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NORTHERN BOBWHITE SURVIVAL RELATED TO MOVEMENT ON A RECLAIMED SURFACE COAL MINE

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ABSTRACT

Reclaimed coal mines represent opportunity to provide large tracts of early succession habitat essential to northern bobwhite (*Colinus virginianus*) populations. However, little research has been conducted to explore the potential of reclaimed mine sites and examine bobwhite ecology on these unique areas. Reclaimed mines in Kentucky were planted to non-native species, such as sericea lespedeza (*Lespedeza cuneata*) and tall fescue (*Festuca arundinacea*), which do not provide suitable structure for northern bobwhite brood-rearing and movement. Fallow disking (in blocks and linear firebreaks) and planting food plots are part of current management efforts to improve food availability and habitat structure for broods. We trapped and radiomarked 266 northern bobwhites between April 2010 and September 2011 on Peabody Wildlife Management Area, a 3,330-ha reclaimed coal mine in western Kentucky, USA to investigate the effects of current management practices on movement and survival. We calculated seasonal daily movement as the Euclidean distance from a location on day 1 to day 2. Breeding season (1 Apr-30 Sep) movement averaged 128 m in 2010 and 147 m in 2011. Daily movement averaged 163 m during the 2010–2011 non-breeding (1 Oct-31 Mar) season. Multiple regression analysis indicated annual food plots, disk blocks, firebreaks, and roads did not explain variation within daily movement regardless of season ($R^2 \leq 0.04$). Individual bird/covey, precipitation, hours between locations, and average temperature also poorly explained movement variation. We used Program MARK to model the effect of season, year, mean daily movement, mean distance to annual food plots, disk blocks, firebreaks, and roads on survival. The season (breeding/non-breeding) model explained 81% of the variation in survival, and the year model explained 13%, suggesting management was not driving survival. We do not believe disking should be discontinued, although it did not influence movement, as it can improve vegetation structure important to nest-site selection and broods.

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Key words: *Colinus virginianus*, disking, firebreaks, Kentucky, movement, northern bobwhite, reclaimed mined land, survival, telemetry

INTRODUCTION

Northern bobwhites have declined at an annual rate of 3% throughout the species' geographic range for the past 3 decades (Sauer et al. 2008). The decline is attributed to deterioration of early succession habitat resulting from clean farming practices, lack of disturbance, and fragmentation (Stoddard 1931, Brennan 1991, Church and Taylor 1992, Burger 2002). More than 607,000 ha of reclaimed coal mines in the eastern United States provide an opportunity to manage large tracts of usable space for northern bobwhites and other early successional species. Compacted soils and dense stands of non-native, aggressive species may inhibit plant succession; thus, these areas remain in early succession for an extended period. These dense stands may prevent more desirable species from germinating. Sericea lespedeza was frequently planted for

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reclamation, and is capable of creating a dense monoculture (Eddy et al. 2003, Ohlenbusch et al. 2007).

Areas with dense sericea lespedeza provide poor nesting habitat, and can reduce native grass and forb cover by 66 and 70%, respectively (Dimmick 1971, Eddy and Moore 1998). Sericea lespedeza can produce 1,500 seeds per stem but, during a controlled feeding study, consumption led to 'critical' weight loss in northern bobwhite (Newlon et al. 1964, Ohlenbusch et al. 2007). Tall fescue is also commonly used in mine reclamation, and was found to limit bare ground and provided poor vertical structure for bobwhite in Kentucky (Barnes et al. 1995). A pilot study on a reclaimed coal 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). Poor quality habitat could result in increased daily movement and vulnerability to predators (Kabat and Thompson 1963, Fies et al. 2002, Lohr et al. 2011, Stauffer 2011).

Current management practices to address these concerns include disking (in blocks and linear firebreaks) and planting annual food plots. Food plots and other management efforts could decrease bobwhite movement, leading to increased survival rates (Scott and Klimstra 1954, Roseberry 1964, Smith et al. 1982, Robel and Kemp 1997). Roads may be another source of sparsely vegetated and bare ground, and could influence bobwhite movement. It is important to understand the response of northern bobwhites to disked blocks, annual food plots, firebreaks, and roads to influence future management decisions on reclaimed mine sites.

We evaluated the effects of continuous bobwhite management practices on daily movement and survival by: (1) measuring the influence of distance to disked areas, annual food plots, firebreaks, and roads on daily movement, and (2) measuring the influence of distance to disked areas, annual food plots, roads, and daily movement on survival. We hypothesized these management practices could decrease daily movements of resident bobwhite, which could increase survival.

STUDY AREA

Peabody Wildlife Management Area (WMA) encompasses 3,330 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 by Peabody and Beaver Dam coal companies before coming under the direction of the Kentucky Department of Fish and Wildlife Resources (KDFWR) in 1995. It is in the Central Hardwoods Region, and its post-mining designated land use is recreation and wildlife habitat. Peabody WMA has been open to public recreation since coming under the direction of KDFWR, and is designated as a focus area in Kentucky's northern bobwhite restoration plan. Current management for bobwhites includes disking (in blocks and linear firebreaks) and planting annual food plots.

We delineated 6 vegetation types on the study area. They included open herbaceous (34%), scrub-shrub (25%), forest (22%), native warm-season grass (8%), water (7%), annual food plots (1%); odd areas (roads, buildings, firebreaks, and wetlands represented <3% of the study site). Open herbaceous was dominated by sericea lespedeza, tall fescue, thistle (*Cirsium* spp., *Carduus* spp.), field brome (*Bromus arvensis*), and goldenrod (*Solidago* spp.). Scrub-shrub was dominated by autumn-olive (*Elaeagnus umbellata*), black locust (*Robinia pseudoacacia*), and common blackberry (*Rubus allegheniensis*). Forests varied from undisturbed hardwoods with oaks (*Quercus* spp.) and maples (*Acer* spp.) to planted monocultures of eastern cottonwood (*Populus deltoides*). Native warm-season grasses included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) as well as other grasses and forbs. Water is recognized separately because of fluctuations in wetland areas with seasonal variation in rainfall. Food plots consisted of a mixture of grain sorghum, Illinois bundleflower (*Desmanthus illinoensis*), partridge pea (*Chamaecrista fasciculata*), and Maximillian sunflower (*Helianthus maximilianii*).

Yearly 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, while 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

Radiotelemetry

We trapped northern bobwhites year-round using funnel traps baited with cracked corn and grain sorghum as attractants during the breeding (1 Apr-30 Sep 2010, 2011) and non-breeding (1 Oct-31 Mar 2010–2011) seasons (Stoddard 1931). Traps were active $\geq$ 5 days per week and checked every afternoon to minimize stress and predation of trapped bobwhites. Each captured bird was fitted with two aluminum bands (unique numbers on each leg), classified to sex and age (juv or ad), 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). Once marked, we released birds in the area where trapped. We located birds $\geq$ 3 times per week, homing to 25–50 m to minimize disturbance of marked bobwhites (White and Garrott 1990). We recorded estimated distance to bird, azimuth, vegetation type where the bird was located, and Universal Transverse

Table 1. *A priori* models and associated hypotheses for a survival analysis of northern bobwhite ($n = 266$) on a reclaimed coal mine in western Kentucky from 1 April 2010 to 30 September 2011 ($n = 266$).

Model	Survival hypotheses
Distance to annual food plots	As distance to annual food plots increases, survival decreases
Distance to disk blocks	As distance to disk blocks increases, survival decreases
Daily movement	As daily movement increases, survival decreases
Distance to firebreaks	As distance to firebreaks increases, survival decreases
Distance to roads	As distance to roads increases, survival decreases
Breeding/non-breeding season	Survival will be greater in the breeding than in the non-breeding season
Time	Days will not be important to survival
Year	Year will not be important to breeding season survival

Mercator (UTM) coordinates at our location using a handheld Global Positioning System (GPS) unit. We estimated distance to the bird from the strength of the telemetry signal. Estimation error was measured in a series of 10 trials where one person hid a radio-transmitter in a known location, and the observer homed-in on it. Actual distance and azimuth were measured, and compared to estimated distance and azimuth.

Movements

Locations were sorted by 2 breeding (1 Apr-30 Sep 2010, 2011) and 1 non-breeding seasons (1 Oct-31 Mar 2010–2011). We censored mortality locations from analyses because predators may have moved dead birds. Nesting and breeding locations were also censored because movements would be influenced by nests and chicks. Locations from individuals within the same covey were excluded because of lack of independence, and 1 location that best represented the covey was used per day. Only individuals or coveys with $\geq$ 20 total locations (consecutive and non-consecutive) were included in the movement analysis. We excluded all locations where the next location for the individual was $\geq$ 2 calendar days. We estimated daily movement of northern bobwhites in Arc Geographic Information Systems (ArcGIS) as the Euclidean distance from a location on day 1 to the location on day 2 (consecutive locations) (Williams et al. 2000, Lohr et al. 2011). We calculated mean daily movement for individuals, coveys, and the entire sample of radio-marked bobwhites by season. We used a 2-tailed Tukey's test to look for significant differences in mean daily movements between the 2010 and 2011 breeding seasons.

We calculated Euclidean distance (m) from each location on day 1 to the nearest road, firebreak, annual food plot, and disked block using the near tool in ArcGIS. We calculated the distance to the 5 closest disk blocks and selected the closest disk block present at the time of the location. Individual or covey and hours between locations were included in the analysis to account for variation among birds and time. Precipitation and average temperature were also included to learn if variation in weather could influence movement. We conducted multiple regression analysis in SAS (SAS Institute 2009) to learn if precipitation, hours between locations, average temperature, individual/covey, and distance to the nearest road, firebreak, annual food plot, and disk block could explain daily movement distance in each season. Multiple regression allowed us to plot continuous daily movement distances against other variables, where analysis of variance methods would require categories within movements. We used a log transformation to correct normality and severe skews of both breeding and non-breeding season data. We removed variables from the analysis as necessary ($P > 0.05$) to better explain movement variation. We attempted polynomial regression with the variable that explained the most variation in movement data when multiple regression was insufficient ($P > 0.05$).

Survival

We obtained survival estimates using the known-fate model in Program MARK (White and Burnham 1999). All birds were left censored. We used a model selection approach based on a group of *a priori* models (Table 1) and Akaike's Information Criterion (AIC) to identify the model that best explained variation in survival. We included null, year dependent, time dependent, mean daily movement dependent, road dependent, disk block dependent, firebreak dependent, and annual food plot dependent models in our analysis. We grouped birds by breeding or non-breeding season to account for expected variation and to be able to detect if different parameters are important based on season. A ΔAIC_c value of < 2 was used to examine how informative a model was in explaining variance in survival (Burnham and Anderson 2002). Seasonal survival rates were obtained from Program MARK using the survival estimate from each model in model averaging. We used the delta method to expand estimates over the course of our biological seasons (Powell 2007).

RESULTS

Radiotelemetry

We used data collected from 266 captured and marked northern bobwhite for analysis. We radiotracked 53 individuals during the 2010 breeding season with 973 total consecutive locations and 43 individuals during the 2011 breeding season with 700 total consecutive locations. Number of consecutive locations per bird averaged ($\pm$ SE) 18 $\pm$ 1.04 during the 2010 breeding season and

Table 2. Mean (± SE) daily movement (m) and distances (m) of northern bobwhite locations to annual food plots, disk blocks, firebreaks, and roads on a western Kentucky reclaimed coal mine during breeding (1 Apr-30 Sep 2010, $n = 53$; 2011, $n = 43$) and non-breeding (1 Oct-31 Mar 2010–2011; $n = 39$ coveys, 206 individuals) seasons.

	2010 Breeding season	2010–2011 Non-breeding season	2011 Breeding season
Mean ± SE distance to:			
Annual food plots	1,109 ± 24.29	1,110 ± 18.53	655 ± 13.48
Disk blocks	435 ± 16.26	578 ± 15.03	357 ± 13.69
Firebreaks	394 ± 15.19	512 ± 14.40	307 ± 11.79
Roads	106 ± 2.32	146 ± 2.81	145 ± 3.47
Mean daily movement	128 ± 4.63	163 ± 6.24	147 ± 6.36

16 ± 0.78 during the 2011 breeding season. We recorded 922 consecutive covey locations during the non-breeding season of 2010–2011 based on 39 coveys representing 206 individuals, which averaged (± SE) 24 ± 1.18 locations per covey. Only 34 birds (15 females, 19 males) survived from one season to another, and 1 individual (male) survived through all 3 seasons.

Telemetry error was estimated among 7 different observers over the course of the study period. 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°.

Movement

There were 43 km of roads, 45 ha of firebreaks, and 20 annual food plots totaling 32 ha during all seasons on the study area. There were 184 disk blocks totaling 131 ha (3% of study area) during the 2010 breeding season, which increased to 243 disk blocks and 129 ha (4% of study area) in the 2010–2011 non-breeding season, and totaled 299 disk blocks and 159 ha (5% of study area) by the 2011 breeding season. Disk block size ranged from 0.07 to 1.7 ha, but averaged 0.5 ha. Mean distances of northern bobwhites from annual food plots on the study area during the breeding and non-breeding seasons were: 655–1,110 m; firebreaks = 307–512 m; roads = 106–146 m; and disk blocks = 357–578 m (Table 2).

We detected a significant difference ($P = 0.015$) between mean (± SE) daily movements in the 2010 (128 ± 4.63 m) and 2011 breeding seasons (147 ± 6.36 m). Thus, the 2 years remained separate in the multiple regression analyses. Distance to annual food plots, precipitation, individual, hours to next location, distance to disk blocks, distance to firebreaks, and average temperature did not improve regression models ($P > 0.10$). The quadratic model with distance to roads was significant ($P = 0.005$, $R^2 = 0.011$) and explained more variation in movement than the linear model ($P = 0.05$, $R^2 = 0.004$). The parameter estimate for distance to roads (–0.0000018) suggests that as daily movement decreases, distance from a road increases.

Covey, hours to next location, distance to annual grain plots, precipitation, and firebreaks each explained < 1% of variation in the non-breeding season, and were successively dropped from the model based on low partial R^2 values and P values > 0.05. The resulting model of average temperature, distance to roads, and disk blocks was significant ($P < 0.0001$, $R^2 = 0.043$). Based on parameter estimates, as distance from roads (0.00123) and average temperature (0.00609) increased, movement increased. However, as distance from disk blocks (–0.00013) increased, movement decreased. Distance from roads explained most of the variation in movement ($R^2 = 0.024$).

Precipitation, distance from annual grain plots, individual, distance to roads, disk blocks, and firebreaks were dropped from the 2011 breeding season analysis based on low partial R^2 values and P values > 0.05. The remaining variables, distance from firebreaks, average temperature, and hours to next location explained 3% of the variation in movement ($P = 0.027$). Parameter estimates indicate that as hours to the next location (0.0313) and average temperature (0.01023) increased, daily movement increased. However, as distance from firebreaks (–0.00028) increased, movement decreased.

Survival

Our best approximating model included only season (breeding/non-breeding), and explained 81% of the variation in bobwhite survival (Table 3). The year and global models were less informative, explaining 13% ($\Delta AIC_c = 3.7277$) and 4% ($\Delta AIC_c = 6.052$) of the variation in survival. All other models had ΔAIC_c scores greater than the null model. Survival estimates (± SE) from model averaging were 48.0 ± 8.08% and 28.1 ± 4.81% during the breeding and non-breeding seasons, respectively.

DISCUSSION

Our breeding season mean daily movements of 128 and 147 m were similar to movements reported in other studies (128–171 m in Georgia, Terhune et al. 2006; 146 m in New Jersey, Lohr et al. 2011). Lui et al. (2002) reported monthly means for the breeding season in a graphical format, and all appear to be within 100–300 m for non-relocated birds. Non-breeding season mean daily movements of 163 m were low compared to covey movements reported by other researchers in Tennessee (390 m; Yoho and Dimmick 1972), Kansas (218–275 m; Madison et al. 2000, Williams et al. 2000), and New Jersey (158 m; Lohr et al. 2011). Our lower mean daily movement estimates are surprising because higher

Table 3. Mean daily movement (m), season (breeding/non-breeding), year, time, and distances (m) of northern bobwhite locations from annual food plots, disk blocks, firebreaks, and roads on a western Kentucky reclaimed coal mine as covariates of survival during breeding (1 Apr-30 Sep 2010, $n = 53$; 2011, $n = 43$) and non-breeding (1 Oct-31 Mar 2010–2011; $n = 39$ coveys, 206 individuals) seasons.

Model	AIC*c*	Delta AIC*c*	AIC*c* weights	Model likelihood	Parameters	Deviance
Season	1,485.2710	0	0.80863	1	2	1,481.2704
Year	1,488.9987	3.7277	0.12540	0.1551	2	1,484.9981
Global	1,491.3230	6.0520	0.03923	0.0485	8	1,475.3162
Null model	1,494.6825	9.4115	0.00731	0.0090	1	1,492.6823
Disk blocks	1,495.5246	10.2536	0.00480	0.0059	2	1,491.5240
Roads	1,495.7278	10.4568	0.00434	0.0054	2	1,491.7272
Firebreaks	1,495.8058	10.5348	0.00417	0.0052	2	1,491.8052
Annual food plots	1,496.2829	11.0119	0.00329	0.0041	2	1,492.2823
Distance to next location	1,496.5719	11.3009	0.00284	0.0035	2	1,492.5713
Time	2,020.9905	535.7195	0	0	366	1,276.1606

[a]Akaike's Information Criterion (Lebreton et al. 1992).

estimates are generally associated with fragmented and marginal habitat, such as a reclaimed coal mine (Kabat and Thompson 1963, Fies et al. 2002, Stauffer et al. 2011). Decreased movement could be attributed to high interspersion of woody vegetation (25% of study area) in drainage ditches, planted patches, and natural scattered succession. Williams et al. (2000) related increased use of woody vegetation during winter to decreased movement on cropland and rangeland containing only 3–4% woody cover.

Decreased movement could also be attributed to increased disturbance, including disk blocks (4% of study area in the breeding season, 5% in non-breeding), disking for firebreaks (1% both seasons), and annual food plots (< 1% in both seasons). Smith et al. (1982) reported little movement between years on Tall Timbers Research Station, which had at least a decade of intensive northern bobwhite management. He suggested movement was so minor that it be disregarded as having a significant effect on population dynamics. Food plots did not affect non-breeding season daily movement of northern bobwhite on Fort Riley, Kansas over a 3-year period (Madison et al. 2000). Our data suggest average proximity of a bird to food plots, disk blocks, or firebreaks did not explain variation within movement data during the breeding or non-breeding seasons. Mean distance to each management practice was a poor covariate of survival, as each explained less variation in the data than the null model.

Increased daily movements may be associated with lower survival rates during breeding and non-breeding seasons because of increased vulnerability to predators (Scott and Klimstra 1954, Roseberry 1964). Decreased northern bobwhite survival rates on Kansas rangelands during winter were influenced by greater covey movement rates (Williams et al. 2000). Vulnerability of bobwhite to predators in New Jersey increased during both breeding and non-breeding seasons as daily movement distances increased (Lohr et al. 2011). Our data do not support this phenomenon. Daily movement was a poor covariate of survival throughout the year and explained less variation than the null model.

MANAGEMENT IMPLICATIONS

Disking, whether in blocks or for firebreaks or food plots, did not influence daily movement distances or survival of northern bobwhites on Peabody WMA. However, this should not suggest disking be discontinued. Disking has a profound effect on vegetation composition and structure, which influences nest-site selection and brood habitat use (Taylor et al. 1999, Rader et al. 2007, Harper and Gruchy 2009). The increased bare ground also benefits other ground foraging and nesting avian species, such as grasshopper (*Ammodramus savannarum*) and field (*Spizella pusilla*) sparrows. Further research should address the potential influence of habitat metrics and landscape configuration on movement, dispersal, and survival of northern bobwhite on reclaimed mined lands.

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