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Research Article

Nest Success of Northern Bobwhite on Managed and Unmanaged Landscapes in Southeast Iowa

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ABSTRACT Range-wide declines in northern bobwhite populations (*Colinus virginianus*) have been attributed to concomitant loss of breeding habitat. Bobwhite management efforts to restore this habitat resource can be informed by empirical studies of associations between breeding success and multi-scale habitat attributes. We compared bobwhite nest success in 2 southern Iowa landscapes as a function of microhabitat and landscape composition. Lake Sugema Fish and Wildlife Area (LSWA) was managed to promote bobwhite recruitment, and Harrisburg Township (HT) was an adjacent landscape dominated by private agricultural production. Survival rate modeling based on telemetry data provided evidence for age-specific daily nest survival rate. Daily survival rates decreased as nest age increased, but the decline was more severe at HT. Nest survival at LSWA ($S = 0.495$, SE $= 0.103$) was nearly twice that on HT ($S = 0.277$, SE $= 0.072$). We found no evidence that habitat composition or spatial attributes within 210 m of a nest site significantly influenced nest success. Forb canopy at the nest site had a positive influence on nest success at HT but not at LSWA. We suggest nesting habitat with greater forb canopy cover will increase the opportunity for nesting success in landscapes with limited nesting habitat.

KEY WORDS *Colinus virginianus*, habitat management, Iowa, landscape composition, nest success, northern bobwhite, predation, reproduction.

The range-wide, long-term decline of northern bobwhite (*Colinus virginianus*) populations is a serious management concern for state wildlife agencies. Between 1980 and 2006 Iowa Department of Natural Resources (IDNR) roadside counts for bobwhite declined 3.3% annually. Trends in Iowa are similar to others reported on bobwhite (Dimmick et al. 2002, Twedt et al. 2007). Most hypotheses about factors responsible for the range-wide decline have focused on land use change and agricultural practices that lead to loss of suitable habitat or useable space (Dinsmore 1994, Guthery 1997, Brennan 2002, Dimmick et al. 2002, Veech 2006).

The Northern Bobwhite Conservation Initiative (NBCI) is the first-ever landscape-scale habitat restoration and population recovery plan for northern bobwhite in the United States (Dimmick et al. 2002). Iowa is in the Eastern tallgrass prairie Bird Conservation Region (BCR 22) and habitat restoration goals were established using prescriptions of suitable habitat derived from models defined in terms of landscape composition and configuration (Dimmick et al. 2002). Within BCR 22, habitat goals focus on creation of early successional habitat using practices such as prescribed burning and disking, creation of field borders and hedgerows, and conversion of cool-season grasses, primarily tall fescue (*Festuca* sp.), to native grasses and forbs. Habitat management plans should be derived from knowledge of the population ecology of the species, as well as hypotheses about critical stages in the annual cycle that are responsible for population declines (Sandercock et al. 2008). The consensus opinion throughout the bobwhite range is that nesting and brood-rearing habitats are major limiting factors (Dimmick et al. 2002), and the stated habitat objectives are a consequence of this assumption.

Several studies have investigated the effects of prescribed burning and strip disking techniques on vegetation and bobwhite use (Taylor et al. 1999*a*, Olinde 2000, Puckett et al. 2000, Taylor and Burger 2000), although few of these involved comparisons between landscapes managed primarily for bobwhite and those dominated by traditional production agriculture. Until recently, information on effects of microhabitat vegetation characteristics and landscape composition on nest survival has been lacking, particularly in the northern fringe of bobwhite breeding range (Taylor et al. 1999*b*). To address these limitations, our objective was to compare nest survival from 2003 to 2005 between a state-owned public area managed for bobwhite and an adjacent landscape devoted primarily to agricultural production and to evaluate the importance of landscape composition, spatial pattern, and microhabitat characteristics in explaining observed differences.

STUDY AREA

Our study sites were Lake Sugema Fish and Wildlife Area (LSWA) and Harrisburg Township (HT) located in Van Buren County in southeastern Iowa (Fig. 1). Lake Sugema Fish and Wildlife Area was a 1,464 ha public wildlife area with a 254 ha man-made lake. The remaining area consisted of grassland, pasture, crop fields, and timber. Approximately 263 ha were leased to private farmers and planted in wheat, soybean rotation, and hay. Lake Sugema Fish and Wildlife Area was open to hunting and fishing.

In 1997, the IDNR began an intensive bobwhite management regimen designed to increase local populations of northern bobwhites. Management techniques included strip

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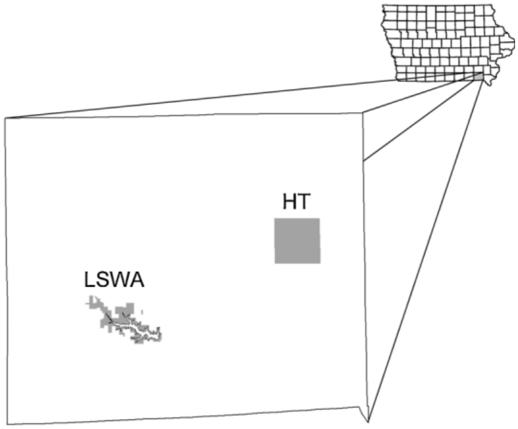

Figure 1. Map of study site locations in Van Buren County in southeastern Iowa, USA.

disking and strip herbicide application (hereafter disked strips), prescribed burning, edge feathering of timber stands and fence lines, and cultivated food plots. No major changes in management practices occurred during our study. In each year, approximately 200 ha were burned (range: 179–257), and approximately 23 ha of disked strips (range: 7–30) and 21 food plots totaling 20 ha were maintained on LSWA. Edge feathering increased from 1.1 km to 2.0 km.

The HT study site was a 2,360-ha area located approximately 16 km northeast of LSWA. We chose the HT study area because we expected that quail density was sufficient to meet sample size requirements and because it was sufficiently distant from LSWA to assume negligible movement of individuals between sites (Fies et al. 2002, Townsend et al. 2003). The HT area was primarily devoted to private agricultural production of corn and soybeans, planted in rotation, and hay. The remainder of HT consisted of grazed pasture, land enrolled in the Conservation Reserve Program (CRP), and timber. With the exception of 4 wildlife food plots planted by landowners to corn and soybeans, the HT area had not undergone any known habitat management for bobwhite populations.

METHODS

Land Cover

We used 2002 color infrared aerial photographs to classify the study sites into habitat types. We hand-digitized aerial photos and assigned habitat types to each patch >0.01 ha. We used ArcView GIS 3.3 to create an approximate 1.6-km buffer surrounding each site and classified patches within the buffer using the same procedure. We defined a habitat patch as an area that consisted of homogenous vegetation that differed from its surroundings (Otis 1998). We delineated 6 habitat types based primarily on vegetation structure characteristics: corn fields, grassland, pasture, roadside, early successional, and timber (Table 1). Early successional habitat on LSWA consisted of idle crop fields, small grain crop fields (wheat), food plots, and no-till soybeans, whereas most early successional habitat on the HT area consisted of no-till and conventionally tilled soybean fields (Minser and Dimmick 1988, Palmer et al. 2001). Early successional habitat was also characterized by dominance of bare ground and the presumed greater availability of invertebrates (Madison et al. 1995, Yates et al. 1995, Benson et al. 2007). Although corn fields also have high percentages of bare ground and canopy cover we did not include them in the early successional habitat type because insects are not as readily accessible to young chicks in corn fields (Minser and Dimmick 1988, Palmer et al. 2001), and we considered insect availability to be an integral characteristic of brood habitat (Sharpe et al. 2002, Smith and Burger 2005). We excluded lakes on LSWA from the total available habitat, and we collapsed farm ponds on LSWA and HT into the habitat category in which they were located. We ground-truthed all habitat categories in 2003, and we ground-truthed crop fields each year. We added polygons to the LSWA landcover for all disked strips and lines for edge feathering created or maintained in 2002–2005.

Field Methods

We used walk-in funnel traps (Stoddard 1931) from 1 February to 1 August to trap both males and females. From March to August, we captured unmarked females using nightlighting techniques (Labisky 1968, Potter 2006). We determined age and sex of all captured bobwhites, and we weighed and marked individuals with a unique #7 aluminum leg band. On a few occasions in late winter we chose only a subsample of individuals captured in coveys, but otherwise we fitted all individuals ≥150 g with a 5.9-g, mortality-sensing, pendant-style necklace radio transmitter (Advanced Telemetry Systems, Isanti, MN) and released them on site. All procedures were approved

Table 1. Classification and description of habitat types on Lake Sugema Wildlife Area (LSWA) and Harrisburg Township (HT) study areas during 2003–2005 in southeastern Iowa, USA.

Habitat types	Description	% Habitat type LSWA	% Habitat type HT
Cornfields	Crop field planted to corn	9.43	27.00
Grassland	Conservation Reserve Program (CRP) lands, haylands, idle[a], waterways	46.08	19.15
Pasture	Any field that has been grazed for agricultural purposes within ≤2 yr	11.17	10.43
Roadside	Adjacent land within ≤4 m of a blacktop or gravel road	1.31	0.97
Early Successional	Food plots, crop fields planted to soybeans, wheat, oats, or a Crop field that has not been seeded to crop for ≤2 yr	15.28	26.87
Timber	Woody cover	16.73	15.58

[a] Land that has not been cropped for ≥3 yr and not enrolled in the CRP.

by the Iowa State University Committee on Animal Care (2-3-5389-Q).

We systematically monitored radiomarked bobwhites every other day on average from 1 April to 31 October. To obtain a representative sample of diurnal habitat use by bobwhite, we stratified each day into 3 time blocks and recorded locations using the homing technique (White and Garrott 1990). We recorded $\geq$1 location within each time block every 7 days. We suspected the onset of incubation when we found an individual in the same location for 2 consecutive days during the breeding season. When a telemetry location indicated the adult was away from the suspected nest location, we visually confirmed the nest location and recorded clutch size and Universal Transverse Mercator (UTM) coordinates. We monitored incubation status $\geq$5 times a week and returned to the nest once every 7–10 days, or approximately twice during incubation, to monitor the status of the clutch.

Within 7 days of nest termination we measured vegetation height, and visually estimated total percent canopy coverage and relative percent canopy coverage, with overlapping percentages of grasses, forbs, woody vegetation <1 m in height, bare ground, and litter within a 50-cm $\times$ 50-cm sampling frame (modified from Daubenmire 1959) centered around the nest bowl. We placed a visual obstruction pole (Robel et al. 1970) directly in the nest bowl and recorded the visual obstruction reading (VOR) from a distance of 4 m in each cardinal direction. We recorded canopy coverage measurements at 2 m and 4 m in each cardinal direction. We recorded litter depth at 1 m, 2 m, 3 m, and 4 m along the same transects.

We used ArcView GIS 3.3 to generate the area and perimeter of each patch within a 13.8-ha buffer (Taylor et al. 1999*a*) centered on each nest site. From these patch statistics we calculated a set of covariates that characterized potentially important spatial attributes related to the amount of edge and habitat patchiness within the buffer (Table 2). To quantify landscape composition within the buffer, we calculated the percent of each habitat type, total number of patches, length of each habitat patch edge, nest patch edge density, and the coefficient of variation of patch area (Table 2). We also recorded habitat type and size of the nest patch.

Table 2. Definition of spatial covariates for a 13.8-ha area centered at each northern bobwhite nest site on Lake Sugema Wildlife Area and Harrisburg Township study areas during 2003–2005 in southeastern Iowa, USA.

Covariate	Description
TOT_PATCH	No. of patches
TOT_EDGE	Length of all patch edge (km)
CORN_EDGE	Length of corn patch edge (km)
ROAD_EDGE	Length of roadside patch edge (km)
PASTURE_EDGE	Length of pasture patch edge (km)
TIMBER_EDGE	Length of timber patch edge (km)
GRASS_EDGE	Length of grassland patch edge (km)
ES_EDGE	Length of early successional patch edge (km)
CV_PATCH_AREA	CV of patch area
NP_EDGE_DEN	Ratio of perimeter to area of nest patch (km/ha)

Nest Survival Modeling

We defined nest survival as the probability that a nest survived from the first day of incubation to the end of the 23-day incubation period. The 130-day nesting season began 15 May and ended 21 September in each year of our study. We assumed that we found all nests on day 1 of incubation. We estimated daily nest survival and the influence of several covariates using the Dinsmore et al. (2002) nest survival model in Program MARK (White and Burnham 1999). We used information-theoretic model selection procedures (Burnham and Anderson 2002) and a 2-stage modeling process. We first compared several models to evaluate if daily survival varied by either nest age or date of nest initiation and if there was either a linear time effect during the nesting season or a year effect. We used a logit link function and modeled nest age and season date as linear effects. We also included models with a study site effect alone and paired with each of the above effects. We used the model with the minimum value of Akaike's Information Criterion corrected for small sample size (AIC_c) for estimation of daily survival and nest survival.

For the second stage modeling, we took the best model from the first stage and created new models by adding 1 of 3 sets of covariates: microhabitat, percent habitat type composition within the nest buffer, and variables that characterize spatial attributes of the habitat within the buffer. We chose individual covariates within each set by using PROC GLM (SAS Institute, Inc., Cary, NC) to test for differences between study sites and between fates of nesting attempt for each covariate. We included microhabitat and composition covariates only if the fate effect was significant ($P < 0.10$) for that variable in the PROC GLM analysis. We included all buffer spatial metrics in one model, after eliminating one of any pair of variables that were highly (>0.8) correlated. To provide a basis for evaluation of the relative strength of second stage covariate effects, we also included in the model set the best model from the first stage. We used the model with the minimum AIC_c value for estimation of daily survival and nest survival.

RESULTS

We radiomarked 158 adult bobwhite ($n = 83$ on LSWA; $n = 75$ on HT) and monitored 67 nests ($n = 34$ on LSWA; $n = 33$ on HT) for success. The {Nest age, Site} model was the best model in the first stage model set. Nest age was the most important variable related to daily survival because its ΔAIC_c score was <1 and nest age was included in the top 4 models (Table 3). Daily survival rates decreased as nest age increased, but the decline was more severe at HT (Fig. 2). We calculated nest survival (S) for each study site as the product of the 23 daily survival rates and it was nearly twice as large at LSWA ($S = 0.495$, SE = 0.102) compared to HT ($S = 0.277$, SE = 0.072).

Potentially important microhabitat covariates from the PROC GLM analyses were VOR and percent forb canopy cover, and the microhabitat model included a Site interaction parameter because of a significant Fate $\times$ Site interaction in the PROC GLM analysis (Table 4). Percent Early

Table 3. Model selection results of the first phase analysis of daily nest survival of northern bobwhite during 2003–2005 in southeastern Iowa.

Model	ΔAIC_c[a]	No. of parameters	Deviance[b]	AIC_c wt
{Site, Nest age}	0.00	3	275.08	0.48
{Nest age}	0.97	2	278.06	0.30
{Site, Nest age, Year}	2.68	5	273.74	0.13
{Nest age, Year}	3.26	4	276.33	0.09
{Time trend}[c]	12.75	2	289.84	<0.01
{Site}	12.86	2	289.95	<0.01
{Site, Time trend}	12.92	3	288.01	<0.01
{Constant}[d]	13.36	1	292.46	<0.01
{Site, Nest initiation}	14.44	3	289.52	<0.01
{Nest initiation}	14.59	2	291.69	<0.01
{Site, Year}	15.79	4	288.86	<0.01
{Year}	16.07	3	291.15	<0.01

[a] ΔAIC_c is the difference in value between each model and the lowest ΔAIC_c model.
[b] Deviance is the difference in -2 ln(Likelihood) of the current model and -2 ln(Likelihood) of the saturated model.
[c] Trend in daily survival over the nesting season.
[d] Daily survival rate is equal for all days.

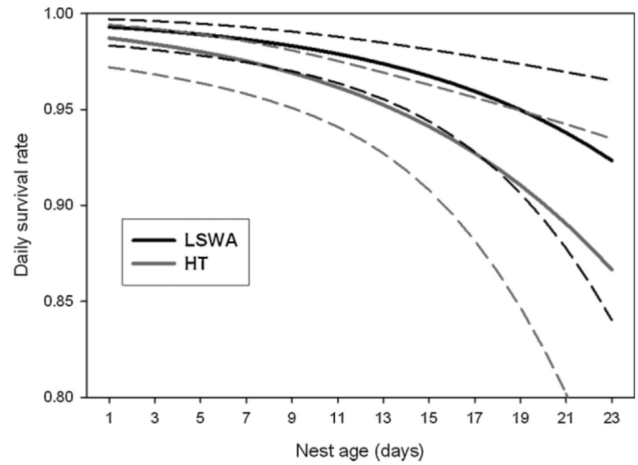

Figure 2. Northern bobwhite nest daily survival rates and confidence intervals (dotted lines) as a function of nest age at Lake Sugema Wildlife Area (LSWA) and Harrisburg Township (HT) study sites in southeastern Iowa, USA, 2003–2005.

Successional and Timber in the nest buffer were potential predictors in the composition model; we also included a Site interaction parameter in this model. In the second modeling phase the covariate model with Microhabitat × Site interaction variable was strongly supported by the data (Table 5). Examination of individual microhabitat covariate coefficients revealed that only percent forb cover at the HT site had a significant positive influence ($\hat{\beta} = 0.033$; 95% CI: 0.003–0.063) on daily survival rate (Fig. 3). Successful HT nests had twice the average forb cover (38%) as unsuccessful nests (19%), whereas successful nests on LSWA had an average forb cover of 27% and failed nests had an average of 36% cover. Models with habitat composition and spatial covariates measured within nest buffers were not predictive of nest success (Table 5).

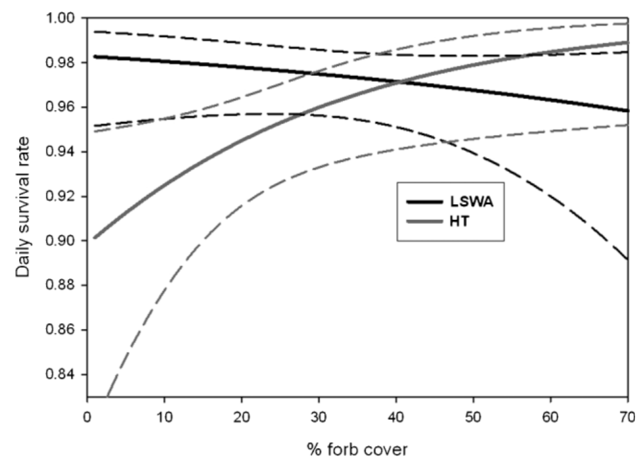

Figure 3. Northern bobwhite nest daily survival rates and confidence intervals (dotted lines) as a function of percentage nest site forb canopy cover at 13 days of incubation at Lake Sugema Wildlife Area (LSWA) and Harrisburg Township (HT) study sites in southeastern Iowa, USA, 2003–2005.

Table 4. Mean and standard deviation of covariates used in nest survival models for Lake Sugema Wildlife Area (LSWA; $n = 34$) and Harrisburg Township (HT; $n = 33$) study sites: nest site visual obstruction reading (VOR; cm) and percentage Forb cover (Forb), and percentage Early Successional (ES) and percentage Timber in the nest buffer, 2003–2005.

		VOR (cm)		Forb		ES		Timber	
Site	Fate	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
LSWA	Successful	54.3	28.2	26.8	18.3	20.5	21.1	11.4	14.3
	Unsuccessful	61.4	32.7	36.4	25.1	10.4	14.2	18.5	17.3
HT	Successful	63.8	25.4	37.9	22.4	14.4	17.7	18.2	12.6
	Unsuccessful	50.4	25.6	19.4	16.9	12.9	16.2	12.6	12.3

Table 5. Model selection results of the second phase analysis of daily nest survival of northern bobwhite during 2003–2005 in southeastern Iowa.

Model	ΔAIC_c[a]	No. of parameters	Deviance[b]	AIC_c wt
{Site, Nest age}	0.00	3	275.08	0.50
{Site, Nest age, Microhabitat × Site}[c]	0.54	7	267.55	0.38
{Site, Nest age, Composition × Site}[d]	2.82	7	269.84	0.12
{Site, Nest age, Spatial}[e]	11.04	12	267.88	<0.01

[a] ΔAIC_c is the difference in value between each model and the lowest ΔAIC_c model.
[b] Deviance is the difference in -2 ln(Likelihood) of the current model and -2 ln(Likelihood) of the saturated model.
[c] Microhabitat covariates were Visual Obstruction Reading and % Forb.
[d] Composition covariates were % Early Successional and % Timber in nest buffer.
[e] Spatial covariates are defined in Table 2.

DISCUSSION

We documented a decline in daily nest survival as the incubation period progressed. The decline may be associated with daily feeding excursions made by the incubating adult. These daily movements may also increase scent and sign surrounding nest locations, which results in higher probabilities of detection by predators (Fields et al. 2006). However, the decrease in daily nest survival was more severe in the study site dominated by private agricultural production (HT) than in the publically owned study site managed for bobwhite (LSWA). As a result, the nest survival estimate at HT fell below the range of estimates (34–59%) reported in southern Illinois (Klimstra and Roseberry 1975), southern Iowa (Suchy and Munkel 1993), northern Missouri (Burger et al. 1995), Nebraska (Taylor et al. 1999*a*,), and Oklahoma (Cox et al. 2005), whereas nest survival in the managed landscape was comparable to these previously published estimates.

Greater nest survival on LSWA is coincident with greater availability of putative nesting habitat (i.e., grassland and roadside; LSWA: approx. 50% vs. HT: approx. 20%). Study sites used by Burger et al. (1995) had about 40% suitable nesting habitat, and Taylor et al. (1999*a*) sites had 50% and 90% suitable nesting habitat, and these authors suggested that their results might not be applicable to sites with much less suitable habitat. We speculate that the proportion of suitable habitat on LSWA was sufficient to dilute ambient predation pressure (Greenwood et al. 1995, Kuehl and Clark 2002), whereas suitable habitat at HT was less than a necessary threshold.

We documented different relationships in our 2 study sites between nest survival and nest forb canopy cover. Nest survival at the HT site was strongly associated with increased forb canopy cover, but we found no association at the LSWA site. Successful nests on HT had twice the average forb cover (38%) as unsuccessful nests (19%), although both successful and failed LSWA nests had higher percentages of forb canopy than HT failed nests. Increased canopy cover that promotes nest concealment has been associated with providing increased visual and olfactory protection from predators (Mankin and Warner 1992, Patterson and Best 1996). Lusk et al. (2006) argued that nest canopy height and shrub cover were important in nest selection and success of bobwhite in Oklahoma and more generally inferred that any of a suite of vegetation characteristics that increase nest concealment was advantageous. Collins et al. (2009) also suggested that covariates related to concealment were important in nest site selection of bobwhite in New Jersey. We note that total canopy coverage and grass canopy coverage did not differ between sites or nest fate categories. Thus, we suggest that the increased functional plant diversity provided by additional forb canopy coverage increased nest concealment and thereby served to mitigate for generally reduced nest survival in a typical Midwestern agricultural landscapes that contained limited suitable nesting habitat.

MANAGEMENT IMPLICATIONS

Nest success in LSWA was well within generally acceptable bounds of sustainable populations, but we did not find associations between any of the covariates we measured within the 13.8-ha nest site buffers and nest success. We thus infer that these attributes were adequately available and of sufficient quality to achieve good nest success on the managed LSWA site. Conversely, we suggest that managers consider practices that strive to provide $\geq$40% forb cover in nesting habitat in landscapes dominated by production agriculture. Further investigation of differences in bobwhite density, chick survival, and predator-landscape interactions between managed and unmanaged landscapes is essential to increase our ability to provide recommendations to managers and private landowners interested in increasing bobwhite populations within agricultural landscapes.

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