrum. 1979. Winter feeding habits of quail in longleaf-slash pine habitat. U. S. Fish Wildl. Serv. Spec. Sci. Rep. 220. 39pp.

Robel, R. J., A. R. Bisset, A. D. Dayton, and K. E. Kemp. 1979. Comparative energetics of bobwhites on six different foods. J. Wildl. Manage. 43:987-992.

Robinson, T. S. and R. H. Baker. 1955. Climate and bobwhite quail in Kansas - 1951-1954. Trans. Kansas Acad. Sci. 58:353-359.

_____. 1957. The ecology of bobwhites in south-central Kansas. Univ. Kans. Mus. Nat. Hist. and State Biol. Surv. Kansas Misc. Publ. 15. 84pp.

Roseberry, J. L. 1964. Some responses of bobwhites to snow cover in southern Illinois. J. Wildl. Manage. 28:245-249.

_____, and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois Univ. Press, Carbondale. 259pp.

Rosene, W. Jr. 1969. The bobwhite quail, its life and management. Rutgers Univ. Press, New Brunswick, N. J. 418pp.

SAS Institute Inc. 1985. SAS user's guide: statistics. Cary, N. C. 956pp.

_____. 1986. SUGI supplemental library user's guide. Cary, N.C. 662pp.

Schroeder, R. L. 1985. Habitat suitability index models: Northern bobwhite. U. S. Fish and Wildl. Serv. Biol. Rep. 82 (10.104). 32pp.

Speake, D. W., and A. D. Haugen. 1960. Quail reproduction and weather in Alabama. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 14:85-87.

_____. 1966. Effects of controlled burning on bobwhite quail populations and habitat of an experimental area in the Alabama Piedmont. Proc. Southeast. Assoc. Game and Fish Comm. 20:19-32.

Stanford, J. A. 1974a. Bobwhite saga part II. Mo. Conserv. 35:4-7.

Stanford, J. A. 1974b. Bobwhite saga part III. Mo. Conserv. 35:16-19.

Steen, M. O. 1950. Road to restoration. Trans. N. Amer. Wildl. Conf. 15:356-363.

Stoddard, H. L. 1931. The bobwhite quail, its habits, preservation, and increase. Charles Scribner's Sons. New York, N. Y. 559pp.

Sweeney, J. M., C. R. Wenger, and N. S. Yoho. 1981. Bobwhite quail food in young Arkansas loblolly pine plantations. Arkansas Exp. Stn. Bull. 852. 18pp.

Swihart, R. K., and R. H. Yahner. 1982. Eastern cottontail use of fragmented farmland habitat. Acta Theriol. 27:257-273.

United States Department of Agriculture. 1934. Soil map of Halifax County, Virginia. Bur. of Chem. and Soils.

_____. 1956. Soil survey, Mecklenburg County, Virginia. U. S. Dept. Agric. Soil Conserv. Serv. 1942, No. 13. 116pp.

_____. 1977. Soil survey of Orange County, North Carolina. Soil Conserv. Serv. 93pp.

United States Department of Commerce. 1984. 1982 census of agriculture, Vol. 1, Geographic area series (AC82-A-46), part 46, Virginia. U. S. Gov. Printing Off. 446pp.

Urich, D. L., J. P. Graham, and C. C. Cook. 1983. A handbook of habitat evaluation in Missouri. Missouri Dept. Conserv., U. S. Soil Conserv. Serv., U. S. Fish Wildl. Serv., Columbia. 148pp.

Vance, D. R. 1976. Changes in land use and wildlife populations in southeastern Illinois. Wildl. Soc. Bull. 4:11-15.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47:893-901.

Virginia Agricultural Statistics Service. 1987. Virginia agricultural statistics. Bull. 56. 96pp.

Virginia Commission of Game and Inland Fisheries. 1986. Virginia wildlife investigations: annual report 1 July, 1985 - 30 June, 1986.

Virginia Crop Reporting Service. 1982. Halifax County farm statistics. Va. Dept. Agric. and Consumer Serv., Richmond, Va. 4pp.

Wiseman, D. S., and J. C. Lewis. 1981. Bobwhite use of habitat in tallgrass rangeland. Wildl. Soc. Bull. 9:248-255.

Yoho, N. S., and R. W. Dimmick. 1972. Habitat utilization by bobwhite quail during winter. Pages 90-99 *in* J. A. Morrison and J. C. Lewis, eds. Proc. First Natl. Bobwhite Quail Symp., Oklahoma State Univ., Stillwater. 390pp.

Vita

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