Northern Bobwhite Seasonal Habitat Selection on a Reclaimed Surface Coal Mine in Kentucky

Ashley M. Unger,[1] *Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington Plant Sciences, Knoxville, TN 37996*

Evan P. Tanner,[1] *Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington Plant Sciences, Knoxville, TN 37996*

Craig A. Harper, *Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington Plant Sciences, Knoxville, TN 37996*

Patrick D. Keyser, *Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington Plant Sciences, Knoxville, TN 37996*

Frank T. Van Manen,[2] *Department of Forestry, Wildlife and Fisheries, University of Tennessee, 274 Ellington Plant Sciences, Knoxville, TN 37996*

John J. Morgan, *Kentucky Department of Fish and Wildlife Resources, Frankfort, KY 40601*

Danna L. Baxley, *Kentucky Department of Fish and Wildlife Resources, Frankfort, KY, 40601*

Abstract: Reclaimed surface mines present an opportunity to provide large tracts of habitat for northern bobwhite (*Colinus virginianus*). Reclaimed surface mine sites are commonly planted to non–native species, including sericea lespedeza (*Lespedeza cuneata*) and tall fescue (*Schedonorus arundinaceus*), which can inhibit growth of more desirable plant species and limit favorable structure for bobwhite. There have been no studies documenting how bobwhites use various vegetation types common to reclaimed surface mine land. Habitat use studies can provide information on selected vegetation types on these unique landscapes and help direct future management decisions. We radio-marked 841 bobwhite from October 2009 to September 2011 on Peabody Wildlife Management Area (PWMA), a 3,330-ha reclaimed surface mine in Kentucky, to investigate how bobwhite used associated vegetation types and responded to habitat management practices. We used 104 individuals, excluding nesting or brooding birds, to describe habitat use during the breeding season (1 April–30 September), and 51 coveys during the nonbreeding season (1 October–31 March). Bobwhite used shrub cover (CI = 0.121–0.339) and firebreaks (CI = 0.034–0.549) planted to winter wheat more than any other vegetation type during the breeding season and avoided areas of dense, planted native warm–season grasses (NWSG) and WMA roads. During the nonbreeding season, density of woody edges was influential (parameter estimates ≤0.017), confirming affinity for scattered patches of shrub cover. Our results suggest that despite supporting plant species that traditionally have been defined as undesirable, reclaimed lands can support bobwhite populations. However, these areas should not be viewed as optimal for bobwhite because dense plant cover limited openness at ground level and nonnative plants inhibited cover of native forbs that provide increased nutrition. We recommend reclaimed surface mine lands be considered when designating focal areas for bobwhite management.

Key words: Colinus virginianus, discrete choice model, habitat selection, northern bobwhite, reclaimed mine lands, sericea lespedeza

Journal of the Southeastern Association of Fish and Wildlife Agencies 2:235–246

Guthery's (1997) idea of increasing usable space to benefit declining northern bobwhite (hereafter, "bobwhite") populations throughout their range has been widely accepted, and is now a major focus of the Northern Bobwhite Conservation Initiative (Dimmick et al. 2002). However, finding contiguous areas to implement management that are large enough to positively influence bobwhite populations is a challenge (Hernandez et al. 2012). Reclaimed surface mines offer an opportunity to provide large tracts of land for bobwhite (McKenzie 2009) and other species that use early successional plant communities. There are more than 153,000 ha of reclaimed surface mines in Kentucky alone and in 2011 53% of the 2,865 ha of surface mine land released from the reclamation bond was designated as fish and wildlife habitat (Lexington Office of Surface Mining 2011). The average surface mine size has been slowly increasing in Kentucky over the past six years. In 2011, there were 207 mines from 202–405 ha in size and 132 mines greater than 405 ha in Kentucky (Lexington Office of Surface Mining 2011).

Reclaimed surface mines, while expansive, have been frequently revegetated with non–native plant species such as sericea lespedeza (*Lespedeza cuneata*) and tall fescue (*Schedonorus arudinaceus*). These non-native species can form dense monocultures that lack structure desirable to bobwhite (Barnes et al. 1995, Eddy et al. 2003, Ohlenbusch et al. 2007). Sericea lespedeza provides poor

1. Current address: Oklahoma State University, 008C Ag Hall, Stillwater, OK 74078
2. Current address: U.S.G.S Northern Rocky Mountain Science Center, 2327 University Way, Suite 2, Bozeman, MT 59715

nesting cover and can reduce native grass and forb cover by 66% and 70% respectively (Dimmick 1971, Eddy and Moore 1998). Tall fescue limited bare ground and vertical structure in studies in Kentucky and Tennessee (Barnes et al. 1995, Harper and Gruchy 2009). Neither are preferred foods (Davison 1945, Ellis 1961, Blocksome 2006) and both present challenges when managing reclaimed surface mine lands for bobwhite. A pilot study on a reclaimed surface mine in Virginia confirmed that dense vegetation resulted in a lack of open structure at ground level, limited nesting cover, and were factors limiting to a potential bobwhite population (Stauffer 2011).

Research in the Central Hardwoods Bird Conservation Region (CHBCR) has focused on the effectiveness of vegetation management techniques to improve habitat, specifically in tall fescue monocultures (Washburn et al. 2000, Madison et al. 2001, Greenfield et al. 2003, Gruchy and Harper 2014). However, few studies in the CHBCR have examined how bobwhites use areas with abundant non–natives. Osborne et al. (2012) reported adult bobwhite relative density in tall fescue fields that were strip disked or sprayed with glyphosate was 200% greater than in unmanaged fields and recommended further reduction of tall fescue cover. If reclaimed surface mine lands are to contribute to bobwhite conservation in the CHBCR, additional research is needed on bobwhite ecology on areas with abundant non-native species.

The Kentucky Department of Fish and Wildlife Resources (KDFWR) has included reclaimed surface mine lands in their bobwhite recovery plan (Morgan and Robinson 2008). However, data are lacking on how birds use these areas and which management practices improve habitat for bobwhite on reclaimed mine lands. The first study to examine bobwhite population ecology on a reclaimed surface mine was initiated in August 2009 to assist bobwhite recovery in Kentucky (Tanner 2012, Peters 2014). Litter depth and amount of open herbaceous core area within a bobwhite home range had a negative effect on survival. Treatments (including disking, prescribed fire, and herbicide applications) positively affected survival during the breeding season. Survival also increased as the amount of shrub vegetation in a home range increased during the nonbreeding season. Although survival estimates are informative, habitat use data can identify specific characteristics that make various vegetation types desirable to bobwhite and identify management practices that provide and lead to improved habitat conditions.

We used radio-telemetry to investigate habitat use of bobwhite included on the Kentucky reclaimed surface mine study. Our primary objective was to determine how bobwhite used vegetation types throughout the year. We also sought to determine how treatment efforts, including burning and disking, influenced habitat use on reclaimed surface mine land. We predicted bobwhites would use areas that had been disturbed through disking and burning more than undisturbed blocks of vegetation that contained dense, planted native grasses and sericea lespedeza, and that they would select dense woody cover over more open areas during the nonbreeding season.

Study Area

Peabody Wildlife Management Area (WMA), located in the CHBCR, encompasses 3,322 ha of Muhlenberg (3714N, 8715W) and Ohio (3717N, 8654W) counties in western Kentucky. It was surface mined and reclaimed with a post-mining land use designation of recreation and wildlife habitat before the Kentucky Department of Fish and Wildlife Resources (KDFWR) assumed management responsibilities in 1995. It was designated as a focus area in Kentucky's bobwhite restoration plan (Morgan and Robinson 2008).

We delineated six vegetation types on the study area. They included open herbaceous (34%), shrub (25%), forest (22%), native warm–season grass (8%), firebreaks, and roads. Open herbaceous was dominated by sericea lespedeza, tall fescue, field brome (*Bromus arvensis*), and goldenrod (*Solidago* spp.). Shrub was dominated by autumn-olive (*Elaeagnus umbellata*), black locust (*Robinia pseudoacacia*), green ash (*Fraxinus pennsylvanica*), and common blackberry (*Rubus allegheniensis*). Forest was mostly planted monocultures of eastern cottonwood (*Populus deltoides*) with coralberry (*Symphoricarpos orbiculatus*), poison ivy (*Toxicodendron radicans*), and dense Japanese honeysuckle (*Lonicera japonica*) in the understory. Native warm-season grasses included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*), all planted at relatively dense seeding rates (i.e., 10 kg ha^{-1} pure live seed).

Habitat management for bobwhite included disking (in blocks and linear firebreaks), dormant-season prescribed fire, and planting annual food plots. Disk blocks were disked with an offset disk and planted with a mixture of sorghum (*Sorghum bicolor*), Illinois bundleflower (*Desmanthus illinoensis*), partridge pea (*Chamaecrista fasciculata*), and Maximillian sunflower (*Helianthus maximilianii*) with a drill. Disk blocks and firebreaks were first disked with an offset disk, followed by a finish disk and cultipacker. There was a total of 53 km (1.97% of study area) of firebreaks which were approximately 8 m wide, disked annually, and seeded with winter wheat (*Triticum aestivum*) in the fall. Disk block sizes varied with topography but averaged 0.53 (±0.02) ha. From 2009 to 2011, 182 ha were disked on our study site, and 319 ha were burned. The majority of the burning took place in October, November, and March.

Methods

Land Cover

We used 1-m resolution aerial imagery (2010) from the National Agriculture Inventory Program, U.S. Department of Agriculture, and the Farm Service Agency to delineate shrub, forest, and open (NWSG or open herbaceous) vegetation in Arc Geographic Information Systems 9.3 (ArcGIS; ESRI, Redlands, California). We selected ground-truthed 1-m × 1-m cells in the study area that best represented woody cover, then used this as a template to classify all other cells as either "woody" or "open" with the Image Analyst tool in ArcGIS. We used the Aggregate Tool to create "woody" or "open" polygons with a minimum patch size of 0.2 ha, reflecting the smallest management activity (disking). Polygons with <10% woody cover were classified as open vegetation, those with 11%–55% woody cover were classified as shrub, and those with >56% woody cover were classified as forest based on knowledge of the groundcover on the site. Shrub areas had a mean (± SE) basal area (stems >4.5 cm diameter at breast height, DBH) of 2.60 ± 0.39 m^2/ha and forest 15.33 ± 1.06 m^2/ha. We separated NWSG areas from open herbaceous based on a criterion of ≥51% NWSG cover. All NWSG areas were mapped in the field with ArcPad 8.0 (ESRI, Redlands, California) on handheld Trimble Global Positioning Systems (GPS; Trimble Navigation Limited, Inc., Sunnyvale, California).

Vegetation Surveys

We conducted vegetation surveys seasonally from February 2010 through August 2011. Vegetation sampling was conducted late May to mid–August (breeding season), and mid–January to late March (nonbreeding season). Sampling efforts were limited to forest, NWSG, shrub, and open herbaceous vegetation types. All vegetation was measured at a series of random points created in each vegetation type with the Random Point Generator Extension (Jenness Enterprises, Flagstaff, Arizona) for ArcGIS. We generated a minimum of 60 sampling points per vegetation type for each season, and each vegetation type was verified at the time of sampling.

Vegetation composition, litter depth, and ground sighting distances were measured along 30–m transects at each sampling point during the breeding season. We randomly selected a transect direction at each sampling point. Live plants bisecting transects were identified to species at each meter following the point intercept method (Owensby 1973). The total number of observations of each species was summed, then divided by 30 (the total number of potential intercepts) to produce percent cover of a species within each transect. Percent cover data from transects within a vegetation type were averaged to obtain mean percent cover for each plant species by vegetation type on the study area. Litter depth (cm) was recorded at 0, 10, 20, and 30 m along the 30-m transect. Litter depth was averaged by transect, then means and standard errors were reported for each vegetation type. Ground sighting measurements were taken at 0, 10, 20, and 30 m along each transect by looking through a PVC pipe (3.8 cm diameter, 15 cm long) mounted horizontally on a stake 15 cm aboveground (Gruchy and Harper 2014). As one observer looked through the tube, a second moved a colored ruler until it was completely obscured by vegetation. The distance (m) between the ruler and PVC tube was recorded and used as a measure of openness at ground level. We averaged the ground sighting distances by transect, then reported means and standard errors for each vegetation type.

Visual obstruction was measured in both seasons with a visual obstruction board (Nudds 1977). Observers estimated the percent plant cover of each section (25 × 25-cm sections in breeding season, 20 × 20-cm in nonbreeding) from 4 m away with eye-level at 1 m aboveground. Observations were taken at 0, 10, 20, and 30 m along transects in the breeding season, and at 5 m from plot center in each cardinal direction in the nonbreeding season. Visual obstruction estimations were recorded in six classes: 0 = 0%, 1 = 1%–20%, 2 = 21%–40%, 3 = 41%–60%, 4 = 61%–80%, 5 = 81%–100%. We assigned each class with the median percent cover of that class (e.g., 1 = 10.5%), then averaged all visual obstruction readings by board section and transect. Means and standard errors are reported for each board section in all four vegetation types. Litter presence/absence also was recorded at these same board locations in the nonbreeding season. Litter presence was defined as dead vegetation covering the ground with or without overhead vegetation. Total litter presence for a transect was divided by 4 (the total number of potential occurrences), then averaged by vegetation type to report mean percent cover of litter by vegetation type in the nonbreeding season.

We recorded woody stem density for trees and shrubs in two size classes: small woody stems (<4.5 cm), which was measured in 5–m radius plots and large woody stems (>4.5 cm DBH) measured in 10-m radius plots. We reported mean basal area (m^2 ha^{-1}) of woody stems for each size class in all four vegetation types. We measured distance (m) to woody cover from point center with a range-finder during the nonbreeding season only.

Radio–telemetry

We trapped bobwhite in funnel traps baited with cracked corn and grain sorghum during the 2010 and 2011 breeding (1 April–30 September) and 2009–2011 nonbreeding (1 October–31 March) seasons (Stoddard 1931). Each captured bird was fitted with two aluminum bands (unique numbers on each leg) to ensure we would be able to identify a bird in the event that one band was lost. We classified each individual by sex and age (juvenile or adult), and recorded weight (g). Age was based on the presence or absence of buff–tipped primary coverts (Rosene 1969). All birds weighing ≥120 g were fitted with a necklace–style radio–transmitter weighing ≤6 g (American Wildlife Enterprises, Monticello, Florida). Trapping and handling methods followed protocols approved by the University of Tennessee's Institutional Animal Care and Use Committee (Permit # 2042-0911). We located birds ≥3 times per week, homing in to 50 m to minimize disturbance of marked bobwhites (White and Garrott 1990). We recorded estimated distance and azimuth to bird, vegetation type where the bird was located, and Universal Transverse Mercator (UTM) coordinates at our location with a handheld GPS unit. Only individuals or coveys with ≥20 locations were included in the analysis. Technician estimation error was measured in a series of 10 trials where one person hid a single radio–transmitter in known locations 10 different times, and each observer (n = 7) homed-in to within at least 50 m. Actual distance and azimuth were measured, then compared with the estimated distance and azimuth.

Locations were sorted by breeding (1 April–30 September) and nonbreeding seasons (1 October–31 March). We censored mortality locations because predators may have moved birds postmortem. Nesting and brooding locations also were censored because habitat use would be influenced by nests and chicks. Thus, during the breeding season, we report habitat use of adults that were not actively nesting or brooding. During the nonbreeding season, locations were recorded for each individual bird. However, because locations of birds within the same covey would not be independent, one location was selected to represent the covey each day. Covey associations were determined by individuals that were together ≥7 days (Janke and Gates 2012). Only individuals or coveys with ≥20 total locations were included in the habitat use analysis (DeVos and Mueller 1993, Taylor et al. 1999).

Resource Selection Analysis

Discrete choice models were developed to analyze consumer choices and are based on the idea that individuals or groups of individuals will choose to maximize their satisfaction (Ben-Akiva and Lerman 1985). This principle can be applied to wildlife, where individuals select one resource over other available resources. Attributes of the individual and the resource can be included (Cooper and Millspaugh 1999). For example, an individual's sex and age, as well as distance to a road are characteristics of the individual and resource, respectively. The multinomial logit form of the discrete choice model is capable of producing parameter estimates which determine a positive or negative association with a resource or one of its characteristics (Cooper and Millspaugh 1999). Attributes of chosen resources are compared with available, but non–chosen resources, similar to logistic regression (Manly et al. 1993, Cooper and Millspaugh 1999).

Availability must be defined to appropriately determine selection (Arthur 1996, Cooper and Millspaugh 1999). We considered availability a circle centered on a location for a given bird with a radius equal to the maximum average daily movement of a bobwhite on Peabody WMA (Arthur 1996, Cooper and Millspaugh 1999, Holt 2009). Average daily movement was defined as the mean distance (m) between an individual bobwhite's locations on consecutive days. Average daily movement during the nonbreeding season was 165 m, and 145 m during the breeding season. We used 165 m for our analysis across seasons. We used the Create Random Points tool in ArcGIS to create five random points within each individual location buffer. These were considered non–chosen, but available comparisons to the chosen location at that point in time (Cooper and Millspaugh 1999). These five random points and the associated recorded location created a "choice set," and the comparisons generated parameter estimates. McFadden (1978) produced consistent parameter estimates with choice sets consisting of one true location and five or more random locations. Each choice set is then considered an individual sample and therefore equal to the number of telemetry locations (Cooper and Millspaugh 1999). The error term within the model accounted for variation among individuals. The average (± SE) time between locations was 65.1 ± 1.1 hours, and we removed all nesting, brooding, and mortality locations from the analysis; therefore, we did not test for autocorrelation among locations.

Choice sets were assigned 16 continuous and categorical variables (Table 1) that were selected based on bobwhite literature and biological insight into the vegetative communities on our study site. We used the Extract Values to Points tool in ArcGIS to assign each choice set with land cover values. The categorical covariate land cover included six vegetation types. Treatment included no treatment, disked, recently burned, first growing season after a burn, and second growing season after a burn. Burn classifications were directly related to the bird location or vegetation sampling date. Recently burned included areas burned during the dormant season that had not yet experienced a growing season. First and second growing–season burns had experienced either one or two growing seasons, respectively, prior to collecting a location or sampling vegetation in the area.

We used the Near Tool in ArcGIS to calculate the Euclidean distance (m) from each location to the nearest road, firebreak, shrub cover, and disk block present at the time that the location was recorded. Measuring the proximity of bobwhite to roads, firebreaks,

Table 1. List of descriptions and abbreviations for variables used to create models in our habitat selection analysis of northern bobwhite in Ohio and Muhlenberg counties, Kentucky.

Variable	Type	Description	Abbreviation
Time	Continuous	Time of day when location was recorded	T
Distance to Disk Block	Continuous	Distance (m) to nearest disked area	DDB
Distance to Road	Continuous	Distance (m) to nearest road	DR
Distance to Shrub	Continuous	Distance (m) to nearest patch of shrub vegetation type	DS
Max Temperature	Continuous	Daily maximum temperature	MT
Forest Core Area	Continuous	Amount (ha) of forest core area in 330-m diameter circle around location	FCA
Shrub Core Area	Continuous	Amount (ha) of shrub core area in 330-m diameter circle around location	SCA
Open Herbaceous Core Area	Continuous	Amount (ha) of open herbaceous core area in 330-m diameter circle around location	OHCA
Native Warm-Season Grass Core Area	Continuous	Amount (ha) of NWSG core area in 330-m diameter circle around location	NGCA
Shrub-Open Edge Density	Continuous	Amount (m/ha) of shrub-open edge in 330-m diameter circle around location	SOED
Forest-Open Edge Density	Continuous	Amount (m/ha) of forest-open edge in 330-m diameter circle around location	FOED
Shrub-Forest Edge Density	Continuous	Amount (m/ha) of shrub-forest edge in 330-m diameter circle around location	SFED
Contagion	Continuous	Measure (scale 1–100) where 100 would contain the least amount of interspersion and dispersion of vegetation types	CONTAG
Treatment	Categorical	Location in 1 of 3 treatments: disk block, burned with 1 growing season, burned with 2 growing seasons	TREAT
Land Cover	Categorical	Location in 1 of 6 vegetation types: open herbaceous, shrub, forest, native warm–season grass, road, and firebreak	LAND

shrub cover and disk blocks allowed us to examine their influence on habitat use, whether the location was just outside the area or in it. We also hypothesized birds would not venture far from woody escape cover in either season and included distance to shrub cover as a variable.

We used a 165-m radius moving window analysis in FRAGSTATS to calculate core area, edge density, and the contagion index (McGarigal et al. 2012). We determined the moving window radius based on the greatest seasonal average daily movement (nonbreeding season 2010–2011). Forest, shrub, open herbaceous, and NWSG were the vegetation types for which we calculated core area (ha) and edge density (m/ha). Open herbaceous and NWSG areas were combined to estimate edge between "open" herbaceous communities and forest and shrub areas. We used an edge depth of 30 m. We also used FRAGSTATS to calculate the contagion index which measured the intermixing of different vegetation types (interspersion) and the spatial distribution of vegetation types (dispersion) on a scale of 0–100. Low values reflect areas that are highly dispersed and interspersed whereas large values reflect large, homogeneous areas.

Maximum daily temperature and time of day were included as variables because they may influence habitat use (Forrester et al. 1998). We obtained maximum temperature from the Kentucky Mesonet (www.kymesonet.org) from a nearby station in Hartford, Kentucky (37°46´N, 86°86´W).

To avoid violating the assumptions of the discrete choice model, we conducted a correlation analysis in SAS (SAS 2000). We used the correlations (CORR) procedure to produce Pearson's correlation coefficients for all of our continuous variables. At a threshold of 0.7, we determined distance to firebreak and distance to disk block were highly correlated (coefficient = 0.948). Firebreaks were one of the six vegetation types represented in our land cover variable. With this representation, we believed it would be best to retain the distance to disk block variable and to remove distance to firebreak. No other variables were correlated.

We used these variables to create 16 nonbreeding and breeding season models to evaluate habitat selection by season. Variables may perform poorly individually, but explain more variation in the data when examined as part of a biologically significant model or as an interaction term. Some variables were the same for random and chosen locations (i.e., precipitation). Therefore, these variables could only be examined as interaction terms. Models were selected based on knowledge of the quail literature, hypotheses about habitat use on Peabody WMA, and survival research conducted on the area (Tanner 2012, Peters 2014). We included as few variables as possible in each of our individual models to avoid violating the assumption that selection is independent of irrelevant alternatives (Luce 1959, McCracken et al. 1998). This assumption requires individuals to be able to clearly differentiate between resources. The probability ration of an individual to select resource A over resource B must be the same if a third resource, resource C, becomes available. Including a large number of variables in a model, or variables that are correlated or irrelevant to selection, could cause bias and unstable parameter estimation (McCracken et al. 1998). We used the proportional hazard regression (PHREG) procedure in SAS (SAS 2000) to estimate parameters and produce Akaike's Information Criterion (AIC) values (Kuhfeld 2000). AIC values were used to rank habitat selection models. The likelihood ratio test was used to assess overall model fit by comparing the log-likelihoods between the null model and model in question (McCullagh and

Nelder 1989). Land cover and treatment type were categorical variables and the discrete choice analysis required a reference class to be designated for all categorical variables. We used open herbaceous as the reference class for the land cover variable because it was the most abundant vegetation type (34% of the study area). Therefore, bobwhite use of every other vegetation type is in reference to how birds used open herbaceous areas. For treatment, we used untreated areas as the reference class because it was more abundant than the actual treatment types. The results can give insight to selection of different vegetation types within our land cover variable, but only in reference to use of open herbaceous or untreated areas. This creates a rank of the parameter estimates for each vegetation type within the land cover variable where open herbaceous representing use as expected.

Results

Radio–telemetry

We captured 841 individual bobwhite from September 2009 to September 2011 (457 males, 326 females, and 58 for which it was not possible to determine sex). We captured more juveniles (n = 674) than adults (n = 167). Based on body weights and transmitter availability, we were able to attach transmitters to 627 birds. However, only 104 individuals had ≥20 nonbreeding locations during the breeding season, and only 51 coveys had ≥20 locations during the nonbreeding season. We recorded 3,039 locations during the breeding season (excluding nesting and brooding locations), averaging (± SE) 32.0 ± 1.1 locations per individual. We recorded 2,213 locations from 51 coveys during the nonbreeding season, and averaged (± SE) 43.4 ± 2.3 locations per covey.

We used the trials of seven observers to determine telemetry estimation error. The mean (± SE) difference between the estimated and true location was 12.31 ± 1.20 m. The mean (± SE) difference between the estimated azimuth and true azimuth was 14 ± 2.49°. We determined that 12.31 m error was acceptable and did not warrant further analysis.

Resource Selection Analysis

Nonbreeding season. The top model (AIC weight = 96.28%) during the nonbreeding season contained the covariates shrub-open edge density, forest-open edge density, distance to a disk block, and distance to road (Table 2). The confidence intervals (CI) for the edge density covariates (SOED CI = 0.006 – 0.009, FOED CI = 0.005 – 0.027) and distance to road (CI = –0.004 – – 0.002) did not overlap 0, indicating these variables influenced habitat selection. The parameter estimates for all three of these covariates indicated a positive impact on habitat selection (Table 3) indicating birds used areas with more woody and open edge density (or more patches of shrub cover) and were closer than would be expected to roads. Exponentiation of the edge density parameter estimates using the average daily movement (165 m) revealed that birds were 13.7% and 3.5% more likely to use areas with 165 m/ha of forest-open and shrub-open edge respectively than at random.

Table 2. Model rankings based on AIC scores for discrete choice analysis of habitat use during the nonbreeding (1 October–31 March) season at Peabody WMA, Kentucky, 2009–2011.

Model	Covariates[a]	AIC	ΔAIC	AIC weights	Parameters
15	SOED, FOED, DDB, DR	7803.17	0.00	0.96	4
13	LAND, CONTAG, DDB, DR	7810.81	7.64	0.02	8
12	DDB, DR, DS	7811.35	8.18	0.02	3
9	DS, TREAT	7822.49	19.32	0.00	4
7	LAND, CONTAG, TREAT	7835.18	32.01	0.00	9
14	SOED, FOED, SFED	7851.81	48.65	0.00	3
6	CONTAG x TREAT	7856.09	52.92	0.00	7
8	DS	7864.12	60.95	0.00	1
10	DS x MT	7865.79	62.62	0.00	2
11	DDB, DR	7875.77	72.60	0.00	2
5	TREAT	7888.93	85.76	0.00	3
1	LAND	7899.06	95.90	0.00	5
4	CONTAG	7900.75	97.58	0.00	1
2	LAND x MT	7903.02	99.85	0.00	10
3	LAND x T	7904.97	101.80	0.00	10
16	SCA, FCA, OHCA, NGCA, DDB, DF	7907.52	104.35	0.00	6
0	Null Model	7930.33	127.16	0.00	0

a. SOED = shrub-open edge, FOED = forest-open edge, DDB = distance to disk block, DR = distance to road, LAND = land cover type, CONTAG = contagion index, DS = distance to shrub, TREAT = treatment, TIME = time of day, MT = maximum daily temperature, SFED = shrub-forest edge, SCA = shrub core area, FCA = forest core area, OHCA = open herbaceous core area, NGCA = native warm–season grass core area

Table 3. Parameter estimates from top models of a discrete choice analysis used to determine habitat selection during the breeding and nonbreeding seasons at Peabody WMA, a reclaimed surface mine in Kentucky from 2009–2011.

Season	Covariates[a]	Parameter estimates	Upper 95% CL	Lower 95% CL	Probability > X^2
Non-breeding	FOED	0.016	0.005	0.027	0.005
	SOED	0.008	0.006	0.009	<0.001
	DDB	–0.001	–0.002	0.000	0.066
	DR	–0.003	–0.004	–0.002	<0.001
Breeding	LAND	–	–	–	<0.001
	Firebreak	0.322	0.068	0.577	0.013
	Shrub	0.233	0.123	0.342	<0.001
	Open herbaceous	0.000	–	–	–
	Forest	–0.006	–0.208	0.196	0.955
	NWSG	–0.401	–0.550	–0.252	<0.001
	Roads	–0.715	–1.017	–0.413	<0.001
	DDB	–0.002	–0.003	–0.002	<0.001
	DR	–0.003	–0.004	–0.002	<0.001
	CONTAG	–0.011	–0.017	–0.006	<0.001

a. SOED = shrub–open edge, FOED = forest–open edge, DDB = distance to disk block, DR = distance to road, LAND = land cover, NWSG = native warm-season grass, CONTAG = contagion index

Table 4. Model rankings based on AIC scores for discrete choice analysis of habitat use by nonnesting and nonbrooding bobwhite during the breeding season (1 April–30 September) at Peabody WMA, Kentucky, 2009–2011.

Model	Covariates[a]	AIC	ΔAIC	AIC weights	Parameters
13	LAND, CONTAG, DDB, DR	10679.34	0.00	1.00	8
12	DDB, DR, DS	10719.14	39.79	0.00	3
15	SOED, FOED, DDB, DR	10737.32	57.98	0.00	4
11	DDB, DR	10783.57	104.23	0.00	2
7	LAND, CONTAG, TREAT	10805.75	126.40	0.00	9
3	LAND x T	10825.43	146.09	0.00	10
1	LAND	10827.35	148.00	0.00	5
2	LAND x MT	10829.06	149.72	0.00	10
16	SCA, FCA, OHCA, NGCA, DDB, DF	10831.71	152.37	0.00	6
9	DS, TREAT	10834.54	155.19	0.00	4
8	DS	10838.49	159.15	0.00	1
10	DS x MT	10840.49	161.15	0.00	2
14	SOED, FOED, SFED	10846.04	166.70	0.00	3
6	CONTAG x TREAT	10866.07	186.72	0.00	7
4	CONTAG	10869.13	189.79	0.00	1
5	TREAT	10887.10	207.75	0.00	3
0	Null Model	10890.31	210.97	0.00	0

a. LAND = land cover, CONTAG = contagion index, DDB = distance to disk block, DR = distance to road, DS = distance to shrub, SOED = shrub–open edge, FOED = forest-open edge, TREAT = treatment, TIME = time of day, MT = maximum daily temperature, SFED = shrub-forest edge, SCA = shrub core area, FCA = forest core area, OHCA = open herbaceous core area, NGCA = native warm-season grass core area

Breeding season. The top model for the breeding season included land cover, the contagion index, distance to a disk block, and distance to a road (Table 4). Bobwhite used firebreaks (CI = 0.068 – 0.577) and shrub vegetation (CI = 0.123 – 0.342) more than any of the other vegetation types on the WMA (Table 3). NWSG and roads were used the least (CI = and respectively), and open herbaceous and forests were used equally (Table 4). The negative parameter estimate for the contagion index (–0.011, CI = –0.017 – – 0.006) indicates that bobwhite used areas with more interspersion and dispersion of vegetation types (Table 3). The relationship between habitat selection and distance to a disk block or road was minimal, but parameter estimates were different from 0 based on CI.

Vegetation Surveys

We documented 295 plant species on Peabody WMA of which 220 were native, 66 were introduced, and we were unable to determine the difference between the native or non-native subspecies for 9. Sericea lespedeza dominated open herbaceous (76%, Table 5), NWSG (54%), and shrub (55%) vegetation types. Forested areas had the least cover of sericea lespedeza (14%), and were dominated by Japanese honeysuckle (30%, Table 5).

Table 5. Percent groundcover of the most common plants found within each vegetation type on Peabody WMA, a reclaimed surface mine in Kentucky, 2009–2010.

Vegetation type		% cover untreated		% cover disked[c]		% cover 1 growing season after burn		% cover 2 growing seasons after burn	
		X̄	SE	X̄	SE	X̄	SE	X̄	SE
Forest	*Lonicera japonica*	29.83	3.43	–	–	–	–	–	–
	Litter or bare ground	20.51	2.44	–	–	–	–	–	–
	Toxicodendron radicans	17.61	2.66	–	–	–	–	–	–
	Lespedeza cuneata	13.68	2.37	–	–	–	–	–	–
NWSG[a]	*Lespedeza cuneata*	54.31	4.23	43.33	6.53	51.90	5.60	71.52	10.43
	Planted NWSG[b]	49.27	3.82	45.26	7.49	77.14	4.25	77.27	13.78
	Ambrosia artemisiifolia	9.55	2.71	26.32	4.49	26.43	5.63	14.72	5.99
	Poa pratensis	4.94	2.20	0.18	0.18	1.90	1.67	4.17	2.73
	Litter or bare ground	1.47	0.55	2.28	1.22	0.00	0.00	0.28	0.28
Open herbaceous	*Lespedeza cuneata*	75.79	2.61	42.02	4.94	72.38	11.81	77.50	6.44
	Schedonorus arudinaceus	15.39	2.66	2.98	2.74	0.00	0.00	0.00	0.00
	Planted NWSG	6.46	1.32	7.62	3.70	2.86	1.35	17.50	13.22
	Solidago canadensis	3.78	0.99	2.86	1.43	2.86	2.86	0.00	0.00
	Ambrosia artemisiifolia	3.42	1.00	25.60	5.74	42.38	34.63	15.83	11.81
	Litter or bare ground	0.67	0.23	4.52	1.60	0.00	0.00	0.83	0.83
Shrub	*Lespedeza cuneata*	55.30	3.21	–	–	55.00	8.33	54.44	12.81
	Rubus allegheniensis	11.00	1.31	–	–	10.00	10.00	23.33	6.67
	Solidago canadensis	10.92	1.91	–	–	1.11	0.89	46.67	15.03
	Litter or bare ground	5.31	1.05	–	–	0.00	0.00	0.00	0.00
	Planted NWSG	3.81	1.26	–	–	0.00	0.00	0.00	0.00
Firebreak	*Triticum aestivum*	24.29	11.15	–	–	–	–	–	–
	Litter or bare ground	21.90	9.32	–	–	–	–	–	–
	Ambrosia artemisiifolia	10.48	3.71	–	–	–	–	–	–
	Lespedeza cuneata	0.00	0.00	–	–	–	–	–	–
	Planted NWSG	0.00	0.00	–	–	–	–	–	–

a. Native warm–season grass

b. Includes: big bluestem (*Andropogon geradii*), broomsedge bluestem (*Andropogon virginicus*), eastern gamagrass (*Tripsacum dactyloides*), indiangrass (*Sorghastrum nutans*), sideoats grama (*Boutelous curtipendula*), silver bluestem (*Bothriochloa saccharoides*), and switchgrass (*Panicum virgatum*)

c. Disked areas were sometimes planted to mixes of birdsfoot trefoil (*Lotus corniculatus*), blackeyed susan (*Rudbeckia hirta*), Illinois bundleflower (*Desmanthus illinoensis*), maximillian sunflower (*Helianthus maximiliani*), partridge pea (*Chamaecrista fasciculata*), proso millet (*Panicum miliaceum*), clover species (*Trifolium* spp.), and other mixes of forbs and legumes beneficial to wildlife.

Table 6. Vegetation and structural measurements collected during the breeding and nonbreeding seasons at Peabody WMA, a reclaimed surface mine in Kentucky, 2009–2010.

		Vegetation type			
Season	Metric	Forest (SE)	NWSG[a] (SE)	Open herbaceous (SE)	Shrub (SE)
Winter 2009–2010	Number of plots	57	50	105	112
	% Visual obstruction at height:				
	0–20 (cm)	49 (3)	75 (2)	80 (2)	74 (2)
	20–40	42 (4)	41 (3)	51 (2)	49 (2)
	40–60	29 (3)	29 (3)	33 (2)	39 (2)
	60–80	20 (3)	11 (2)	10 (1)	22 (2)
	80–100	15 (2)	6 (1)	5 (1)	19 (2)
	% Litter cover	96 (2)	66 (4)	62 (3)	82 (2)
	distance to woody cover (m)	2.4 (0.5)	39.1 (4.0)	26.5 (2.6)	9.2 (1.2)
Summer 2010	Number of plots	65	49	112	115
	% Visual obstruction at height:				
	0–25 (cm)	48 (3)	90 (2)	86 (1)	77 (2)
	25–50	28 (3)	71 (2)	73 (2)	61 (2)
	50–75	16 (2)	46 (4)	54 (2)	45 (2)
	75–100	10 (1)	25 (3)	26 (2)	29 (2)
	100–125	8 (1)	11 (2)	9 (1)	17 (2)
	125–150	8 (1)	6 (2)	4 (1)	13 (1)
	150–175	8 (1)	3 (1)	2 (0)	10 (1)
	175–200	8 (1)	2 (1)	2 (0)	10 (1)
	Litter depth (cm)	1.5 (0.1)	0.7 (0.1)	0.6 (0.1)	0.9 (0.1)
	Ground sighting distance (m)	1.9 (1.0)	0.7 (0.3)	0.6 (0.3)	0.9 (0.7)
	Basal area (m^2/ ha) of woody stems ≤ 4.5 cm DBH	0.12 (0.01)	0.00 (0.00)	0.02 (0.01)	0.13 (0.03)
	Basal area (m^2/ ha) of woody stems > 4.5 cm DBH	15.33 (1.06)	0.15 (0.09)	0.15 (0.05)	2.60 (0.39)

a. Native warm–season grass

Nonbreeding season. Forested areas had the least amount of visual obstruction 0–20 cm aboveground (49%, Table 6). Visual obstruction 0–20 cm aboveground within shrub (74 ± 2%) overlapped with the average (± SE) for NWSG (75 ± 2%, Table 6). Disking reduced visual obstruction 0–20 cm aboveground during the nonbreeding season following treatment within NWSG (≥75% to ≤23 %) and open herbaceous (≥80% to ≤19%, Table 6).

Breeding season. Open herbaceous and NWSG areas had the most visual obstruction 0–25 cm aboveground (≥86%) during the breeding season, and forest had the least (48%, Table 6). Firebreaks were dominated by planted winter wheat (24% cover) and contained nearly as much area devoid of live vegetation (22% cover, Table 5). Thus, there was considerable bare ground within firebreaks. Disk blocks increased bare ground as well with the greatest increase seen in open herbaceous (0.67% cover in untreated to 4.52% cover in treated, Table 5). Visual obstruction within disked and untreated open herbaceous and NWSG areas varied little, with cover ≥74% 0–25 cm aboveground in all cases. Disking increased visibility at ground level in open herbaceous from 0.60 m to 1.81 m. Disking reduced cover of sericea lespedeza from 76% to 42% in open herbaceous; however, cover of sericea lespedeza within burned areas did not differ from non-treated areas (Table 5). Burning increased cover of NWSG within NWSG areas from 49% to 77% (Table 5).

Discussion

The goal of our research was to identify variables important to habitat selection on a reclaimed surface mine as part of an ongoing effort to improve these areas for bobwhite and assess their potential for bobwhite conservation efforts. Habitat use by bobwhite on Peabody WMA was driven by selection for woody cover across seasons. Bobwhite selected for areas with a greater edge density between woody and open areas during the nonbreeding season. Although parameter estimates (forest-open edge = 0.016, shrub-open edge = 0.008) were small, exponentiation revealed a strong affinity for edge density. This means bobwhite on the open landscape of Peabody WMA were selecting for patches of shrub cover, which we expected. During the breeding season, firebreaks and shrub cover were used more than all other vegetation types. Distance to a disk block and road appeared in the top three models in both seasons, but their parameter estimates were low in the top performing models, reflecting a weak relationship.

Nonbreeding season. The use of woody edge is consistent with preference for woody cover during the nonbreeding season reported in Ohio (Janke and Gates 2013), Kansas (Williams et al. 2004), Illinois (Roseberry and Sudkamp 1998), and Tennessee (Yoho and Dimmick 1972). Although many eastern forests are not suitable for bobwhite (Seckinger et al. 2008), forests on reclaimed surface mine sites have traditionally been planted on highly compacted soils resulting in trees that are often stunted and grow slowly. Forests on Peabody contained many gaps in the canopy and were more similar to woodland structure than closed-canopy forest with a basal area of 15.33 m^2/ha. The brushy cover available in the understory, particularly along edges where openings allowed more sunlight to penetrate, was likely why bobwhite used these areas more than expected. Disturbed woodlots with a broken canopy and well-developed understory were used by bobwhite in Ohio (Janke and Gates 2013), whereas woodlots with a mature overstory were avoided.

Forests and shrub areas also contained more Japanese honeysuckle than any other vegetation type (30% and 9% cover respectively), which has been reported as roosting and loafing cover for bobwhite in Virginia (Tonkovich and Stauffer 1993), Illinois

(Roseberry and Klimstra 1984), and Tennessee (Yoho and Dimmick 1972). We found cover of sericea lespedeza within forests (14%) and shrub areas (55%) was far less than that within open herbaceous vegetation (76%). Woody edge, such as that found along forests and shrub areas of Peabody WMA, may have contained more desirable food plants and cover than surrounding open herbaceous or NWSG vegetation. Lohr et al. (2011) observed a similar relationship where the use of forests in southern New Jersey may have been a response to low food availability in grasslands. Shrubs also may have provided thermal cover; however, the interaction of maximum daily temperature and vegetation poorly explained habitat selection across seasons. Bobwhite at Peabody likely selected areas that maximized resources available to them, such as food and security, which can be found in the mixed vegetation available between woody and open edge.

Breeding season. Firebreaks were used more than any other vegetation type on Peabody WMA during the breeding season. They resembled the "weedy-wheat" fields described by Doxon and Carroll (2010) in Kansas, which contained extensive cover of annual forbs/weeds, and provided easy mobility (no thatch with an open structure under a plant canopy) and supported healthy feeding rates for bobwhite chicks (Doxon and Carroll 2007). Firebreaks on Peabody consisted of a similar plant composition and structure and may have provided the same foraging opportunity. Brooding adults were not included in this analysis; however, nonbrooding adults apparently found these areas equally valuable for ease of movement and feeding. Unharvested wheat, such as that in the firebreaks, and two types of Conservation Reserve Program fields (CP10 and improved CP10) in Kansas contained the greatest number of insect prey (Doxon and Carroll 2007). Conservation reserve program (CP10) fields were seeded to grasses native to Kansas such as western wheatgrass (*Pascopyrum smithii*) and indiangrass, and improved CP10 was seeded to the same native grasses but also included alfalfa as forb component.

Native warm-season grass is considered important to bobwhite for escape cover and nesting cover during the breeding season (Stoddard 1931, Roseberry and Klimstra 1984). However, bobwhite at Peabody used NWSG areas less than open herbaceous areas. Our vegetation profile board data revealed dense visual obstruction in both vegetation types 0–25 cm aboveground during the breeding season. Visual obstruction was always >86% in NWSG (90% ± 2) and open herbaceous (86% ± 1), and there were no differences between the ground sighting distance readings. Thus, these two vegetation types were structurally similar for bobwhite with NWSG slightly denser. The dense vegetation of NWSG likely discouraged use by bobwhite, particularly sections that had been burned where NWSG cover increased from 49% to 77% cover. Holcomb et al. (2014) reported NWSG density was maintained or increased regardless of timing of burning in Tennessee.

The contagion index value for Peabody WMA (50.39) was similar to the average value used by bobwhite during the breeding season on the study site (52.97). Roseberry and Sudkamp (1998) found contagion index was a useful indicator of bobwhite habitat use as bobwhite selected more interspersed and dispersed areas and were rarely found where the contagion index value was >65%. The overall negative relationship with the contagion index during the breeding season on Peabody WMA suggests selection for more interspersed and dispersed areas or edge of any type. This contrasts our nonbreeding season results where the specific type of edge was included in the top model and important to bobwhite selection as opposed to edge in general as measured by the contagion index. Woody edge was selected for specifically during the nonbreeding season, whereas edge in general was important during the breeding season. Shrub cover was the second-most used vegetation type during the breeding season. As discussed in the nonbreeding season results, the protective cover of and vegetation structure within shrubs was important to birds during the breeding season.

We predicted bobwhite would use treatment areas (disked or burned) more than expected; however, our top models did not contain the treatment variable. Concurrent work on Peabody WMA indicated disking, burning, and herbicide treatments had a positive effect on breeding season survival of bobwhite, but had a negative influence on survival during the nonbreeding season (Tanner 2012, Peters 2014). Disking and burning on the WMA began during late winter and early spring 2010. Thus, any effect on habitat use from treatment was limited through spring 2011. Much of the resident bobwhite population may not have even had access to a treated area for the first year of our study. Disk blocks were first placed within large blocks of homogenous vegetation in an attempt to increase vegetation heterogeneity and therefore were in areas that were otherwise undesirable for bobwhite. In addition, burning increased cover of already dense NWSG (49% to 77%) and failed to reduce the cover of sericea lespedeza (76% to 72% after one year). This dense vegetation likely discouraged bobwhite use of burned areas.

A weak but positive parameter estimate suggested birds were closer to roads than would be expected at random. However, roads were used less than any other vegetation type. The bare and exposed nature of the WMA roads and associated traffic likely discouraged use. Stoddard (1931) and Rosene (1969) reported dense vegetation bordering bare ground, such as a dirt road or disked block, may be used by bobwhite during the breeding season. Our parameter estimates for distance to disk block and distance to road were small, indicating that their impact on selection was minimal.

Sericea lespedeza is widely considered an undesirable plant for bobwhite (Dimmick 1971, Blocksome 2006) and efforts to control its density and spread are considerable (Koger et al. 2002, Eddy et al. 2003, Farris 2006, Mantz 2013). However, bobwhite can live and maintain populations in areas with sericea lespedeza, even though habitat quality may not be optimal. Sericea lespedeza is capable of producing more than 1,500 seeds per stem, and the seed are long-lived in the seedbank (Ohlenbusch et al. 2007). Thus, sericea lespedeza likely will remain a substantial component of herbaceous vegetation communities at Peabody WMA, regardless of control treatments implemented. Although areas with sericea lespedeza may be usable, it is not a preferred food (Ellis 1961, Blocksome 2006) and is not capable of sustaining a bobwhite (Newlon et al. 1964). Bobwhite fed sericea lespedeza during a two-week study experienced a 29% weight loss on average (Newlon et al. 1964). Therefore, management practices should focus on reducing the cover of sericea lespedeza while promoting cover of desirable food plants on areas managed for bobwhite. We found disking effectively reduced cover of sericea lespedeza, increased ground sighting distance, and promoted increased cover of more desirable plants, such as common ragweed (*Ambrosia artemisiifolia*). Prescribed fire during the dormant season did not reduce density or cover of sericea lespedeza. Although some land managers may be discouraged by the presence of sericea lespedeza, relatively large reclaimed surface mine lands, such as Peabody WMA, may be important areas of conservation for bobwhite and other species dependent on early successional communities, even if sericea lespedeza is present. Guthery (1999) reported "slack" in the configuration of bobwhite habitat and suggested there is a range of acceptable habitat configurations rather than one, optimal configuration. Similarly, there likely is slack in the plant composition of bobwhite habitat. An open landscape with sufficient protective cover, such as that found on reclaimed surface mines, is likely much more important to bobwhite than the native or non-native status of the plant species on the area.

Management Implications

Maintaining early successional communities in the eastern United States where there is considerable precipitation requires continuous management because of rapid plant growth and associated succession (albeit often more slowly on a reclaimed surface mine). Disking improved vegetation structure, enhanced vegetation composition, and maintained an early seral stage at Peabody WMA. Periodic disking also can improve the structure of dense native grass plantings (Gruchy and Harper 2014) and reduce cover of sericea lespedeza. Burning during the dormant season increased cover of NWSG. Therefore, dormant-season burns should be discontinued in areas with rank NWSG unless burning is in preparation for disking. Prescribed fire should be used to maintain a broken forest canopy (or woodland structure) with a diverse understory. Burning or disking within shrub cover on reclaimed surface mine sites should be restricted to situations where shrub cover is excessive or groundcover within the shrub cover has become too sparse. Reclaimed surface mines can provide relatively large areas of contiguous habitat for bobwhite, and recent efforts to include these areas in conservation highlight their potential. In 2011, the Northern Bobwhite Conservation Initiative released a second version of their range-wide plan (Northern Bobwhite Technical Committee 2011), and reclaimed surface mines were included as a major land-use opportunity. Building relationships with mining companies could result in future reclamation that discontinues planting sericea lespedeza and includes more beneficial native species and practices that benefit not only bobwhite, but other wildlife as well.

Acknowledgments

Our project was funded by the Kentucky Department of Fish and Wildlife Resources with additional support from the Federal Aid in Wildlife Restoration Program, University of Tennessee, and Quail Forever. We thank K. Wethington for his assistance with GIS vegetation classification. We also thank E. S. Williams, F. L. Adkins, J. R. Arnold (KDFWR), and our past and present technicians for their hard work, advice, and support.

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