ABSTRACT

BOWLING, SHANNON ARNOLD. Influence of Landscape Composition on Northern Bobwhite Population Response to Field Border Establishment. (Under the direction of Christopher E. Moorman and Christopher S. DePerno).

Since the 1960's, habitat loss resulting from cleaner farming, increased urbanization, and maturation of early successional cover has caused rangewide decline of northern bobwhite (*Colinus virginianus*). Although field borders increase useable bobwhite habitat and increase local bobwhite populations, understanding how the surrounding landscape influences bobwhite response to this management practice is critical to efficient implementation. We determined the relative influence of landscape composition and field border implementation on bobwhite densities and occupancy dynamics around crop fields in North Carolina and South Carolina, USA. We used 10-minute distance point counts to estimate density, occupancy, colonization, and extinction rates of male bobwhite around 154 agriculture fields, half of which had a fallow field border. We estimated percent of crop, forest, pasture, early successional, and urban cover within 1-km radius buffers (314 ha) surrounding all point count locations. We conducted a linear regression analyses to determine the influence of six predictor variables (landscape composition metrics and field border presence) on bobwhite density and occupancy dynamics. Bobwhite density increased with the presence of field borders. Conversely, bobwhite density decreased as the percentage of urban, pasture, and forest lands increased. The presence of a field border did not influence occupancy, colonization, or extinction rates. However, as the percentage of crop increased within the landscape, bobwhite occupancy increased and as the percentage of pasture increased, bobwhite colonization decreased. As the percentage of forest, urban, and pasture increased, bobwhite extinction rate increased. Our results indicated that local establishment of field

borders does not increase bobwhite occupancy rates, but field borders can increase bobwhite densities in suitable landscapes where bobwhite already are present. Habitat restoration for northern bobwhite will most effectively increase population densities if focused in landscapes dominated by suitable cover types, where bobwhite occurrence is high.

Influence of Landscape Composition on Northern Bobwhite Populations
Response to Field Border Creation

by
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BIOGRAPHY

I was born in the town of Newberg, Maryland, where my family farmed a small piece of land along the Wycomico River. I spent my early childhood days on the farm exploring the woods and river and discovering my passion for the outdoors. My father and mother both love being outdoors and helped instill that love in me. In 1994, my family moved to Fuquay Varina, North Carolina, were I continued to hunt and fish and build my interest in wildlife and the outdoors. After high school, I knew I wanted a career that allowed me to be outdoors, so I attended North Carolina State University and graduated with a Bachelors degree in Fisheries and Wildlife Sciences in 2009. Upon completing my Bachelors, I began my Masters at North Carolina State University in Fisheries, Wildlife, and Conservation Biology. In the summer of 2009, I married the love of my life, Lauren, who pushed me in the pursuit of my career. Even though she isn't the outdoors enthusiast that I am, she has spent countless hours with me camping, fishing, scouting for ducks, and enjoying the great outdoors. Being at North Carolina State University since 2005, I have discovered that while I like the city of Raleigh, I am ready to return to the rural environment that I fell in love with as a child. Upon completion of my Masters, I will continue my passion for studying wildlife and being outdoors by starting my career as a Farm Bill Biologist with Pheasants Forever in Colorado.

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I thank all those who helped in the completion of this project. My technicians went above and beyond the call, especially my lead technician Justin Smith. Justin worked along side me through all three summers of my field work and excelled through the early mornings, hot field borders, and South Carolina swamps. All of the landowners throughout North Carolina and South Carolina were incredibly helpful and welcomed us onto their property to conduct our field work, sharing stories and teaching me much about farm life and bobwhite. The North Carolina Wildlife Resources Commission and the South Carolina Department of Natural Resources were especially generous in letting us use their housing through my field seasons, allowing me access to their first three years of data, and provide much feedback.

My wife, Lauren, has been supportive and helpful throughout all of my studies and research. Even through the preparation of our wedding and the surgery to repair her ACL, she never complained that I was gone for weeks at a time conducting my field research. She has been the rock that I have leaned on. As a school teacher, she understands that neither of our career paths is going to make us rich, but has supported me throughout the pursuit of my career.

My parents, Arnold and Theresa, were unconditionally supportive and helpful throughout my college career, as all great parents are. My father taught me the love of the outdoors and the determination that was needed to stay true throughout my college career. My mother taught me the patience and dedication that has inspired me throughout my field research and especially the later part of my Master's. They have both helped me academically and personally, and I could not have gone this far without them.

My graduate advisors Chris Moorman and Chris DePerno have been essential to the pursuit of my degrees and growth through my education. They have both helped me in developing as a student and professional by pushing me in all aspects of my college career. Chris DePerno encouraged me to go to graduate school after my completion of my Bachelors degree and believed in me enough to help me in the pursuit of my Master's degree. Chris Moorman has shown me the example of a true professional in the Wildlife Sciences field and has helped prepare me for the expectations I will face in my future endeavors.

I thank Ted Simons for his guidance and expertise in the design of our field study and analysis of our point count data, and Stacy Nelson for his help in acquiring the land cover data and GIS analysis. Outside of my committee, I'd like to thank Kristine Evans (Mississippi State University) for allowing us to be part of CP33 monitoring project, supplying us funding for my Masters project, and providing inexhaustible guidance and assistance throughout the project. Also, Jaime Collazo (North Carolina State University) and Beth Gardner (North Carolina State University) were incredibly generous with their time in aiding us in our occupancy analysis.

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CHAPTER 1

Field Border Establishment Increases Northern Bobwhite Densities but not Occupancy.

ABSTRACT Since the 1960's, habitat loss resulting from cleaner farming, increased urbanization, and maturation of early successional cover has caused rangewide decline of northern bobwhite (*Colinus virginianus*). Although field borders increase useable bobwhite habitat and increase local bobwhite populations, understanding how the surrounding landscape influences bobwhite response to this management practice is critical to efficient implementation. We determined the relative influence of landscape composition and field border implementation on bobwhite densities and occupancy dynamics around crop fields in North Carolina and South Carolina, USA. We used 10-minute distance point counts to estimate density, occupancy, colonization, and extinction rates of male bobwhite around 154 agriculture fields, half of which had a fallow field border. We estimated percent of crop, forest, pasture, early successional, and urban cover within 1-km radius buffers (314 ha) surrounding all point count locations. We conducted linear regression analyses to determine the influence of six predictor variables (landscape composition metrics and field border presence) on bobwhite density and occupancy dynamics. Bobwhite density increased with the presence of field borders. Conversely, bobwhite density decreased as the percentage of urban, pasture, and forest lands increased. The presence of a field border did not influence occupancy, colonization, or extinction rates. However, as the percentage of crop increased within the landscape, bobwhite occupancy increased and as the percentage of pasture increased, bobwhite colonization decreased. As the percentage of forest, urban, and pasture increased, bobwhite extinction rate increased. Our results indicated that local establishment of field borders does not increase bobwhite occupancy rates, but field borders can increase bobwhite densities in suitable landscapes where bobwhite already are present. Habitat restoration for northern bobwhite will most effectively increase population densities if focused in landscapes dominated by suitable cover types, where bobwhite occurrence is high.

KEY WORDS agriculture, *Colinus virginianus*, colonization, extinction, field border, habitat, landscape, northern bobwhite, occupancy.

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Since the 1960's, northern bobwhite (*Colinus virginianus*; hereafter bobwhite) have declined rangewide, but most dramatically in the southeastern United States (Church et al. 1993, Sauer et al. 2005, Terhune et al. 2006). The decline has been attributed to the degradation and loss of useable habitat (Best et al. 1997, Brady et al. 1998, Burger 2002, Okay 2004). Large-scale farming and intensive pine silviculture reduced habitat quality and landscape heterogeneity (Brennan 1991, Burger 2002, Fies et al. 1992, Jones et al. 2010, Pociak 2007). Fire suppression facilitated forest maturation and degradation of herbaceous ground cover, and urbanization eliminated useable bobwhite habitat and fragmented residual habitat patches (Best et al. 1997, Burger 2002, Jones et al. 2009, Okay 2004, Terhune et al. 2006).

Field borders create an herbaceous buffer between cropland and adjacent habitat, and have been suggested as a means to restore bobwhite populations in agricultural landscapes (Blank et al. 2011, Doxon and Carroll 2010, Greenfield 2002, Puckett et al. 1995, Stamps et al. 2008). Bobwhite densities may be greater on farms with field borders than on those without field borders (Blanks et al. 2011, Palmer et al. 2005) and initial increases of 45% in bobwhite abundance after field border establishment have been observed (Riddle et al. 2008).

Conversely, Smith and Burger (2006a) showed breeding season bobwhite density was similar in border and non-border fields.

Mixed responses by bobwhite to field border establishment may be related to the surrounding landscape composition and the associated influence on bobwhite ability to disperse and gain access to field borders (Brady et al. 1998, Guthery et al. 2001, Pociak 2007, Puckett et al. 1995, Riddle et al. 2008, Seckinger et al. 2006, Smith and Burger 2006). Bobwhite abundance has been shown to be higher in landscapes with higher percentages of useable habitat, so bobwhite may be more likely to colonize new habitat patches in these landscapes (Lusk et al. 2002, Roseberry and Sudkamp 1998, Schairer et al. 1999). Additionally, certain cover types (e.g., row crop and recent timber harvests) are more permeable to dispersing bobwhite and may facilitate colonization or decrease local extinction when present on the landscape (Brady et al. 1993, Guthery 1997, Roseberry and Sudkamp 1998). Conversely, urban, pasture, and closed canopy forest cover lack food and cover for bobwhite, reduce landscape permeability, and fragment patches of useable space (Guthery 1999, Veech 2002). The lack of useable cover in landscapes with high percentages of urban or forest cover may decrease bobwhite occupancy and colonization, and increase bobwhite extinction rates in the same way it decreases bobwhite abundance (Guthery 1999, Riddle et al. 2008). Landscapes with low percentages of useable habitat may elevate extinction rates and reduce colonization rates, which may be the mechanisms explaining bobwhite decline in these landscapes.

Field borders established in landscapes with more useable habitat may be more successful at increasing bobwhite abundance than borders created in unsuitable landscapes because bobwhite are better able to disperse through continuous areas of useable cover (Riddle et al. 2008, Roseberry and Sudkamp 1998, Williams et al. 2004). Field borders located in landscapes with sparse useable habitat may not be used because the borders are isolated from other useable habitat patches and dispersing bobwhite are more susceptible to predation (Fies et al. 1992, Guthery 1999, Riddle et al. 2008).

Most studies investigating landscape influence on bobwhite populations have focused on bobwhite abundance (Blank et al. 2011, Palmer et al. 2005, Riddle et al. 2008), but the mechanisms underlying this relationship are less studied. Riddle et al. (2008) noted a difference in bobwhite response to field borders related to the composition of the surrounding landscape, but only compared landscapes dominated by crop or forest. A more extensive analysis of the influence of landscape composition (i.e., crop, early successional, forest, urban, pasture) on border efficacy is needed to better guide bobwhite conservation through habitat creation. Estimates of colonization and extinction rates may help identify mechanisms of local population change and can be quantified using occupancy analysis. Therefore, we determined the relative influence of landscape composition and field border presence on bobwhite density and occupancy, colonization, and extinction rates over 6 years and across two states. Understanding the influence the landscape has on habitat restoration efforts will aid managers in targeting resources in the most suitable landscapes and in the most cost efficient manner (White et al. 2005, Williams et al. 2004, Winter et al. 2006).

STUDY AREA

We surveyed bobwhite around 154 agriculture fields located in North Carolina and South Carolina (Figure 1). Fields were located in the Piedmont and Coastal Plain physiographic regions in 21 counties in North Carolina and 15 counties in South Carolina. We selected fields randomly from all established Conservation Practice 33 (CP33) fields in each state. CP33 is a field border practice created under the Conservation Reserve Program (CRP-479: United States Department of Agriculture) and was designed in response to bobwhite and early successional species declines across the United States (Burger et al 2006b and Stamps et al. 2008). CP33 borders are linear strips of fallow vegetation between cropland and the adjacent habitat (Burger et al 2006b, Doxon and Carroll 2010, Stamps et al. 2008). A third of the border typically is disturbed each year to maintain beneficial cover. We paired each field with a CP33 border with a nearby field without a border (40 pairs of fields in North Carolina and 37 pairs in South Carolina). Fields without a border were located greater than 1 km away but within 3 km of the corresponding CP33 field (Burger et al. 2006a). Fields with and without borders were in active crop management rotation, but could be fallow if part of the normal rotation (Burger et al. 2006a).

Agricultural crops grown on fields included tobacco, soybean, cotton, peanuts, potatoes, and corn. Fallow borders consisted of various species of forbs [old field aster (*Aster spp.*), common ragweed (*Ambrosia artemisiifolia*), horseweed (*Conzya canadensis*), dogfennel (*Eupatorium capillifolium*), morning glory (*Ipomoea spp.*), prickly lettuce (*Lactuca serriola*), Chinese lespedeza *(Lespedeza cuneata*), bicolor lespedeza (*Lespedeza bicolor*), American pokeweed (*Phytolacca americana*), pigweed (*Portulaca oleracea*), java-bean (*Senna obtusifolia*), goldenrod (*Solidago spp.*), and clover (*Trifolium spp.)*], grasses [broomsedge (*Andropogon virginicus*), common oat (*Avena spp.*), bermudagrass (*Cynodon dactylon*), and tall fescue (*Fecus arundinacea*)], shrubs [baccharis *(Baccharis halimifolia),* and blackberry (*Rubus argutus*)], and seedling trees [red maple (*Acer rubrum),* sweetgum (*Liquidambar styraciflua*), loblolly pine (*Pinus taeda*), longleaf pine (*Pinus palustris*), black cherry (*Prunus serotina*), and oak (*Quercus spp*.)].

METHODS

Northern Bobwhite Surveys

We surveyed paired fields simultaneously between sunrise and 10am from May to August. We randomly assigned an observer to one of the paired fields during each round of counts. Using distance sampling point counts, we recorded male bobwhite seen or heard during a 10-minute time interval (Burger et al. 2006a). We estimated the distance to each singing male using distance intervals (e.g. 0-25, 25-50, 50-100, 100-250, 250-500, and >500 m). To aid in distance estimation, we referred to pre-measured distance rings marked on aerial photography maps created in ArcMap 9.3 (Earth Systems Research Institute, Redlands, CA, 2008). We recorded measures of cloud cover, fog level, and wind speed for each survey.

We conducted point counts from mid-May until mid-July to coincide with the bobwhite breeding season in North Carolina and South Carolina. During 2006-2008, surveys were conducted by the North Carolina Wildlife Resources Commission and South Carolina Department of Natural Resources, and from 2009- 2011 surveys were conducted by North Carolina State University. In North Carolina, fields were not surveyed in 2006 but were surveyed 3 times a field season in 2007-2008 and twice a field season in 2009-2011. In

South Carolina, sites were surveyed only once a field season in 2006-2008 and surveyed twice a field season in 2009-2011.

Landscape Composition Analysis

We described landscape composition using a 1-km buffer around each field, which reduced the overlap among buffers while maximizing our scale of analysis. We quantified landscape composition using Southeast Gap Analysis Program data (hereafter SE-GAP) in ArcMap 9.3 (Earth Systems Research Institute, Redlands, CA, 2008). We combined the landcover categories used in the SE-GAP into 8 categories (crop, urban, forest, open water, pasture, early successional, wetland, and other).

We calculated estimates of landscape composition using Patch Analyst for ArcGIS 9.3 (Centre for Northern Forest Ecosystem Research, Ontario, Canada, 2008). The 5 landscape composition metrics we used to determine landscape influence on bobwhite were percent crop, forest, pasture, early successional, and urban cover (Table 1, Table 2).

Density Analysis

We used Program Distance 6.0 (hereafter Distance) to estimate male bobwhite densities and used the multi-covariate sampling engine to estimate the influence of observational covariates (cloud cover, fog level and wind speed) on detection probability (Buckland et al 1993, Thomas et al. 2009). To remove outliers and improve the precision of the analysis, we truncated detections to the 500-m distance (Somershoe et al. 2006). Because we did not have sufficient detections at individual sites (<30 observations) to estimate site-level detection probability, we estimated detection probability based on 3 categories of forest cover at the 500-m buffer (0-25%=1, 25-50%=2, >50%=3, Somershoe et al. 2006). We applied the detection probability that was calculated for each percent forest category to each site within that particular forest category.

Within Distance, we analyzed multiple models containing various key functions (half-normal and hazard-rate), series expansion (simple, cosine and hermite), and observation covariates (cloudcover, fogscore, and windspeed). We selected the model that best estimated male bobwhite densities according to Akaike's Information Criterion adjusted for small sample size (AICc) (Buckland et al 1993, Burnham and Anderson 1998, Thomas et al 2009).

We conducted a linear regression analysis with bobwhite density as the dependent variable and 5 landscape metrics and presence or absence of a CP33 border as predictor variables (PROC REG; SAS Institute, Cary NC). All landscape metrics were standardized using a z-score transformation to improve normality of the data (Osborne and Waters 2002). We used a global model to calculate standardized parameter estimates (coefficients) for all predictor variables. We determined statistical significance of predictor variables by calculating 95% confidence intervals for each coefficient. We considered a variable significant if the 95% confidence interval of the coefficient did not overlap zero (Nakagawa and Cuthill 2007). The more the confidence interval was centered over zero, the less statistically significant we considered the variable (Shake et al. 2011).

Occupancy Dynamics Analysis

To calculate occupancy (ψ), colonization (γ), and extinction (ε) rates, we used the multi-season analysis within program PRESENCE (Hines 2008). Occupancy is the probability bobwhite are present at a field. Colonization is the probability bobwhite not present during one sampling period are present at the next sampling period, and extinction is the probability that bobwhite present during one sampling period are not present at the next sampling period.

The multi-season analysis allowed us to infer the latent occupancy state for years when there were missing observations due to varying survey effort (MacKenzie et al. 2003). Only data from 2007-2011 were used in occupancy dynamic analysis because of limited surveys in 2006. Within the multi-season analysis, we used the default parameterization model in which occupancy in the first season, local colonization, and seasonal extinction are directly calculated, and occupancy in the subsequent seasons are derived from the first season's estimates (Hines 2008).

To establish the best model for estimating occupancy parameters, we first determined the model that best captured the component of detection variability in our study (Kéry et al. 2010). While holding the state variables (occupancy, extinction, and colonization) constant, we examined all possible combinations of sampling-occasion covariates (windspeed, cloudcover, and fogscore) and the effect of year in the detection probability. We used the Akaike Information Criterion (AIC) model selection technique (Burnham and Anderson 1998) to determine the best model for describing detection variability. This model was then used as a base for modeling the occupancy, extinction, and colonization parameters.

Within PRESENCE, we compared models with combinations of the landscape covariates and field border presence, but limited models to 3 covariates to prevent over parameterization. We hypothesized occupancy and colonization rates would increase and extinction rates would decrease as the percentage of crop and early successional cover increased. We hypothesized that occupancy and colonization would decrease and extinction would increase as the percentage of forest, urban, and pasture increased.

Because of the high number of possible models (6 variables and all possible combinations for 3 variables), we followed a robust procedure to identify the best model. We chose one of the three state variables (occupancy, colonization, or extinction) and determined the top models describing landscape influence on that state variable, while holding the other two constant. We selected the top two models using Akaike Information Criterion adjusted for small sample size (AICc) (Burnham and Anderson 1998, Thomas et al 2009). We used those top models for the selected state variable, and examined all possible models for the second state variable, while continuing to hold the third state variable constant. After determining the top two models from the model-set examining 2 state variables, we examined all combinations of covariates for the third state variable.

We repeated the process 6 times, changing the order to include all combinations of the 3 state variables thus ensuring a robust process to examine all covariates and the parameters. The process resulted in 6 separate model-sets examining field border presence and landscape composition influence on occupancy, colonization, and extinction. The final combined model-set consisted of the null and full models and the top 2 models from each of the 6 iterations (duplicate models removed). Top overall models were selected as those with ΔAICc < 2 using Akaike Information Criterion adjusted for small sample size (AICc) model selection (Burnham and Anderson 1998, Thomas et al 2009).

We determined significance of covariates present in the top models by examining the coefficient values and 95% confidence intervals (Nakagawa and Cuthill 2007). The more the confidence interval was centered over zero, the less statistically significant we considered the variable (Shake et al. 2011).

RESULTS

Density Analysis

Detection probability decreased as the percentage of forest cover increased (0-25% forest cover: 0.1823, 25-50% forest cover: 0.1326, and >50% forest cover: 0.1042). The model containing the hazard-rate key functions with cosine series expansion parameters and all 3 observational covariates (windspeed, cloudcover, and fogscore) best modeled male bobwhite detection probabilities at the site-level. We used the density estimates from this model for all other analyses.

Bobwhite densities were greater around fields that contained field borders than those without. The confidence interval for the border presence coefficient only slightly overlapped zero (Figure 2), and border presence had a larger coefficient than any landscape composition metric (Table 3). Bobwhite densities decreased as percent forest, urban, and pasture cover increased (Figure 2).

Occupancy Dynamics Analysis

The model that best estimated the detection probability of bobwhite included year and the windspeed sample-occasion covariate. In the final model-set describing the influence of landscape composition on bobwhite occupancy, colonization, and extinction rates, there were 4 models with ΔAICc < 2 (Table 4). Because coefficient values for the top models were similar, covariate relationships were extrapolated from the single top model. The field border covariate was not present in the top models. Percent crop cover was a predictor of bobwhite occupancy and extinction (Table 4), and as the percent cropland in the landscape increased, bobwhite occupancy increased and extinction decreased) (Figure 3). Although it was present in one of the top models, the percent urban cover covariate was not a significant predictor of occupancy because its confidence interval was centered over zero (Figure 3).

Percent pasture cover was a predictor of bobwhite colonization (Table 4) and as pasture cover increased, bobwhite colonization decreased (Figure 3). Percent forest and urban cover were predictors of bobwhite extinction (Table 4) and as percent forest and urban cover increased, bobwhite extinction increased (Figure 3).

DISCUSSION

The presence of a field border was a stronger predictor of bobwhite density than landscape composition. Bobwhite densities were 29% higher in fields with field borders than those without, which is consistent with other studies of bobwhite use of field borders (Blank et al. 2011, Palmer et al. 2005, Riddle et al. 2008). Field borders provide useable habitat for bobwhite, including foraging and nesting cover (Blank et al. 2008, Burger et al. 2006b, Riddle et al. 2008, Smith and Burger 2006).

However, the presence of a field border was not a significant predictor of occupancy, colonization, or extinction rates. Although field borders may increase bobwhite abundance locally, they have less influence than landscape composition on bobwhite occurrence. Field borders may provide useable bobwhite habitat, but these and other small-scale efforts to establish habitat do not influence landscape-scale processes such as dispersal. Therefore, field borders will be most effective if implemented in landscapes that promote bobwhite presence and facilitate dispersal.

Landscapes dominated by cropland are permeable to dispersing bobwhite and may yield higher occupancy and lower extinction in local habitat patches (e.g., field borders) (Brady et al. 1993, Schairer et al. 1999). Previous studies similarly showed higher bobwhite abundance was correlated with increased cropland within the landscape (Brady et al. 1993, Lusk et al. 2002, Peterson et al. 2002, Riddle et al. 2008, Schairer et al. 1999). Cropland is critical to bobwhite populations during the growing season because of the useable habitat provided, including foraging, nesting, and escape cover (Brady et al. 1993).

Cover types (e.g., closed-canopy forest, urban, and pasture) that lack ground cover bobwhite require to forage efficiently and escape predation are barriers to dispersal and likely influence colonization and extinction of bobwhite in local habitat patches (Barnes et al. 1995, Dimmick et al. 2002, Guthery 1999, Veech 2006). Because dispersal from surrounding areas (i.e. >2km) may alleviate local population decline, the reduced ability of bobwhite to disperse through landscapes dominated by unsuitable cover types may increase extinction rates (Fies et al. 2002, Riddle et al. 2008, Townsend et al. 2003,). Mature closed canopy forest shades ground cover and reduces seed bearing plants that produce important bobwhite foods (Lohr et al. 2011). Though bobwhite may disperse through closed canopy forest, reduced ground cover increases bobwhite vulnerability to predation, causing decreased colonization and increase extinction (Riddle et al. 2008, Rollins and Carroll 2001).

Pastures in the eastern US are comprised primarily of non-native grass species that restrict movement and provide limited overhead cover for bobwhite, possibly restricting bobwhite survival and ability to colonize new areas, including areas with field borders (Dimmick et al. 2002, Fies et al. 1992). Similarly, urban landscapes lack appropriate cover and increase the risk of predation for bobwhite (Lohr et al. 2010). Residual useable habitat in urban areas is fragmented, decreasing the benefit to bobwhite (Brady et al. 1998). Bobwhite have been noted to go locally extinct as the percent of urban cover in the landscape approaches 30% (Veech 2002). Although the scale of our analysis (314 ha) was much smaller than the 20,000 ha landscapes studied by Veech (2002), we observed decreases in bobwhite densities with small percentages of urban cover in the landscape, indicating urbanization influences bobwhite demography at multiple scales.

MANAGEMENT IMPLICATIONS

The CP33 field border program successfully increased local bobwhite populations within North Carolina and South Carolina, which is further evidence of the value of field borders as a means of bobwhite conservation in agricultural settings. However, field borders did not influence bobwhite occurrence within the landscape, which suggests future conservation efforts should consider the surrounding landscape when implementing localized habitat improvement practices for northern bobwhite. Establishing habitat in areas that contain high probability of bobwhite occurrence (i.e., higher percentages of crop cover and minimized percentages of urban, exotic pastures, and closed canopy forest) will maximize the efficiency of the conservation efforts. Additionally, increasing useable cover on the landscape by managing forest to open the canopy and promoting ground cover could aid in creating landscapes that promote bobwhite occurrence.

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Associate Editor

Tables and Figures

Table 1. Descriptions of landscape metrics selected for analysis of influence on northern bobwhite densities in North Carolina and South Carolina, USA (2006-2011).

Landscape metrics	Units	Descriptions
Border Presence (BP)	n/a	Presence/absence of CP33 border
Percent Crop (CROP)	%	Percentage comprised of agriculture
Percent Forest (FOR)	%	Percentage comprised of forest areas
Percent Pasture (PAST)	%	Percentage comprised of pastures
Percent Early Successional (SUCC)	%	Percentage comprised of early successional
Percent Urban (URB)	%	Percentage comprised of developed areas

Table 2. Mean, minimum, maximum, and range values of landscape metrics[a] used to determine the influence of landscape composition on bobwhite densities in North Carolina and South Carolina, USA (2006-2011).

Landscape Metrics	Units	Mean	Min	Max	Range
CROP	%	30.11	1.36	79.20	77.84
FOR	%	45.01	6.28	79.76	73.48
PAST	%	9.23	0.18	47.65	47.47
SUCC	%	7.48	0.41	22.75	22.33
URB	%	4.76	0.00	23.43	23.43

[a]See Table 1 for landscape metric descriptions

Table 3. Linear regression coefficients, standard errors (SE), and 95% confidence intervals (CI) for landscape metrics[a] used to investigate the influence of the surrounding landscape on northern bobwhite densities in North Carolina and South Carolina, USA (2006-2011).

Landscape Metrics	Coefficients	SE	95% CI
BP	0.30	0.15	-0.01, 0.60
FOR	-0.43	0.26	-0.93, 0.07
CROP	-0.22	0.23	-0.67, 0.22
SUCC	0.08	0.14	-0.19, 0.35
PAST	-0.22	0.11	-0.44. 0.01
URB	-0.12	0.04	-0.20, -0.05

[a]See Table 1 for landscape metric descriptions

Table 4. Model-set including the Delta Akaike Information Criterion (ΔAIC_c), model weight (W_i), likelihood, and number of model parameters (K) for determining the influence of field border establishment and landscape composition on bobwhite occupancy (psi), colonization (gamma), and extinction rates (eps) around agriculture fields in North Carolina and South Carolina, USA (2007-2011).

Model	**ΔAICc**	**W_i**	**Likelihood**	**K**
psi(+CROP),gamma(+PAST),eps(+FOR+CROP+URB),p(year+WS)[a]	0	0.31	1.00	14
psi (+CROP),gamma(.),eps(+FOR+CROP+URB),p(year+WS)	0.53	0.24	0.77	13
psi(+CROP+URB),gamma(+PAST),eps(+FOR+CROP+URB),p(year+WS)	1.55	0.14	0.46	15
psi (+CROP+URB),gamma(.),eps(+FOR+CROP+URB),p(year+WS)	1.92	0.12	0.38	14
psi(+CROP),gamma(+CROP),eps(+FOR+CROP+URB),p(year+WS)	2.6	0.08	0.27	14
psi(+CROP),gamma(+CROP+URB),eps(+FOR+CROP+URB),p(year+WS)	3.92	0.04	0.14	15
psi(+CROP),gamma(+CROP+SUCC+URB),eps(+FOR+CROP+URB),p(year+WS)	5.26	0.02	0.07	16
psi (+ALL),gamma(+ALL),eps(+ALL),p(year+WS)	24.74	0.00	0.00	27
psi(.),gamma(.),eps(.),p(year+WS)	50.49	0.00	0.00	9

[a] Top Model AICc= 1898.82

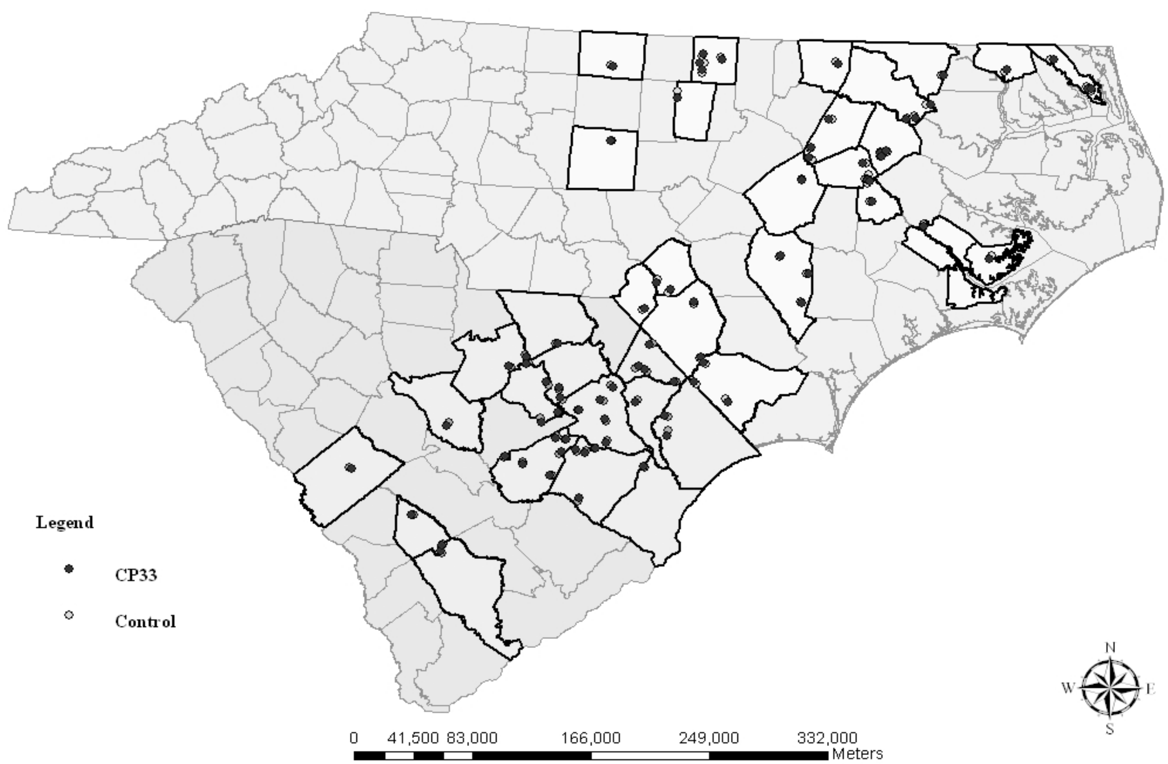

Figure 1. Locations of distance sampling point counts (154) for northern bobwhite in 21 counties in North Carolina and 15 counties in South Carolina, USA (2006-2011).

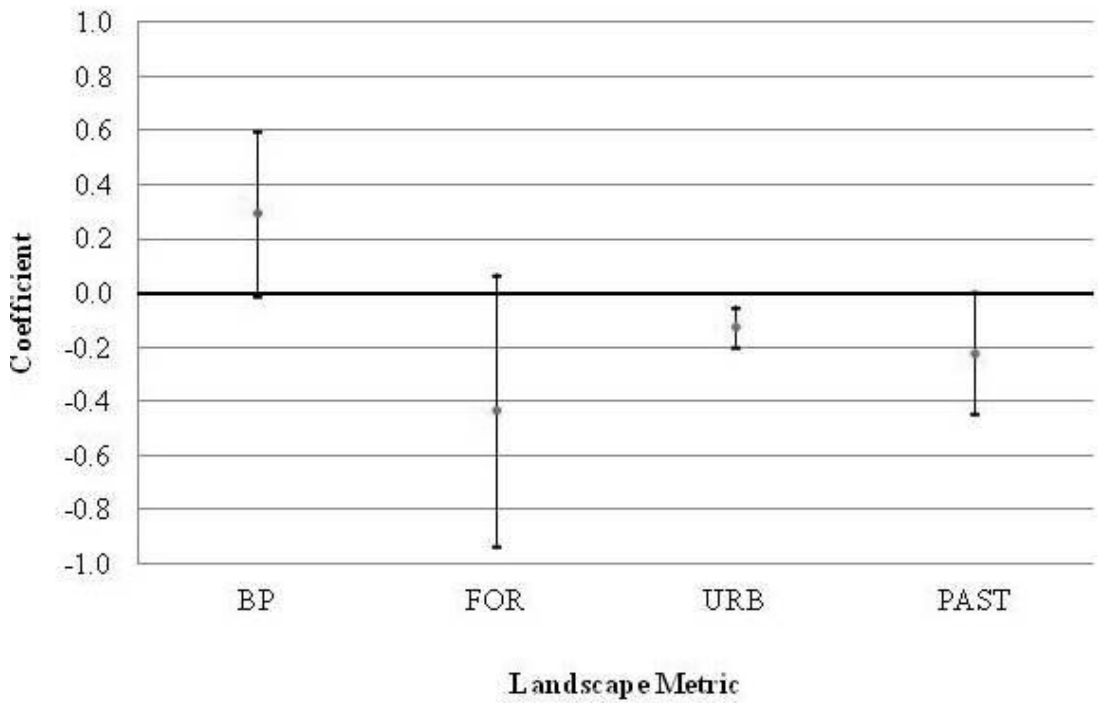

Figure 2. Coefficient estimates and 95% confidence intervals for metrics estimating landscape composition influence on bobwhite density around crop fields in North Carolina and South Carolina, USA (2006-2011).

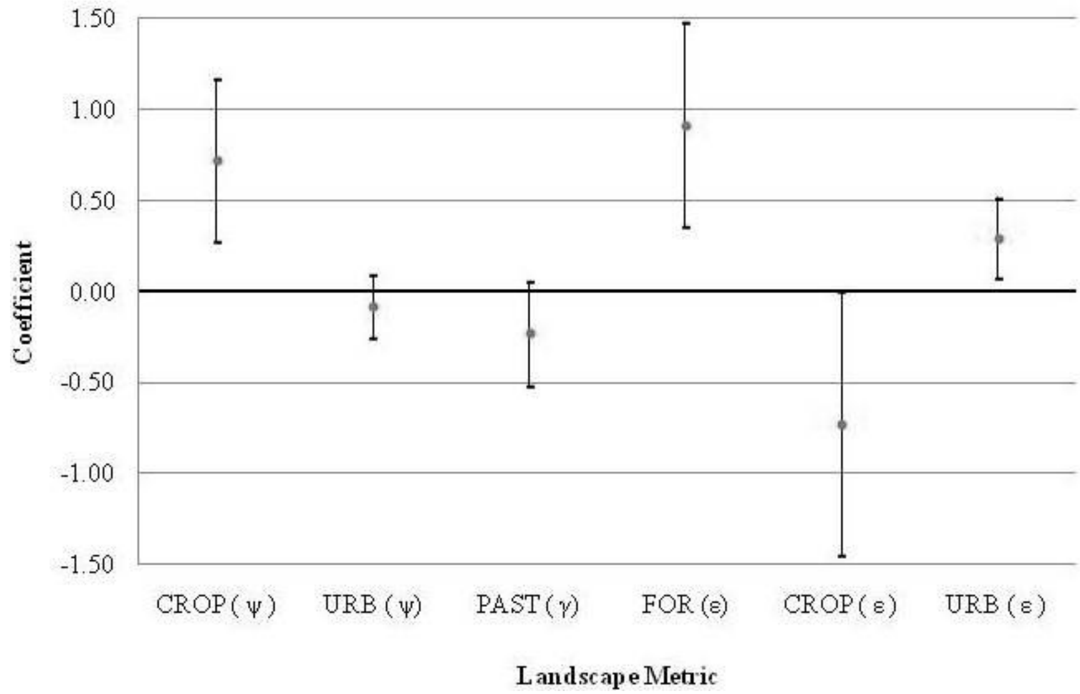

Figure 3. Coefficient estimates and 95% confidence intervals for metrics in the top models for estimating landscape composition influence on bobwhite occupancy (ψ), colonization (γ), and extinction rates (ε) around crop fields in North Carolina and South Carolina, USA (2007-2011).