Northern Bobwhite (*Colinus virginianus*) Habitat Selection on a Reclaimed Surface Mine in Western Kentucky

A Thesis Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

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August 2014

ACKNOWLEDGMENTS

I am seldom at a loss for words; however I do not know that I can find the right ones to express how thankful I am to be surrounded by kind people and endless support. My gratitude extends far beyond those I mention here.

This study would not have been possible without the Kentucky Department of Fish and Wildlife Resources (KDFWR). I am privileged to have worked with creative biologists such as John Morgan and Ben Robinson of the small game department. They managed to keep my demanding project well–equipped, funded, and offered valuable advice along the way. I appreciate the valuable feedback from Danna Baxley, who worked hard to improve my thesis. I am also grateful to have worked with Eric Williams, Freddie Adkins, and Jarrod Arnold of Peabody Wildlife Management Area (WMA). Your hard work, insight, and patience were crucial to the success of this project. Whether it was a leaky camper or an abandoned donkey, you met each phone call with a good–natured attitude. I would also like to extend this thanks to the KDFWR technicians who helped with covey surveys, vehicle maintenance, and put management on the ground. I have not thanked you all enough.

My project demanded the time and year–round effort of hardworking technicians, and I am grateful for their dedication and good company. I know that cramming in a FEMA camper and nursing endless poison ivy was tough, but your hard work has made this project a success. I owe a special thanks to my summer vegetation technician, Caitie Mitchel, who endured outrageously hot conditions and my lame sense of humor. I also owe a special thanks to the first and longest technician, Jason Diaferio, who taught me how to collar a quail. I would have been lost without your knowledge of bobwhite.

I am forever indebted to my committee, who provided endless support, valuable insight, and taught me more than I thought possible in my time with UT. Dr. van Manen guided me through the depths of FRAGSTATS and the discrete choice analysis, and patiently answered my long lists of questions. I appreciate your kindness and help. John Morgan worked hard to keep the Peabody project running smoothly, a task easier said than done. I cannot imagine anyone would have answered each of our many phone calls with a better attitude than you. I am fortunate that Dr. Patrick Keyser kept his door open just down the hall for anything I needed. Thank you for always giving advice and offering kind words when I needed to hear them. I am especially grateful for the support of my advisor, Dr. Craig Harper, who was nothing short of inspirational. I would not have even applied to graduate school without your encouragement. Thank you for instilling in me a love of extension and vegetation. I am lucky to have an excellent role model.

The graduate students at UT were an incredible support system. Whether it was a few beers on a Friday night or help with SAS, you all kept me sane through graduate school. My office mates, Jarred Beaver, Jessie Birckhead, and Seth Basinger made collecting thousands of acorns or clipping plots of clover fun, and I am grateful for your good company and support. Thanks to Alex Richman, Andrew West, Andy Vander Yacht, Chris Lituma, Emily Hockman, Kaitlin O’Connell–Goode, Matt Goode, Katie Percy and Stephen Brinkley for many good memories and help. I am especially grateful for the friendship of Melissa Lituma, who made Knoxville feel a lot more like home.

I have always loved wildlife, but our family friends and neighbors Dayton and Barbara Baker helped me realize it could be a career. I am deeply thankful for your letters of recommendation, advice, and encouragement. I also owe a special thanks to a dear friend, Steph

Knox, who helped me get to where I am today. I cannot thank you enough for always listening to and supporting me.

My family has been an endless source of love and support throughout graduate school. I owe my love of the outdoors to my parents, Lisa and Victor Unger, who believe in me even when I fail to believe in myself. Thank you for teaching me to hunt, fish, and respect the world we live in. Thank you to my brother, Shane Unger, who reminds me that a good laugh can cure anything. Thank you to my grandmothers, Evelyn Unger and Darlene Cornman, for your love, phone calls, and care packages. They mean more to me than you know. I also wish to thank my grandfathers, Joe Unger and Ronald Cornman. Although they are no longer with us, I am still inspired by the love they had for the outdoors.

Last, but certainly not least, thank you to my incredible fiancé Evan Tanner. Your unbelievable patience, support, and love for me is appreciated more every day. Thanks for being my best friend, making me laugh, and keeping me from falling apart through my M.S.

ABSTRACT

Reclaimed mines present an opportunity to provide large tracts of habitat for northern bobwhite (*Colinus virginianus*). Reclaimed mine sites are commonly planted to non–native species, including sericea lespedeza (*Lespedeza cuneata*) and tall fescue (*Schedonorus phoenix*), which can inhibit growth of more desirable plant species and limit favorable structure for bobwhite. Although bobwhite are found on reclaimed mine sites, there have been no studies documenting how bobwhites use various vegetation types common to reclaimed mine land. Habitat use studies can provide information on how bobwhite select vegetation types on these landscapes and help direct future management decisions. We trapped and radio–marked 841 bobwhite, October 2009 to September 2011, on Peabody Wildlife Management Area, a 3,330 ha reclaimed mine in Kentucky, USA, to investigate how bobwhite used vegetation types and responded to habitat management practices. We used 104 individuals to describe habitat use during the breeding season (1 April–30 September). We found 57 nests and analyzed the movements of 23 brooding adults. We used 51 coveys to describe habitat use during the non–breeding season (1 October–31 March). During the non–breeding season, woody edge was used more than would be expected at random (parameter estimates ≤0.017). During the breeding season, nonbreeding bobwhite used firebreaks dominated by winter wheat and shrub vegetation more than any other vegetation types, and used dense, planted native warm–season grasses (NWSG) and WMA roads least (*P* <0.05). Nests were placed in areas with lower contagion index values than in paired, random locations (parameter estimate = –0.045). Broods used annually disked firebreaks (1.4% of study area) more than any other habitat feature or vegetation type (parameter estimate = 0.933), and used undisturbed areas more than dormant–season burns or disk blocks. The structure and composition of firebreaks likely provided areas that optimized chick mobility and promoted vegetation that encouraged presence of insect–prey for feeding bobwhite broods and adults. Our results suggest that despite plant composition that has traditionally been defined as undesirable, reclaimed lands can provide habitat for bobwhite populations.

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INTRODUCTION

Northern bobwhite (hereafter bobwhite) have declined at an annual rate of 3.8% throughout the species' geographic range for the past 3 decades (Sauer et al. 2011). The decline is attributed to deterioration of early successional habitat resulting from clean farming practices, lack of disturbance, and fragmentation (Brennan 1991, Church and Taylor 1992, Burger 2002). In an effort to increase usable space for bobwhite, state and non–government agencies have focused on creating and managing large–tracts of early successional vegetation (Guthery 1997, Dimmick et al. 2002). With more than 607,000 ha in the eastern United States, reclaimed surface mines provide an opportunity to manage large, often continuous tracts of early successional vegetation for bobwhite and other early succession species. Poor soil and non–native species may inhibit plant succession; thus, these areas remain in early succession for an extended period of time. However, these dense monocultures can pose a problem for potential bobwhite occupation. A pilot study on a reclaimed mine in Virginia cited a lack of open structure at ground level and limited nesting cover as a result of dense vegetation as factors limiting to a future bobwhite population (Stauffer 2011).

With management, reclaimed surface mined lands may present an opportunity to increase usable space for bobwhite (Guthery 1997), however little is known about how bobwhite use reclaimed surface mine lands (Tanner 2012, Peters 2014). To better understand the relationship between bobwhite and reclaimed surface mined land, I initiated a study on a reclaimed surface mine site in western Kentucky that was a focal area for bobwhite. My objectives were to (1) evaluate seasonal movement and habitat selection and (2) determine nest site selection and brood habitat use. In Chapter I, I analyzed how management and vegetation characteristics may affect habitat selection during the breeding and non–breeding seasons. In Chapter II, I determined characteristics of nest site selection, and documented brood habitat use in relation to management and vegetation characteristics. Chapters I and II are presented as stand–alone manuscripts for future publication.

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CHAPTER 1

NORTHERN BOBWHITE SEASONAL HABITAT SELECTION ON A RECLAIMED SURFACE MINE IN WESTERN KENTUCKY

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 phoenix*), 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, October 2009 to September 2011 on Peabody Wildlife Management Area (PWMA), a 3,330 ha reclaimed surface mine in Kentucky, USA, to investigate how nonbreeding bobwhite used associated vegetation types and responded to habitat management practices. We used 104 nonbreeding individuals to describe habitat use during the breeding season (1 April–30 September), and 51 coveys during the nonbreeding season (1 October–31 March). Nonbreeding bobwhite used shrub cover and firebreaks planted to winter wheat more than any other vegetation type during the breeding season ($P < 0.05$), and avoided areas of dense, planted native warm–season grasses (NWSG) and WMA roads. During the nonbreeding season, woody edge density was used more than would be expected at random, however the relationship was weak (parameter estimate ≤0.017). Our results suggest that despite plant composition that has traditionally been defined as undesirable, reclaimed lands can support bobwhite populations. However, these areas should not be viewed as optimal for bobwhite because the nonnative plants limited cover of native plants that provide increased nutrition. We recommend reclaimed surface mine lands be considered when designating focal areas for bobwhite management.

INTRODUCTION

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 (McKenzie 2009). 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 and other species that use early successional plant communities. There are more than 153,000 ha of reclaimed surface mines in Kentucky and, in 2011, 53% of the 2,865 ha of surface mine land released from the bond was designated as fish and wildlife habitat (Lexington Office of Surface Mining 2011). The average surface mine size has been slowly increasing over the past 6 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).

A pilot study in Virginia examined the potential for a reclaimed mine to support bobwhite populations and cited a lack of open structure at ground level and limited nesting cover as a result of dense vegetation as factors limiting bobwhite populations (Stauffer 2011). Reclaimed surface mine lands have been frequently revegetated with non–native plant species, such as sericea lespedeza (*Lespedeza cuneata*) and tall fescue (*Schedonorus phoenix*), which typically form dense monocultures that lacks structure desirable to bobwhite (Barnes et al. 1995, Eddy et al. 2003, Ohlenbusch et al. 2007). Sericea lespedeza provides poor 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.

Monocultures of non–native species have been identified as limiting bobwhite populations (Kuvlesky et al. 2002, Hernandez et al. 2012, Sands et al. 2012). 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, *in press*). However, few studies in the CHBCR has examined how bobwhites use areas with abundant non–natives (Osborne et al. 2012). In that study, adult bobwhite relative density in tall fescue fields that were strip disked or sprayed with glyphosate was 200% greater than in unmanaged fields; further reduction of tall fescue cover was recommended.

Tanner (2012) conducted the first study to examine bobwhite population ecology on a reclaimed surface mine. Survival was most influenced by year, time of year (breeding or nonbreeding season), and the percent of forest within a home range (Tanner 2012). Survival was lowest during the nonbreeding season (1 Oct–31 March), and slightly increased as forest cover increased within a home range. This positive relationship with the forest was attributed to the broken–canopy structure of the reclaimed forest, which allowed valuable woody escape cover to develop in the understory. Further research on this reclaimed mine site by Peters (2014) documented the adverse effects of litter depth and amount of open herbaceous core area within a bobwhite home range on survival. Although survival estimates are informative, habitat use studies can identify specific characteristics that make various vegetation types desirable to bobwhite and identify management practices that provide and lead to increased habitat.

The Kentucky Department of Fish and Wildlife Resources (KDFWR) has included reclaimed surface mine lands as part of their bobwhite recovery plan (Morgan and Robinson 2008). If these reclaimed surface mine sites are to benefit bobwhite populations, it is important to understand how birds use these areas and which management practices improve habitat for bobwhite. We initiated a radio–telemetry study on a reclaimed surface mine in August 2009. Our primary objective was to determine how bobwhite used vegetation types throughout the year. We also sought to determine how 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 (37° 14' N, 87° 15' W) and Ohio (37° 17' N, 86° 54' W) counties in western Kentucky, USA. 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 6 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. NWSG included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*), all planted at high 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. Firebreaks 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, United States Department of Agriculture, and the Farm Service Agency into Arc Geographic Information Systems 9.3 (ArcGIS; ESRI, Redlands, CA, USA) to delineate shrub, forest, and open (NWSG or open herbaceous) vegetation. 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” using 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, 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 using a criterion of ≥51% NWSG cover. All NWSG areas were mapped in the field using ArcPad 8.0 (ESRI, Redlands, CA, USA) on handheld Trimble Global Positioning Systems (GPS; Trimble Navigation Limited, Inc., Sunnyvale, CA).

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 using the Random Point Generator Extension (Jenness Enterprises, Flagstaff, AZ, USA) 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. 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. All percent covers were averaged to obtain a 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 *In press*). As one observer looked through the tube, a second moved a colored ruler until it was mostly 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 using 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 6 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 4 vegetation types. Litter presence/absence was also 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 4 vegetation types. We measured distance (m) to woody cover from point center using a range–finder during the nonbreeding season only.

Radio–telemetry

We trapped bobwhite using funnel traps baited with cracked corn and grain sorghum during the 2010 and 2011 breeding (1 Apr–30 Sep) and 2009–2011 nonbreeding (1 Oct–31 March) seasons (Stoddard 1931). Each captured bird was fitted with two aluminum bands (unique numbers on each leg), classified by sex and age (juvenile or adult), and weighed (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, FL, USA). 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 using 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 Apr–30 Sep) and nonbreeding seasons (1 Oct–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 nonbreeding adults. During the nonbreeding season, locations of individuals within the same covey were excluded because of lack of independence, and one location was used to represent the covey each day. Covey associations were determined by individuals that were together ≥7 days (Jenke 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 165 m, 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 traveled (m) between consecutive days. We created 5 random points within this circle using the Create Random Points tool in ArcGIS. These were considered non–chosen, but available comparisons to the chosen location (Cooper and Millspaugh 1999). These 5 random points and the associated recorded location created a "choice set," and the comparisons generated parameter estimates. Individual birds are the sampling unit, and the error term within the model accounts for variation among individuals. McFadden (1978) produced consistent parameter estimates using a choice set consisting of 1 true location and 5 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).

Choice sets were associated with 16 continuous and categorical habitat variables (Table A.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 6 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 1 or 2 growing seasons, respectively, prior to collecting a location or sampling vegetation in the area.

We calculated 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 using the Near Tool in ArcGIS. Measuring the proximity of bobwhite to these areas allowed us to examine their effects 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.

It is important to note that the contagion index and edge density variables were correlated. However, both were included as variables because we hypothesized that not only could the arrangement of vegetation types be important (contagion index), but also specifically what type of edge those vegetation types created (edge density). By including both variables, we were able to examine how specific types of edge and general edge on the landscape influenced bobwhite habitat selection. To avoid violating the assumptions of the discrete choice model, we never included the contagion index and edge density within the same model.

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

We used these variables to create 16 nonbreeding and breeding season models to evaluate habitat selection by season. 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 (McCracken et al. 1998). We used the proportional hazard regression (PHREG) procedure in SAS (SAS Institute 2000, Cary, NC, USA) to estimate parameters and produce Akaike's Information Criterion (AIC) values (Kuhfeld 2000). AIC values were used to rank habitat selection models. 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, which were dominated by sericea lespedeza. For treatment, we used no treatment 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 vegetation types within the land cover variable using parameter estimates with open herbaceous in the center representing use as expected.

RESULTS

Radio–telemetry

We captured 841 individual bobwhite from September 2009 to September 2011 (457 males, 326 females, and 58 of 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 from nonbreeding birds during the breeding season, 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 7 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 = 99.43%) during the nonbreeding season contained the covariates shrub–open edge density, forest–open edge density, distance to a disk block, distance to a firebreak, and distance to road (Table A.2.). The confidence intervals (CI) for the edge density covariates (SOED CI = 0.006–0.010, FOED CI = 0.006–0.028), distance to firebreak (CI = –0.002—0.001), and distance to road (CI = –0.003—0.002) did not overlap 0, indicating these variables influenced habitat selection. The parameter estimates for all 4 of these covariates indicated a positive impact on habitat selection (Table A. 4.) indicating birds used areas with more woody and open edge density, and were closer than would be expected to firebreaks and roads.

Breeding season.–The top model for nonbreeding adults during the breeding season included land cover, the contagion index, distance to a disk block, distance to a firebreak, and distance to a road (Table A.3.). Bobwhite used firebreaks (CI = 0.034–0.549) and shrub vegetation (CI = 0.121–0.339) more than any of the other vegetation types on the WMA (Table A.4.). NWSG and roads were used the least (CI = –0.549—0.250 and –1.020—0.416 respectively), and open herbaceous and forests were used equally (Table A.4.). The negative parameter estimate for the contagion index (–0.011, CI = –0.017—0.006) indicates that bobwhite were using areas with more interspersion and dispersion of vegetation types (Table A.4.). The relationship between habitat selection and distance to a disk block, firebreak, or road was minimal as parameter estimates were not different from 0 based on CI.

Vegetation Surveys

We documented 296 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 (Table C.1). Sericea lespedeza dominated open herbaceous (76%, Table A.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 A.5.).

Nonbreeding season.–Forested areas had the least amount of visual obstruction 0–20 cm aboveground (49%, Table A.6.). Visual obstruction 0–20 cm aboveground within shrub (74 ± 2%) overlapped with the average (± SE) for NWSG (75 ± 2%, Table A.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 A.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 A.6). Firebreaks were dominated by planted winter wheat (24% cover) and contained nearly as much area devoid of live vegetation (22% cover, Table A.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 A.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 A.5.). Burning increased cover of NWSG within NWSG areas from 49% to 77% (Table A.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 nonbreeding adult 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, though parameter estimates (forest–open edge = 0.017, shrub–open edge = 0.008) revealed a weak relationship. During the breeding season, firebreaks and shrub cover were used more than all other vegetation types. Distance to a disk block, firebreak, and road appeared in the top 3 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 preferred 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 (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 may have also 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 maximize 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 (bare ground) 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 non–brooding 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.

NWSG 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 preferred 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 during the breeding season edge in general was important. Shrub cover was also 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 and burning treatments had no effect on seasonal survival of bobwhite (Tanner 2012, Peters 2014). Disking and burning on the WMA began during late winter and early spring, 2010; thus, any effect 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 cover of NWSG (49% to 77%) and failed to reduce the cover of sericea lespedeza (76% to 72% after 1 year). This dense vegetation likely discouraged bobwhite use of burned areas.

Our top model did include distance to disk blocks and roads. Weak but positive parameter estimates suggested birds were closer to these features 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, it is clear that 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 is long–lived in the seedbank (Ohlenbusch et al. 2007). Thus, it is likely that sericea lespedeza 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 2 week study experienced a 29% weight loss on average (Newlon et al. 1964). Therefore, it is important that management practices reduce cover of sericea lespedeza while promoting cover of desirable food plants on areas being managed for bobwhite. We found that 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 may be 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. Maintaining early successional communities in the eastern US where there is considerable precipitation requires continuous management because of rapid plant growth and associated succession (albeit more slowly on a reclaimed surface mine).

MANAGEMENT IMPLICATIONS

Disking improved vegetation structure, enhanced vegetation composition, and maintained an early seral stage at Peabody WMA. Periodic disking can improve the structure of dense native grass plantings (Gruchy and Harper, *in press*) 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. 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 and D. Baxley for her review of this manuscript. 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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APPENDIX A

Table A.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, USA.

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 firebreak	Continuous	Distance (m) to nearest firebreak	DF
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–shrub edge in 330–m diameter circle around location	FOED
Shrub–forest edge density	Continuous	Amount (m/ha) of forest core area 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 one of 3 treatments: disk block, burned with 1 growing season, burned with 2 growing seasons	TREAT

Land cover	Categorical	Location in one of 10 vegetation types: wetland, water, open herbaceous, shrub, forest, annual grain, developed, native warm–season grass, road, and firebreak	LAND

Table A.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, USA, 2009 – 2011.

Model	Covariates[1]	AIC	ΔAIC	AIC weights	No. of parameters
15	SOED, FOED, DDB, DF, DR	7,795.71	0.00	.994	5
13	LAND, CONTAG, DDB, DF, DR	7,806.63	10.92	0.0042	9
12	DDB, DF, DR, DS	7,808.69	12.97	0.0015	4
9	DS, TREAT	7,822.49	26.78	0.00	4
7	LAND, CONTAG, TREAT	7,835.18	39.47	0.00	9
14	SOED, FOED, SFED	7,851.81	56.10	0.00	3
6	CONTAG x TREAT	7,856.09	60.38	0.00	7
8	DS	7,864.12	68.41	0.00	1
10	DS x MT	7,865.79	70.08	0.00	2
11	DDB, DF, DR	7,871.34	75.63	0.00	3
5	TREAT	7,888.93	93.21	0.00	3
1	LAND	7,899.06	103.35	0.00	5
4	CONTAG	7,900.75	105.03	0.00	1
2	LAND x MT	7,903.02	107.31	0.00	10
3	LAND x T	7,904.97	109.26	0.00	10
16	SCA, FCA, OHCA, NGCA, DDB, DF	7,907.52	111.80	0.00	6
0	Null Model	7,930.33	134.61	0.00	0

[1] SOED = shrub–open edge, FOED = forest–open edge, DDB = distance to disk block, DF = distance to firebreak, DR = distance to road, LAND = land cover type, CONTAG = contagion index, DS = distance to shrub, TREAT = treatment, T = 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 A.3. Model rankings based on AIC scores for discrete choice analysis of habitat use during the breeding season (1 April – 30 September) at Peabody WMA, Kentucky, USA, 2009 – 2011.

Model	Covariates[1]	AIC	ΔAIC	AIC weights	Parameters
13	LAND, CONTAG, DDB, DF, DR	10,676.22	0.00	1.00	9
12	DDB, DF, DR, DS	10,716.82	40.59	0.00	4
15	SOED, FOED, DDB, DF, DR	10,730.68	54.45	0.00	5
11	DDB, DF, DR	10,776.61	100.38	0.00	3
7	LAND, CONTAG, TREAT	10,805.75	129.52	0.00	9
3	LAND x T	10,825.43	149.21	0.00	10
1	LAND	10,827.35	151.12	0.00	5
2	LAND x MT	10,829.06	152.84	0.00	10
16	SCA, FCA, OHCA, NGCA, DDB, DF	10,831.71	155.49	0.00	6
9	DS, TREAT	10,834.54	158.31	0.00	4
8	DS	10,838.49	162.27	0.00	1
10	DS x MT	10,840.49	164.27	0.00	2
14	SOED, FOED, SFED	10,846.04	169.82	0.00	3
6	CONTAG x TREAT	10,866.07	189.84	0.00	7
4	CONTAG	10,869.13	192.91	0.00	1
5	TREAT	10,887.10	210.88	0.00	3
0	Null Model	10,890.31	214.09	0.00	0

[1]LAND = land cover, CONTAG = contagion index, DDB = distance to disk block, DF = distance to firebreak, DR = distance to road, DS = distance to shrub, SOED = shrub–open edge, FOED = forest–open edge, TREAT = treatment, T = 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 A.4. 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, USA from 2009 – 2011.

Season	Covariates[1]	Parameter estimates	Lower 95% CI	Upper 95% CI	Probability > X^2
Nonbreeding	**SOED**	**0.008**	**0.006**	**0.010**	**<0.001**
	FOED	**0.017**	**0.006**	**0.028**	**0.002**
	DDB	0.000	–0.001	0.001	0.612
	DF	**–0.002**	**–0.002**	**–0.001**	**0.002**
	DR	**–0.003**	**–0.003**	**–0.002**	**<0.001**
Breeding	**LAND**	**–**	**–**	**–**	**<0.001**
	Firebreak	**0.292**	**0.034**	**0.549**	**0.026**
	Shrub	**0.230**	**0.121**	**0.339**	**<0.001**
	Open herbaceous[2]	0.000	–	–	–
	Forest	–0.009	–0.211	0.193	0.929
	NWSG	**–0.399**	**–0.549**	**–0.250**	**<0.001**
	Roads	**–0.718**	**–1.020**	**–0.416**	**<0.001**
	CONTAG	**–0.011**	**–0.017**	**–0.006**	**<0.001**
	DDB	**–0.002**	**–0.003**	**–0.001**	**<0.001**
	DF	–0.001	–0.001	0.000	0.138
	DR	**–0.003**	**–0.004**	**–0.002**	**<0.001**

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

[2]Open herbaceous is the reference class for LAND.

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

Vegetation type	% cover untreated		% cover disked[3]		% 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	–	–	–	–	–	–
Symphoricarpos orbiculatus	9.83	1.44	–	–	–	–	–	–
Parthenocissus quinquefolia	7.74	1.34	–	–	–	–	–	–
NWSG[1]								
Lespedeza cuneata	54.31	4.23	43.33	6.53	51.90	5.60	71.52	10.43
Planted NWSG[2]	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
Acalypha gracilens	4.55	0.98	3.33	1.84	1.67	1.67	0.56	0.56
Lotus corniculatus	4.49	2.23	6.84	4.65	3.81	2.15	3.61	3.06
Setaria faberi	4.23	1.65	7.72	3.58	0.00	0.00	2.50	1.97
Melilotus spp.	3.46	1.53	7.72	2.47	0.24	0.24	2.50	1.97
Litter or bare ground	1.47	0.55	2.28	1.22	0.00	0.00	0.28	0.28
Trifolium pratense	0.64	0.43	9.30	3.85	0.00	0.00	0.00	0.00
Helianthus annuus	0.45	0.33	2.28	1.77	9.29	3.05	0.28	0.28
Bromus arvensis	0.06	0.06	0.18	0.18	0.95	0.95	11.11	7.20
Open herbaceous								
Lespedeza cuneata	75.79	2.61	42.02	4.94	72.38	11.81	77.50	6.44
Schedonorus phoenix	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
Rubus allegheniensis	3.31	0.86	0.71	0.43	6.67	6.13	0.00	0.00
Carduus nutans	2.03	0.79	10.71	3.86	1.43	0.99	0.00	0.00
Melilotus spp.	1.72	0.66	13.10	4.48	3.81	2.56	8.33	5.53
Iva annua	0.78	0.43	10.60	4.82	1.90	1.43	19.17	17.02
Litter or bare ground	0.67	0.23	4.52	1.60	0.00	0.00	0.83	0.83
Bromus arvensis	2.19	0.87	3.93	1.80	26.19	14.52	21.67	21.67
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
Schedonorus phoenix	9.31	1.80	–	–	8.33	8.33	0.00	0.00
Lonicera japonica	8.69	1.61	–	–	10.00	10.00	18.89	18.89
Poa pratensis	6.67	1.50	–	–	33.33	26.67	1.11	1.11
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
Bromus arvensis	1.19	0.47	–	–	38.33	38.33	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	–	–	–	–	–	–
Digitaria spp.	9.76	6.63	–	–	–	–	–	–
Oxalis stricta	7.62	4.08	–	–	–	–	–	–
Lactuca serriola	7.14	3.84	–	–	–	–	–	–
Lespedeza cuneata	0.00	0.00	–	–	–	–	–	–
Planted NWSG	0.00	0.00	–	–	–	–	–	–

[1]Native warm–season grass

[2]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*).

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

		Vegetation type			
Season	Metric	Forest (SE)	NWSG[1] (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)
	$\bar{x}$ 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)
	$\bar{x}$ Litter depth (cm)	1.5 (0.1)	0.7 (0.1)	0.6 (0.1)	0.9 (0.1)
	$\bar{x}$ 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 ≤ 4.5cm 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 > 4.5cm DBH	15.33 (1.06)	0.15 (0.09)	0.15 (0.05)	2.60 (0.39)

[1]Native warm–season grass

CHAPTER II

NORTHERN BOBWHITE NEST SITE AND BROOD HABITAT SELECTION ON A RECLAIMED SURFACE MINE IN WESTERN KENTUCKY

ABSTRACT

Reclaimed surface mines represent 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 phoenix*), which can limit favorable nesting and brooding structure for bobwhite. Understanding factors affecting nest site selection and brood habitat use is important for effective management and reproductive success on reclaimed surface mine sites. To better understand bobwhite nest site selection and brood habitat use on reclaimed lands, we trapped and radiomarked 841 bobwhite October 2009 to September 2011 on Peabody Wildlife Management Area, a 3,330 ha reclaimed surface mine in western Kentucky, USA. We found 57 nests and analyzed the movements of 23 brooding adults. Nests were placed in areas with lower contagion index values than in paired, random locations (parameter estimate = –0.045). Broods used annually disked firebreaks (1.4% of study area) more than any other habitat feature or vegetation type (parameter estimate = 0.933), and used undisturbed areas more than areas that had been recently burned or disked. Broods used forested areas and roads least of all the vegetation types and habitat features (parameter estimates = –1.335 and –1.569 respectively). Firebreaks were dominated by winter wheat (*Triticum aestivum*), abundant bare ground, and naturally occurring forbs. Firebreaks likely provided areas that optimized chick mobility and annual disking may have promoted vegetation that encouraged presence of insect–prey for feeding bobwhite broods. Although bobwhite used undisturbed areas more than disked blocks, more frequent or more intensive disking may create a similar composition to that found within firebreaks on other areas of Peabody WMA. Disking can also reduce cover of sericea lespedeza and potentially improve mobility for broods.

INTRODUCTION

Northern bobwhite (hereafter bobwhite) populations have declined throughout most of their range at an annual rate of 3.8% over the past 3 decades (Sauer et al. 2011). Concern for the declining population lead to the creation of the Northern Bobwhite Conservation Initiative (NBCI), whose goals include increasing habitat for bobwhite by targeting large–scale habitat restoration (Dimmick et al. 2002). However, finding large contiguous areas in which to focus restoration efforts can be a challenge (Hernandez et al. 2012). Reclaimed surface mines offer an opportunity to provide large tracts of land for bobwhite and other species that use early successional plant communities in the eastern US. There are more than 153,000 ha of reclaimed surface mines in Kentucky, and in 2011, 53% of the 2,865 ha of the released surface mine land was designated as fish and wildlife habitat (Lexington Office of Surface Mining 2011).

A pilot study in Virginia examined the potential for a reclaimed mine to support bobwhite populations and cited a lack of open structure at ground level and limited nesting cover as a result of dense vegetation as factors limiting bobwhite populations (Stauffer 2011). Reclaimed surface mine lands have been frequently revegetated with non–native plant species, such as sericea lespedeza (*Lespedeza cuneata*) and tall fescue (*Schedonorus phoenix*), which typically form a dense monoculture that lacks structure desirable to nesting and brooding bobwhite (Barnes et al. 1995, Eddy et al. 2003, Ohlenbusch et al. 2007). Dense sericea lespedeza has been reported to diminish the value of an area for nesting, and can reduce native grass and forb cover by 66 and 70%, respectively (Dimmick 1971, Eddy and Moore 1998).

Bobwhite experience high annual mortality in the Southeast (Speake 1967, Simpson 1976), therefore understanding cover important to reproduction is critical to managing stable populations. Studying bobwhite needs for nesting and brooding allows for the implementation of more effective conservation and management practices. Tanner (2012) is the only study to document factors affecting nest survival on a reclaimed surface mine, and reported nest survival estimates (*S* = 0.317) were lower than other studies in Missouri (*S* = 0.437, Burger 1995) and Mississippi (*S* = 0.39, Taylor and Burger 1997). Survival was most influenced by nest age. The effects of nest substrate and landscape metrics did not differ from 0 (Tanner 2012). Although nest survival estimates are important, research with blackcaps (*Sylvia atricapilla*) in the Czech Republic reported that factors affecting nest site selection differed from factors that contributed to nest success (Remeš 2003). The authors hypothesized that blackcaps preferred to construct nests in vegetation where nest success was lower than in non–preferred natural vegetation because of the attractive early leaf–out of non–native black locust (*Robinia pseudoacacia*) in plantations. Understanding factors that contribute to both nest site selection and survival can help managers avoid creating population sinks, especially on a landscapes heavily influenced by disturbance, such as a reclaimed surface mine.

The Kentucky Department of Fish and Wildlife Resources (KDFWR) has included reclaimed surface mine lands as part of their bobwhite recovery plan (Morgan and Robinson 2008). If these reclaimed surface mine sites are to benefit bobwhite populations, it is important to understand variables affecting nest site selection and brood habitat use. We initiated a radiotelemetry study a reclaimed surface mine in August 2009. One of the objectives was to determine how vegetation metrics influenced nest site and brood habitat selection. We also sought to determine how management activities (burning and disking) influenced habitat use on reclaimed land. We predicted bobwhite would construct nests within native warm–season grass and/or near disked or burned areas (proximity to brooding cover). We also predicted bobwhites would selectively brood in areas that had been disturbed through disking and burning more than undisturbed blocks of vegetation that contained dense, planted native grasses and sericea lespedeza.

STUDY AREA

Peabody Wildlife Management Area (WMA), located in the Central Hardwoods Bird Conservation Region, encompasses 3,322 ha of Muhlenberg (37° 14' N, 87° 15' W) and Ohio (37° 17' N, 86° 54' W) counties in western Kentucky, USA. 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 6 vegetation types on the study area. They included open herbaceous (34%), shrub (25%), forest (22%), native warm–season grass (8%), water (7%), and 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 consisted mostly of post–mining, 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 grass (NWSG) cover was represented primarily by big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*), all planted at high seeding rates.

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 often planted with a mixture of sorghum (*Sorghum bicolor*), Illinois bundleflower (*Desmanthus illinoensis*), partridge pea (*Chamaecrista fasciculata*), Maximillian sunflower (*Helianthus maximilianii*), and additional species with a drill (Table B.1). Disk blocks and firebreaks were first disked with an offset disk, followed by a finish disk and cultipacker. Firebreaks 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 the study site, and 319 ha were burned. The majority of the burning took place in October, November, and March.

Daily weather data were gathered online from the Kentucky Mesonet (www.kymesonet.org) using a nearby station in Hartford, Kentucky (37° 46' N, 86° 86' W). Annual rainfall was 142 cm in 2009, 109 cm in 2010, and 180 cm in 2011. August and September 2010 were particularly dry, receiving <3 cm each month, whereas April 2011 received 42 cm of precipitation. Yearly average temperature ranged from 13 to 14°C with the minimum of –19 °C in January 2009 and maximum of 39 °C in August 2011.

METHODS

Land Cover

We used 1–m resolution aerial imagery (2010) from the National Agriculture Inventory Program, United States Department of Agriculture, and the Farm Service Agency into Arc Geographic Information Systems 9.3 (ArcGIS; ESRI, Redlands, CA, USA) to delineate shrub, forest, and open (NWSG or open herbaceous) vegetation. We selected ground–truthed, 1– m × 1–m cells in the study area that we knew best represented woody cover, then used this as a template to classify all other cells as either “woody” or “open” using 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, 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 from open herbaceous using a criterion of ≥51% cover of NWSG. Areas with <50% cover of NWSG were classified as open herbaceous. All NWSG areas were mapped in the field using ArcPad 8.0 (ESRI, Redlands, CA, USA) on handheld Trimble Global Positioning Systems (GPS; Trimble Navigation Limited, Inc., Sunnyvale, CA).

Vegetation Surveys

Vegetation sampling was conducted late May to mid–August. 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 using the Random Point Generator Extension (Jenness Enterprises, Flagstaff, AZ, USA) for ArcGIS. We generated a minimum of 60 sampling points per vegetation type, and each vegetation type was confirmed at the time of sampling. Vegetation composition, litter depth, and ground sighting distances were measured along 30–m transects 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. All percent covers were averaged to obtain a 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 *In press*). As one observer looked through the tube, a second moved a colored ruler until it was mostly 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 using 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 non–breeding) from 4 m away, with eye–level at 1 m aboveground. Observations were taken at 0, 10, 20, and 30 m along transects. Visual obstruction estimations were recorded in 6 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 by vegetation type.

We recorded woody stem density for trees and shrubs in two size classes: small woody stem density (<4.5 cm DBH) measured in 5–m radius plots and large woody stem density (>4.5 cm DBH) measured in 10–m radius plots. We reported mean basal area (m^2/ha) of woody stems for each size class in all 4 vegetation types. We also recorded nest substrate to species at each nest site.

Radiotelemetry

We trapped bobwhite year–round using funnel traps baited with cracked corn and grain sorghum during the breeding (1 Apr–30 Sep) and non–breeding (1 Oct–31 March) seasons (Stoddard 1931). Each captured bird was fitted with two aluminum bands (unique numbers on each leg), classified by sex and age (juvenile or adult), and weighed (g). Age was based on the presence or absence of buff–tipped primary coverts (Rosene 1969). All birds weighing $\geq$120 g were fitted with a necklace–style radio–transmitter weighing $\leq$6 g (American Wildlife Enterprises, Monticello, FL, USA). 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 $\geq$3 times per week by homing in to approximately 50 m and thus minimizing 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 using a handheld GPS unit. 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 50 meters or less. Actual distance and azimuth were measured, then compared with the estimated distance and azimuth.

Locations were sorted by breeding (1 Apr–30 Sep) and non–breeding (1 Oct–31 March) seasons. Birds with identical, subsequent locations were considered nesting (Burger et al. 1995). When the radio–marked bird was away from the nest, we walked–in to confirm the nest location and recorded UTM coordinates on a handheld GPS unit. We monitored nesting birds daily by locating the radiocollared adult. When the adult was away from the nest, we returned to the nest location to monitor the clutch every 7 – 10 days (Taylor et al 1999*a*). We monitored broods daily by following the radiocollared bird, and recorded UTM coordinates, vegetation type, and azimuth for each location. Brooding birds were flushed weekly to confirm the presence of a brood.

Both successful and unsuccessful nests were included in the site selection analysis. We censored mortality locations from our brood locations because predators may have moved radiocollared birds postmortem.

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 clearly defined to appropriately determine selection (Arthur 1996, Cooper and Millspaugh 1999). We defined availability for brooding birds as a circle centered on a brooding location with a radius equal to 145 m, the average distance (m) a bobwhite traveled between locations on consecutive days during the breeding season (Arthur 1996, Cooper and Millspaugh 1999, Holt 2009). We defined availability for nest sites with a 210 m buffer based on bobwhite literature (Taylor et al. 1999*a*, Potter et al. 2011). We created 5 random points to be paired with each nest, and within each buffer using the Create Random Points tool in ArcGIS. These were considered non–chosen, but available comparisons to the chosen location (Cooper and Millspaugh 1999). These 5 random points and the associated recorded location created a "choice set," and the comparisons generated parameter estimates. Individual birds are the sampling unit, and the error term within the model accounts for variation among individuals. McFadden (1978) produced consistent parameter estimates using a choice set consisting of 1 true location and 5 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).

Choice sets were associated with 11 continuous and categorical variables (Table B.2) 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 the points in each choice set with land cover values. The categorical covariate land cover included 9 vegetation types. Treatment included no treatment, disked, 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. First and second growing season burns had experienced either 1 or 2 growing seasons prior to collecting a location or sampling vegetation in the area.

We calculated the Euclidean distance (m) from each location to the nearest road, firebreak, patch of the shrub vegetation type, and disk block present at the time the location was recorded using the Near Tool in ArcGIS. Measuring the proximity of bobwhite to these areas allowed us to examine their effects 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 (non–breeding season 2010–2011). We calculated core area (ha) and edge density (m/ha) in forest, shrub, open herbaceous, and NWSG. 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.

It is important to note that the contagion index and edge density variables were correlated. However, both were included as variables because we hypothesized that not only could the arrangement of vegetation types be important (contagion index), but also specifically what type of edge those vegetation types created (edge density). By including both variables, we were able to examine how specific types of edge and general edge on the landscape influenced bobwhite habitat selection. To avoid violating the assumptions of the discrete choice model, we never included the contagion index and edge density within the same model.

We used these variables to create 8 nesting and brooding candidate models to evaluate brood habitat select and nest site selection. 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 ratio of an individual selecting 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 (McCracken et al. 1998). We used the proportional hazards regression (PHREG) procedure in SAS (SAS Institute 2000, Cary, NC, USA) to estimate parameters and produce Akaike's Information Criterion (AIC) values (Kuhfeld 2000). AIC values were used to rank habitat selection models. Land cover and treatment type were categorical variables and the discrete choice analysis required a reference class 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%). Therefore bobwhite use of every other vegetation type is in reference to how birds used open herbaceous areas (34% of the study area). For treatment, we used no treatment 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 vegetation types within the land cover variable using parameter estimates with open herbaceous in the center representing use as expected.

We included 2 interaction terms in our models to help explain nest and brooding habitat selection. All main effects of the interaction variables were also included in the model (McCullagh and Nelder 1989). We examined a land cover and treatment interaction as treatment may influence the use of a particular vegetation type. We also included a contagion index and landcover interaction term because the spatial distribution of a vegetation type could influence habitat selection (Roseberry and Sudkamp 1998).

RESULTS

Resource Selection

We captured 841 individual bobwhites from September 2009–2011 (457 males, 326 females, and 58 of an unknown sex). We were able to attach transmitters to 627 birds. We found 57 nests, 46 of which were incubated by females and 11 by males. Three nests were found without an associated collared bird, and 4 nests were second nesting attempts by females. Of the 57 nests found, 27 were successful (Tanner 2012). Broods from all 27 successful nests were monitored, however 6 birds were no longer found with their broods after 1–5 days and were excluded from the analysis. An additional 2 birds were captured while brooding and were included in the analysis. We collected 402 locations on these 23 broods, averaging (±SE) 17.5 (2.0) locations per brood.

We used the trials of 7 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.

Most of our nesting models did not improve the AIC value from the no covariate or null model (Table B.3). Three models ranked above the null model, but they did not greatly improve the AIC value. The top model (AIC weight = 0.48) included the contagion index value only. The negative parameter estimate (–0.045) suggested the contagion index was less (more interspersion/dispersion) at selected sites than at random (Table B.4).

The top model for brood habitat selection included distance to shrub cover, land cover type, and treatment type (Table B.5). Our second–best model was nearly identical to the first, but it did not include distance to shrub cover. The AIC weight for the second best model (0.22) improved with addition of the distance to shrub cover variable (0.45, Table B.5), but the parameter estimate for the distance to shrub variable was 0.004, indicating the effect of distance to shrub was positive (Table B.4). Brood habitat selection was driven by the landcover and treatment variables. Birds used firebreaks (parameter estimate = 0.933, Table B.4) more than any other habitat feature or vegetation type, and used untreated areas more than disk blocks and areas 1 growing season after a burn on Peabody WMA (Table B.5). Parameter estimates for roads (–1.134) and forest (–1.798) indicate roads and forest were particularly undesirable for broods compared with other habitat features or vegetation types.

Vegetation Surveys

We documented 296 plant species on Peabody WMA, of which 220 were native, 66 were introduced, and we were unable to differentiate between the native or non–native subspecies for 9 (Table C.1). The majority of nests (*n* = 57) were constructed of cool–season grasses, such as Kentucky bluegrass (*Poa pratensis*) and field brome (42%), followed by sericea lespedeza (33%), native warm–season grasses, such as little bluestem and big bluestem (19%), and we were unable to determine the substrate for 3 nests. Cover of sericea lespedeza was at least 76% within open herbaceous, NWSG, and shrub areas (Table B.6). Cover of NWSG was greatest in NWSG at 49% (± 3.82) but scant in other vegetation types with <7%. Firebreaks contained more areas with litter or bare ground (22%) than forests (21%), shrub (5%), NWSG (2%), and open herbaceous (1%). Disking increased bare ground in open herbaceous and NWSG, but covered far less of the area than firebreaks (≤5%). Firebreaks were dominated by winter wheat (24% cover) and common ragweed (11%, Table B.6). Open herbaceous and NWSG areas had the most visual obstruction 0 – 25 cm aboveground with cover ≥86%. Structurally, disked open herbaceous and

NWSG areas varied slightly from untreated areas, with ≥74% vegetation cover at 0 – 25 cm aboveground, and burning did not reduce visual obstruction (≥ 88%) in either vegetation type.

DISCUSSION

The contagion index, a measure of interspersion and dispersion of vegetation types, was the most influential factor in nest site selection. Nest sites had a lower contagion value, and therefore were placed in areas with more interspersion and dispersion of vegetation types than random locations. Broods used firebreaks more than any other habitat feature or vegetation type on Peabody WMA. Use of forest and roads was less than expected compared to the use of open herbaceous areas, with forests being used least.

The negative relationship between the contagion index and nest site selection suggests bobwhites selected to nest in areas with greater dispersion and interspersion of vegetation types. Similar results were reported in Georgia by White et al. (2005) using the interspersion and juxtaposition index (IJI) and patch density (PD). They observed that bobwhite used areas with many patches of vegetation consisting of just 2 or 3 vegetation types. Patchy areas consisting of 2 or 3 vegetation types can reduce the distance a bobwhite would need to travel to reach another vegetation type, provided that these patches are vegetation types that bobwhite are able to use. Bobwhite on Peabody WMA likely used areas with a configuration similar to those described by White et al. (2005) in Georgia, however the use of these areas did not affect nest survival (Tanner 2012, Peters 2014). The presence of the contagion index alone within the top nest site selection model likely indicates that bobwhite are able to nest successfully in an array of conditions given that adequate habitat exists with residual vegetation for nest building. Nesting cover does not appear to be limited on Peabody WMA for bobwhite.

The majority of the nests on Peabody WMA were constructed of sericea and cool–season grasses, such as Kentucky bluegrass, field brome, and tall fescue. The birds were able to use the vegetation that was available in the various vegetation types at Peabody WMA and did not select a particular vegetation type or substrate for constructing the nest. Dimmick (1971) observed that dramatic changes in the vegetative community, the growth of dense sericea lespedeza post–disturbance, can greatly reduce the value of an area for nesting. However, Dimmick (1971) was studying the effects of controlled burning on nesting bobwhite, and on Peabody WMA fire maintained and even increased the cover of sericea lespedeza (78% cover untreated, 72% cover 1 year after burn, 78% cover 2 years after burn). Fire would immediately reduce residual vegetation used for nest construction and stimulate dense sericea lespedeza growth, which likely accounts for Dimmick's (1971) observations. On sites such as Peabody WMA, it appears that the structure and residual vegetation needed for nest construction and obscuration can be found regardless of sericea lespedeza cover. Cool season grasses, such as tall fescue, can provide sufficient material for nest construction and nesting cover (Barnes et al. 1995), and were the second most common plant in open herbaceous areas on Peabody WMA (15% cover, Table B.6).

Broods used firebreaks (1.4% of the study site) more than any other vegetation type. Firebreaks were disked annually, planted to winter wheat, and were uniform in size (9 m wide). Winter wheat was usually dead, but still standing (24% cover, Table B.6) by the time broods began using firebreaks soon after hatching, and the frequent disking resulted in short, sparse vegetation cover (litter or bare ground covered 22% of firebreak area). Broods selected patches of vegetation with relatively abundant bare ground (14.1% cover) and forb cover (34.4% cover) in Kansas (Taylor et al. 1999*b*), and appear to prefer areas with similar characteristics on Peabody WMA, such as those found within firebreaks. Firebreaks also were similar to the “weedy–wheat” fields described by Doxon and Carroll (2010). These untreated/fallow wheat fields had extensive cover of annual forbs/weeds, and provided easy mobility with an open structure at ground level and supported healthy feeding rates for bobwhite chicks (Doxon and Carroll 2007). Firebreaks on Peabody were similar in composition and structure, and provided the same foraging opportunity for bobwhite chicks. Additionally, unharvested wheat and two varieties of Conservation Reserve Program fields (CP10 and improved CP10) in Kansas had the greatest number of insect prey (Doxon and Carroll 2007). 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.

The combination of bare ground, abundant forbs, and high–quality insect prey likely enabled bobwhite chicks to feed easily and successfully within firebreaks on Peabody WMA. Although disking increased bare ground in open herbaceous and NWSG to at least 5%, and increased the cover of common ragweed to 26%, firebreaks contained far more bare ground (22% cover, Table B.6). This lack of vegetation provided areas better for chick mobility than those within disk blocks. Firebreaks were disked annually and often used to drive equipment to new places for management. In contrast, disk blocks were disked once and not disturbed again for the duration of this study, allowing these areas to return to an untreated state much quicker than firebreaks. As a linear feature, firebreaks also may have served as a travel corridor for brooding birds. Disk blocks, however, were often placed within large blocks of homogenous vegetation with the objective of creating vegetation heterogeneity. They were therefore mostly isolated treatments, especially during the first year of management. This placement likely made disk blocks poor travel corridors and less desirable.

We conducted a post–hoc analysis to further investigate the use of disk blocks by brooding birds on Peabody WMA. Based on the aforementioned results, we predicted that certain vegetation types may influence the use or non–use of disk blocks. Using the discrete choice model, we evaluated the interaction of bobwhite use of disk blocks and vegetation type. Parameter estimates for the interaction terms did not differ from 0, indicating that vegetation type did not influence selection of disk blocks on Peabody WMA.

Burned areas after 1 growing season also were used less than expected by brooding bobwhite. These burns often were implemented in dense stands of NWSG where residual vegetation was abundant, which resulted in an increase of NWSG from 49% cover to 77% cover. Dormant–season burns also failed to effectively reduce sericea lespedeza cover (76% cover untreated, 72% cover 1 growing season after a burn), and actually resulted in a slight increase of sericea lespedeza cover by the second growing season (78% cover). The structure created by burning open herbaceous areas dominated by sericea and NWSG likely discouraged use of burned areas by brooding bobwhite.

MANAGEMENT IMPLICATIONS

Management of reclaimed surface mines should focus on improving the structure and composition of the plant community where management objectives include improving habitat for bobwhite. Dense NWSG plantings may restrict movements of broods and adult birds, and therefore should be discontinued. Disking can provide bare ground important for chick mobility, and stimulate the growth of annual forbs where needed. Heavy disturbance, such as several passes with an offset disk, may be required for effective reduction of NWSG and sericea lespedeza cover. Herbicide applications may be necessary in addition to mechanical disturbance to reduce plant cover within dense NWSG and sericea lespedeza stands. Forest conditions may be improved for bobwhite by burning or by converting forested areas to early successional vegetation (if limiting), which would increase amount of habitat for bobwhite. Reclaimed surface mines can provide relatively large areas of contiguous, habitat for bobwhite and with management, support a breeding population.

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 (KDWFR) 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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APPENDIX B

Table B.1. List of plant species planted in disk blocks on Peabody WMA, a reclaimed surface mine in western Kentucky, USA.

Scientific Name[1]	Common Name	Status
Chamaecrista fasciculata	Partridge pea	Native
Coreopsis lanceolata	Lanceleaf tickseed	Native
Coreopsis tinctoria	Golden tickseed	Native
Dalea purpurea	Purple prairie clover	Native
Desmanthus illinoensis	Illinois bundleflower	Native
Dracopis amplesicaulis	Clasping coneflower	Native
Echinacea purpurea	Eastern purple coneflower	Native
Eryngium yuccifolium	Button eryngo	Native
Fagopyrum esculentum	Buckwheat	Introduced
Gaillardia pulchella	Indian blanket	Native
Helianthus maximiliani	Maximillian sunflower	Native
Kummerowia stipulacea	Korean clover	Native
Lotus corniculatus	Bird's–foot trefoil	Introduced
Panicum miliaceum	Proso millet	Introduced
Ratibida columnifera	Upright prairie coneflower	Native
Ratibida pinnata	Pinnate prairie coneflower	Native
Rudbeckia hirta	Blackeyed Susan	Native
Sorghum bicolor	Sorghum	Introduced
Trifolium hybridum	Alsike clover	Introduced
Trifolium pratense	Red clover	Introduced
Trifolium repens	White clover	Introduced
Triticum aestivum	Winter wheat	Introduced
Urochloa ramosa	Browntop millet	Introduced

[1]Scientific names, common names, and statuses were determined using the USDA NRCS PLANTS database.

Table B.2. List of descriptions and abbreviations for variables used to create models in our selection analysis of northern bobwhite in Ohio and Muhlenberg Counties, Kentucky, USA.

Variable	Type	Description	Abbreviation
Distance to disk block	Continuous	Distance (m) to nearest disked area	DDB
Distance to road	Continuous	Distance (m) to nearest road	DR
Distance to firebreak	Continuous	Distance (m) to nearest firebreak	DF
Distance to shrub	Continuous	Distance (m) to nearest patch of the shrub vegetation type	DS
Open herbaceous core area	Continuous	Amount (ha) of open herbaceous core area in 330m diameter circle around location	OHCA
Native warm–season grass core area	Continuous	Amount (ha) of NWSG core area in 330m diameter circle around location	NGCA
Shrub–open edge density	Continuous	Amount (m/ha) of shrub–open edge in 330m diameter circle around location	SOED
Forest–open edge density	Continuous	Amount (m/ha) of forest–shrub edge in 330m diameter circle around location	FOED
Contagion	Continuous	Measure (1–100) of interspersion and dispersion based on 330m diameter circle around location	CONTAG
Treatment	Categorical	Location in one of 4 treatments: disk block, recent burn, burned with 1 growing season, burned with 2 growing seasons	TREAT
Land cover	Categorical	Location in one of 10 vegetation types: wetland, water, open herbaceous, shrub, forest, annual grain, developed, native warm–season grass, road, and firebreak	LAND

Table B.3. Model ranking based on AIC scores for discrete choice analysis of nest site selection on Peabody WMA, Kentucky, USA, 2009 – 2011.

Model	Covariates	AIC	ΔAIC	AIC weight	No. of parameters
6	CONTAG	200.61	0.00	45.19	1
3	DDB, DR, DF	202.08	1.46	21.73	3
8	DS	203.73	3.12	9.52	1
5	NGCA, OHCA, DDB, DR, DF, DS	203.75	3.14	9.41	6
0	No covariate	204.26	3.65	7.29	0
1	LAND	206.69	6.08	2.16	5
7	TREAT	206.81	6.19	2.04	3
4	NGCA, OHCA	207.25	6.64	1.64	2
2	LAND, TREAT	208.20	7.59	1.02	8

[1]CONTAG = contagion index, DDB = distance to disk block, DF = distance to firebreak, DR = distance to road, DS = distance to shrub, NGCA = native warm–season grass core area, OHCA = open herbaceous core area, LAND = land cover, TREAT = treatment.

Table B.4. Parameter estimates for covariates of top models from a discrete choice analysis used to analyze nest site and brood habitat selection at Peabody WMA, a reclaimed surface mine in Kentucky, USA from 2009 – 2011.

Season	Covariates	Parameter estimates	Lower 95% CI	Upper 95% CI	Probability > X^2
Nesting	CONTAG	–0.045	–0.084	–0.007	0.022
Brooding	LAND	–	–	–	<0.001
	Firebreaks	0.933	0.469	1.398	<0.001
	Open herbaceous	0.000	–	–	–
	NWSG	–0.089	–0.430	0.253	0.611
	Shrub	–0.252	–0.650	0.146	0.215
	Forest	–1.335	–2.414	–0.257	0.015
	Roads	–1.569	–2.770	–0.367	0.011
	TREAT	–	–	–	<0.001
	2 growing seasons after burn	0.035	–0.704	0.775	0.925
	None	0.000	–	–	–
	Disk	–0.764	–1.204	–0.324	0.001
	1 growing season after burn	–0.977	–1.317	–0.636	<.0001
	DS	0.004	0.000	0.007	0.045

[1]CONTAG = contagion index, LAND = land cover type, NWSG = native warm–season grass, TREAT = treatment type, DS = distance to shrub cover.

Table B.5. Model rankings based on AIC scores for discrete choice analysis of brood habitat selection on Peabody WMA, Kentucky, USA, 2009 – 2011.

Model	Covariates	AIC	ΔAIC	AIC weights	No. of parameters
3	LAND, TREAT, DS	1,341.53	0.00	73.12	9
2	LAND, TREAT	1,343.59	2.06	26.17	8
6	LAND, CONTAG, DDB, DF, DR	1,350.80	9.27	0.71	9
7	TREAT	1,368.88	27.35	0.00	3
1	LAND	1,373.73	32.20	0.00	5
8	SSOPENED, FORESTOPENED, DDB, DF, DR	1,374.23	32.70	0.00	5
4	DDB, DF, DR	1,375.23	33.69	0.00	3
0	No covariate	1,397.57	56.04	0.00	0
5	NGCA, OHCA	1,399.03	57.50	0.00	2

[1]LAND = land cover, TREAT = treatment type, DS = distance to shrub cover, CONTAG = contagion index, DDB = distance to a disk block, DF = distance to a firebreak, DR = distance to a road, SSOPENED = shrub–open edge density, FORESTOPENED = forest–open edge density, NGCA = native warm–season grass core area, OHCA = open herbaceous core area.

Table B.6. Percent cover of the most common plants found within each vegetation type on Peabody WMA, a reclaimed surface mine in Kentucky, USA.

	% cover untreated		% cover disked[3]		% cover 1 growing season after burn		% cover 2 growing seasons after burn	
Vegetation type	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	–	–	–	–	–	–
Symphoricarpos orbiculatus	9.83	1.44	–	–	–	–	–	–
Parthenocissus quinquefolia	7.74	1.34	–	–	–	–	–	–
NWSG[1]								
Lespedeza cuneata	54.31	4.23	43.33	6.53	51.90	5.60	71.52	10.43
Planted NWSG[2]	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
Acalypha gracilens	4.55	0.98	3.33	1.84	1.67	1.67	0.56	0.56
Lotus corniculatus	4.49	2.23	6.84	4.65	3.81	2.15	3.61	3.06
Setaria faberi	4.23	1.65	7.72	3.58	0.00	0.00	2.50	1.97
Melilotus spp.	3.46	1.53	7.72	2.47	0.24	0.24	2.50	1.97
Litter or bare ground	1.47	0.55	2.28	1.22	0.00	0.00	0.28	0.28
Trifolium pratense	0.64	0.43	9.30	3.85	0.00	0.00	0.00	0.00
Helianthus annuus	0.45	0.33	2.28	1.77	9.29	3.05	0.28	0.28
Bromus arvensis	0.06	0.06	0.18	0.18	0.95	0.95	11.11	7.20
Open herbaceous								
Lespedeza cuneata	75.79	2.61	42.02	4.94	72.38	11.81	77.50	6.44
Schedonorus phoenix	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
Rubus allegheniensis	3.31	0.86	0.71	0.43	6.67	6.13	0.00	0.00
Carduus nutans	2.03	0.79	10.71	3.86	1.43	0.99	0.00	0.00
Melilotus spp.	1.72	0.66	13.10	4.48	3.81	2.56	8.33	5.53
Iva annua	0.78	0.43	10.60	4.82	1.90	1.43	19.17	17.02
Litter or bare ground	0.67	0.23	4.52	1.60	0.00	0.00	0.83	0.83
Bromus arvensis	2.19	0.87	3.93	1.80	26.19	14.52	21.67	21.67
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
Schedonorus phoenix	9.31	1.80	–	–	8.33	8.33	0.00	0.00
Lonicera japonica	8.69	1.61	–	–	10.00	10.00	18.89	18.89
Poa pratensis	6.67	1.50	–	–	33.33	26.67	1.11	1.11
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
Bromus arvensis	1.19	0.47	–	–	38.33	38.33	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	–	–	–	–	–	–
Digitaria spp.	9.76	6.63	–	–	–	–	–	–
Oxalis stricta	7.62	4.08	–	–	–	–	–	–
Lactuca serriola	7.14	3.84	–	–	–	–	–	–
Lespedeza cuneata	0.00	0.00	–	–	–	–	–	–
Planted NWSG	0.00	0.00	–	–	–	–	–	–

[1]Native warm–season grass

[2]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*).

[3]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.

APPENDIX C

Table C.1. List of native and introduced plant species found during vegetation sampling on Peabody WMA, a reclaimed surface mine in western Kentucky, USA.

Scientific name[1]	Common name	Status
Acalypha gracilens	Slender threeseed mercury	Native
Acalypha rhomboidea	Common threeseed mercury	Native
Acer negundo	Box elder	Native
Acer rubrum	Red maple	Native
Acer saccharinum	Silver Maple	Native
Acer saccharum	Sugar maple	Native
Achillea millefolium	Common yarrow	Native/Introduced
Agrimonia parviflora	Harvestlice	Native
Agrostis gigantea	Redtop	Introduced
Ailanthus altissima	Tree of heaven	Introduced
Allium vineale	Wild garlic	Introduced
Alnus glutinosa	Black Alder	Introduced
Amaranthus spinosus	Spiny amaranthus	Native
Ambrosia artemisiifolia	Common ragweed	Native
Ambrosia trifida	Great ragweed	Native
Amelanchier arborea	Common serviceberry	Native
Amphicarpaea bracteata	American hogpeanut	Native
Anagallis arvensis	Scarlet pimpernel	Introduced
Andropogon gerardii	Big bluestem	Native
Andropogon virginicus	Broomsedge bluestem	Native
Antennaria plantaginifolia	Woman's tobacco	Native
Apocynum cannabinum	Hemp dogbane	Native
Aralia spinosa	Devil's walkingstick	Native
Arisaema dracontium	Green dragon	Native
Asclepias syriaca	Common milkweed	Native
Asimina triloba	Pawpaw	Native
Asplenium platyneuron	Ebony spleenwort	Native
Barbarea vulgaris	Garden yellowrocket	Introduced
Betula nigra	River birch	Native
Bidens coronata	Crowned beggarticks	Native
Bignonia capreolata	Crossvine	Native
Bothriochloa sacchoroides	Silver bluestem	Native
Bouteloua curtipendula	Sideoats grama	Native
Bromus arvensis	Japanese brome	Introduced
Bromus hordeaceus	Soft brome	Introduced
Campsis radicans	Trumpet creeper	Native

Scientific name	Common name	Status
Carduus nutans	Nodding plumeless thistle	Introduced
Carex crinita	Fringed sedge	Native
Carex frankii	Frank's sedge	Native
Carex glaucodea	Blue sedge	Native
Carex grayi	Gray's sedge	Native
Carex hirsutella	Fuzzy wuzzy sedge	Native
Carex lupulina	Hop sedge	Native
Carex lurida	Shallow sedge	Native
Carex rosea	Rosy sedge	Native
Carex tribuloides	Blunt broom sedge	Native
Carex vulpinoidea	Fox sedge	Native
Carya alba	Mockernut Hickory	Native
Carya cordiformis	Bitternut Hickory	Native
Carya glabra	Pignut Hickory	Native
Carya illinionensis	Pecan	Native
Carya laciniosa	Shellbark Hickory	Native
Carya ovata	Shagbark hickory	Native
Celtis laevigata	Sugarberry	Native
Celtis occidentalis	Common hackberry	Native
Centaurea cyanus	Bachelor's button	Introduced
Cephalanthus occidentalis	Buttonbush	Native
Cerastium brachypetalum	Gray chickweed	Introduced
Cercis canadensis	Eastern redbud	Native
Chaerophyllum tainturieri	Hairyfruit chervil	Native
Chamaecrista fasciculata	Partridge pea	Native
Chamaesyce maculata	Spotted sandmat	Native
Chasmanthium latifolium	Indian woodoats	Native
Chenopodium album	Lambsquarters	Native/Introduced
Circaea lutetiana	Broadleaf enchanter's nightshade	Native
Cirsium discolor	Field Thistle	Native
Cirsium vulgare	Bull thistle	Introduced
Commelina communis	Asiatic dayflower	Introduced
Conyza canadensis	Canadian horseweed	Native
Cornus amomum	Silky dogwood	Native
Cornus florida	Flowering dogwood	Native
Crataegus viridis	Green hawthorn	Native
Croton capitatus	Hogwort	Native
Croton monanthogynus	Prairie tea	Native
Cruciata pedemontana	Piedmont bedstraw	Introduced
Cuphea viscosissima	Blue waxweed	Native

Scientific name	Common name	Status
Cuscuta spp.	Dodder	Native/Introduced
Cynanchum laeve	Honeyvine	Native
Cynoglossum virginianum	Wild comfrey	Native
Cyperus echinatus	Globe flat–sedge	Native
Cyperus esculentus	Yellow nutsedge	Native/Introduced
Cyperus pseudovegetus	Marsh flatsedge	Native
Dactylis glomerata	Orchardgrass	Introduced
Danthonia spicata	Poverty oatgrass	Native
Daucus carota	Queen Anne's lace	Introduced
Desmanthus illinoensis	Illinois bundleflower	Native
Desmodium obtusum	Stiff ticktrefoil	Native
Desmodium pauciflorum	Fewflower ticktrefoil	Native
Dianthus armeria	Deptford pink	Introduced
Dichanthelium aciculare	Needleleaf rosette grass	Native
Dichanthelium commutatum	Variable panicgrass	Native
Dichanthelium scoparium	Velvet panicum	Native
Diervilla lonicera	Bush honeysuckle	Introduced
Diodia teres	Poor joe	Native
Dioscorea villosa	Wild yam	Native
Diospyros virginiana	Common persimmon	Native
Dipsacus fullonum	Fuller's teasel	Introduced
Echinochloa crus–galli	Barnyard grass	Introduced
Elaeagnus umbellata	Autumn olive	Introduced
Eleocharis ovata	Ovate spikerush	Native
Elymus canadensis	Canada wildrye	Native
Elymus hystrix	Bottle brush grass	Native
Elymus virginicus	Virgina wildrye	Native
Eragrostis spectabilis	Purple lovegrass	Native
Erigeron philadelphicus	Philadelphia fleabane	Native
Eupatorium hyssopifolium	Hyssop–leaf thoroughwort	Native
Eupatorium perfoliatum	Common boneset	Native
Eupatorium rotundifolium	Roundleaf throroughwort	Native
Euphorbia dentata	Toothed spurge	Native/Introduced
Euthamia graminifolia	Flat–top goldentop	Native
Fagus grandifolia	American Beech	Native
Fraxinus americana	White Ash	Native
Fraxinus pennsylvanica	Green ash	Native
Galium aparine	Stickwilly	Native
Galium pilosum	Hairy bedstraw	Native
Geranium carolinianum	Carolina geranium	Native

Scientific name	Common name	Status
Geum canadense	White avens	Native
Geum laciniatum	Rough avens	Native
Gleditsia triacanthos	Honey locust	Native
Grindelia squarrosa	Curlycup gumweed	Native
Guara mollis	Velvetweed	Native
Hackelia virginiana	Beggarslice	Native
Helenium autumnale	Common sneezeweed	Native
Helianthus annuus	Common sunflower	Native
Helianthus divaricatus	Woodland sunflower	Native
Helianthus maximiliani	Maximilian sunflower	Native
Hibiscus spp.	Hibiscus	Introduced
Hibiscus trionum	Flower of an hour	Introduced
Hordeum vulgare	Common barley	Introduced
Hypericum drummondii	Nits and lice	Native
Hypericum hyperidoides	Saint Andrew's cross	Native
Hypericum perforatum	Common St. John's wort	Introduced
Hypericum prolificum	Shrubby St. Johnswort	Native
Impatiens capensis	Jewelweed	Native
Ipomoea spp.	Morning glory	Introduced
Iva annua	Annual marsh elder	Native
Juglans nigra	Black walnut	Native
Juncus effusus	Common rush	Native
Juncus marginatus	Grassleaf rush	Native
Juncus scirpoides	Needlepod rush	Native
Juniperus virginiana	Eastern red cedar	Native
Kummerowia stipulacea	Korean clover	Introduced
Lactuca canadensis	Canada lettuce	Native
Lactuca saligna	Willow leaf lettuce	Introduced
Lactuca serriola	Prickly lettuce	Introduced
Lathyrus latifolius	Perennial pea	Introduced
Leersia oryzoides	Rice cutgrass	Native
Lemna minor	Common duckweed	Native
Lepidium campestre	Field Pepperweed	Introduced
Lepidium virginicum	Virginia pepperweed	Native
Lespedeza bicolor	Bicolor lespedeza	Introduced
Lespedeza cuneata	Sericea lespedeza	Introduced
Lespedeza hirta	Hairy lespedeza	Native
Lindera benzoin	Spicebush	Native
Liquidambar styraciflua	Sweet gum	Native
Liriodendron tulipifera	Tuliptree	Native

Scientific name	Common name	Status
Lobelia inflata	Indian–tobacco	Native
Lolium perenne	Italian ryegrass	Introduced
Lonicera japonica	Japanese honeysuckle	Introduced
Lotus corniculatus	Birds foot trefoil	Introduced
Ludwigia alternifolia	Seedbox	Native
Lycopus americanus	American water horehound	Native
Maianthemum racemosum	Feathery false lily of the valley	Native
Matelea gonocarpos	Angularfruit milkvine	Native
Medicago sativa	Alfalfa	Introduced
Melilotus indicus	Annual yellow sweetclover	Introduced
Melilotus officinalis	Sweetclover	Introduced
Melothria pendula	Guadeloupe cucumber	Native
Mentha spicata	Spearmint	Introduced
Microstegium vimineum	Nepalese browntop	Introduced
Mikania scandens	Climbing hempvine	Native
Mimulus alatus	Sharpwing monkeyflower	Native
Monarda citriodora	Lemon beebalm	Native
Morus rubra	Red mulberry	Native
Muhlenbergia schreberi	Nimblewill	Native
Myosotis macrosperma	Large–seed forget–me–not	Native
Nyssa sylvatica	Blackgum	Native
Onoclea sensibilis	Sensitive fern	Native
Ostrya virginiana	Hophornbeam	Native
Oxalis stricta	Common yellow oxalis	Native
Oxydendrum arboreum	Sourwood	Native
Panicum anceps	Beaked panicgrass	Native
Panicum capillare	Witchgrass	Native
Panicum virgatum	Switchgrass	Native
Parthenocissus quinquefolia	Virginia creeper	Native
Paspalum floridanum	Florida paspalum	Native
Passiflora incarnata	Purple passionflower	Native
Phleum pratense	Timothy	Introduced
Phragmites australis	Common reed	Native/Introduced
Phryma leptostachya	American lopseed	Native
Phyla lanceolata	Lanceleaf fogfruit	Native
Physalis longifolia	Longleaf groundcherry	Native
Physalis pubescens	Husk tomato	Native
Phytolacca americana	American pokeweed	Native
Pinus strobus	White pine	Native
Pinus taeda	Loblolly pine	Native

Scientific name	Common name	Status
Pinus virginiana	Virginia Pine	Native
Plantago lanceolata	Narrowleaf plantain	Introduced
Plantago virginica	Virginia plantain	Native
Platanus occidentalis	American sycamore	Native
Poa pratensis	Kentucky bluegrass	Native/Introduced
Polygala verticillata	Whorled milkwort	Native
Polygonum lapathifolium	Curlytop knotweed	Introduced
Polygonum pensylvanicum	Pennsylvania smartweed	Native
Polygonum persicaria	Lady's thumb	Introduced
Polygonum ramosissimum	Small bushy knotweed	Native
Polygonum sagittatum	Arrowleaf tearthumb	Native
Polygonum scandens	Climbing false buckwheat	Native/Introduced
Polystichum acrostichoides	Christmas fern	Native
Populus deltoides	Eastern cottonwood	Native
Potentilla simplex	Common cinquefoil	Native
Prunella vulgaris	Common selfheal	Native/Introduced
Prunus americana	American plum	Native
Prunus serotina	Black cherry	Native
Pseudognaphalium obtusifolium	Rabbit–tobacco	Native
Pycnanthemum incanum	Hoary mountainmint	Native
Pycnanthemum tenuifolium	Slender mountain mint	Native
Quercus acutissima	Sawtooth oak	Introduced
Quercus alba	White oak	Native
Quercus coccinea	Scarlet Oak	Native
Quercus falcata	Southern Red Oak	Native
Quercus macrocarpa	Bur Oak	Native
Quercus marilandica	Blackjack Oak	Native
Quercus muehlenbergii	Chinkapin Oak	Native
Quercus nigra	Water Oak	Native
Quercus pagoda	Cherrybark Oak	Native
Quercus palustris	Pin oak	Native
Quercus phellos	Willow oak	Native
Quercus prinus	Chestnut oak	Native
Quercus rubra	Northern red oak	Native
Quercus stellata	Post oak	Native
Quercus velutina	Black Oak	Native
Ratibida columnifera	Upright prairie coneflower	Native
Ratibida pinnata	Pinnate prairie coneflower	Native
Rhexia virginica	Handsome harry	Native
Rhus copallinum	Winged sumac	Native

Scientific name	Common name	Status
Rhus glabra	Smooth sumac	Native
Robinia pseudoacacia	Black locust	Native
Rosa multiflora	Multiflora rose	Introduced
Rubus allegheniensis	Allegheny blackberry	Native
Rubus occidentalis	Black raspberry	Native
Rudbeckia hirta	Black–eyed susan	Native
Ruellia humilis	Fringeleaf wild petunia	Native
Rumex crispus	Curly dock	Introduced
Saccharum alopecuroides	Silver plumegrass	Native
Salbia lyrata	Lyreleaf sage	Native
Salix nigra	Black willow	Native
Sanicula canadensis	Canadian blacksnakeroot	Native
Sassafras albidum	Sassafras	Native
Schedonorus phoenix	Tall fescue	Introduced
Schizachyrium scoparium	Little bluestem	Native
Scleria triglomerata	Whip nutrush	Native
Scutellaria incana	Hoary skullcap	Native
Securigera varia	Crown vetch	Introduced
Setaria faberi	Japanese bristlegrass (giant foxtail)	Introduced
Setaria italica	Foxtail millet	Introduced
Setaria pumila	Yellow foxtail	Introduced
Setaria viridis	Green bristlegrass (foxtail)	Introduced
Silene antirrhina	Sleepy silene	Native
Silene latifolia	Bladder campion	Introduced
Smilax bona–nox	Saw greenbrier	Native
Smilax glauca	Cat greenbrier	Native
Smilax routundifolia	Roundleaf greenbrier	Native
Solanum carolinense	Carolina horse nettle	Native
Solanum ptycanthum	West Indian nightshade	Native
Solidago canadensis	Canada goldenrod	Native
Sorghastrum nutans	Indiangrass	Native
Sorghum bicolor	Grain sorghum	Introduced
Sorghum halepense	Johnsongrass	Introduced
Spiranthes vernalis	Spring lady's tresses	Native
Stylosanthes biflora	Sidebeak pencilflower	Native
Symphoricarpos orbiculatus	Coralberry	Native
Thlaspi arvense	Field pennycress	Introduced
Torilis arvensis	Spreading hedgeparsley	Introduced
Toxicodendron radicans	Poison ivy	Native
Trifolium campestre	Field clover	Introduced

Scientific name	Common name	Status
Trifolium pratense	Red clover	Introduced
Trifolium repens	White clover	Introduced
Triodanis perfoliata	Clasping Venus' looking–glass	Native
Tripsacum dactyloides	Eastern gamagrass	Native
Typha latifolia	Broadleaf cattail	Native
Ulmus alata	Winged elm	Native
Ulmus americana	American elm	Native
Ulmus rubra	Slippery Elm	Native
Valerianella radiata	Beaked cornsalad	Native
Verbascum blattaria	Moth mullein	Introduced
Verbascum thapsus	Common mullein	Introduced
Verbena hastata	Swamp verbena	Native
Verbena simplex	Narrowleaf vervain	Native
Verbena urticifolia	White vervain	Native
Vernonia baldwinii	Baldwin's ironweed	Native
Vernonia gigantea	Giant ironweed	Native
Veronica arvensis	Corn speedwell	Introduced
Vicia sativa	Narrowleaf vetch	Introduced
Vitus rotundifolia	Muscadine grape	Native

[1]Scientific names, common names, and statuses were determined using the USDA NRCS PLANTS database.

Table C.2. Number of individuals with at least 1 location within 330m of a disk block, firebreak, NWSG, road, and shrub vegetation on Peabody WMA, a reclaimed surface mine in Kentucky, USA.

Season	Within 330m[1] of:	Coveys	Individuals	Percent of total sample
Nonbreeding	Disk block	27	–	52.94
	Firebreak	38	–	74.51
	NWSG[2]	50	–	98.04
	Road	51	–	100.00
	Shrub	51	–	100.00
Breeding	Disk block	–	81	77.88
	Firebreak	–	81	77.88
	NWSG	–	84	80.77
	Road	–	95	91.35
	Shrub	–	95	91.35
Brooding	Disk block	–	21	91.30
	Firebreak	–	21	91.30
	NWSG	–	22	95.65
	Road	–	23	100.00
	Shrub	–	23	100.00

[1]330m is twice the nonbreeding season average daily movement (165m).

[2]NWSG = native warm–season grass

Figure C.1. Visual representation of a choice set used in the discrete choice analysis of habitat selection on Peabody WMA, a reclaimed surface mine in Kentucky, USA.

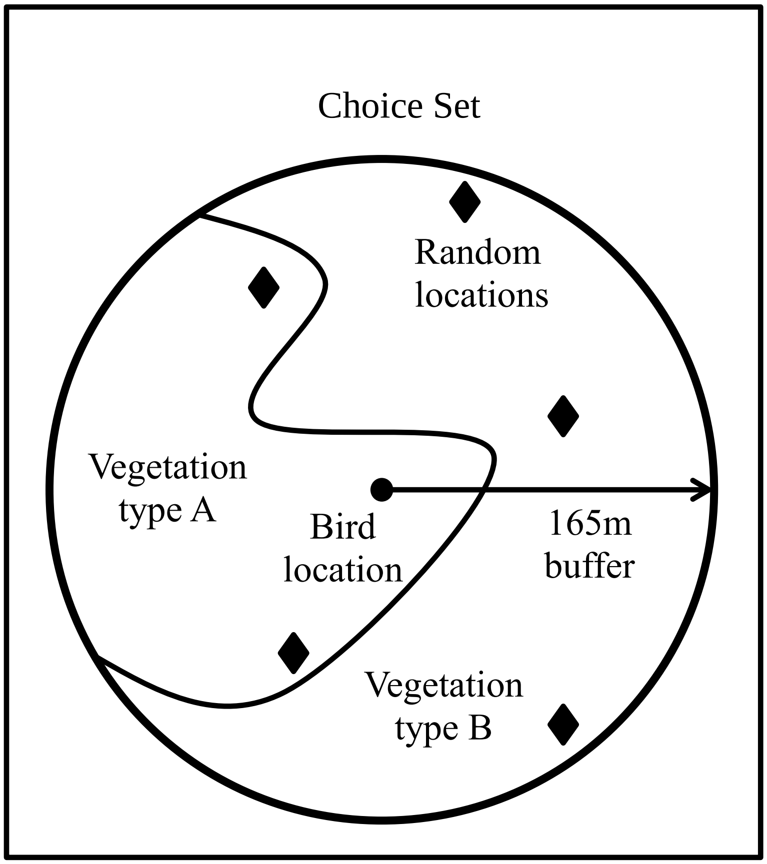


Figure C.2. Number of real and random (divided by 5) locations for nonbreeding northern bobwhite within 5m distance intervals from a road during the breeding season, 2010–2011, on Peabody WMA, a reclaimed surface mine in Kentucky, USA.

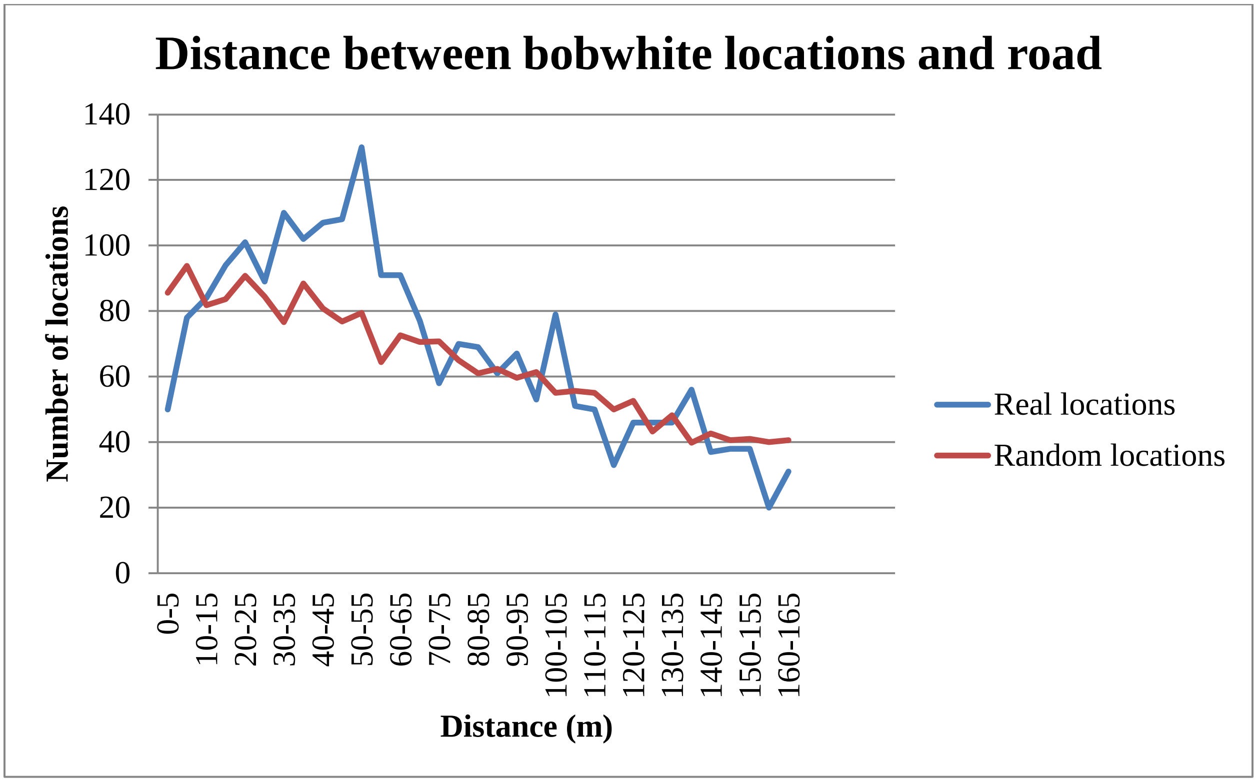


Figure C.3. Number of real and random (divided by 5) locations for nonbreeding northern bobwhite within 5m distance intervals from a firebreak during the breeding season, 2010– 2011, on Peabody WMA, a reclaimed surface mine in Kentucky, USA.

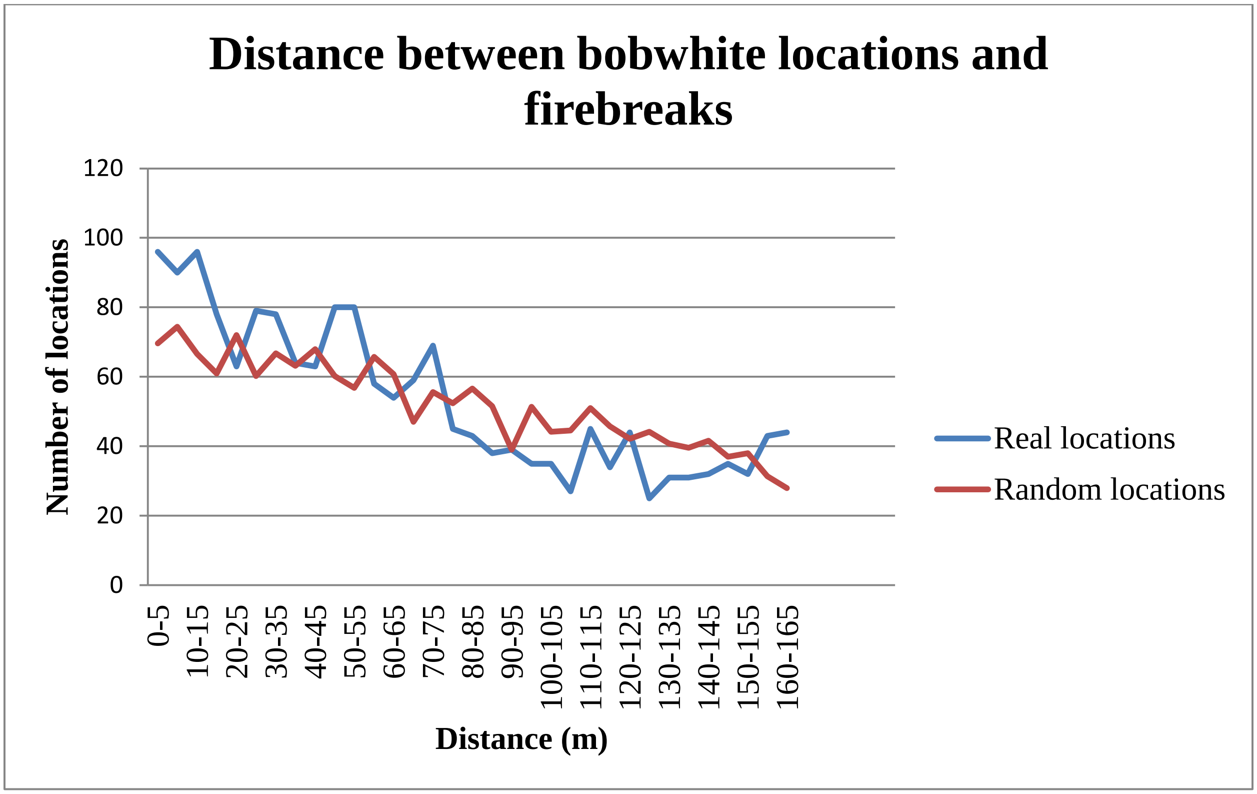


Figure C.4. Number of real and random (divided by 5) locations for nonbreeding northern bobwhite within 5m distance intervals from shrub vegetation during the breeding season, 2010–2011, on Peabody WMA, a reclaimed surface mine in Kentucky, USA.

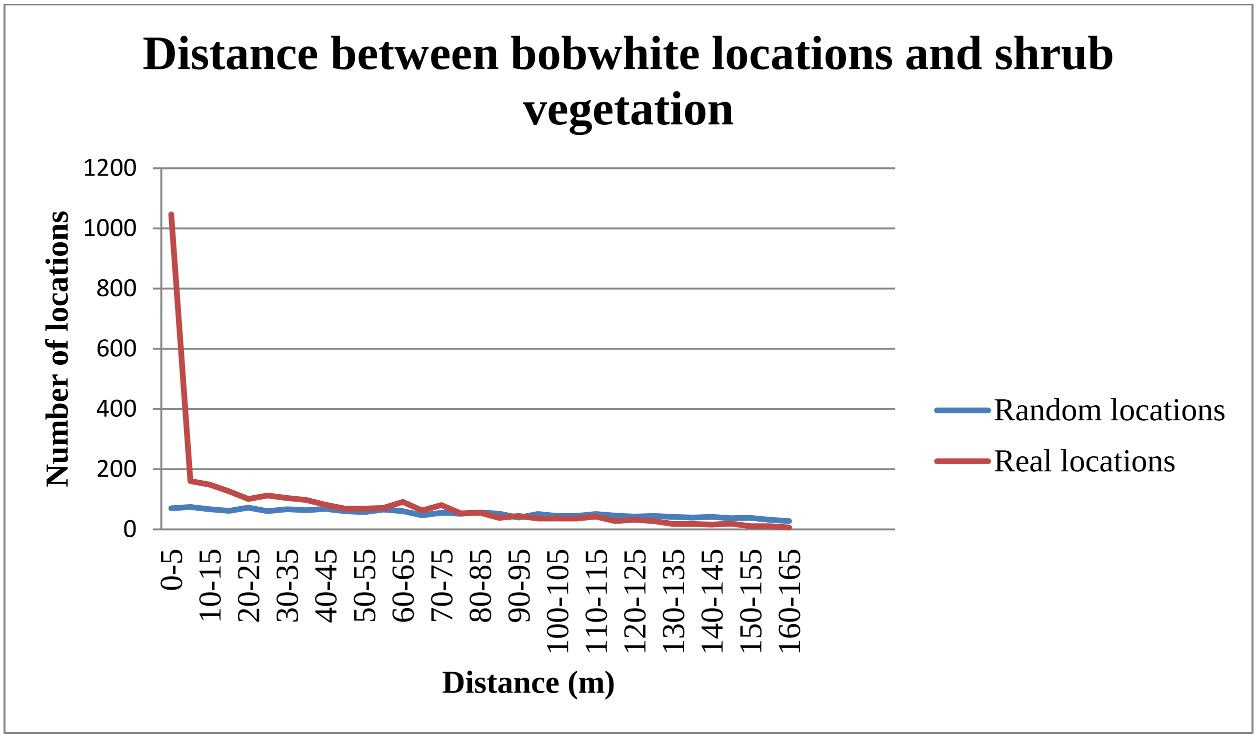
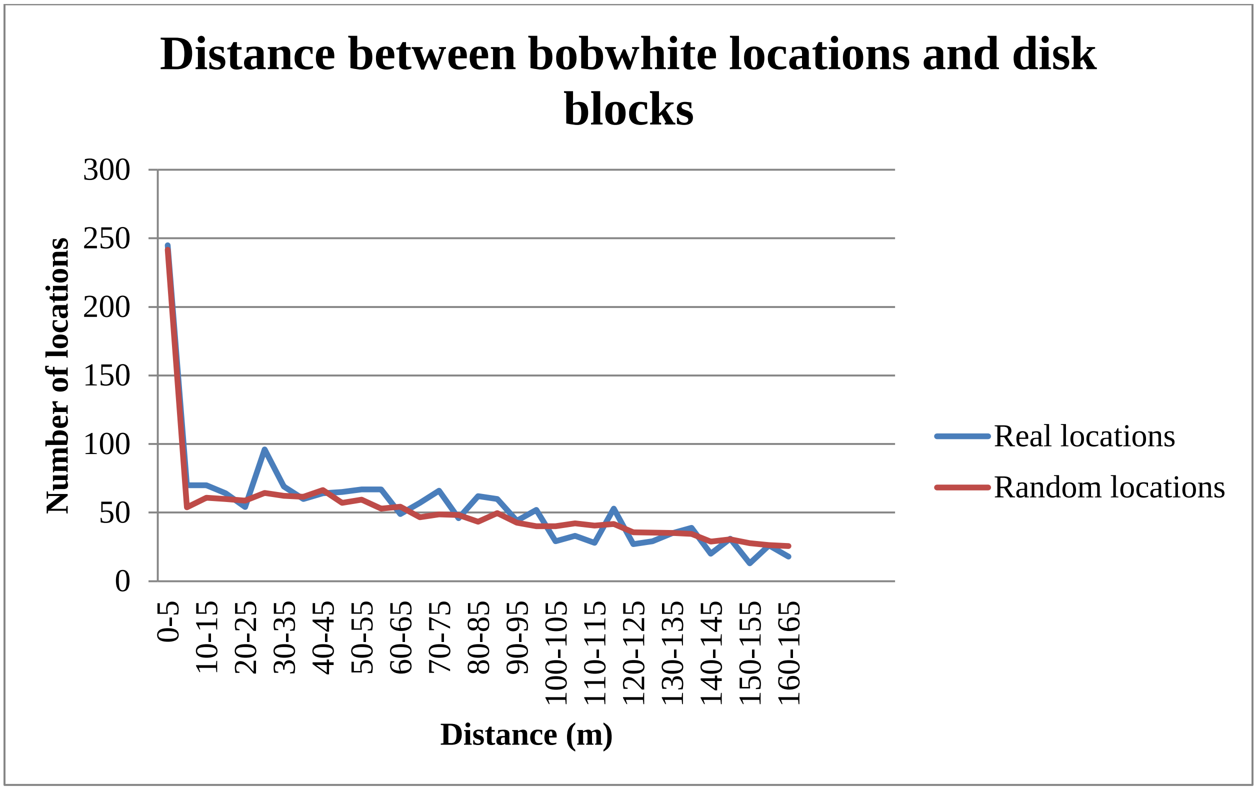


Figure C.5. Number of real and random (divided by 5) locations for nonbreeding northern bobwhite within 5m distance intervals from a disk block during the breeding season, 2010–2011, on Peabody WMA, a reclaimed surface mine in Kentucky, USA.



CONCLUSIONS

Habitat use by nonbreeding adult bobwhite on Peabody WMA was driven by selection for woody cover across seasons. Bobwhite used areas with a greater edge density between woody and open areas more than expected during the nonbreeding season, and parameter estimates (forest–open edge = 0.017, shrub–open edge = 0.008) revealed a positive relationship with both types of woody edge. During the breeding season, firebreaks and shrub cover were used more than all other vegetation types. Distance to a disk block, firebreak, and road appeared in the top 3 models in both seasons, and their parameter estimates reflected a weak but positive relationship. Bobwhite were therefore closer than would be expected to disk blocks, firebreaks, and roads.

The contagion index, a measure of interspersion and dispersion of vegetation types, was the most influential factor in nest site selection. Nest sites had a lower contagion value, and therefore were placed in areas with more interspersion and dispersion of vegetation types than random locations. Broods used firebreaks more than any other habitat feature or vegetation type on Peabody WMA. Use of forest and roads was less than expected compared to the use of open herbaceous areas, with forests being used the least.

Management of reclaimed surface mines for bobwhite should focus on maintaining existing early succession areas and improving habitat quality using intensive disking, prescribed fire in the forest, and potentially herbicide applications. Frequent disking can provide bare ground important for chick mobility, and potentially stimulate the growth of annual forbs as seen in the firebreaks. Disking can also improve vegetation structure, enhance vegetation composition, and maintaine an early seral stage on Peabody WMA. Heavy disking (additional passes with an offset disk) may be required where reduction in the cover of dense NWSG and sericea lespedeza is desired. Herbicide applications can assist in further reducing NWSG and sericea lespedeza coverage when needed. Burning during the dormant season increased cover of NWSG, therefore, we recommend dormant–season burns be discontinued where increased NWSG cover is undesirable. Prescribed fire could be used in forested areas to improve conditions for bobwhite on reclaimed surface mine lands by maintaining broken forest canopy or woodland structure with a diverse understory. Burning or disking within shrub cover on these sites should be restricted to situations when reducing shrub cover is desirable or when groundcover within the shrub cover needs rejuvenating. 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 and reclaimed surface mines were included as a major land–use opportunity. Building relationships with mining companies could result in future reclamation practices that discontinue planting sericea lespedeza and include more beneficial native species and practices that benefit not only bobwhite, but other wildlife as well.

VITA

Ashley Unger is from Cheswick, Pennsylvania, where she developed a love for the outdoors on the Allegheny River. A summer internship at the National Aviary in Pittsburgh sparked what would become a life–long obsession with birds. She earned her B.S. in Conservation and Wildlife Management at Delaware Valley College in Doylestown, Pennsylvania. She was fortunate to augment her education with summer jobs as a Natural Resource Instructor at Green Mountain Conservation Camps in Hardwick, Vermont and as a River Management Intern for the Bureau of Land Management in Glennallen, Alaska. After graduation, she was hired as a research technician by Dr. Craig Harper of the University of Tennessee working on a white–tailed deer project on Arnold Air Force Base in Tullahoma, Tennessee. She then was then given the opportunity to work under Dr. Harper on her M.S. degree in Wildlife Science, where she learned to identify early successional vegetation, developed a passion for northern bobwhite, and discovered the finer points of barbeque.