SURVIVAL OF RADIO-MARKED VERSUS LEG-BANDED NORTHERN BOBWHITE IN KENTUCKY

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

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

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

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

Joseph D. Clark
USGS Southern Appalachian Research Branch, Department of Forestry, Wildlife, and Fisheries, University of Tennessee, 274 Ellington Plant Sciences, Knoxville, TN 37996, USA

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

ABSTRACT

Understanding the impact of radiomarking northern bobwhite (*Colinus virginianus*) survival is essential because of the widespread reliance on radiotelemetry to assess vital population parameters. We conducted an assessment of bobwhite populations within the Central Hardwoods Bird Conservation Region using leg banding and radiotelemetry on Peabody Wildlife Management Area, a 3,330-ha reclaimed surface mine in western Kentucky. We captured bobwhites using baited funnel traps during a 112-day period (23 Jul-11 Nov 2010) and marked 180 with necklace-style radio-transmitters (6 g) and 256 birds with only leg bands. Eighty-five birds were opportunistically recaptured in funnel traps, of which 81 were used in developing survival estimates. We used the Cormack-Jolly-Seber model in Program MARK to estimate periodic survival rates (PSR) of both sample groups. Candidate models which included body mass as a covariate explained the most variability in survival. The estimated PSR was 0.309 $\pm$ 0.109 based on the best approximating model and was 0.302 $\pm$ 0.108 from model averaging. We calculated a point of inflection for this model, which suggested a mass 'threshold' of 131g, above which survival improved at a decreasing rate. The model including only the radio-transmitter effect had a $\Delta AIC_c > 3$ and was considered to be non-plausible. Further research with larger samples is needed to develop more robust survival models to fully assess the effects of radiomarking bobwhites. It does not appear, based on our study, that radio transmitters adversely affect survival of northern bobwhite.

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Key words: capture-recapture, *Colinus virginianus,* Cormack-Jolly-Seber, Kentucky, Program MARK, radiomarking, reclaimed mined land

INTRODUCTION

Use of radiotelemetry in northern bobwhite research to estimate survival has become increasingly popular (Burger et al. 1995, Dixon et al. 1996, Taylor et al. 2000, Seckinger et al. 2008, Holt et al. 2009). Researchers assume radio-marked birds have a survival probability similar to unmarked birds (Pollock et al. 1989, Burger et al. 1991). Some studies have questioned this assumption (Parry et al. 1997, Cox et al. 2004, Guthery and Lusk 2004), but few have directly compared contemporary survival estimates of radio-marked versus banded bobwhites within the same population.

Mueller et al. (1988) reported post-capture mortality of radio-marked (27%) versus unmarked (24%) bobwhites

[1] *E-mail: evanpt@ostatemail.okstate.edu*

was not different, based on changes in covey sizes over time. However, using changes in covey size to estimate mortality may be biased because of emigration and immigration of birds (Williams et al. 2004). Parry et al. (1997) directly compared survival rates of radio-marked versus banded bobwhites ($n = 296$ and 308, respectively) through hunting recoveries and re-trapping efforts. They reported radio-marked bobwhites had higher survival ($S = 0.56$) than banded birds ($S = 0.19$). However, these results could have been affected by biased behavior of radio-marked birds including a tendency to hold tight or flush less than banded birds because of potentially lower lipid mass as well as becoming habituated to humans through constant radio-tracking. Palmer and Wellendorf (2007) compared winter survival rates of radio-marked ($n = 951$) versus banded ($n = 3{,}149$) bobwhites in Florida through hunting recoveries. They concluded radio transmitters did not influence survival of males or females as the transmitter effect on survival did not occur in plausible models. Terhune et al. (2007) evaluated summer and winter survival of radio-marked ($n = 2{,}527$) versus banded ($n = 6{,}568$) bobwhites over 8 years through hunting recoveries and re-trapping efforts. They did not find evidence for a radio-transmitter effect on survival of bobwhite and concluded variation in survival within their population was site specific, and was affected by age, sex, and temporal factors. Abbott et al. (2005) suggested trapping and handling birds may be the actual cause of a negative bias related to survival rather than radiomarking birds, because of an increased chance of capture myopathy.

No studies have examined the influence of radio transmitters on bobwhite survival on reclaimed-mined land. Negative biases of radio transmitters may be exacerbated on reclaimed-mined lands because these areas are dominated by species that may not provide adequate food resources (sericea lespedeza, *Lespedeza cuneata*). Our objective was to evaluate possible bias relating to survival of radio-marked bobwhites versus banded bobwhites between summer and fall (excluding the hunting season) on a reclaimed surface mine in western Kentucky.

STUDY AREA

We conducted the study on a reclaimed coal mine managed by the Kentucky Department of Fish and Wildlife Resources as Peabody Wildlife Management Area (WMA) (3,323 ha) in Muhlenberg (37° 14′ N, 87° 15′ W) and Ohio (37° 17′ N, 86° 54′ W) counties in western Kentucky, USA. The study area consisted of open herbaceous vegetation (36%) dominated by sericea lespedeza and annual forbs including common ragweed (*Ambrosia artemisiifolia*), sumpweed (*Iva annua*), and goldenrod (*Solidago* spp.). Shrub vegetation (25%) was characterized by an abundance of black locust (*Robinia pseudoacacia*), winged sumac (*Rhus copallinum*), and blackberry (*Rubus* spp.). Deciduous forests (22%) primarily consisted of eastern cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), and American sycamore (*Platanus occidentalis*); forests typically had a well-developed understory consisting of blackberry (*Rubus* spp.) and honeysuckle (*Lonicera japonica* and *L. maakii*). More recently, native warm-season grasses (NWSG), including mixtures of big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*), have been established (8%). Small lakes, wetlands, and annual grain food plots comprised the remainder (9%) of our study area.

METHODS

We captured bobwhites continuously during 2010 using funnel traps (Stoddard 1931) covered by burlap and vegetation to help reduce stress and predation of captured birds, and evaluated survival of marked birds during a 112-day period (23 Jul-11 Nov 2010). We placed traps ($n = 120$) in areas thought to have bobwhites or where bobwhites were heard or seen. We attached radio transmitters to captured birds that weighed > 120 g. We used 6-g necklace-style radio transmitters (crystal-controlled, 2-stage design, pulsed by a CMOS multivibrator, American Wildlife Enterprises, Monticello, FL, USA). We double leg banded all captured birds including those radiomarked. We classified each bird by sex and age, and weighed all bobwhites before releasing them at the capture site. Our trapping and handling methods complied with the University of Tennessee's Institutional Animal Care and Use Committee Permit (#2042-0911). We opportunistically recaptured radio-marked and banded birds throughout the period of the study.

Statistical Analysis

We calculated survival estimates for radio-marked and banded birds using the Cormack-Jolly-Seber (CJS) model within Program MARK (White and Burnham 1999). We adjusted the radio-marked sample to match the banded data set by randomly censoring selected juveniles and males until the ratios between male: female and juvenile: adult groups were equal. Trapping on a daily basis during the study period provided 111 encounter occasions for both samples combined. We assumed equal recapture rates (Seber 1982). We used a model-selection approach based on Akaike's Information Criterion to identify the model that best explained survival. We included null, time dependent, sex dependent, age dependent, mass dependent, covariate (radio-marked vs. banded) dependent, and additive models in our survival analysis (Table 1). We also included an interactive model between mass and radio-marked or banded variables to test whether there were confounding factors related to the difference in mass between radio-marked versus banded bobwhites. We used a ΔAIC_c value of < 3 (Palmer and Wellendorf 2007) to examine relative validity of a model for explaining variance in survival. We used Akaike weights (*wi*) to examine the overall strength of a model relative to candidate models within $\Delta AIC_c < 3$ for explaining variance in survival. We obtained daily survival rates from the best approximating model and

Table 1. Metrics used to assess effects of radiomarking on survival of northern bobwhites on Peabody WMA, Kentucky, USA, 23 July-11 November 2010.

Metric	Description
Age	juvenile or adult
Radio	presence/absence of radio transmitter
Sex	male/female
Time	temporal scale
Mass	body mass (g) of bobwhite

from model averaging using Program MARK. We used the delta method (Powell 2007) to expand estimates to a temporal scale that encompassed the entire 112-day study period. We used Program MARK to plot survival based on the individual covariate receiving the most support within the best approximating model. We calculated the second derivative for the individual covariate plot to identify the point of inflection for the survival function based on that covariate.

RESULTS

We captured and banded 436 bobwhites during the 112-day period (23 Jul-11 Nov 2010) of which 180 were fitted with a radio transmitter. Eighty-five of the 436 birds captured were recaptured. We randomly censored 4 birds (3 juveniles and 1 male) from the data set to remove any age- or sex-related bias; only 8**1** were used in developing survival estimates (Table 2). The average (± SD) body mass of banded-only bobwhites was 101.9 ± 4.1 g; it was 155.9 ± 2.7 g for radio-marked birds. The range of mass measured during our study was 68–196 g.

Five models tested were supported as being plausible for explaining variance in survival based on ΔAIC_c scores; all 5 included the effect of body mass on survival (Table 3). The highest ranked model based on ΔAIC_c scores included the effect of mass on survival ($\beta = 0.021$; CI = 0.005 – 0.036) with equal recapture rates. The Akaike weight for this model (0.34546; Table 3) indicated this was the best approximating model of those examined for survival. The mass variable also had an importance value (*wi*) > 0.98, suggesting a strong effect of this variable on survival (Table 4). The daily survival rate (DSR) using the body mass model was 0.989 ± 0.003 for both samples. The average recapture probability was 0.078 ± 0.005 for both samples and the periodic survival rate (PSR) was 0.309 ± 0.106. The point of inflection was 131g based on the second derivative of the covariate (mass) plot for this model (Fig. 1). The periodic survival rate at the point of inflection was 0.366 ± 0.125 and was 0.288 ± 0.099 at our 120-g marking requirement.

The second strongest model, based on ΔAIC_c scores, was the additive model of mass and radio effects on survival with equal recapture rates ($\Delta AIC_c = 0.8737$; Table 3). This model had an Akaike value (*wi*) of 0.22141 and was 1.5 times less likely than the strongest model. The effect of radio transmitters was negligible based on the beta value of this covariate ($\beta = -0.840$; CI = –2.318–0.637), which did not differ from 0. Our interactive model

Table 2. Age and sex of captured bobwhites on Peabody WMA, Kentucky, USA, 23 July-11 November 2010.

	Banded only	Radiomarked
Male	25 (61%)	25 (61%)
Female	16 (39%)	16 (39%)
Juvenile	30 (73%)	30 (73%)
Adult	11 (27%)	11 (27%)
Totals	41 (100%)	41 (100%)

between mass and radio-marked or banded variables was not a competing model. There was no evidence of confounding factors related to difference in mass between radio-marked versus banded birds. Model averaging was used to examine overall PSR because of ambiguity among competing models. The period survival rate from model averaging was estimated as 0.302 ± 0.108.

DISCUSSION

Body mass was the most influential parameter affecting northern bobwhite survival during our study. There was a positive, third-order polynomial relationship between survival probability and mass. This suggests bobwhites captured below our 120-g requirement for receiving a transmitter would have a lower probability of survival than birds > 120 g. This criteria may have been set too low, given the point of inflection was higher, suggesting a possible 'threshold' at 131g. This threshold, based on the weight of our collars (6 g), is 4.5% of the bird's total weight. This estimate of 131 g is consistent with previous literature (Terhune et al. 2007), which suggests a threshold of > 132 g. Our requirement of a mass of 120 g may have reduced survival, as these birds would have experienced an 8% decrease in periodic survival compared to those marked at the 131-g threshold. The effect of mass observed during our study may be related to a potential lack of food availability on reclaimed-mined lands. Robel and Linderman (1966) suggested higher body mass may be related to higher survival rates, and observed that food availability was the primary causative factor in mass gains for bobwhites. Peabody WMA was initially re-vegetated with species, such as sericea lespedeza, that may not provide optimal food resources.

Bobwhites may not attain acceptable mass gains for radiomarking until at an older age on reclaimed-mined areas, and lighter bobwhites may be prone to decreased survival, as indicated with our top model. The difference in mass between radio-marked and banded bobwhites was not of concern because our interactive model incorporating these variables was not a competing model.

We did not detect any bias for bobwhite survival on Peabody WMA as a result of using radio transmitters. The radio-transmitter effect was included in a model with a $\Delta AIC < 3$, but the effect of this covariate did not differ from 0 based on the beta value confidence interval.

Previous research has shown site, temporal scale, age, and sex of bobwhites to be more influential on survival

Table 3. Model selection statistics from the Cormack-Jolly-Seber model in Program MARK estimating survival (ϕ) and recapture probability (ρ) of northern bobwhites on Peabody WMA, Kentucky, USA, 23 July-11 November 2010.[a]

Model	AIC_c	ΔAIC_c	AIC_c (*wi*)	Model likelihood	Parameters	Deviance
$\phi_{mass}\ \rho.$	1861.7956	0	0.34270	1	3	1855.7213
$\phi_{mass+radio}\ \rho.$	1862.6693	0.8737	0.22141	0.6461	4	1854.5451
$\phi_{mass*weight^{2}}\ \rho.$	1863.4558	1.6602	0.14942	0.4360	4	1855.3316
$\phi_{mass+age}\ \rho.$	1863.5837	1.7881	0.14016	0.4090	4	1855.4595
$\phi_{mass+sex}\ \rho.$	1863.8434	2.0478	0.12309	0.3592	4	1855.7192
$\phi_{mass \times radio}\ \rho.$	1869.3143	7.5187	0.00798	0.0233	3	1863.2400
$\phi_{radio}\ \rho.$	1869.4884	7.6928	0.00732	0.0214	3	1863.4141
$\phi_{age}\ \rho.$	1870.7681	8.9725	0.00386	0.0113	3	1864.6938
$\phi_{sex}\ \rho.$	1871.5717	9.7761	0.00258	0.0075	3	1865.4974
$\phi.\ \rho.$	1872.6933	10.8977	0.00147	0.0043	4	1864.5691
$\phi_{time}\ \rho.$	2150.1011	288.3055	0	0	112	1807.8207

[a] Notation generally follows Lebreton et al. (1992): ϕ = P(survival), ρ = P(recapture), radio = radio transmitter.

than the presence of a radio transmitter (Palmer and Wellendorf 2007, Terhune et al. 2007). Our study was conducted at only one site and we did not include a site-specific model in our analysis. The temporal scale did not explain variation in survival rates because of the relatively short duration of our study. Additional seasons/years of data and larger sample sizes would help better understand any possible temporal effects that may exist. There was no direct effect on survival in relation to age or sex; these effects were influential in additive models that included mass (Table 3). This suggests body mass is the most influential factor affecting survival among our candidate models. We may have not observed similar age- and sex-related effects on survival as in previous studies because of sample size, seasonality, and temporal scale of our research. Greater discrimination of age (i.e., days post-hatching) at capture would be necessary to better account for a potential age effect. Age and mass were likely confounding influences in our study. Our results suggest body mass is a much more important factor influencing survival.

Recapture rates were extremely low ($\rho = 0.0783$) during the study period, which may have led to the wide confidence limits and the imprecise survival estimates we observed. We were unable to use a Release goodness-of-fit test (White et al. 2001) to calculate a variance inflation factor ($\hat{c}$) to correct for over dispersion of our data.

Table 4. Importance values (*wi*) for parameters used to model northern bobwhite survival in Program MARK on Peabody WMA, Ohio and Muhlenberg counties, Kentucky, USA, 23 July-11 November 2010.

Parameter	Number of candidate models	(*wi*)[a]
Mass	5	0.98465
Radio	2	0.23057
Age	2	0.14518
Sex	2	0.12669

[a] Importance value (*wi*) of a parameter is estimated as the sum of Akaike weights from candidate models containing the parameter.

MANAGEMENT IMPLICATIONS

Our results support use of radio transmitters on northern bobwhites for research as they did not significantly bias survival. Survival estimates of bobwhites obtained through the use of telemetry, specifically in environments without intensive habitat management typical of reclaimed-mined lands, should be viewed as valid. Our results support use of a minimum body mass criterion for attaching radio transmitters to northern bobwhites. Traditional guidelines based on not using transmitters if they were > 5% of body mass may not be sufficiently conservative. Researchers should consider using 4.0 or 4.5% of body mass as a threshold to account for the effects of body mass on survival. Factors that influence survival of bobwhite may vary regionally, and future studies should assess the influence of radio transmitters on survival within different vegetation communities using larger samples over a longer period.

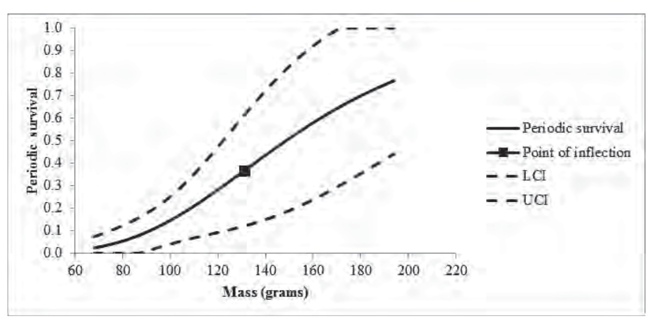

Fig. 1. Individual covariate plot of periodic survival over mass (g) of northern bobwhites, lower (LCI) and upper confidence intervals (UCI) (adjusted where values were below 0 and above 1 to allow for biological meaning), and point of inflection based on estimates in Program MARK derived from the best approximating model ($\phi_{mass}\ \rho.$), Peabody WMA, Ohio and Muhlenberg counties, Kentucky, USA, 23 July-11 November 2010.

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