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INFLUENCE OF HABITAT MANIPULATIONS ON NORTHERN BOBWHITE RESOURCE SELECTION ON A RECLAIMED SURFACE MINE

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INFLUENCE OF HABITAT MANIPULATIONS ON NORTHERN BOBWHITE RESOURCE SELECTION ON A RECLAIMED SURFACE MINE

A Thesis Presented for the

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Degree

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Jarred Milford Brooke

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DEDICATION

I dedicate this thesis to my lovely wife who has provided unwavering love and support through this journey and to my family who were instrumental in instilling and cultivating my passion for the outdoors.

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ABSTRACT

Northern bobwhite populations have declined range-wide over the past 40 years. The intensification of agriculture, conversion of pastures to nonnative cool-season grasses, advanced succession, and urbanization have resulted in the deterioration and elimination of bobwhite habitat. Recent conservation efforts have called for a landscape-level approach to the conservation of northern bobwhite populations. However, identifying large areas to manage bobwhite populations is problematic. Reclaimed mine lands offer an opportunity to manage large contiguous tracts of early successional vegetation to conserve northern bobwhite populations. We studied northern bobwhite resource selection throughout the year from August 2009 to March 2014. We investigated the influence of disking, prescribed fire, and herbicide application on bobwhite resource selection. Our study was conducted on Peabody Wildlife Management Area (PWMA), which is a 3,300 ha reclaimed surface mine in Western Kentucky. We used the discrete-choice analysis to compare resource selection on unmanaged and managed units of PWMA. We used locations from 283 bobwhite during the breeding season (1 April – 30 September) and 136 coveys during the non-breeding season (1 October – 31 March). Resource selection on PWMA was influenced most by availability of shrub cover, regardless of season. Bobwhite were found closer to shrub cover than would be expected and selected areas with greater amounts of shrub-open edge density. Similarly, bobwhite selected areas with vegetation characteristics consistent with shrub cover on PWMA, including increased visual obstruction >1 m aboveground and an increased density of woody stems. Management aimed at reducing the density of sericea lespedeza and increasing the openness at ground level positively influenced resource selection. Bobwhite were found closer to disked areas than would be expected and selected areas treated with herbicide to control sericea lespedeza. Bobwhite avoided burned areas during the breeding season but selected burned areas during the non-breeding season. Our results suggest management should focus on increasing the interspersion of shrub cover on reclaimed mine lands. Also, management focused on enhancing the composition and structure of the vegetation (disking and herbicide) should continue. Reclaimed mine land can provide habitat for northern bobwhite, and our results suggest habitat management can improve habitat quality for bobwhite on these lands.

PREFACE

We studied northern bobwhite resource selection throughout the year from August 2009 to March 2014 on a reclaimed surface mine in western Kentucky, USA. Part I contains background information on northern bobwhite and reclaimed coal mines, and part II has been formatted for publication in the Journal of Wildlife Management.

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I. NORTHERN BOBWHITE AND RECLAIMED SURFACE MINES

BACKGROUND

Northern bobwhite (*Colinus virginianus;* hereafter bobwhite) populations have been declining precipitously over the past 40 years. Range-wide declines exceed 4% per year, with declines of 4.1% in the Central Hardwoods Bird Conservation Region and 3.0% in Kentucky (Sauer et al. 2011). Traditional bobwhite management is conducted at a fine-scale, improving the quality of single fields or farms. Although improving the quality of individual areas for bobwhite is important, Guthery (1997) suggested the amount of usable space on the landscape influenced bobwhite populations more than the quality of existing areas. Williams et al. (2005) and Hernandez et al. (2013) suggested bobwhite conservation should be approached at a broader, regional scale in order to impact bobwhite populations positively. However, with >80% of the land base in the eastern United States privately owned, large contiguous areas to manage bobwhite on a landscape scale are limited.

Reclaimed mine lands provide opportunity to manage large contiguous areas for bobwhite populations across a landscape. Reclaimed mine lands often provide habitat for a variety of wildlife dependent on early successional plant communities (Bajema et al. 2001, DeVault et al. 2002, Scott et al. 2002, Monroe and Ritchison 2005) and more than 600,000 ha have been reclaimed in the eastern United States. Reclamation guidelines in the Surface Mining Control and Reclamation Act (SMCRA 1977) resulted in the creation of large open communities dominated by stands of non-native herbaceous species (Brothers 1990). Reclaimed mine land in the Central Hardwoods Bird Conservation Region lies in the Illinois basin coalfield of Kentucky, Indiana, and Illinois and exists mainly in a fragmented agricultural matrix (Brothers 1990). The change in land use practices resulting from the intensification of row crop agriculture, conversion of pastures to non-native species, the advancement of succession, and urbanization has been identified as the ultimate cause of range-wide bobwhite population declines (Brennan 1991, Hernandez et al. 2013).

Bobwhite often thrive in areas with interspersed vegetation types. The exact combination of vegetation types that characterize optimal bobwhite habitat is highly variable and multiple combinations result in usable space for bobwhite (Guthery 1999). Guthery (1999) defined this condition as “slack.” Roseberry and Sudkamp (1998) suggested the landscape in an agricultural matrix was suitable with 30-65% row crops, 15-30% grassland, and ≥30 m/ha of woody edge. Similarly, Dailey (1989) suggested landscapes in Missouri should consist of 75-90% open land (grassland and row crops). Lusk et al. (2002) suggested bobwhite populations declined with >20% row crop agriculture in 6 eco-regions of Texas. However, bobwhite exist and thrive in areas largely void of agriculture, such as parts of South Texas and the Rolling Plains of Texas (Hernandez and Peterson 2007).

The importance of woody cover is less variable. Most studies suggest bobwhite require 5-30% woody cover in a home range (Lehmann 1984, Fulbright and Guthery 1996, Hernandez and Guthery 2012). Woody cover is important through the year for multiple reasons. Woody cover allows bobwhite to escape predators, provides thermal refuge from extreme weather, provides food, and singing perches for males (Johnson and Guthery 1988, Wood et al. 1986, Guthery et al. 2005, and Perkins et al. 2014). Guthery and Bingham (1992) suggested the quaility of open areas decreased as the distance from woody cover increased, a concept they defined as “radius of full use.” Based on this concept and the average distance of bobwhite flights, studies have recommended shrub cover should be no further than 50-150 m apart (Kassinis and Guthery 1996, Hernandez et al. 2007, Perkins et al. 2014).

Bobwhite habitat selection also is a function of the composition and structure of the vegetation available. Multiple studies have quanitfied the perctange of bare gorund and different plant groups (e.g. grass, forb, woody) required by bobwhite (Edminster 1954, Schroeder 1985, Bidwell et al. 1991, Rice et al. 1993). Kopp et al. (1998) proposed hypothetical values for the ideal mixture of vegetation. They suggested areas should be interspersed with approximatly 44% bare ground (area void of plant cover and litter), 38% herbaceous cover, and 53% woody cover. However, like the composition of the landscape, the ideal composition of vegetation for bobwhite is highly varible because multiple species or plant groups may have similar structural characteristics (e.g., taller herbaceous cover and woody cover; Lehmann 1984). Guthery (1999) defined this condition as "slack". Furthermore, multiple studies have reported bobwhite selection at the microhabitat scale is more related to the structure of vegetation rather than composition (Johnson and Guthery 1988, Ransom et al. 2008, Wiley 2011, Perkins et al. 2014).

More than 150,000 ha of mine lands have been reclaimed in Kentucky (Lexington Office of Surface Mining 2012) and such areas have been identified as quail focus areas (Morgan and Robinson 2008). Unfortunately, non-native invasive species are commonly used when reclaiming mine lands and these altered vegetation communities may not be beneficial to some wildlife species. Non-native invasive vegetation limits establishment of native herbaceous and woody species and extends the successional trajectory on these areas (Cavender et al. 2014). Sericea lespedeza (*Lespedeza cuneata*) is commonly planted during reclamation, quickly dominates sites and often results in dense monotypic cover. Sericea lespedeza may reduce native grass and forb richness by 66% and 70%, respectively (Eddy and Moore 1998), and supports fewer insects than other cover crops (Bugg and Dutcher 1989). Using a modified habitat suitability index for bobwhite, Stauffer (2011) suggested the structure provided by dense non-native vegetation on reclaimed mine sites in Virginia was a major limiting factor for bobwhite populations. Dense stands of vegetation were not conducive to bobwhite nesting and movement and limited the establishment of native plants, which were important as food and cover for bobwhite. Stauffer (2011) also identified a lack of woody cover as a limiting factor. Although the lack of woody encroachment on reclaimed mine sites can be beneficial to grassland obligates, such as grasshopper (*Ammodramus savannarum*), Henslow's, and savannah sparrows (*Passerculus sandwichensis*) (Graves et al. 2010), it could be detrimental for a species, such as bobwhite, which is dependent on woody vegetation for cover.

Multiple studies have examined the influence of habitat management on the quality of bobwhite habitat (Madison et al. 2001, Greenfield et al. 2003, Gruchy and Harper 2014) and the subsequent use by bobwhite (Hughes et al. 2005, Seckinger et al. 2008, Potter et al. 2011, Singh et al. 2011, Osborne et al. 2012). However, management of reclaimed mine lands supporting non-native plant communities on displaced soils present a unique set of challenges. Managers must understand the factors influencing bobwhite resource selection and the associated effects of management decisions if the conservation potential of reclaimed mine land is to be realized.

The data for this study were collected from August 2009 to March 2014. We investigated year-round northern bobwhite resource selection at 2-spatial scales. We also studied the response of bobwhite to different habitat management practices, including disking, prescribed fire, and control of sericea lespedeza with herbicide applications. Although bobwhite resource selection studies are numerous, most studies have focused on resource selection in agricultural landscapes and pine savannas of the eastern United States (Stoddard 1931, Roseberry and Klimstra 1984) and semi-arid rangelands west of the Mississippi River (Kopp et al. 1998). Furthermore, most resource selection studies focus on either the breeding season or non-breeding season rather than considering resource selection throughout the year. Understanding resource selection of bobwhite on reclaimed mine land and investigating the influence of management practices will guide future management decisions on these areas.

II. HABITAT MANIPULATIONS INFLUENCE NORTHERN BOBWHITE RESOURCE SELECTION ON A RECLAIMED SURFACE MINE

ABSTRACT More than 600,000 ha of mine land have been reclaimed in the eastern United States, providing large contiguous tracts of early successional vegetation that can be managed for northern bobwhite. However, habitat quality on reclaimed mine lands can be limited by extensive coverage of non-native invasive species, which are commonly planted during reclamation. We used a discrete-choice analysis to investigate bobwhite resource selection throughout the year on unmanaged and managed units of Peabody Wildlife Management Area, a 3,330 ha reclaimed surface mine in western Kentucky. We studied resource selection at 2-spatial scales to identify important aspects of mine land vegetation and how habitat management influenced selection. We used locations from 283 bobwhite during the breeding season (1 April – 30 Sep) and 136 coveys during the non-breeding season (1 Oct – Mar 31) from August 2009 to March 2014, to characterize resource selection. Bobwhite were located closer to shrub cover than would expected at random throughout the year. During the breeding season, bobwhite on managed units used areas with lower contagion index values compared to bobwhite on unmanaged units. During the non-breeding season, bobwhite on both units selected areas with greater shrub-open edge compared to random, but bobwhite on treatment units were found closer to shrub and forest cover than bobwhite on control units. At the microhabitat scale, bobwhite selected areas with increased visual obstruction >1 m aboveground. Management positively influenced bobwhite resource selection throughout the year. During the breeding season, bobwhite were closer to disked areas (linear and non-linear) than would be expected at random, and selected areas treated with herbicide to control sericea lespedeza. Bobwhite selected non-linear disked areas during winter, but did not select linear disked areas (firebreaks) because they were planted to winter wheat in the fall and lacked any cover during the non-breeding season. Bobwhite also selected areas treated with herbicide to control sericea lespedeza during the non-breeding season.

Bobwhite did not select areas that had been burned the previous dormant season consistently across seasons. Habitat quality of reclaimed mine lands for bobwhite may be limited by interspersion of shrub cover and extensive coverage of non-native herbaceous vegetation. Management should focus on increasing interspersion of shrub cover, with no area >100 m from shrub cover. We recommend disking and herbicide application to control invasive species and improve the structure and composition of vegetation for bobwhite. Reclaimed mine lands should be included in landscape management planning for northern bobwhite.

KEY WORDS *Colinus virginianus*, discrete choice, habitat management, northern bobwhite, reclaimed surface mine, resource selection

Reclamation of surface mines in the Illinois Coal Basin of Kentucky, Indiana, and Illinois has created more than 100,000 ha of open land dominated by herbaceous plant communities. The contiguous open matrix provided by reclaimed mine land offers an opportunity to conserve wildlife dependent on early successional vegetation (Bajema et al. 2001, Scott et al. 2002, Stauffer et al. 2011). Reclaimed mine lands can be valuable to northern bobwhite conservation because they tend to be large (>1000 ha), contiguous, and under single-ownership (e.g. state wildlife agencies; DeVault et al. 2002). These factors are especially important in the eastern United States where more than 80% of the land base is privately owned (Heimlich 2003), and bobwhite habitat has been lost as a result of the intensification of agriculture and fragmentation of the landscape (Brennan 1991). Guthery (1997) suggested bobwhite habitat management should focus on increasing the amount of usable space on the landscape. Furthermore, Williams et al. (2005) and Hernandez et al. (2013) suggested bobwhite conservation should be approached at a broader, regional scale in order to impact bobwhite populations positively. Reclaimed mine lands offer the opportunity to increase large amounts of habitat for bobwhite.

Lands reclaimed under guidelines outlined in the Surface Mining Control and Reclamation Act (SMCRA 1977) are dominated by non-native invasive plant species, such as tall fescue (*Schedonorus arundinaceus*), field brome (*Bromus arvensis*), and sericea lespedeza (*Lespedeza cuneata*). Non-native species are commonly planted during reclamation because they establish quickly and allow mining companies to fulfill their bond requirements (SMCRA 1977). Extensive coverage of non-native plants limits establishment of native herbaceous and woody vegetation by arresting succession and causing reclaimed mine lands to persist in these plant communities for decades (Brothers 1990, Groniger et al. 2007, Cavender et al. 2014). Standard reclamation practices may not provide high-quality habitat for bobwhite because the vegetation is extremely dense at ground level, potentially impeding bobwhite movement and foraging, and the invasive communities reduce establishment of native herbaceous plants important as food sources, and limit woody encroachment needed for thermal and escape cover (Stauffer 2011).

The suitability of unmanaged reclaimed mine land is considered poor for bobwhite. However, proper management should increase and enhance habitat for bobwhite (Stauffer 2011). Multiple studies have examined the influence of management on the quality of bobwhite habitat (Madison et al. 2001, Greenfield et al. 2003, Gruchy and Harper 2014) and the subsequent use by bobwhite (Hughes et al. 2005, Seckinger et al. 2008, Osborne et al. 2012). However, no studies have investigated the effects of habitat management and subsequent use by bobwhite on reclaimed mine lands, which have extensive coverage of non-native invasive plant communities. Peters (2014) investigated the influence on habitat management on bobwhite survival on reclaimed mine land during a concurrent study, but did not consider bobwhite resource selection.

Resource selection studies can help identify important landscape features and management practices, providing opportunities to focus management efforts.

We conducted a radio-telemetry study during the breeding season (1 April – 30 September) and non-breeding season (1 October – 31 March) from August 2009 to March 2014 to determine 3rd and 4th order resource selection (Johnson 1980) of non-nesting and non-brooding bobwhite. We defined macrohabitat (3rd order) as the influence of landscape attributes (composition and configuration) on bobwhite resource selection. We defined microhabitat (4th order) as the influence of the vegetation characteristics (composition and structure) on bobwhite resource selection. Our objectives were to (1) determine year-round bobwhite resource selection and identify important aspects of vegetation on reclaimed surface mines and (2) determine how management practices, including disking, prescribed fire, and herbicide applications to control sericea lespedeza, influenced resource selection.

STUDY AREA

Our study site was Peabody Wildlife Management Area (PWMA) in Muhlenberg and Ohio counties in western Kentucky, USA. PWMA was in the Central Hardwoods Bird Conservation Region and comprised 18,000 ha of reclaimed mine land with the post-reclamation designation of fish and wildlife habitat. Kentucky Department of Fish and Wildlife Resources (KDFWR) assumed control of PWMA in 1995. PWMA was located in the western coalfield physiographic region of Kentucky. We conducted our study on 2 separate areas of PWMA, the Sinclair and Ken areas (1471 ha and 1853 ha, respectively). The areas were separated by the Green River and were identified as quail focus areas prior to the study.

We delineated vegetation types on PWMA using aerial imagery from the National Agriculture Inventory Program (USDA, Farm Service Agency) in ArcGIS 9.3 (ESRI, Redlands, CA, USA). We ground-truthed representative areas of each vegetation type to validate our classifications. We delineated 4 major vegetation types, representing 91% of our 2 study areas: open herbaceous (36%), shrub (25%), forest (22%), and native warm-season grass (8%), with odd areas (firebreaks, roads, water, food plots, and wetlands) making up the remaining area (9%).

Open herbaceous (OH) areas were dominated by sericea lespedeza, tall fescue, goldenrod (*Solidago* spp.), common ragweed (*Ambrosia artemisiifolia*), and field brome (*Bromus arvensis*). Native warm-season grass (NWSG) areas were dominated by planted native grasses, including big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), and switchgrass (*Panicum virgatum*), but still contained extensive coverage of sericea lespedeza. Shrub areas (SHRUB) were characterized by woody or semi-woody vegetation, such as black locust (*Robinia pseudoacacia*), sumac (*Rhus* spp.), autumn olive (*Elaeagnus umbellata*), brambles (*Rubus* spp.), and coralberry (*Symphoricarpos orbiculatus*). Forested areas (FOREST) were characterized by a broken canopy dominated by eastern cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), and red maple (*Acer rubrum*), and an understory dominated by Japanese honeysuckle (*Lonicera japonica*) and brambles.

We divided our 2 study areas into approximately equal halves to assess the influence of habitat management on bobwhite resource selection. Control units (673 ha and 1,043 ha) were minimally disturbed during the course of the study and only contained firebreaks (6 km), and food plots planted for mourning dove (*Zenaida macroura*) (11 ha). Treatment units (798 ha and 810 ha) were specifically managed for bobwhite during the course of the study. The KWDFR intensively managed the open areas on treatments units, using block disking (349 ha), strip disking (56 km), prescribed fire (329 ha), and aerial application of herbicide to control sericea lespedeza (142 ha). Over the course of the study, 50% of the open areas on the treatments units received at least 1 form of management.

Disking was performed using an offset disk to incorporate standing vegetation into the topsoil, followed by a finish disk and cultipacker to break up clods of soil and smooth the soil surface. Any woody cover in or surrounding disked areas was left undisturbed. The majority of disking (64%) occurred August through March. Disked areas averaged 0.54 ha and were disked on a 3-year return interval. Some disked areas were planted in small grains (wheat or sorghum) after disturbance, whereas others were left fallow. Strip-disking was represented by firebreaks, which were 7-9 m in width, disked annually in August or September, planted to winter wheat, and remained fallow during the following growing season. Fifty-six km of firebreaks were disked and planted annually. Prescribed burns averaged 12.1 ha and were conducted during the dormant season with 68% in March or April and 32% in Sep-Nov. Sericea lespedeza was sprayed with aerial application of metsulfuron methyl (19.05 g/ha AI, Escort XP, DuPont, Wilmington, DE, USA) during flowering (Aug-Sep). Areas treated with herbicide averaged 71 ha.

METHODS

Trapping and Radio-telemetry

We captured bobwhite year-round from August 2009 to March 2014 using Stoddard (1931) funnel traps. We baited traps with cracked corn and grain sorghum and placed them opportunistically across the study area in areas used by bobwhite. We used cast nets during the non-breeding season to capture unmarked individuals from coveys with at least 1 radio-marked individual in order to maintain a minimum of 2 radio-marked individuals in each covey (Truitt and Daily 2000). We recorded weight (g), sex, and age of all captured individuals (Rosene 1969).

Birds weighing >90 g received 2 aluminum leg bands and individuals >120 g were fitted with a necklace-style VHF radio transmitter (~6g, American Wildlife Enterprises, Monticello, FL, USA). Transmitters were equipped with a 12-hour mortality sensor. Trapping, handling, and banding protocols complied with the University of Tennessee Institutional Animal Care and Use Committee Permit 2042-0911.

We located radio-marked bobwhite >3 days/week via the homing method (White and Garrott 1990). We recorded locations 30 to 50 m from the radio-marked individual to obtain an accurate location without flushing the bird. We estimated the distance and the azimuth to the radio-marked bird and recorded the GPS coordinates (UTM) of the location. We also recorded the vegetation type in which the bird was located. We obtained locations for each individual at varying times on successive days to capture the temporal variation in diurnal habitat selection.

Vegetation Sampling

We collected vegetation data at bobwhite locations during the 2012 and 2013 breeding season and the 2012-2013 and 2013-2014 non-breeding season. We randomly selected a subset of 40 individuals (20 per area, 10 per unit) at the beginning of each breeding season to be included in our vegetation sampling, and additional individuals were added to account for mortalities. We selected all available coveys during the non-breeding season with at least 2 radio-marked individuals for vegetation sampling. We sampled vegetation at 1 telemetry location per individual or covey per week until the end of the season or until mortality. Vegetation sampling occurred ≤7 days from when the telemetry location was collected.

Breeding season. - We estimated the percent coverage of all plant species along a 30-m point-intercept transect centered on the telemetry location, recording the presence of all species bisecting the transect at 1-m intervals (Bonham 2013). The presence of a species was recorded as a hit, and percent coverage was calculated by dividing the number of hits by the number of points along the transect (30 points). Litter depth, ground sighting distance, and visual obstruction readings were taken every 10 m along the transect (0, 10, 20, 30 m). We measured litter depth (cm) with a ruler. Ground sighting distance provided an index of openness at ground level and was measured by looking through a PVC pipe (3.8 cm diameter; 15.2 cm long) mounted 15.2 cm aboveground (Gruchy and Harper 2014). One observer looked through the tube while another observer moved a colored ruler away from the tube until the vegetation completely obscured the bottom 14 cm of the ruler. We then recorded the distance (cm) between the PVC pipe and ruler. We measured the vertical structure of the vegetation using a modified Nudds (1977) profile board. Our profile board consisted of 8 25-cm x 25-cm strata, with each stratum alternating black and white in color, and numbered sequentially from top to bottom. One observer kneeled 5 m from the board and visually estimated the obstruction of each stratum, assigning a value of 0 to 5 for each stratum (0 = 0%, 1 = 1-20%, 2 = 21 – 40%, etc.). Litter depth, ground sighting distance, and structural data were averaged per telemetry point, giving 1value for each measurement. We counted the number of woody stems >1.37 m in height and ≤11.4 cm DBH in a 5-m radius plot centered on the telemetry location. We conducted the same measurements at 1 random location per telemetry location in the same vegetation type in a 165-m radius around the location. We used a 165-m radius because it was the maximum daily average movement of bobwhite during any season on our study area. We chose the random location by selecting a distance and azimuth from a randomly generated list.

Non-breeding season. – We measured the vertical structure of the vegetation using a modified Nudds (1977) profile board. We estimated vertical structure in each cardinal direction centered on the telemetry location. Observers estimated the percentage each stratum obstructed by vegetation from 10 m and assigned a value from 0 to 5 to each stratum (0 = 0%, 1 = 1-20%, 2 = 21 – 40%, etc.). Litter depth (cm) measurements were taken in each cardinal directions around the telemetry location. Vertical structure and litter depth measurements were averaged per telemetry location, giving one value for each measurement. We counted the number of woody stems >1.37 m in height and ≤11.4 cm DBH in a 10-m radius plot centered on the telemetry location. We measured the distance to escape cover using a rangefinder. Escape cover was defined as the nearest woody cover providing sufficient protection from predators. We conducted the same measurements at 1 random location per telemetry location in the same vegetation type within a 165 m radius around the location. We chose the random location by selecting a distance and azimuth from a randomly generated list.

We used vegetation data from random locations during the breeding season in different habitat management practices to characterize the effects of management on reclaimed mine vegetation. We used an analysis of variance (ANOVA) to compare the attributes of vegetation in unmanaged open areas, disked areas, burned areas, firebreaks, and areas treated with herbicide. Disked areas were split into 2 groups, disked areas in the first and second growing season after disking, and disked areas in their third growing season after disking. A least significant difference mean comparison test was used to determine differences between managed areas and unmanaged areas and among the different management practices. Significance for all tests was determined at an alpha of 0.05.

Resource Selection

We used discrete choice models to examine resource selection for non-nesting and non-brooding bobwhite. Discrete choice uses the logit model of logistic regression to determine resource selection, with a use vs. available framework, and allows availability to change over time and space (Cooper and Millspaugh 1999). Discrete choice assumes resource selection is characterized by a series of choices by individuals through time and choices are based the utility to the individual. Given a set of available resources, animals will choose the resources that maximize their utility (Cooper and Millspaugh 1999, Manly et al. 2002, Hoffman et al. 2010). Availability is defined by a "choice set" containing all available resources at a given time and place (Cooper and Millspaugh 1999). Each choice set is defined uniquely per sample (telemetry location) and selection is determined by comparing attributes of used locations (telemetry locations) to attributes of available locations (random locations) in the choice set.

The extent of the choice set is defined by the researchers and should be biologically relevant to the species in question (Hoffman et al. 2010). We defined a choice set as resources available in the maximum average daily movement of bobwhite of our study area (165 m). We defined average daily movement as the average distance between bobwhite locations on consecutive days. We assessed macrohabitat availability by creating 5 points within 165 m of each telemetry location using the Geospatial Modeling Environment software (GME, Spatial Ecology 2014). We also defined availability at the microhabitat scale at 165 meters, but we compared 1 random location to each telemetry location.

We measured resource selection during the breeding season based on individual bobwhite. We only used locations from individuals with ≥20 locations to assess macrohabitat resource selection (DeVos and Mueller 1993, Taylor et al. 1999). During the non-breeding season, resource selection by individual bobwhite in the same covey was not independent of other members. Therefore, we determined non-breeding season resource selection for coveys, not individuals. Only coveys with ≥20 locations were used in the non-breeding season analyses

*Model Covariates***. -** We derived landscape composition and configuration covariates from digitized aerial imagery in ArcGIS (ESRI, Redlands, CA, USA) with a cell size of 10 m. We created rasters with a base layer of the vegetation types on the study area overlaid with the habitat management activities across the study area to address questions of composition and configuration of the area and the influence of management activities. We updated maps monthly throughout the breeding season and prior to the beginning of the season for the non-breeding season to account for the ongoing management on the area, providing temporally precise estimates of areas influenced by management. We measured the distance (m) from each telemetry location or random point to each of the four vegetation types and different habitat features (Table 1). We measured the proximity to undisturbed open areas because management focused on improving conditions in open areas (NWSG or OH). We used continuous distance variables to estimate the selection of vegetation types rather than indicator (0 or 1) variables because it avoided misclassifications as a result of telemetry error and it allowed selection to be influenced by the composition of vegetation surrounding the location, rather than just the vegetation type the where the point lied (Conner et al. 2003). Bobwhite are commonly associated with the edge between different vegetation types and the interspersion and dispersion of differing vegetation (Roseberry and Klimstra 1984). Therefore, we used Fragstats 4.0 (McGarigal et al. 2012) to measure the shrub-open edge density, forest-open edge density, and the contagion index within 165 m of all telemetry and random locations (Table 1). The contagion index is a measure of the evenness or interspersion and dispersion of the landscape, with smaller values (closer to 0) indicating smaller more interspersed areas of differing vegetation, compared with larger (closer to 1) more dispersed areas of differing vegetation (McGarigal et al. 2012).

We used only the locations from bobwhite on treatment units to assess the influence of habitat management because only these individuals had access to areas that had received management. We determined the influence of habitat management by measuring the proximity of locations to disked areas and firebreaks. We measured the proximity to the nearest disked areas in OH or NWSG that was in its first, second, or third growing season after disking. We used indicator variables (0 or 1) if a location was in a burned area or an area treated with herbicide (Table 1). We used the proximity to disked areas because the small patch size of disked areas combined with our telemetry error (12 m) could increase the likelihood a point would be misclassified as untreated when it actually was in a disked area (Montgomery et al. 2011). Prescribed fire and herbicide applications were implemented on a larger scale, and the probability of correctly identifying a location in those areas was >90% (Montgomery et al. 2011). We also calculated the total disked area (ha) in a 165-m buffer around telemetry and random locations. We included all disked area, regardless of the time since disking (1, 2, or 3 years).

We selected variables from the vegetation surveys conducted at telemetry locations and random locations to assess microhabitat resource selection during the breeding season. We used the percent coverage of planted native warm-season grass (NWSG), forbs excluding sericea (FORB), bobwhite summer food plants (FOOD), sod-forming cool-season grasses (SOD), sericea lespedeza (SERICEA), common ragweed (RAGWEED), total grass coverage (GRASS), and low woody cover (LSHRUB) as variables for composition (Table 2). The average litter depth, sight tube measurement, woody stem density, and structural measurements at each location and random point also were used to assess breeding season selection (Table 2). We evaluated microhabitat selection during the non-breeding season using the 8 visual obstruction measurements from our profile board, litter depth, woody stem density, and the distance to escape cover (Table 2).

Statistical Analysis

We used the COXPH package in program R (R package version 3.1.1; R Development Core Team 2014) to conduct our discrete choice analysis. Locations were separated by season, and separate analyses were conducted for the breeding and non-breeding season. We did not detect any differences in selection between our 2 study areas (Ken and Sinclair). Therefore, locations from each area were pooled for all subsequent analyses. We tested for autocorrelation among observations by identifying the number of subsequent locations from each bobwhite that lacked independence. Autocorrelation can bias the standard error estimates of variables used to explain resource selection, increasing the likelihood of type I errors (rejecting the null hypothesis when it is actually true; Dormann et al. 2007). Five subsequent locations from each individual were autocorrelated at the macrohabitat scale, therefore, we generated robust standard errors to account for autocorrelation (Dormann et al. 2007). We used the purposeful model-building strategy outlined in Hosmer and Lemeshow (2000) to determine candidate models for the macrohabitat and microhabitat analysis. We first analyzed each variable independently, in a univariate model, to determine its influence on explaining bobwhite resource selection. Variables with a $p < 0.25$ were retained, and a global model containing all variables $p < 0.25$ was analyzed. We then removed non-significant variables ($p > 0.05$) 1 by 1 from the global model, based on the magnitude of their p-value, until we had a model containing only significant ($p < 0.05$) variables. Variables eliminated in the first step were added back into the reduced global model, individually, to determine if the significance of the variable changed with the inclusion of other variables.

Once the best main effects model was created, we evaluated the influence of biologically relevant interactions.

To determine the influence of management on bobwhite macro- and microhabitat selection, we first developed models using locations from individuals on treatment units and individuals on control units. We then used a UNIT (treatment vs. control) interaction term to determine if factors influencing resource selection differed between treatment and control units. Additionally, at only the macrohabitat scale, we took the model containing the important factors influencing selection on treatment units and used it as a base model, to which we added management variables, to determine the selection of areas with different management. Data from all 4 breeding seasons were used in our treatment unit-only analysis. However, data from the 2009-2010 non-breeding season were not used because habitat manipulations did not begin prior to the non-breeding season.

We used an information theoretic approach to evaluate the models created by purposeful variable selection. We used Akaike's Information Criterion adjusted for small sample sizes (AICc) to rank models based on their ability to explain the variation in population level resource selection (Burnham and Anderson 2002). All models with a $\Delta AIC < 2$ were considered competing models and explained some of the variation in resource selection. We used the most supported model to predict the probability of use given the significant variables. We created selection ratios by the exponentiation of beta estimates (βi) to measure the multiplicative change in the probability of selection when a variable is increased or decreased by 1 unit, while all other variables are held constant (McDonald et al. 2006). Only variables with confidence limits not overlapping zero were considered as significantly influencing resource selection. We used a variable adequacy analysis to rank the importance of each variable in the model (Harrell 2001).

RESULTS

Trapping and Radio-telemetry

We captured 2,127 individual bobwhite from Aug 2009 to March 2014. We were able to radiomark 1,639 individuals (n = 816 in breeding season, n = 823 in non-breeding season), including 668 females, 810 males, and 161 that we could not determine the sex. Of the 816 individuals radiomarked during the breeding season, 283 had ≥20 locations and were included in our analyses. We recorded an average of 34 locations/individual (SD = 13), with 174 individuals on the treatment units and 109 individuals on the control units. We recorded ≥20 locations for 136 coveys during the non-breeding season, with 58 coveys on control units and 78 coveys on treatment units. Coveys averaged 48 locations (SD = 18). We used 9,264 and 6,721 telemetry locations for our macrohabitat analysis during the breeding and non-breeding season, respectively. We used 573 locations from 72 individuals in our microhabitat analysis during the breeding season and 429 telemetry locations from 52 coveys during the non-breeding season.

Macrohabtiat

Breeding season. – We fit 16 models to assess the influence of landscape composition and structure on bobwhite breeding season resource selection. We found 3 competing models accounted for 83% of the model weights (Table 3). The top model accounted for 41% of the weight and included 12 degrees of freedom, 7 main effects, and the interaction of 5 variables and UNIT (treatment or control) (Table 3). Bobwhite on both units were closer to ROAD and SHRUB than would be expected at random (Table 4). Bobwhite on control units avoided areas with greater FOREST.ED and SHRUB.ED, whereas bobwhite on treatment units selected areas with greater SHRUB.ED (Table 4). Individuals on treatment units selected areas with a lower CONTAGION, whereas there was no relationship with CONTAGION for bobwhite on control.

Bobwhite on control units were closer to NWSG than would be expected at random, but bobwhite on treatment units were farther from NWSG than expected at random. Similarly, bobwhite on control units were closer to FOREST than would be expected at random whereas bobwhite on treatment units were farther from FOREST than would be expected at random. The variable adequacy analysis suggested the distance to SHRUB, SHRUB.ED, and CONTAGION were the most important variables in the model. Although the confidence intervals for FOREST and NWSG did not overlap zero and were significant on both units, the variable adequacy analysis and the exponentiation of the beta coefficients revealed a minimal impact on selection (Table 4).

We fit 8 additional models to assess the influence of habitat management on bobwhite habitat selection. The top model contained the OH.DISK, NWSG.DISK, FB, BURN, and HERB variables and accounted for 62% of the model weight. There was one other competing model which included all the variables in the top model plus the DB.AREA variable (Table 3). However, the confidence interval for the DB.AREA variable overlapped zero. Adequacy analysis indicated selection was influenced most by the proximity to SHRUB, amount of SHRUB.ED, and the proximity to disked areas, regardless of shape (Table 5). Selection decreased 4% with every 10 m increase in the distance to SHRUB, 2% with every 10 m increase in the distance to disked OH and NWSG, and 1% with every 10 m increase in the distance to a FB. The relative probability a point was selected increased 12% if it had been treated with herbicide and decreased 22% if it had been burned (Table 5). A post-hoc analysis including the interaction of D.OH.DISK and SHRUB indicated the probability of a point being selected in or near a disked area decreased if it was farther away from shrub cover ($\beta = 0.0000088$, CI = 0.0000015 – 0.0000036).

Non-breeding season. – We fit 17 models to assess non-breeding season macrohabitat resource selection. The top model contained 4 variables and the interaction of 2 of those variables with UNIT (treatment vs. control), and 2 other models were <2 AICc from the most supported model (Table 6). The top model suggested coveys selected areas with greater SHRUB.ED and were closer to SHRUB, FOREST, and NWSG than would be expected at random (Table 4). However, parameter estimates indicated distance to NWSG weakly influenced selection with a less than 2% decrease in the probability of selection with a 100 m increase in the distance to NWSG. Coveys on treatment units were closer to FOREST and SHRUB compared to coveys on control units (Table 7). The variable adequacy analysis indicated the distance to SHRUB and the SHRUB.ED were the most important variables in the top model. Selection ratios indicated the relative probability a covey selected a location increased 2% with every 10 m/ha increase in SHRUB.ED for coveys on control and treatment units and decreased 6% and 8% with every 10 m increase from SHRUB for coveys on control units and treatment units, respectively.

Habitat management positively influenced resource selection. The top model contained the OH.DISK, DB.AREA, and DB.AREA × DB.AREA, HERB, and BURN variables (Table 8). The top model accounted for 75% of the model weight, with no other competing models (Table 6). The confidence intervals for DB.AREA and DB.AREA × DB.AREA overlapped zero, indicating they did not strongly influence selection (Table 8). Variable adequacy analysis indicated SHRUB, SHRUB.ED, FOREST, and OH.DISK were the most important variables in the model. The relative probability of selection decreased 2% with every 10 increase from a disked open herbaceous area. Bobwhite were 72% more likely to select a location if it had been treated with herbicide and 31% more likely to select a location if it had been burned the previous dormant season. Similar to the breeding season, our pot-hoc analysis revealed a significant OH.DISK and SHRUB interaction (β = 0.00001, CI = 0.000008 – 0.000012).

Microhabitat

We fit 35 models to test for the influence of microhabitat variables on bobwhite breeding season resource selection, including a null model, 19 univariate models, and 15 models with different combinations of variables. The model containing variables for the visual obstruction from 1.25 to 1.5 meters (ND3) and the amount of woody stems per hectare (STEMS) was the most supported model, but only accounted for 16% of the model weight. Ten other models were within 2 ΔAIC of the top model. Each model contained the ND3 and STEMS variables plus other variables (Table 9). However, the confidence intervals for all other variables in the top models included 0, indicating the effect of each added variable was not strong. The beta coefficient for the ND3 (β = 0.2764 CI = 0.053 - 0.4994) and STEMS (β = 0.000168, CI = 0.000034 - 0.000301) variables were both positive, suggesting bobwhite selected areas with more stems per ha than available at random and an increased vertical structure from 1.25 to 1.5 m from the ground.

We fit 17 models to assess non-breeding season microhabitat resource selection. There were 6 competing models (ΔAICc < 2) accounting for 86% of the model weights (Table 10). The model including the distance to woody cover (DWC), woody stems per hectare (STEMS), and the vegetation density from 1.75 to 2 m (ND1) was the most supported model (w_i = 22.5%), however the confidence interval for woody stems per ha overlapped zero (β = 0.000169, CI = -0.000026 - 0.00036), indicating the variable was not significant. The beta coefficients suggested selection increased when coveys were closer to woody cover (β = -0.035, CI = -0.052 - -0.018) and when the structure of the vegetation was denser from 1.75 to 2 m aboveground ($\beta = 0.439$, CI = 0.245 - 0.632).

We tested for differences in the structure and composition of vegetation following different management practices on PWMA. Compared to unmanaged open areas (control) disking (<2 yr and firebreaks) and herbicide application increased the FOOD plants and decreased coverage of SERICEA, but only disking increased FORB (Table 11). Burned and disked areas in the 3rd growing season after treatment had similar coverage of FOOD and FORB, compared to control (Table 11). However, in the third year after disking, coverage of sericea lespedeza was greater than unmanaged areas (Table 11). Coverage of SERICEA was similar between burned areas and unmanaged areas. Herbicide application and disking (< 2 yr and firebreaks) increased openness at ground level compared to unmanaged areas and decreased the density of vegetation from 0.25 to 0.5 m aboveground (Table 11). On the contrary, the structure at ground level in burned areas and areas in the third growing season after disking was similar to unmanaged areas (Table 11). The amount of litter was less in burned, disked, and herbicide areas compared to unmanaged areas.

DISCUSSION

We aimed to identify variables important to bobwhite resource selection on a reclaimed surface mine throughout the year and to evaluate how habitat management influenced selection. Our results suggested bobwhite occupying an open landscape are limited by interspersion of shrub cover across the area. The distance to SHRUB and the amount of SHRUB.ED were the important variables influencing resource selection during both the breeding and non-breeding season. At the microhabitat scale, bobwhite selected areas with structural characteristics representative of shrub cover. Bobwhite selected disked areas and areas sprayed with herbicide to control sericea lespedeza throughout the year. Selection of these areas likely was related to the change in vegetation composition and structure following treatment, allowing bobwhite to move and forage more efficiently.

The largest proportion of bobwhite locations during the breeding and non-breeding season were in the OH vegetation type (51% and 40%, respectively), but the distance to OH was not a significant variable in either season, indicating bobwhite used OH similar to what would be expected based on availability. However, distance to SHRUB was important throughout the year, with locations averaging 45±1 m (±SE) and 32±1 m (±SE) from SHRUB cover during the breeding and non-breeding season, respectively. The average distance from locations to shrub cover is consistent with reported average flight distances of bobwhite in Texas (47m and 60m; Kassinis and Guthery 1996, Perez et al. 2002, respectively) and supports Kassinis and Guthery's (1996) recommendation of having interspersed shrub cover <100 m from any open area. The importance of shrub cover during the breeding season and non-breeding season is well documented (Johnson and Guthery 1988, Williams et al. 2000, Guthery et al. 2005, Janke and Gates 2013). Our results suggest use of open areas decreases as distance to woody cover increases. Thus, management aimed at improving the distribution of woody cover on these open landscapes, through planting or the advancement of succession will improve the quality of reclaimed mine sites for bobwhite.

Our microhabitat resource selection analysis corroborated the affinity for woody cover by bobwhite on PWMA. Our results are consistent with Ransom et al. (2008), who reported bobwhite occupying an open landscape in Texas selected areas with increased coverage of woody vegetation and increased visual obstruction during spring and summer. Vegetation on PWMA with structural characteristics consistent with those selected by bobwhite may be important during the breeding season for a variety of reasons, including evasion from predators, thermal refuge, and singing perches for males (Johnson et al. 1990, Hiller and Guthery 2005). Increased coverage of ND3 is consistent with the structure presented by various shrubs, such as winged sumac, but it also can be associated with taller forbs (e.g., horseweed and musk thistle) and native grasses found in open areas on PWMA.

The selection of areas with increased visual obstruction during the non-breeding season is consistent with other studies of bobwhite microhabitat in an open landscape (Johnson and Guthery 1988, Kopp et al. 1998, Perkins et al. 2014). Increased obstruction is important to provide concealment from predators and refuge from severe weather or snow cover (Johnson and Guthery 1988, Wiley 2011, Perkins et al. 2014). Shrubs on PWMA that provided increased visual obstruction also provided food sources selected by bobwhite throughout the non-breeding season. Seeds from sumac, autumn olive, and black locust were commonly found in bobwhite crops harvested on PWMA. The structure of the vegetation in areas where these plants were dominant is consistent with areas selected by bobwhite during the non-breeding season.

Interspersion of vegetation types has been reported as an important characteristic of bobwhite habitat (Roseberry and Klimstra 1984, Roseberry and Sudkamp 1998). During the breeding season, bobwhite on control units at PWMA selected areas with a greater CONTAGION compared to bobwhite on treatment units, and bobwhite on control units avoided areas with greater SHRUB.ED and FOREST.ED, suggesting bobwhite on control units selected areas with homogenous open vegetation (OH or NWSG). Conversely, bobwhite on treatment units selected areas with a greater interspersion of vegetation types, especially areas with a greater amount of SHRUB.ED. Peters (2014) reported breeding season survival on Peabody WMA decreased as the amount of open herbaceous cover increased in a bobwhite’s home range, suggesting survival decreased with more homogenous areas of open cover. Our results suggest the difference in the selection of contagion index between control and treatments units is a result of management on PWMA.

The contagion index was not an important variable during the non-breeding season. However, bobwhite on both units selected areas with greater amounts of SHRUB.ED compared to random. Coveys selected areas with an average of 105±0.77 m/ha (±SE) of shrub-open edge and only 12% of locations were in areas with <30 m/ha of shrub edge. Roseberry and Sudkamp (1998) reported bobwhite were rarely found in areas with <30 m/ha of woody edge. Our results suggest interspersion of the vegetation types at PWMA was influential during the breeding season, but during the non-breeding season, bobwhite were dependent on the transition from shrub cover to open areas.

Our results suggest disking was the most influential management practice on PWMA throughout the year. Bobwhite were found closer to disked areas, regardless of shape (linear or blocks), during the breeding season, but were only found closer to disked blocks in OH during the winter. The attraction to disked areas is likely a result of the change in vegetation composition and structure. Disking increased openness at ground level, decreased coverage of sericea, and increased coverage of bobwhite food plants. Stauffer (2011) suggested vegetation density at ground-level limited the quality of reclaimed mine lands for bobwhite. Our results suggest disking can improve the structure at ground level in areas dominated by sericea lespedeza and planted NWSG, thus improving the quality for bobwhite. However, disking must be completed on a relatively short rotation as sericea coverage increased above control levels within 3 years after disking. Multiple studies have identified the importance of disking for bobwhite broods (Manley et al. 1994, Yates et al. 1995, Carver et al. 2001). However, its effectiveness has been questioned on reclaimed surface mines where the native seedbank may be lacking. At least on PWMA, a seedbank containing desirable annual forbs (e.g., common ragweed) and grasses (e.g., *Setaria* spp.) existed. Furthermore, disking near shrub cover can increase interspersion of food and cover. Although the beta estimate for the relationship was not large, our post-hoc analysis revealed an interaction with disking and distance to SHRUB, indicating selection of disked areas decreased as the distance from SHRUB increased, regardless of the season. This relationship is not surprising as the usability of open areas that provide food resources decreases as bobwhite move away from escape cover (Guthery and Bingham 1992).

The fact bobwhite were closer to FB during the breeding season but not during the non-breeding season is not surprising because firebreaks were covered with standing wheat and annual forbs, such as common ragweed, three-seed mercury (*Aclaphya virginica*), and horseweed (*Conyza canadensis*), during the breeding season but were void of cover during the non-breeding season. Doxon and Carroll (2010) reported fallow wheat fields, similar to our firebreaks, provided the structure needed for adequate mobility and feeding rates for bobwhite chicks. Additionally, fallow wheat fields along with fields under two Conservation Practices (CP10 and improved CP10) contained more insect prey for bobwhite chicks than CP2 and CP25 fields (Doxon and Carroll 2007). The structure and composition of annually disked firebreaks likely provided increased mobility and foraging opportunities and access to cover needed by bobwhite throughout the day during the breeding season.

Similar to disking, herbicide application to control sericea lespedeza improved the composition and structure of vegetation on PWMA, and areas treated with herbicide were selected by bobwhite throughout the year. Extensive coverage of sericea can limit the quality of open areas for bobwhite by outcompeting desirable native plants important as food (Adams et al.

1973, Wade 1989, Foster and Gross 1998), reducing the abundance of invertebrates (Bugg and Dutcher 1989), and limiting the mobility of bobwhite. Sericea lespedeza seeds are commonly consumed by bobwhite; however they provide limited nutritional benefit (Newlon et al. 1964). Sericea is a hard-seeded legume that requires scarification to germinate. Blocksome (2006) suggested digestion of sericea seeds by bobwhite increased the germination rate and bobwhite lost an average of 44% of their bodyweight when fed sericea during a 2-week feeding trial (Newlon et al. 1964).

Prescribed fire is a management tool commonly used to improve the structure and composition of vegetation and maintain early successional communities for bobwhite (Stoddard 1931, Brennan et al. 1998, Cram et al. 2002, Gruchy and Harper 2014). However, selection of burned areas was inconsistent on PMWA. Bobwhite avoided burned areas during the breeding season, but selected burned areas during the non-breeding season. Prescribed fire did not reduce coverage of sericea lespedeza or planted NWSG, and fire did not enhance the structure of the vegetation (Unger et al. In press). Wong et al. (2012) reported dormant-season prescribed fire increased coverage of sericea lespedeza by increasing the germination rate. Holcomb et al. (2014) reported prescribed fire did not decrease the density of planted NWSG regardless of season of burning. Consequently, prescribed fire did not reduce the density of vegetation at ground-level in open areas on PMWA. Additionally, prescribed fire may have consumed small patches of shrub cover in open areas, which may have provided thermal and escape cover in large homogenous blocks of open cover during the breeding season. The selection of burned areas during the non-breeding may be attributed to a reduction in litter following treatment, providing easier access to seeds.

Our results suggest the quality of reclaimed mine lands is limited by the distribution of shrub cover and the quality of the open areas. Bobwhite were rarely >130 m from shrub cover regardless of the season. Our results are consistent with other bobwhite studies conducted on open landscapes in Texas and Oklahoma. Our study area contained 25% shrub cover, which is consistent with the recommended amount of shrub cover (5-30%) for bobwhite in an open landscape (Fulbright and Guthery 1996, Hernandez and Guthery 2012). However, the distribution of woody cover is not uniform on PWMA. Furthermore, reclaimed mine lands can be dominated by large blocks of nonnative vegetation that persists for decades (Cavender et al. 2014); thus, management aimed at setting back succession (prescribed fire) is not needed as much as management aimed at enhancing the structure and composition of the existing vegetation (disking and herbicide applications). Non-native invasive species likely will always be an issue on reclaimed mine land. However, our results suggest the condition of existing reclaimed mine land can be improved with proper management.

MANAGEMENT IMPLICATIONS

Management of reclaimed surface mines where bobwhite is a focal species should concentration on improving the distribution of shrub cover and the composition and structure of open areas dominated by nonnative invasive species and dense, planted NWSG. Use of open areas by bobwhite on reclaimed surface mines is often limited by distance to shrub cover. Bobwhite locations averaged approximately 40 m from shrub cover; thus, we recommend distributing shrub cover so that it is not more than 100 m between patches (Kassinis and Guthery 1996). Use of non-native invasive species when reclaiming mine land should be discontinued, in favor of native species. We recommend disking areas dominated by sericea lespedeza and rank native-warm season grasses on a 3-year return interval to enhance composition and structure of the vegetation. An alternative management strategy is treating areas extensively covered by sericea lespedeza with herbicide, such as metsulfuron methyl. However, care should be taken to not treat shrub cover in or adjacent to areas covered with sericea lespedeza because herbicides that control sericea lespedeza also control certain shrub species. We do not recommend burning areas dominated with sericea lespedeza or dense, planted NWSG in an effort to reduce those species. However, fire may be useful prior to disking or herbicide application, or to manage forest or woodland patches on reclaimed mine land. Reclaimed mine land can provide large contiguous tracts of habitat for bobwhite and our results suggest proper management can increase bobwhite habitat quality.

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APPENDIX

Table 1. Variables used to assess macrohabitat resource selection for northern bobwhite during the breeding and non-breeding season on PWMA, Kentucky, 2009-2014.

Variable	Description	Units
Landscape		
SHRUB.ED	Density of shrub to open (OH or NWSG) edge in a 165 m radius	m/ha
FOREST.ED	Density of forest to open (OH or NWSG) edge in a 165 m radius	m/ha
CONTAGION	Contagion index a measure of interspersion and juxtaposition	%
FOREST	Distance to deciduous forest	m
SHRUB	Distance to shrub cover	m
NWSG	Distance to undisturbed planted NWSG	m
OH	Distance to undisturbed open herbaceous	m
ROAD	Distance to nearest road	m
Management		
UNIT	Indicated if the bird was located on a treatment or control unit	
DB.AREA	Total disked area in a 165 radius	ha
NWSG.DISK	Distance to nearest disked area in planted native warm-season grass	m
OH.DISK	Distance to nearest disked area in open herbaceous	m
FB	Distance to nearest firebreak	m
BURN	Does the location fall in a burned area	1 or 0
HERB	Does the location fall in an area treated with herbicide	1 or 0

Table 2. Variables used to assess microhabitat resource selection for northern bobwhite during the breeding and non-breeding season at PWMA, Kentucky, 2009-2014.

Variable	Description	Units
<u>Breeding</u>		
LITTER	Average litter depth	cm
SIGHT	Average sight tube measurement	cm
ND1 – ND8	Visual obstruction reading, 8 variables (1 for each strata)	0-6
STEMS	Number of woody stems (<15 cm DBH) in a hectare	stems/ha
NWSG	Coverage of planted native warm-season grass species	%
FOOD[a]	Coverage of plants important as summer foods for bobwhite	%
FORB	Coverage of all forbs, excluding sericea lespedeza	%
LSHRUB	Coverage of brambles, woody, and semi-woody species	%
SOD	Coverage of sod-forming cool season grasses	%
GRASS	Total coverage of grass species	%
SERICEA	Coverage of sericea lespedeza	%
RAGWEED	Coverage of common ragweed	%
<u>Non-breeding</u>		
LITTER	Average litter depth	cm
ND1 – ND8	Visual obstruction reading, 8 variables (1 for each strata)	0-5
STEMS	Number of woody stems (<15 cm DBH) in a hectare	stems/ha
DWC	Distance to woody escape cover	m

[a] FOOD were plants known to produce seed commonly collected from crops during the breeding season (Eubanks 1974, Buckner and Landers 1979, Brennan and Hurst 1995)

Table 3. Competing models explaining the variation in macrohabitat resource selection of northern bobwhite on a reclaimed surface mine during the breeding season, Kentucky, 2010-2013. Support for each model is indicated by the difference in AICc values (ΔAIC) and by Akaike model weights (w_i).

Model	log(L)	AICc	ΔAIC	w_i
Treatment and Control Models				
SHRUB.ED × UNIT+FOREST.ED × UNIT + CONTAGION × UNIT + FOREST × UNIT + NWSG × UNIT + SHRUB + ROAD	-16446.90	32919.80	0.00	0.41
SHRUB.ED × UNIT + FOREST.ED × UNIT + CONTAGION × UNIT + FOREST × UNIT + NWSG × UNIT + SHRUB + ROAD × UNIT	-16446.51	32921.03	1.22	0.22
SHRUB.ED × UNIT + FOREST.ED × UNIT + CONTAGION × UNIT + FOREST × UNIT + NWSG + SHRUB + ROAD	-16448.67	32921.35	1.55	0.19
NULL	-16598.90	33197.7	277.9	0.00
Treatment Models				
CONTAGION + SHRUB.ED + FOREST + NWSG + SHRUB + ROAD + OH.DISK + NWSG.DISK + FB + BURN + HERB	-9968.06	19958.14	0.00	0.62
CONTAGION + SHRUB.ED + FORSET + NWSG + SHRUB + ROAD + OH.DISK + NWSG.DISK + FB + BURN + HERB + DB	-9967.56	19959.14	1.00	0.38
NULL	-10161.07	20322.10	363.9	0.00

Table 4. Model coefficients, standard errors, confidence intervals, and selection ratios for the most supported model for northern bobwhite breeding season resource selection. Rank is based on the adequacy of each variable. Variables accounting for a larger proportion of the top model's deviance are ranked higher, Kentucky, 2010-2013.

Variable	**Estimate**	**SE**	**95% CI**		**Selection Ratio**	**Rank**
SHRUB.ED[a]	-0.0012	0.0003	-0.0017	-0.0007	0.9988	3
FOREST.ED	-0.0138	0.0001	-0.0139	-0.0137	0.9863	10
CONTAGION	-0.0011	0.0029	-0.0067	0.0045	0.9989	6
NWSG	-0.0004	0.0000	-0.0005	-0.0004	0.9996	8
SHRUB	-0.0036	0.0001	-0.0037	-0.0035	0.9964	1
ROAD	-0.0011	0.0001	-0.0013	-0.0009	0.9989	5
FOREST	-0.0003	0.0000	-0.0003	-0.0003	0.9997	12
SHRUB.ED × UNIT[b]	0.0032	0.0002	0.0028	0.0036	1.0032	2
FOREST.ED × UNIT	0.0119	0.0001	0.0117	0.0120	1.0120	9
CONTAGION × UNIT	-0.0074	0.0033	-0.0138	-0.0010	0.9926	4
NWSG × UNIT	-0.0008	0.0002	-0.0012	-0.0003	0.9992	7
FOREST × UNIT	0.0014	0.0000	0.0013	0.0014	1.0014	11

[a] The beta estimates for variable without a unit interaction represent the magnitude of the effect on both control and treatment units.

[b] The beta estimates for variables with a unit interaction represent the difference in the beta estimate between control units (no interaction term) and treatment units.

Table 5. Model coefficients, standard errors, confidence intervals, and selection ratios for the most supported model for northern bobwhite breeding season resource selection. Rank is based on the adequacy of each variable. Variables accounting for a larger proportion of the top model's deviance are ranked higher, Kentucky, 2010-2013.

Variable	Estimate	SE	95% CI		Selection Ratio	Rank[b]
SHRUB.ED	0.0016	0.0001	0.0015	0.0018	1.0017	2
CONTAGION	-0.0067	0.0000	-0.0068	-0.0066	0.9933	6
NWSG	0.0003	0.0001	0.0001	0.0006	1.0003	8
SHRUB	-0.0039	0.0001	-0.0040	-0.0038	0.9961	1
ROAD	-0.0012	0.0002	-0.0015	-0.0008	0.9988	7
FOREST	0.0007	0.0000	0.0006	0.0008	1.0007	11
OH.DISK	-0.0021	0.0000	-0.0022	-0.0020	0.9979	4
NWSG.DISK	-0.0017	0.0000	-0.0018	-0.0016	0.9983	5
FB	-0.0014	0.0000	-0.0014	-0.0013	0.9986	3
BURN[a]	-0.2410	0.0639	-0.3305	-0.1379	0.7862	10
HERBICIDE[a]	0.1136	0.0148	0.0845	0.1426	1.1203	9

[a] Indicator variables coded as 1 if the point was in a burned area or an area sprayed with herbicide to control sericea lespedeza.

Table 6. Competing models explaining the variation in macrohabitat resource selection of northern bobwhite on a reclaimed surface mine during the non-breeding season, Kentucky, 2009-2014. Support for each model is indicated by the difference in AICc values (ΔAIC) and by Akaike model weights (w_i).

Model	log(*L*)	AICc	ΔAIC	w_i
Treatment and control models				
SHRUB.ED + NWSG + SHRUB + FOREST + FOREST × UNIT + SHRUB × UNIT	-11850	23712	0	0.34
SHRUB.ED + NWSG + SHRUB + FOREST + FOREST × UNIT + SHRUB × UNIT + SHRUB.ED × UNIT	-11850	23713	0.58	0.26
SHRUB.ED + NWSG + SHRUB + FOREST + FOREST × UNIT	-11852	23714	1.70	0.15
NULL	-12042	24085	373	0.00
Treatment models				
FOREST + NWSG + SHRUB + SHRUB.ED + OH.DISK + DB.AREA + DB.AREA^2 + HERB + BURN	-6456	12930	0	0.75
NULL	-6604	13209	279	0

Table 7. Model coefficients, standard errors, confidence intervals, and selection ratios for the most supported model for northern bobwhite non-breeding season resource selection. Rank is based on the adequacy of each variable. Variables accounting for a larger proportion of the top model's deviance are ranked higher, Kentucky, 2009-2014.

Variable	**Estimate**	**SE**	**95% CI**		**Selection Ratio**	**Rank**
SHRUB.ED[a]	0.0027	0.0001	0.0024	0.0030	1.0027	3
NWSG	-0.0009	0.0000	-0.0009	-0.0008	0.9991	6
SHRUB	-0.0060	0.0001	-0.0061	-0.0058	0.9941	2
FOREST	-0.0001	0.0002	-0.0005	0.0003	0.9999	5
SHRUB × UNIT[b]	-0.0018	0.0009	-0.0035	0.0000	0.9982	1
FOREST × UNIT	-0.0007	0.0001	-0.0009	-0.0006	0.9993	4

[a] The beta estimates for variable without a unit interaction represent the magnitude of the effect on both control and treatment units.

[b] The beta estimates for variables with a unit interaction represent the difference in the beta estimate between control units (no interaction term) and treatment units.

Table 8. Model coefficients, standard errors, confidence intervals, and selection ratios for the most supported model for northern bobwhite non-breeding season resource selection. Rank is based on the adequacy of each variable. Variables accounting for a larger proportion of the top model's deviance are ranked higher, Kentucky, 2010-2014.

Variable	Estimate	SE	95% CI		Selection Ratio	Rank
SHRUB.ED	0.0021	0.0004	0.0014	0.0028	1.0021	2
NWSG	-0.0006	0.0000	-0.0007	-0.0006	0.9994	9
SHRUB	-0.0080	0.0006	-0.0092	-0.0069	0.9920	1
FOREST	-0.0013	0.0001	-0.0015	-0.0012	0.9987	3
OH.DISK	-0.0015	0.0003	-0.0021	-0.0009	0.9985	4
DB.AREA	0.0923	0.1592	-0.2197	0.4043	1.0967	8
DB.AREA^2	-0.1489	0.0817	-0.3090	0.0112	0.8617	5
HERB[a]	0.5419	0.0677	0.4093	0.6745	1.7192	7
BURN[a]	0.2733	0.0495	0.1763	0.3703	1.3143	6

[a] Indicator variables coded as 1 if the point was in a burned area or an area sprayed with herbicide to control sericea lespedeza

Table 9. Competing models explaining the variation in microhabitat resource selection of northern bobwhite on a reclaimed surface mine, Kentucky, 2010-2013. Support for each model is indicated by the difference in AICc values (ΔAIC) and by Akaike model weights (w_i).

Model	**log(*L*)**	**AICc**	**ΔAIC**	w_i
ND3 + STEMS	-388.37	780.75	0.00	0.15
ND3 + STEMS + FOOD	-387.54	781.11	0.36	0.13
ND3 + STEMS + NWSG	-387.86	781.74	0.99	0.09
ND3 + STEMS + LSHRUB	-388.08	782.18	1.42	0.08
ND3 + STEMS + ND8	-388.14	782.31	1.55	0.07
ND3 + STEMS + RAGWEED	-388.19	782.40	1.64	0.07
ND3 + STEMS + LITTER	-388.20	782.42	1.67	0.07
ND3 + STEMS + ND7	-388.25	782.51	1.76	0.06
ND3 + STEMS + SIGHT	-388.31	782.64	1.89	0.06
ND3 + STEMS + SOD	-388.36	782.74	1.99	0.06
NULL	-397.17	794.31	9.46	0.00

Table 10. Competing models and null model explaining the variation in microhabitat resource selection of northern bobwhite on a reclaimed surface mine, Kentucky, 2009-2014. Support for each model is indicated by the difference in AICc values (ΔAIC) and by Akaike model weights (w_i).

Model	log(L)	AICc	ΔAIC	w_i
DWC + ND1 + STEMS	-264.40	534.83	0.00	0.23
DWC × UNIT + ND1 + STEMS	-263.62	535.28	0.45	0.18
DWC + ND1	-265.89	535.79	0.97	0.14
DWN + ND1 + STEMS + ND7	-263.95	535.94	1.11	0.13
DWC + ND1 + LITTER	-265.23	536.49	1.67	0.10
DWC × UNIT + ND1 × UNIT + STEMS × UNIT	-263.23	536.54	1.71	0.10
NULL	-297.36	594.72	59.89	0.00

Table 11. Results for the ANOVA comparing vegetation composition and structural variables between different management practices during the breeding season on PWMA, KY, 2012-2013.

Variable	Treatment[a]	Mean	SE	
FOOD	Control[b]	0.17	(0.01)	C
	Burn[c]	0.22	(0.06)	BC
	Disk[d]	0.50	(0.03)	A
	3-yr Disk[e]	0.12	(0.06)	C
	Firebreak	0.55	(0.06)	A
	Herbicide[f]	0.28	(0.03)	B
FORB	Control	0.47	(0.02)	B
	Burn	0.36	(0.09)	B
	Disk	0.65	(0.05)	A
	3-yr Disk	0.55	(0.08)	AB
	Firebreak	0.37	(0.09)	B
	Herbicide	0.35	(0.05)	B
SERICEA	Control	0.66	(0.02)	B
	Burn	0.72	(0.09)	AB
	Disk	0.47	(0.05)	C
	3-yr Disk	0.84	(0.08)	A
	Firebreak	0.00	(0.09)	D
	Herbicide	0.50	(0.05)	C
SIGHT	Control	59.94	(2.63)	D
	Burn	52.95	(13.77)	CD
	Disk	91.19	(7.36)	B
	3-yr Disk	70.73	(12.50)	BCD
	Firebreak	193.43	(13.77)	A
	Herbicide	82.20	(7.14)	C
LITTER	Control	2.16	(0.06)	A
	Burn	1.21	(0.33)	BC
	Disk	1.17	(0.18)	C
	3-yr Disk	1.71	(0.30)	ABC
	Firebreak	0.24	(0.33)	D
	Herbicide	1.68	(0.17)	B
ND7	Control	4.23	(0.06)	A
	Burn	4.38	(0.32)	AB
	Disk	3.88	(0.17)	B
	3-yr disk	3.94	(0.29)	AB
	Firebreak	2.18	(0.32)	C
	Herbicide	3.89	(0.17)	B

[a] All locations were in the OH or NWSG vegetation type

[b] Control points were in unmanaged OH or NWSG (*n* = 384).
[c] Burn points were collected during the first growing season after application (*n* = 14).
[d] Disk points were collected during the first or second growing season after application (n = 49).
[e] 3-yr disk points were collected during the third growing season after application (*n* = 17).
[f] Herbicide points were collected during the first or second growing season after application (*n* = 52).

Table 12. Mean values and 95% confidence intervals for variables used in the macrohabitat resource selection analysis during the breeding season, Kentucky, 2010-2013.

	Location		Random	
Variable	$\bar{x}$	CI	$\bar{x}$	CI
Control				
SHRUB.ED	85.77	(87.66 - 83.88)	85.27	(86.12 - 84.41)
FOREST.ED	1.92	(2.16 - 1.68)	2.13	(2.26 - 2.01)
CONTAGION	55.80	(55.80, 56.26)	55.96	(56.16, 55.76)
FOREST	280.36	(289.53 - 274.48)	281.09	(285.20 - 278.46)
SHRUB	45.73	(47.78 - 43.68)	49.10	(50.02 - 48.19)
NWSG	238.28	(247.47 - 229.10)	239.28	(243.42 - 235.18)
OH	22.17	(23.57 - 20.77)	23.89	(24.57 - 23.21)
ROAD	201.07	(206.73 - 195.40)	204.58	(207.16 - 202.01)
Treatment				
SHRUB.ED	111.74	(113.45 - 110.03)	106.21	(106.97 - 105.44)
FOREST.ED	7.02	(7.50 - 6.54)	7.40	(7.63 - 7.18)
CONTAGION	52.62	(52.62, 52.91)	53.27	(53.71, 53.43)
FOREST	230.67	(236.67 - 226.25)	228.97	(231.64 - 226.99)
SHRUB	39.97	(41.35 - 38.59)	45.20	(45.84 - 44.56)
NWSG	291.46	(300.42 - 282.49)	295.87	(299.90 - 291.85)
OH	37.17	(38.71 - 35.62)	37.58	(38.29 - 36.86)
ROAD	230.06	(236.28 - 223.83)	236.35	(239.13 - 233.57)
DB.AREA	0.60	(0.62 - 0.64)	0.59	(0.59 - 0.60)
FB	107.32	(109.98 - 104.66)	114.88	(116.08 - 113.68)
NWSG.DISK	346.94	(356.96 - 336.91)	354.46	(358.94 - 349.97)
OH.DISK	161.07	(165.26 - 155. 93)	167.20	(169.15 - 164.89)

Table 13. Mean values and 95% confidence intervals for variables used in the macrohabitat resource selection analysis during the non-breeding season, Kentucky, 2009-2014.

	Location		Random	
Variable	$\bar{x}$	CI	$\bar{x}$	CI
Control				
SHRUB.ED	95.81	(98.12 - 93.50)	91.23	(92.26 - 90.21)
FOREST.ED	6.19	(6.80 - 5.57)	6.54	(6.84 - 6.25)
CONTAGION	54.82	(55.31 - 54.34)	55.47	(55.70 - 55.25)
FOREST	228.76	(235.14 - 222.39)	229.06	(231.94 - 226.19)
SHRUB	37.99	(40.45 - 35.53)	45.08	(46.17 - 44.00)
NWSG	380.72	(395.63 - 365.81)	382.61	(389.32 - 375.90)
OH	40.07	(42.55 - 37.60)	41.33	(42.49 - 40.17)
ROAD	292.57	(301.5 - 283.63)	292.96	(297.00 - 288.93)
Treatment				
SHRUB.ED	112.25	(114.23 - 110.27)	106.07	(106.97 - 105.17)
FOREST.ED	11.60	(12.28 - 10.92)	11.32	(11.64 - 11.00)
CONTAGION	52.93	(53.29 - 52.27)	53.69	(53.86 - 53.21)
FOREST	175.80	(181.67 - 169.92)	180.37	(182.93 - 177.82)
SHRUB	27.37	(28.61 - 26.13)	35.12	(35.74 - 34.51)
NWSG	357.59	(369.27 - 345.91)	358.73	(364.00 - 353.45)
OH	48.19	(50.70 - 45.69)	48.28	(49.43 - 47.14)
ROAD	252.20	(259.08 - 245.33)	253.92	(257.05 - 2570.79)
DB.AREA	0.34	(0.36 - 0.33)	0.35	(0.36 - 0.35)
FB	137.51	(141.79 - 133.24)	141.53	(143.48 - 139.58)
NWSG.DISK	423.64	(435.98 - 411.30)	425.61	(431.18 - 420.05)
OH.DISK	139.22	(144.18 - 134.25)	142.70	(144.95 - 140.44)

Table 14. Mean and 95% confidence intervals for variables used to assess microhabitat selection by bobwhite during the breeding season, Kentucky, 2012-2013.

	Location		Random	
Variable	$\bar{x}$	CI	$\bar{x}$	CI
Structure				
LITTER	1.91	(2.12 - 1.68)	1.89	(2.09 - 1.69)
SIGHT	76.99	(89.20 - 64. 77)	74.70	(89.68 - 59.72)
ND1	0.41	(0.53 - 0.28)	0.32	(0.42 - 0.21)
ND2	0.50	(0.62 - 0.37)	0.40	(0.51 - 0.29)
ND3	0.63	(0.76 - 0.50)	0.52	(0.64 - 0.40)
ND4	1.03	(1.19 - 0.97)	0.92	(1.07 - 0.77)
ND5	1.74	(1.93 - 1.55)	1.63	(1.83 - 1.44)
ND6	3.03	(3.25 - 2.82)	2.98	(3.21 - 2.75)
ND7	4.04	(4.23 - 3.86)	4.05	(4.26 - 3.84)
ND8	4.77	(4.87 - 4.67)	4.80	(4.89 - 4.70)
STEMS	555.80	(831.37 - 280.23)	331.48	(531.23 - 131.72)
Composition				
NWSG	0.14	(0.18 - 0.10)	0.13	(0.17 - 0.09)
FOOD	0.27	(0.31 - 0.23)	0.26	(0.30 - 0.22)
FORB	0.43	(0.49 - 0.38)	0.43	(0.49 - 0.37)
LSHRUB	0.05	(0.07 - 0.03)	0.04	(0.06 - 0.03)
SOD	0.07	(0.10 - 0.04)	0.07	(0.10 - 0.04)
GRASS	0.32	(0.35 - 0.24)	0.31	(0.34 - 0.24)
SERICEA	0.59	(0.65 - 0.54)	0.63	(0.68 - 0.57)
RAGWEED	0.08	(0.11 - 0.05)	0.08	(0.11 - 0.05)

Table 15. Mean and 95% confidence intervals for variables used to assess microhabitat selection by bobwhite during the non-breeding season, Kentucky, 2012-2013 and 2013-2014.

	Location		Random	
Variable	$\bar{x}$	CI	$\bar{x}$	CI
DWC	7.90	(10.30 - 5.49)	12.11	(15.18 - 9.05)
LITTER	2.57	(2.86 - 2.28)	2.68	(3.07 - 2.29)
ND1	1.54	(1.77 - 1.31)	1.18	(1.38 - 0.98)
ND2	1.71	(1.94 - 1.47)	1.34	(1.55 - 1.13)
ND3	1.75	(1.97 - 1.54)	1.41	(1.60 - 1.21)
ND4	2.18	(2.41 - 1.95)	1.89	(2.11 - 1.68)
ND5	2.47	(2.70 - 2.25)	2.21	(2.42 - 1.99)
ND6	3.46	(3.46 - 3.25)	3.24	(3.47 - 3.01)
ND7	3.86	(4.06 - 3.66)	3.74	(3.97 - 3.51)
ND8	4.64	(4.74 - 4.53)	4.62	(4.74 - 4.50)
STEMS	1019.71	(1251.19 - 788.23)	812.49	(1029.67 - 595.30)

Table 16. Chesson's habitat selection index for the breeding season on PWMA. The used values are based on telemetry locations and the available values are based on the composition of the study area. Selection is based on the inverse of the number of vegetation types (1/6). Values with confidence intervals >0.167 were selected, values with confidence intervals <0.167 were avoided, and values with confidence intervals overlapping 0.167 were used equal to available.

	Used	Available	Chesson's Index	Lower CI	Upper CI	Selection[a]
Control						
NWSG	0.10	0.09	0.14	0.11	0.17	=
OH	0.53	0.33	0.36	0.30	0.41	+
SHRUB	0.33	0.26	0.25	0.20	0.29	+
FOREST	0.03	0.21	0.03	0.02	0.04	-
ROAD	0.01	0.01	0.12	0.08	0.15	=
FB	0.01	0.00	0.11	0.06	0.16	=
Treatment						
NWSG	0.10	0.07	0.18	0.15	0.21	=
OH	0.49	0.36	0.24	0.21	0.27	+
SHRUB	0.29	0.22	0.22	0.19	0.25	+
FOREST	0.06	0.23	0.05	0.04	0.07	-
ROAD	0.01	0.01	0.12	0.09	0.15	=
FB	0.04	0.02	0.19	0.16	0.22	+

[a] (+) selected, (-) avoided, and (=) used equal to available

Table 17. Chesson's habitat selection index for the breeding season on PWMA. The used values are based on telemetry locations and the available values are based on the composition of the study area. Selection is based on the inverse of the number of vegetation types (1/6). Values with confidence intervals >0.167 were selected, values with confidence intervals <0.167 were avoided, and values with confidence intervals overlapping 0.167 were used equal to available.

	Used	Available	Chesson's Index	Lower CI	Upper CI	Selection[a]
Control						
NWSG	0.08	0.09	0.13	0.08	0.19	=
OH	0.40	0.33	0.31	0.24	0.38	+
SHRUB	0.40	0.26	0.32	0.26	0.32	+
FOREST	0.10	0.21	0.11	0.05	0.16	=
ROAD	0.01	0.01	0.11	0.06	0.16	=
FB	0.00	0.00	0.02	-0.01	0.02	-
Treatment						
NWSG	0.07	0.07	0.14	0.09	0.18	=
OH	0.40	0.36	0.23	0.18	0.27	+
SHRUB	0.35	0.22	0.30	0.26	0.30	+
FOREST	0.16	0.23	0.13	0.09	0.17	=
ROAD	0.01	0.01	0.08	0.04	0.11	-
FB	0.02	0.02	0.12	0.09	0.12	=

[a] (+) selected, (-) avoided, and (=) used equal to available

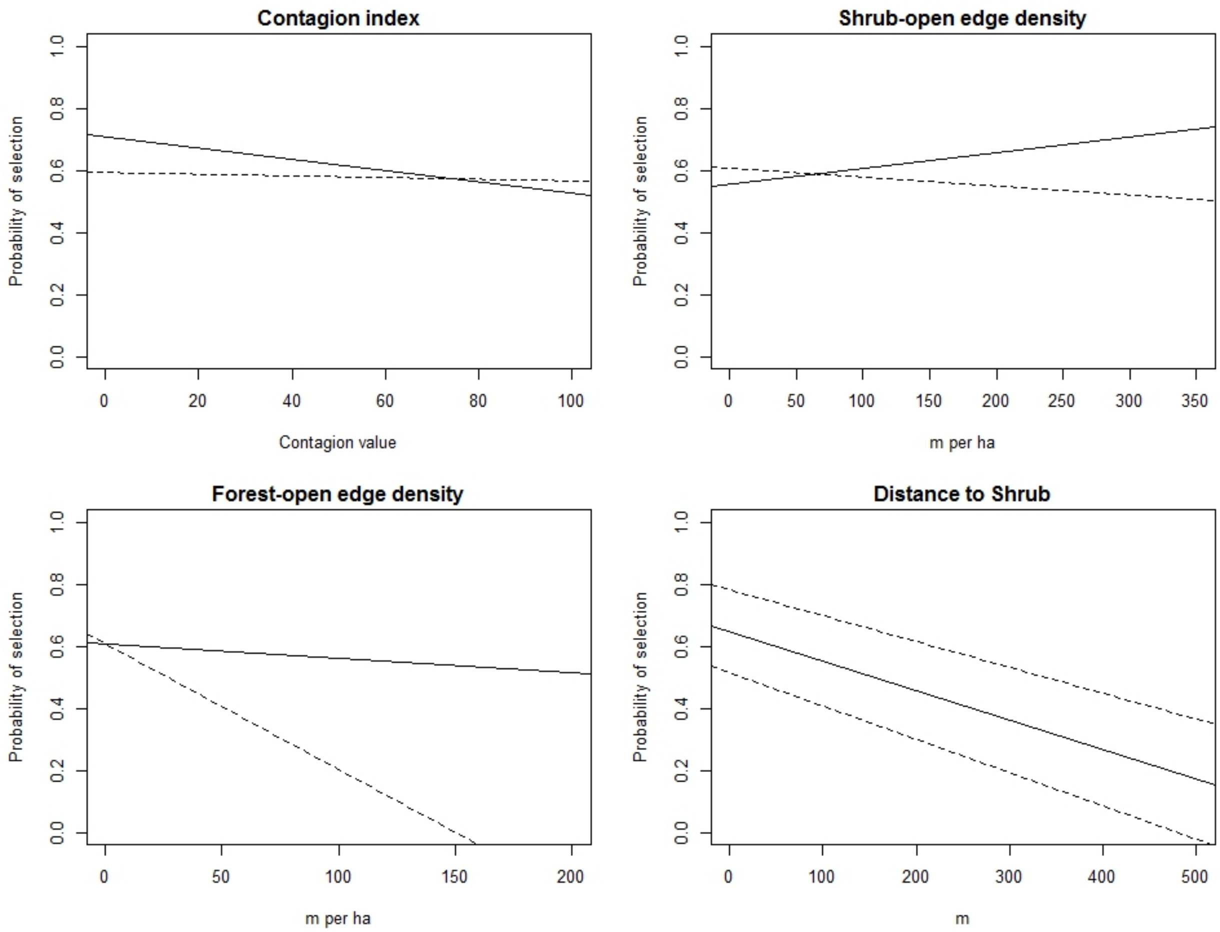

Figure 1. Probability of selection for northern bobwhite as related to the landscape composition and structure during the breeding season. For the contagion index, shrub-open edge density, and forest-open edge density graphs the dashed lines represent the probability of selection on control units and the solid line represents the probability of selection on treatment units. The solid line on the distance to shrub graph represents the mean probability of selection and the dashed lines represent the 95% confidence intervals. PWMA, Kentucky 2010-2013.

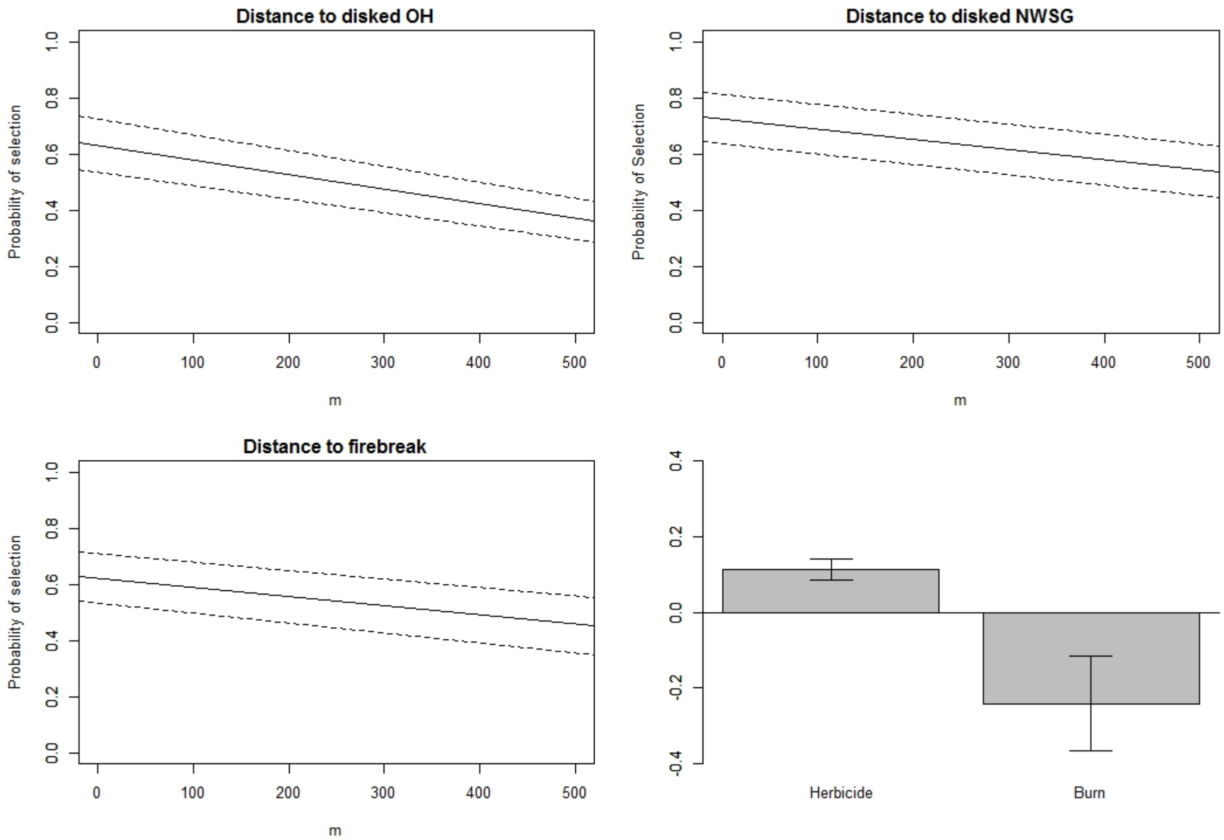

Figure 2. The probability of selection during the breeding season based on variables related to management activities on PWMA. The solid lines represent the mean probability of selection and the dashed lines represent the 95% confidence intervals. PWMA, Kentucky, USA, 2010-2013.

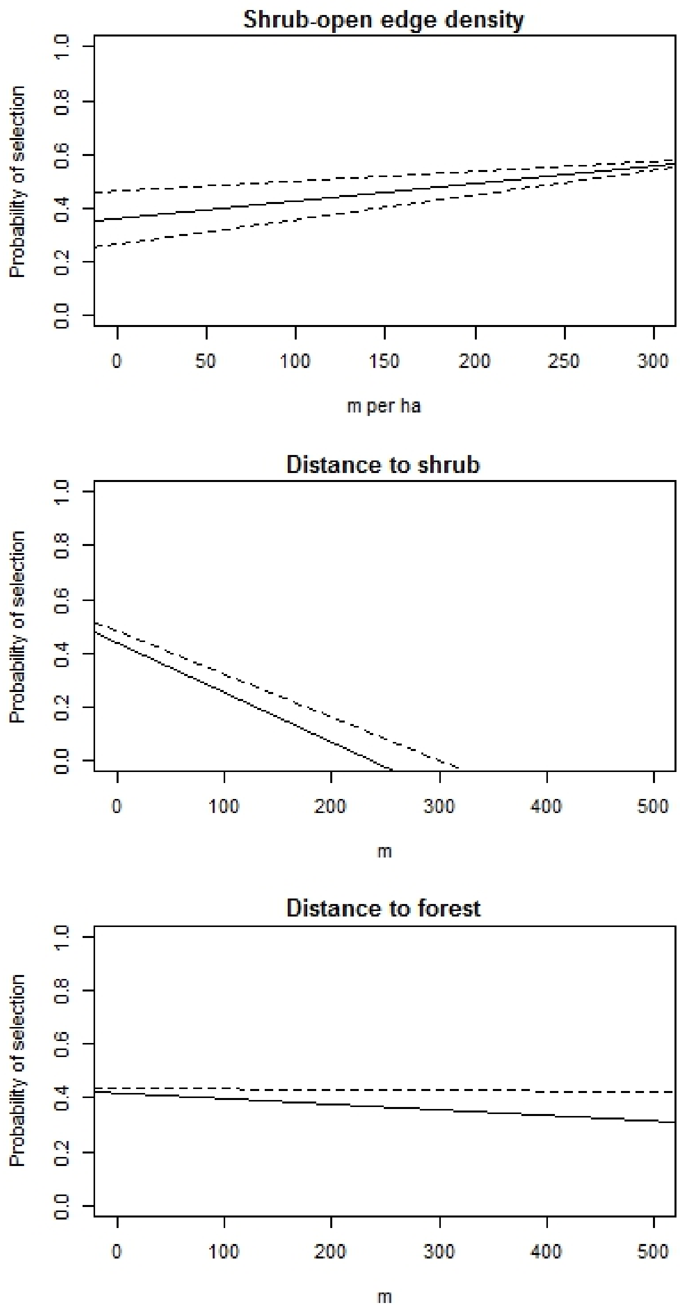

Figure 3. Probability of selection for northern bobwhite as related to the landscape composition and structure during the non-breeding season. For the shrub-open edge density graph the solid lines represent the mean probability of selection and the dash lines represent the 95% confidence intervals. For the distance to shrub and distance to forest graphs the dashed lines represent the probability of selection on control units and the solid line represents the probability of selection on treatment units. PWMA, Kentucky, USA 2009-2014.

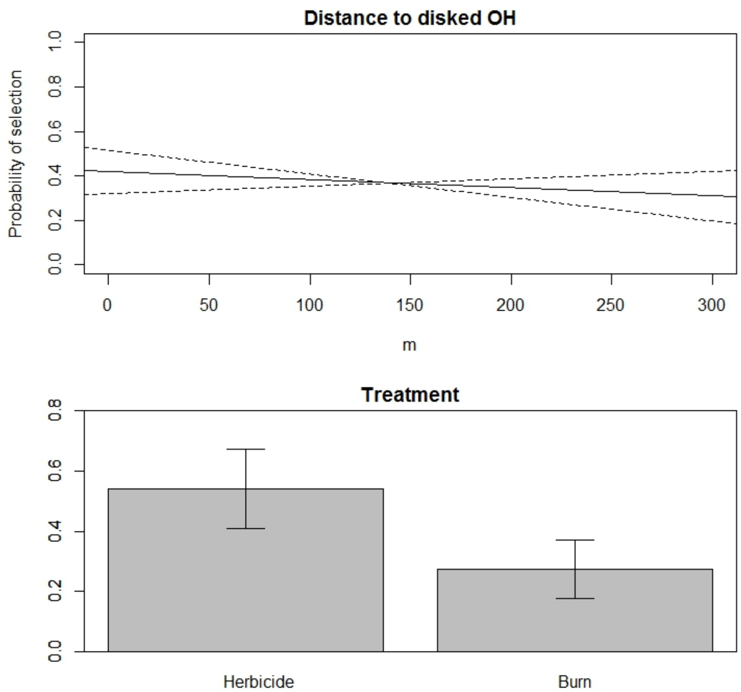

Figure 4. The probability of selection during the non-breeding season based on variables related to management activities on PWMA. The solid lines represent the mean probability of selection and the dashed lines represent the 95% confidence intervals. PWMA, Kentucky, 2009-2014.

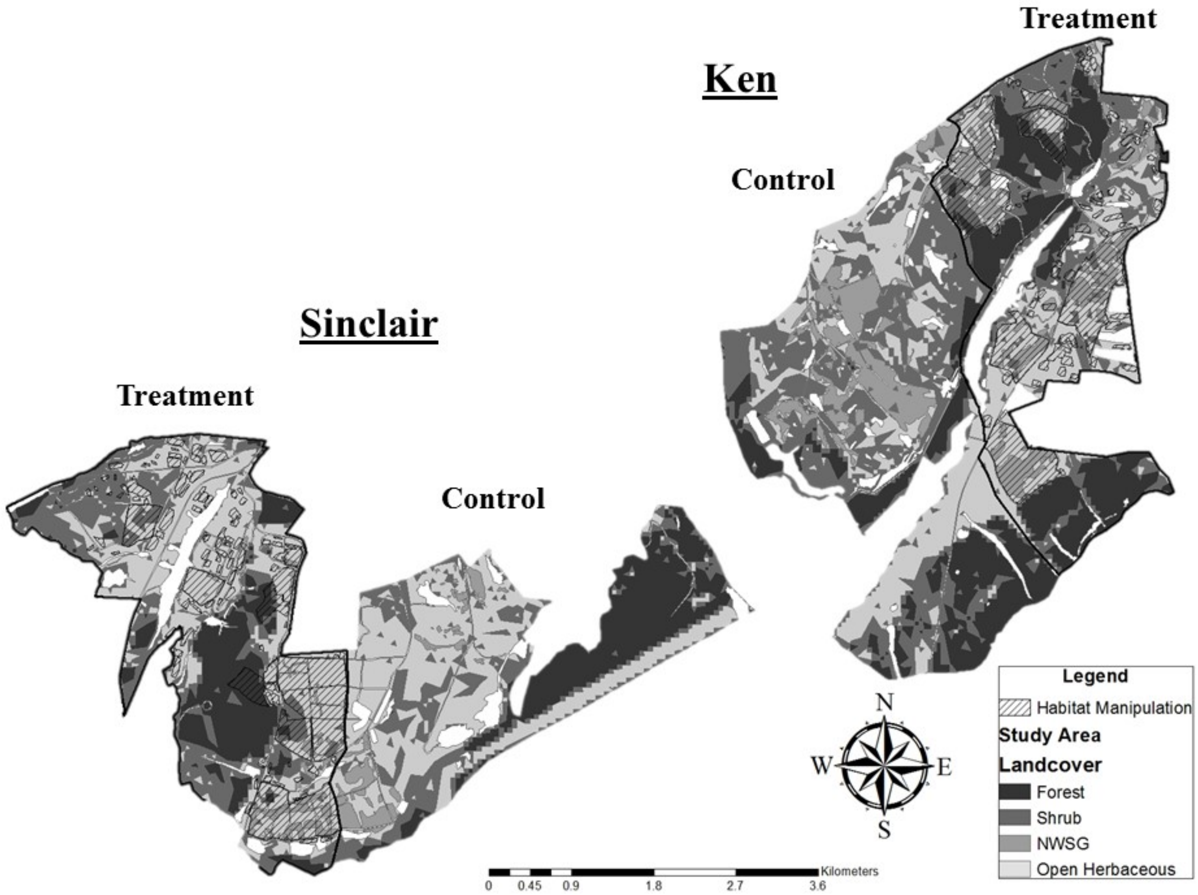

Figure 5. Study areas used to investigate northern bobwhite resource selection on reclaimed surface mines in Kentucky, 2009-2014. The dashed areas represent areas manipulated at least once during the study period. Manipulations included prescribed fire, disking, and herbicide application to control sericea lespedeza.

VITA

Jarred was born and raised in east central Indiana. He was raised in a rural community and was involved in various aspects of agricultural from an early age. He spent his free time in the outdoors, exploring, hiking, fishing, and hunting. His family's passion for upland gamebird hunting and dog handling and training led him to complete a high-school internship at a local hunting preserve. There Jarred cultivated his passion for habitat management and the effects of disturbance on plant communities. Jarred's passion for the outdoors led him to Purdue University, where he completed a Bachelor's of Science degree in Wildlife Science with a minor in Soil Science. While at Purdue, Jarred was involved with the student Wildlife Society Chapter, Department of Forestry and Natural Resource Student Council, and the College of Agriculture Student Council. Jarred also worked as a research technician on a black walnut plantation and for the Department of Forestry and Natural Resources Habitat Specialist, investigating the use of herbicides for forestry and wildlife applications.