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Multi-Region Response to Conservation Buffers Targeted for Northern Bobwhite

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ABSTRACT We coordinated a large-scale evaluation of northern bobwhite (*Colinus virginianus*) population response to establishment of 9-m to 37-m linear patches (buffers) of native herbaceous vegetation along row-crop field margins as part of the Conservation Reserve Program practice Habitat Buffers for Upland Birds (CP33). We compared northern bobwhite covey densities on 1,088 paired row-crop fields with and without native herbaceous buffers in 13 states during autumn, 2006–2008. We used a 2-stage random effects modeling approach that incorporates the effective area as an offset in generalized linear mixed models to assess regional relationships among autumn bobwhite covey densities and covariates of field type (i.e., fields with vs. without native herbaceous buffers), ecological region, year, survey week, and contracted vegetative cover (i.e., planting native grasses and forbs vs. establishing through natural regeneration). Covey density was correlated with year and interaction effects of field type and ecological region. The year effect suggested annual variation in covey densities, whereas the field type by ecological region interaction suggested covey response to buffers was dependent on spatial location, likely reflecting differences in buffer establishment, succession, and characteristics of the surrounding landscape among regions. Mean fitted covey density on fields across all survey sites was 0.047 (±0.008 bootstrap standard error [BSE]) and 0.031 coveys/ha (±0.003 BSE) on row-crop fields with and without herbaceous buffers, respectively. Covey density was greater on fields with buffers relative to matched, comparison fields without buffers in the Mississippi Alluvial Valley (241%; $P < 0.001$) and both the eastern (123%; $P < 0.001$) and western (60%; $P = 0.01$) portions of the Southeastern Coastal Plain region. Covey density was an order of magnitude greater in the central Texas region compared to other regions, but exhibited a small response to native herbaceous buffers, as did density of coveys in the Eastern Tallgrass Prairie and Central Hardwoods regions. Disproportionate response to buffers in the Mississippi Alluvial Valley and Southeastern Coastal Plain suggests native herbaceous habitats might be limiting during autumn in these regions, whereas lack of response in the Eastern Tallgrass Prairie, Central Hardwoods, and central Texas regions suggests that herbaceous habitat either was not limiting or buffers failed to provide adequate requirements for bobwhites during autumn. Selection of other habitats to meet security and thermoregulatory needs might have resulted in lack of response in these regions. Native herbaceous cover provided by buffers can provide critical habitat in row-crop agricultural systems in some regions, and can contribute to regional population recovery objectives of the Northern Bobwhite Conservation Initiative (NBCI). However, range-wide NBCI recovery objectives will best be met through multiple conservation practices in row-crop agricultural systems. © 2013 The Wildlife Society.

KEY WORDS agricultural conservation, *Colinus virginianus*, conservation buffers, conservation reserve program, CP33, density estimation, multi-scale assessment, northern bobwhite, targeted conservation practices, 2-stage modeling.

Large-scale changes in land use, including expansion and intensification of agriculture and forestry, have caused habitat loss and subsequent population declines in early-succession bird species (Peterjohn 2003, Green et al. 2005). Northern bobwhite (*Colinus virginianus*; hereafter, bobwhite) have exhibited some of the greatest population declines because of large-scale losses of habitat, and major efforts like the National Bobwhite Conservation Initiative (NBCI; Dimmick et al. 2002, National Bobwhite Technical

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Committee 2011) are underway to recover range-wide populations (Klimstra 1982, Brennan 1991). The NBCI is predicated on the ecological assumption that relatively small changes in land use can elicit biologically significant increases in autumn density. Specifically, the NBCI predicts an additional 2.4–2.7 million coveys could be added to existing populations with only a 6–7% change in primary land use (e.g., establishing native herbaceous habitats along row-crop field edges), which would contribute to large-scale habitat and population recovery goals of the NBCI plan (Dimmick et al. 2002, National Bobwhite Technical Committee 2011).

Replacing biologically sterile row-crop field margins with herbaceous cover (hereafter, field buffers) to increase upland bird populations has been suggested since the 1930s (Stoddard 1931, Davison 1941). Field buffers benefit overwintering upland passerine species (Marcus et al. 2000, Smith et al. 2005, Conover et al. 2007, Blank et al. 2011). Autumn bobwhite response to field buffers has typically been positive, but varies in magnitude in different parts of the range (Palmer et al. 2005, Moorman and Riddle 2009, Smith and Burger 2009, Pitman and Sams 2010). A disproportionately large response in autumn covey density (relative to percent of land use actually altered) might occur if buffers alter utility of both the field margin and the adjacent habitats (Smith 2004). However, limiting habitat factors (driven by differences in land use and available non-breeding season habitat) and habitat selection strategy might vary among regions, and drive differences in bobwhite response to field buffers during autumn.

Recent conservation practices have been established to target specific objectives of national conservation initiatives (Burger et al. 2006*a*). We evaluated bobwhite covey densities on row-crop fields with and without native herbaceous field buffers that were enrolled in continuous Conservation Reserve Program (CRP) practice Habitat Buffers for Upland Birds (CP33), which was developed to help meet bobwhite population recovery objectives of the NBCI (U.S. Department of Agriculture [USDA] 2004). The CP33 practice offers row-crop producers incentives to establish 9-m to 37-m linear patches of native herbaceous vegetation (i.e., field buffers) along row-crop field margins to provide temporary habitat for bobwhite and other upland bird species (USDA 2004). Our objective was to estimate density of bobwhite coveys in response to CP33 upland habitat buffers in row-crop production systems across 9 ecological regions (13 states). We used a 2-stage analytical approach to evaluate relationships between bobwhite covey densities and characteristics of field type (i.e., fields with and without buffers), ecological region, and other covariates (Buckland et al. 2009).

STUDY AREA

Under our coordination, collaborating agencies (see Acknowledgments Section) conducted annual bobwhite covey surveys in 13 states (Burger et al. 2006*b*; Fig. 1) from 2006 to 2008. Using parameter estimates from a pilot study and a stochastic simulation, we determined a coefficient of variation <15% on regional estimates could be achieved with 40–50 survey points per state if a mean of 1 covey/point were detected (Smith et al. 2009). Our target population included bobwhite coveys on privately owned row-crop agricultural fields containing CP33 buffers. Conservation Reserve Program landowner contracts were the unit of filing and enrollment for USDA conservation programs and individual fields were not subject to direct sampling in this study. We therefore used a multi-stage approach to select randomly 40 sampling units (i.e., landowner contracts to establish CP33 upland habitat buffers under CRP) from the list of all available landowner CP33

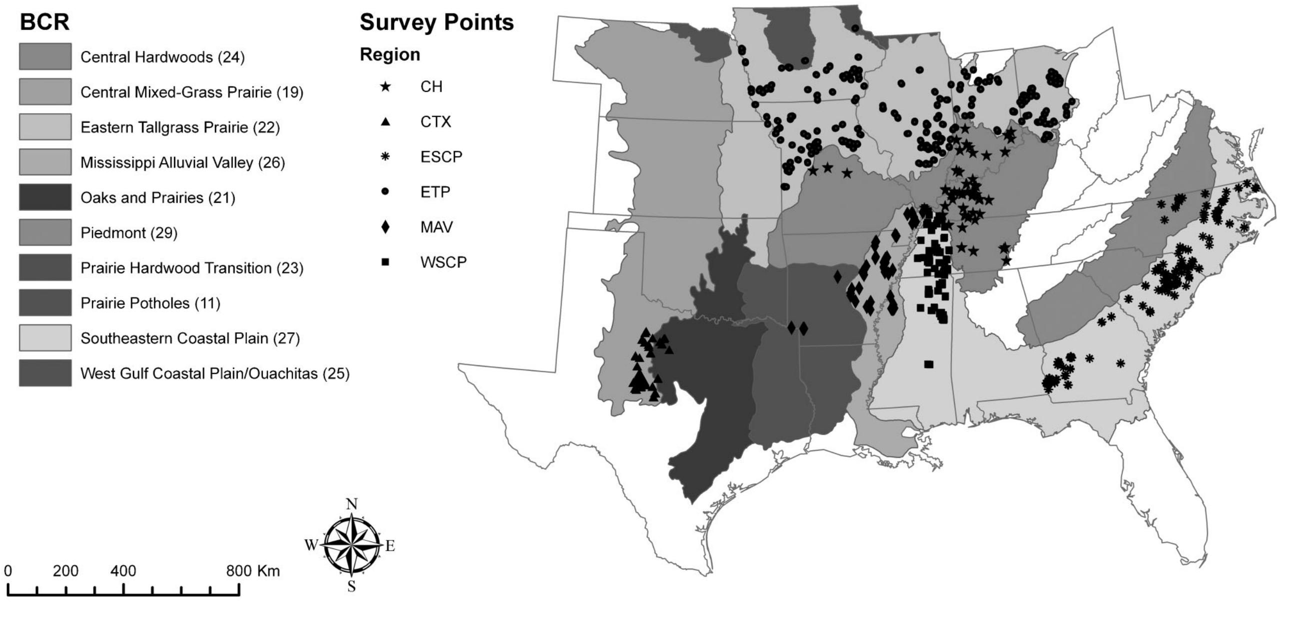

Figure 1. Point transect survey locations in 10 Bird Conservation Regions (BCR) on row-crop fields with and without CP33 field buffers, categorized by location of point clusters within ecological region (Central Hardwoods [CH], Central Texas [CTX], Eastern Southeastern Coastal Plain [ESCP], Eastern Tallgrass Prairie [ETP], Mississippi Alluvial Valley [MAV], Western Southeastern Coastal Plain [WSCP]) in 13 states on which autumn northern bobwhite covey surveys were conducted, 2006–2008. Parenthetic numbers represent BCR numerical codes.

contracts (31 Dec 2005) within each state (Burger et al. 2006*b*). From within each sampling unit (CRP contract), we selected randomly 1–3 sub-sampling units (i.e., row-crop fields with CP33 buffers along field margins) and located survey points on the linear mid-point of the field buffer. We selected multiple fields within a single landowner CP33 contract only if survey points were >500 m apart to avoid double counting. We then selected paired, row-crop fields without buffers that were 1–3 km from row-crop fields with buffers, but that had a similar cropping system and landscape. Survey points were located on 546 row-crop fields with buffers and 542 fields without buffers (Fig. 1).

We sampled survey points in 10 Bird Conservation Regions (BCR; i.e., ecological regions with similar bird communities, habitats, and land use; North American Bird Conservation Initiative 2000; Fig. 1). However, because locations of survey points depended on locations of CP33 contracts (i.e., non-random locations with respect to landscape), survey points may not have been representative of every BCR. Therefore, we sub-grouped survey points based on natural groupings within or adjacent to BCRs (Fig. 1). Most natural groupings were contained within a single BCR (e.g., Eastern Tallgrass Prairie) or a subdivision of a BCR (e.g., Eastern Southeastern Coastal Plain, Western Southeastern Coastal Plain). We classified points in Texas as a Central Texas grouping because they represented a contiguous sub-group of points overlapping both Central Mixed-grass Prairie and Oaks and Prairies BCRs (Fig. 1).

METHODS

We coordinated annual point transect surveys for bobwhite coveys (min. of 1 survey per autumn per point) from the last week of September to the second week of November, 2006–2008 based on calling rates observed in Wellendorf et al. (2004). Observers visited paired survey points (i.e., row-crop fields with and without herbaceous buffers) simultaneously to reduce weather-related variation. Observers conducted covey surveys during favorable weather conditions (i.e., winds <6.5 km/hr, <75% cloud cover, no precipitation, and <0.05 in./Hg change in barometric pressure [0100–0700 hr]; Burger et al. 2006*b*). We defined coveys as single or grouped series of "koi-lee" vocalizations coming from a fixed location. Observers recorded uniquely identifiable coveys and time of calling once at their initial estimated location from 45 minutes before sunrise to 5 minutes before sunrise (Burger et al. 2006*b*). Observers marked each estimated covey location onto National Agricultural Imagery Program aerial imagery (USDA 2007) and classified and measured radial distance from survey point to covey locations in ArcGIS (Environmental Systems Research Institute, Redlands, CA).

Two-Stage Analytic Approach

Ability to detect calling bobwhite coveys within survey plots may vary (Rusk et al. 2009), and thus the NBCI recommends survey and analytical methods account for detection probability (i.e., detectability; Evans et al. 2011). We assumed detectability decreased as a function of distance between observers and calling bobwhite coveys and therefore used distance sampling to model a covey detection function (Buckland et al. 2001). We assumed survey points were distributed randomly relative to covey distribution, distances were measured accurately, coveys did not move in response to observers, and probability of detecting a covey at the survey point was 100% (Buckland et al. 2001).

Our interest was the influence of covariates on densities at survey points. However, to adjust the observed counts for imperfect detection, we adopted a 2-stage modeling strategy (Buckland et al. 2009). In the first stage, we estimated a detection function, which models the decay in detection probabilities with increasing distance from the point. The detection function also included covariates to account for heterogeneity in detection probabilities. In the second stage, we related adjusted counts to covariates we believed might influence covey densities. To quantify the precision of parameter estimates, we used a non-parametric bootstrap routine. Our specific steps were as follows.

Stage 1: assessing detection probability.—We excluded all survey points from Arkansas and Ohio (because of small sample size), those points not surveyed at least once each year (2006–2008), and those points not paired spatially (with and without buffers) prior to analysis, which left 369 paired survey points (2,214 point surveys) from 11 states. We pooled covey data at each point across years (2006–2008). We inspected detection function plots within DISTANCE 6.0 (Thomas et al. 2010) and removed radial distances beyond distance w (500 m) where detection probability fell to, at most, 0.1 (Buckland et al. 2001). We evaluated fits of half-normal (HN) and hazard rate (HR) key function models with series adjustments (cosine [HN, HR], hermite polynomial [HN]) within the multiple covariate distance sampling engine of DISTANCE 6.0 (Thomas et al. 2010). We assessed model fit with and without covariates, and with and without post-stratification (i.e., accounting for heterogeneous detection probabilities by fitting separate detection functions for each specified stratum) by state, physiographic region, and field type (i.e., fields with vs. without buffers; Buckland et al. 2001; Table 1). Multiple covariate distance sampling models included factor-level covariates state, region, field type, year, state + year, and state + field type, and continuous covariates Julian day, cloud cover (%), 6-hour change in barometric pressure (in./Hg; 0100–0700 hr), wind speed (km/hr), and number of adjacent calling coveys (Table 1). We included region to account for potential variation in detectability from differing land use, land form, and vegetation structure among regions. We included state to reflect variable state-level implementation of the buffer practice (planting schema and dates, recommended species mixes, etc.). We included year to reflect changing vegetative structure within herbaceous buffers due to succession, and outside of buffers due to cropping regime or land use. We used Akaike's Information Criterion (AIC; Akaike 1973), visual inspection of quantile–quantile plots, and Kolmogorov–Smirnov and Cramer–von Mises goodness-of-fit tests to determine the best fitted model of the detection function (Buckland et al. 2001, 2004). For

Table 1. Differences in Akaike's Information Criterion scores (ΔAIC) and number of parameters (K) for candidate models of the detection function for northern bobwhite covey data truncated at 500 m on row-crop fields with and without CP33 field buffers (type) in 11 states (7 regions; 2006–2008). Continuous covariates Julian day (day), wind speed (wind; km/hr), cloud cover (cloud; %), 6-hour change in barometric pressure (bp; in./Hg; 0100–0700 hr), and number of adjacent coveys (adj) have been shown to influence calling rate of bobwhite coveys (Wellendorf et al. 2004). Covariates were not evaluated in post-stratified models to minimize the candidate model set.

Key function[a]	Post-stratified	Covariates	K	ΔAIC
HR		State[b] + year[b]	14	0.00
HR		State[b] + type[b]	13	9.91
HR	State		22	21.43
HR		State[b]	12	22.40
HN		State[b] + year[b]	13	24.51
HN		State[b] + type[b]	12	48.35
HN		State[b]	11	56.66
HN	State		11	57.56
HR		Region[b]	8	75.12
HR	Region		14	76.35
HN		Region[b]	7	107.13
HN	Region		7	108.03
HR		Day	3	158.56
HR		Wind	3	180.23
HR		Year[b]	4	185.51
HR	Type		4	185.69
HR		Cover[c]	4	195.11
HR			2	196.12
HR		Type[b]	3	197.51
HN		Wind	2	199.51
HR		Cloud	3	200.83
HN		Day	2	201.42
HR		adj	3	202.48
HR		bp	3	203.43
HN		Cover[c]	3	210.79
HN		Year[b]	3	211.05
HN		Type[b]	2	212.48
HN	Type		2	213.36
HN		Cloud	2	224.03
HN			1	227.85
HN		adj	2	228.69
HN		bp	2	228.97

[a] Key function models – hazard rate (HR), half-normal (HN).

[b] Factor-level covariate.

[c] Contracted cover (natural regeneration, planted to native grass, landowner choice).

post-stratified analysis, we summed AIC values across strata for comparison to other models (Buckland et al. 2001).

Using the best approximating model in program R, we fitted a probability density function to the observed distance data (Buckland et al. 2004). We then used the probability density function to estimate the effective area v, defined as the area beyond which as many coveys are presumed to have been observed as were missed (Buckland et al. 2001). Effective area per point is the circular area out to the radial truncation distance w times the probability of detection. Using the best covariate model, we then implemented a non-parametric bootstrap ($B = 999$) routine in R (R Foundation for Statistical Computing, Vienna, Austria), which calls the multiple covariate distance sampling engine of DISTANCE 6.0, to account for uncertainty in parameter estimation and estimate precision of detection function parameters using bootstrap replicates (Buckland et al. 2009). The bootstrap is a simulation mechanism that uses B random resamples with replacement from the original data set (Efron 1979). We used sample variance of parameter estimates from B total resamples and estimated bootstrap standard error (BSE) as the square root of sample variance. Thus with each bootstrap resample, we re-estimated all detection function parameter estimates and re-calculated effective area (Buckland et al. 2009).

Stage 2: Poisson regression incorporating effective area offset.—Because we could not assume perfect detectability out to truncation distance w, we incorporated the estimate of effective area as an offset into a Poisson-distributed generalized linear mixed model with spatial structure of paired points representing sites j as a random effect (Buckland et al. 2004, C. S. Oedekoven, University of St. Andrews, unpublished data). If analysis in stage 1 suggested heterogeneity in detectability, we used the log of effective area ν_{jkl} as an offset in equation (1) and with a log-link function we would consider expected count λ at visit l to point k of paired site j, a Poisson random variable to be

$$\lambda_{jkl} = \exp\left(\beta_0 + b_j + \sum_{i=1}^{1} x_{ijkl}\beta_i + \ln(\nu_{jkl})\right) \qquad (1)$$

thus, modeling density where λ_{jkl}/ν_{jkl} represented the density at visit l to point k of paired site j, and where β_0 is the fixed effect intercept, b_j is the random effect for paired sites with and without buffers j where $b_j \sim N\left(0, \sigma_b^2\right)$, x_i is the ith fixed effect, x_{ijkl} are measured fixed effect values, and β_i are associated coefficients for each fixed effect (Buckland et al. 2009).

We fitted 31 Poisson generalized linear mixed models (log-link function) with a log effective area offset with the glmer function of the lme4 package in R (Bates 2010; Table 2). Potential fixed effects included field type (fields with vs. without buffers), state-recommended cover types (i.e., state-specific practice standards related to establishing cover in buffers (native warm-season grass only, natural regeneration only, landowner choice), region, year, and weekly period. Because of the broad geographic range of survey points, we anticipated interactions among region × field type, region × year, region × weekly period, field type × year, and contract cover × year. We included field type because we presumed additional herbaceous habitat provided by field buffers may influence bobwhite covey density in the immediate and surrounding landscape. A significant field type term in the model would provide evidence that densities on fields with buffers were different from those without buffers, with a positive coefficient for the factor level, with buffer, indicating greater covey densities on buffered fields compared to non-buffered fields. We included state-recommended cover types to assess variation in autumn covey density related to differences in plant species composition of buffers. We included region as a covariate and in subsequent interactions involving region because bobwhite densities may have varied among regions, reflecting differences in land form, land use, and climate. We included year to account for annual variation in covey density and changes in buffer vegetation structure related to succession or

Table 2. Akaike's Information Criterion (AIC), change in AIC relative to the best approximating model (ΔAIC), and model degrees of freedom (df) for the candidate set of Poisson count models evaluating categorical fixed effects year, type (non-buffered, buffered), region, state-planned contract cover (contcov; natural regeneration, planted to native grass, landowner choice), and continuous effect of survey week on northern bobwhite covey densities in 11 states, 2006–2008.

Model	AIC	ΔAIC	df
Year + type + region + type × region	3351.279	0.000	15
Region + type + region × type	3355.224	3.945	13
Type + region + contcov + year + week	3365.334	14.055	13
Type + region + week + region × week	3368.681	17.402	14
Type + region + year + week	3379.300	28.021	11
Type + region + week	3387.245	35.966	9
Type + contcov + region	3389.832	38.553	10
Region + type + year + type × year	3396.633	45.354	12
Year + type + region	3400.018	48.739	10
Region + type	3403.959	52.680	8
Type + region + year + region × year	3408.449	57.170	20
Region + week + region × week	3462.236	110.957	13
Contcov + year + type + year × type	3481.233	129.954	9
Region + week	3481.425	130.146	8
Contcov + region	3484.579	133.300	9
Type + contcov + year	3484.628	133.349	7
Type + contcov	3488.473	137.194	5
Year + region	3494.745	143.466	9
Type + week	3497.015	145.736	4
Region	3498.685	147.406	7
Year + region + year × region	3503.112	151.833	19
Year + type + year × type	3504.357	153.078	7
Year + type	3507.741	156.462	5
Type	3511.604	160.325	3
Year + contcov	3579.377	228.098	6
Contcov	3583.221	231.942	4
Year + week	3583.725	232.446	5
Week	3591.199	239.920	3
Week + week × week	3593.199	241.920	4
Year	3602.464	251.185	4
Intercept only	3606.325	255.046	2

crop rotation. We did not include buffer width on our study sites as a covariate in analysis because width data was not collected in some states, and was measured inconsistently in other states. Because calling activity may have fluctuated during the survey period (Seiler et al. 2002, Wellendorf et al. 2004), we modeled linear and quadratic effects of weekly period. For all candidate models fitted with glmer, we manually set the number of quadrature points [nAGQ] for the Gauss–Hermite approximation to 10 (Lasaffre and Spiessens 2001).

We evaluated the global model for overdispersion by assessing the χ^2 variance inflation factor prior to implementing the remaining candidate model set (Burnham and Anderson 2002). Provided data were not overdispersed; therefore, we used an automated selection routine in R to compare candidate models and selected the best approximating model based on minimum AIC (Buckland et al. 1997, Burnham and Anderson 2002). We used a non-parametric bootstrap ($B = 999$) in R to estimate precision of model parameters of the best approximating model using survey point pairs as the resampling unit (Buckland et al. 2009). Because measures of precision from Poisson count model parameters do not account for uncertainty in the offset, we used the bootstrap to propagate uncertainty from fitting the detection function into the count model (Buckland et al. 2009). We determined significance of model parameters using 95% confidence intervals generated from the bootstrap in combination with Z-tests from analytical point estimates (Buckland et al. 2009).

Estimating density.—We could not access lands under private ownership adjacent to survey points and many landowners did not allow the flushing of detected coveys, so we were limited to estimating covey densities and not individual bird densities. We estimated covey density based on fitted values from the best count model by dividing estimated expected count λ_{jkl} at each point visit by effective area ν_{jkl}. We estimated density at the field type level and by field type within region level by subsetting densities from overall fitted values. We estimated analytical variances and standard errors (ASE) by field type within region each year. However, analytical variances do not incorporate variance in effective area and are thus non-representative of full variability of density estimates. Variance estimates must account for uncertainty in fitted counts n, derived from the model, and effective area v (Buckland et al. 2004). We used combined bootstrap variances of fitted counts and effective area (above; Buckland et al. 2004) to incorporate multiple variance components into density estimates. This assumes independence among variance components (Buckland et al. 2004).

RESULTS

Stage 1: Detection Probability

The multiple covariate distance sampling hazard rate model with no adjustment terms and state and year as covariates was the best approximating model (Table 1), with a Kolmogorov–Smirnov fit of 0.016 ($P = 0.597$), Cramer–von Mises uniform weighted fit of 0.079 ($0.600 < P < 0.700$), and Cramer–von Mises cosine weighted fit of 0.044 ($0.700 < P < 0.800$). Differences in vegetation structure among fields with and without buffers did not influence covey detectability. Effective area, effective detection radii, and probability of detection within a 500-m radius from the point varied among states and years (Table S1, available online at www.onlinelibrary.wiley.com).

Stage 2: Regression Model

Our global model was not overdispersed ($\chi^2 = 1.00$, $P = 0.550$). The best approximating model indicated covey densities were determined by year of survey in combination with an interaction where buffer effects (fields with vs. fields without herbaceous buffers) varied among ecological regions ($\chi^2 = 1.00$, $P = 0.540$; Table 2). Differences across geographic location reflect variable baseline population densities and variable relationships to buffers. Differences in AIC values between the best and all remaining models were sufficiently large (≥3.95 ΔAIC), indicating low model selection uncertainty (Burnham and Anderson 2002, Buckland et al. 2009). Point estimates and subsequent analytical and bootstrapped precision estimates were therefore conditioned on the best approximating model.

Relationship Between Herbaceous Buffers and Covey Density

Covey densities were greater on fields with herbaceous buffers in the Eastern Southeastern Coastal Plain ($P \leq 0.001$), Mississippi Alluvial Valley ($P \leq 0.001$), and Western Southeastern Coastal Plain ($P = 0.010$; Table 3). After reversing the log-transformation of coefficients from equation (1) in the best model to allow for interpretation on the response scale, significant interactions suggested covey densities were 123%, 241%, and 60% greater on fields having buffers vs. fields without buffers in the Eastern Southeastern Coastal Plain, Mississippi Alluvial Valley, and Western Southeastern Coastal Plain, respectively, over all years.

Fitted densities from the best count model demonstrated that covey densities on both field types were greater in the central Texas region compared to other regions (Fig. 2). Covey density on fields without buffers over all years ranged from 0.008 coveys/ha (ASE = 0.001; BSE = 0.003) in the Mississippi Alluvial Valley region to 0.168 coveys/ha (ASE = 0.006; BSE = 0.036) in the central Texas region (Fig. 2). Density on fields with buffers over all years ranged from 0.029 coveys/ha in the Mississippi Alluvial Valley (ASE = 0.004; BSE = 0.010) and Western Southeastern Coastal Plain (ASE = 0.002; BSE = 0.005) regions to 0.204 coveys/ha (ASE = 0.007; BSE = 0.044) in the central Texas region (Fig. 2). Based on the best approximating model, we estimated covey density across all survey points to be 0.031 coveys/ha (ASE = 0.001; BSE = 0.006) for fields without buffers and 0.047 coveys/ha (ASE = 0.002; BSE = 0.008) for fields with buffers (effect size = 0.016 coveys/ha [52%; 95% CI = 0.011–0.020 coveys/ha]; Fig. 2). Note that type-specific density estimates lack independence because a single detection function model was fitted across field types (Buckland et al. 2009).

DISCUSSION

Bobwhite coveys exhibited a disproportionate response to establishment of field buffers composed of native herbaceous vegetation. Based on overall mean fitted covey densities, a 5% change in primary land use resulted in 52% greater densities on fields with buffers versus fields without buffers across the study area. We assumed observed density changes represented population increases from carry-over effects of enhanced annual reproductive success and not an artifact of population redistribution directly into buffers from the surrounding landscape. Although we did not address this directly in this study, other studies suggest this assumption may be valid. Terhune et al. (2009) found home range selection by bobwhite coveys was influenced by presence of linear habitat patches (woody hedgerows, terraces, field borders), but not site selection within home range in agricultural landscapes. Therefore, bobwhite may not have re-distributed directly into herbaceous buffers, but habitat selection and subsequent survival and reproductive success may be influenced by a greater proportion of usable space (Guthery 1997) available in the immediate landscape. Oakley et al. (2002) also found released bobwhite home ranges to be smaller in landscapes containing fields with buffers compared to other landscapes. Consistent with this hypothesis, Smith and Burger (2009) showed that herbaceous field borders increased usable space in agricultural landscapes disproportionate to actual change in land use.

Most previous studies of autumn bobwhite response to herbaceous field buffers were insufficient in scale to address regional variability. Three previous studies demonstrated autumn covey abundances were 62–119% greater on fields containing buffers than on fields without buffers in Kansas, Oklahoma, and North Carolina (Palmer et al. 2005, Moorman and Riddle 2009, Pitman and Sams 2010), whereas 1 study showed no significant population

Table 3. Parameter estimates from the best approximating generalized linear mixed model with analytic (ASE) and bootstrap (BSE) standard error estimates and 95% bootstrap confidence interval for northern bobwhite covey data collected in 11 states, 2006–2008. The best approximating model included fixed main effects of year, treatment type (non-buffered, buffered), region (Central Texas [CTX], Eastern Southeastern Coastal Plain [ESCP], Eastern Tallgrass Prairie [ETP], Mississippi Alluvial Valley [MAV], Western Southeastern Coastal Plain [WSCP]), and a type × region interaction. The Central Hardwoods region is the reference.

				CI	
	Estimate	**ASE**	**BSE**	**2.50%**	**97.50%**
Intercept	−13.2904	0.16207	0.184112	−13.7371	−12.9982[***]
2007	0.1439	0.05155	0.122218	−0.07935	0.39981
2008	0.04963	0.05049	0.108213	−0.16689	0.244963
Type	0.14058	0.10906	0.137221	−0.11404	0.410388
CTX	2.14963	0.24516	0.218921	1.773474	2.617148[***]
ESCP	−0.57589	0.20755	0.233293	−1.05334	−0.14655[**]
ETP	−0.12696	0.19646	0.207859	−0.55865	0.255363
MAV	−1.22328	0.39979	0.517821	−2.49117	−0.43939[**]
WSCP	−0.43902	0.22911	0.226293	−0.88326	0.050224
Type × CTX	0.05459	0.14058	0.159604	−0.26329	0.351027
Type × ESCP	0.80394	0.15279	0.200464	0.417559	1.184144[***]
Type × ETP	0.09585	0.13526	0.177587	−0.27094	0.434587
Type × MAV	1.22772	0.32169	0.554695	0.290428	2.484078[***]
Type × WSCP	0.46724	0.16617	0.213381	0.045535	0.883561[**]

[**] Significant at $P = 0.01$ (analytical Z-test), and 95% bootstrap confidence interval does not include 0.

[***] Significant at $P < 0.001$ (analytical Z-test), and 95% bootstrap confidence interval does not include 0.

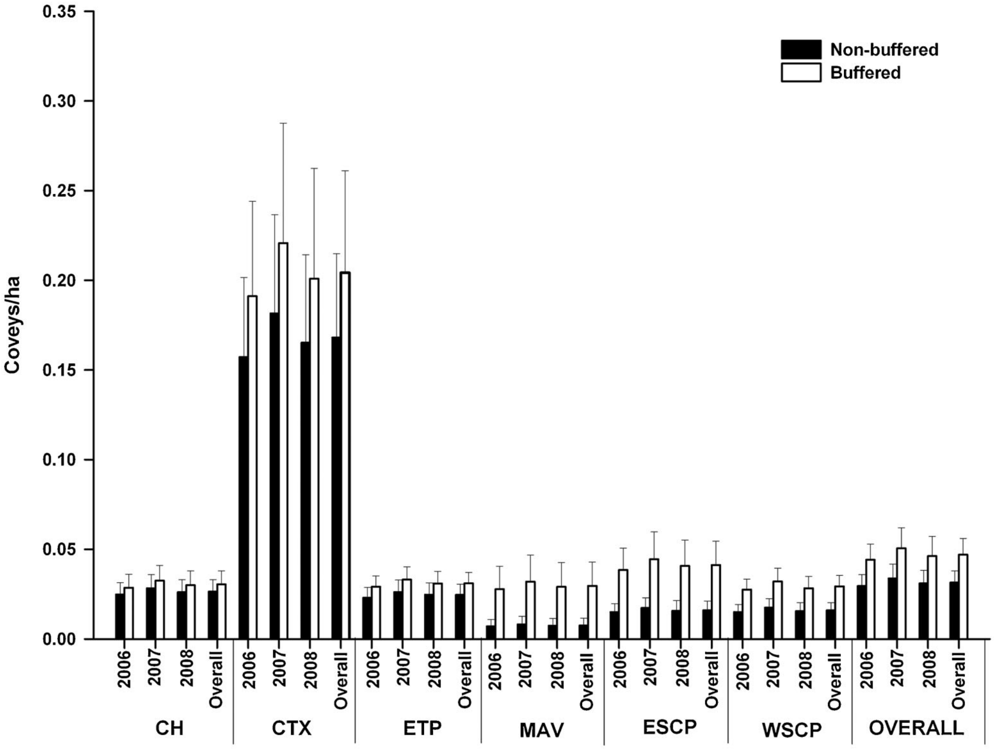

Figure 2. Regional and overall fitted northern bobwhite covey densities (coveys/ha ± 95% bootstrap confidence intervals) in 13 states, 2006–2008, derived from the best Poisson count model (year + region + type + region × type) on row-crop fields with and without CP33 field buffers. Regions were categorized based on spatial clustering of survey points within Bird Conservation Regions (Central Hardwoods [CH], Central Texas [CTX], Eastern Southeastern Coastal Plain [ESCP], Eastern Tallgrass Prairie [ETP], Mississippi Alluvial Valley [MAV], Western Southeastern Coastal Plain [WSCP]).

response to narrow native herbaceous buffers in Mississippi, but a comparable mean relative effect size (64%) to our results (Smith and Burger 2009). Observed differences in response among studies may be related to differences in buffer width, planting strategy, seed mix, surrounding landscapes, or cropping regimes. However, inferences regarding quality of buffer habitats based on density or abundance alone should be drawn with caution, as increased covey densities in buffered habitats may not reflect habitat quality (Van Horne 1983, Vickery et al. 2002).

Regional variation in our study supports NBCI recommendations that prescriptions for bobwhite conservation and population recovery be developed by region (National Bobwhite Technical Committee 2011) because land use, agricultural systems, climate, baseline population densities, and requirements for vegetation structure vary among regions. Composition of patch types (e.g., row-crop, woody cover, grass cover) in the landscape surrounding survey points also differs among regions, with some dominated by row-crop agriculture and others with a more even distribution of patch types. Observed regional variation in our study suggests scale of inference is an important factor for studies of bobwhite response to conservation and habitat management practices. However, coveys in all regions in our study exhibited either positive or null relationships with native herbaceous buffers; we found no negative relationships.

The greatest positive relationship between autumn bobwhite densities and native herbaceous field buffers was observed in the Mississippi Alluvial Valley, Eastern Southeastern Coastal Plain, and Western Southeastern Coastal Plain. The region with the greatest relationship (Mississippi Alluvial Valley) is dominated by row-crop agriculture and exhibited the lowest covey densities compared to other regions. On average, covey densities in the Mississippi Alluvial Valley increased from 1 covey/132 ha on fields without buffers to 1 covey/34 ha on fields with buffers. Populations having lower density in intensively cropped landscapes with little grass cover may have benefitted from linear patches of native herbaceous vegetation along row-crop field margins. However, covey densities were also greater on fields with buffers in the Eastern and Western Southeastern Coastal Plain regions, which typically have greater proportions of woody cover than the Mississippi Alluvial Valley. Increased density on fields with buffers suggested coveys responded to increased availability of native herbaceous habitat provided by field buffers regardless of variation in composition of other landscape features in these regions. Increased grassland amount relative to existing cover may be driving observed responses in these different regions. Given response was greater in the intensively cropped Mississippi Alluvial Valley region, our results support the conclusion of Riddle et al. (2008) that bobwhite will respond more positively to field buffers in agriculture-dominated landscapes than in forest-dominated landscapes.

In contrast, we observed small responses (approx. 10% increase) of autumn covey density to native herbaceous buffers in the Eastern Tallgrass Prairie region even though the prairie is row-crop dominated like the Mississippi Alluvial Valley. Latitudinal differences in rate of succession may explain this contrast. Surveying covey densities 1–3 years after establishment may not have been enough time for development of vegetation structure in field buffers necessary to provide adequate autumn cover in the more northern Eastern Tallgrass Prairie. Bobwhite may also require greater composition of woody cover to meet thermoregulatory requirements and enhance predator avoidance in the northern portion of their range (i.e., in the Eastern Tallgrass Prairie) during autumn. Bobwhite in Kansas and Ohio selected woody and herbaceous CRP cover during the non-breeding season (Flock 2006, Janke 2011), and selection for woody cover in row-crop landscapes may have decreased predation risk (Williams et al. 2000, Janke 2011) and provided foraging and thermoregulatory opportunities for autumn bobwhite coveys during snow events (Roseberry and Klimstra 1984).

Differences in covey density between fields with buffers and fields without buffers were negligible in the central Texas region although covey density in general was an order of magnitude greater in central Texas compared to the other regions. Texas typically has greater bobwhite densities than other parts of the range (Brennan 1999). However, abundant Texas bobwhite populations showed little response to field buffers in autumn, suggesting that rangeland and other grassland habitats in the surrounding landscape might have provided sufficient herbaceous and woody cover to reduce the potential effect of field buffers on bobwhite density.

We assumed survey points were distributed randomly in relation to the distribution of bobwhite coveys (Buckland et al. 2001), and density estimates may be biased if this assumption was violated and survey points were not distributed randomly with respect to covey distribution. The large extent of our study precluded us from empirically testing this assumption. However, Smith (2004) and Terhune et al. (2009) suggested autumn bobwhite coveys demonstrated a non-random distribution, and selected landscapes with greater proportions of herbaceous cover, but were not directly influenced by presence of linear field buffer habitats. Therefore, our sampling points should have been random relative to covey distribution. Another assumption included no bias in distance estimation by observers detecting coveys. Covey locations marked on aerial imagery were approximations by skilled observers. However, potential for bias existed if approximate locations were incorrect, and could have resulted in density estimates biased low (if approximated covey locations were further than actual covey locations) or high (if approximated covey locations were closer than actual covey locations). The extent of this study also precluded using multiple observers to triangulate covey locations, and flushing coveys was prohibited. Because we estimated covey densities in our study, estimates of bird densities could be more variable than covey densities, as number of birds in coveys might vary across regions. We recommend future studies incorporate number of birds per covey detected when possible to gain a better estimate of bird density.

Assuming coveys are being added to extant populations instead of redistributed from the surrounding landscape, we estimated number of coveys added to the population based on observed effect size in our study. We estimated average amount of CP33 field buffers at 5.41% and 0.27% in the 78.54-ha (500-m radius) landscape surrounding survey points for fields with and fields without buffers, respectively, representing an increase of 5.14% grassland cover in landscapes surrounding fields with buffers compared to landscapes surrounding fields without buffers. On average, 5.14% of 78.54 ha was 4.04 ha of buffer area in the survey radius. Overall, effect size (0.016 coveys/ha) observed across the study region translated to 1.26 additional coveys in the 78.54-ha survey region around fields with versus fields without buffers. Given observed effect size, 44,090 coveys could be added to the fall population if CP33 buffer enrollment was maximized to the 2010 acreage cap (141,640 ha; USDA 2010). However, 7.71 million ha of CP33 buffers would be necessary to meet the target population recovery goal of 2.4 million added coveys described in the NBCI (National Bobwhite Technical Committee 2011). Similar to NBCI predictions based from general knowledge of bobwhite ecology, such a change would constitute a 5% difference from current land use practices on approximately 145 million ha of cropland in the contiguous United States (USDA 2009). Although our projection served to illustrate inference from our study to the range of established CP33 field buffer acres, we did not account for expected regional differences. However, it did support the NBCI prediction that minimal change in primary land use at large spatial scales has potential to restore bobwhite to sustainable levels.

Addition of 7.71 million ha of CP33 field buffers is an unrealistic objective in agricultural landscapes in the United States. To meet the NBCI recovery goals based on herbaceous field buffers alone would require a transformative shift in the current agricultural management paradigm. Yet a 5% change in land use is plausible. Managers are advocating avoiding diffuse "piecemeal conservation" at the farm-level in exchange for strategic use of conservation practices targeted intentionally for the greatest wildlife and ecosystem benefits across the landscape (Sotherton 1998, Williams et al. 2004, Clark and Reeder 2007). Conservation systems that employ a variety of conservation practices hold tremendous potential to establish wildlife habitat (Kostyack et al. 2011), and provide opportunities for landowners to promote resource stewardship while offsetting income losses from enrolling productive fields into conservation programs (Burger et al. 2006*a*).

We found variable correlations between covey density and the presence of field buffers among regions. Therefore, we feel these differences warrant further study. This includes evaluation of effects of surrounding landscape composition on bobwhite population response (e.g., Riddle et al. 2008), effects of successional management to maintain habitat quality throughout the contract period (Best 2000, Gray and Teels 2006, Harper 2007), and development of strategies that encompass other declining species that make use of similar habitat structure and composition (Giocomo et al. 2009).

MANAGEMENT IMPLICATIONS

Our results suggest that management practices be developed that are specific to regions. Managers and policy makers must address regional variability in population response to conservation practices prior to practice development and initiation. Native herbaceous buffer habitats are not a panacea for bobwhite conservation (Williams et al. 2004), but can be an important conservation mechanism in regions where population gains can be anticipated because they represent small-scale management that has a relatively large positive impact. Habitat and population goals embodied within the NBCI may not be attainable across the entire range, but our results support many of their predictions, assuming management is focused at the regional scale.

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