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DEPREDATION PATTERNS AND NORTHERN BOBWHITE NEST SUCCESS IN FIELD BORDERS

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ABSTRACT

Northern bobwhite (*Colinus virginianus*) populations have declined because of habitat loss and fragmentation. Field borders provide additional habitat for northern bobwhites and other wildlife that depend on early-succession habitat. However, their proximity to woods as well as other edge types may result in increased bobwhite nest depredation. We examined if northern bobwhite nest survival in field borders decreased with increasing proximity to edges such as woods, crop fields, ditches, and roads; effects of year, camera presence, and field border width also were considered. We examined if snakes are the primary nest predator with 24-hr video camera surveillance. We searched for and monitored northern bobwhite nests on $\sim$ 77 ha of field borders in southeast North Carolina during summers 2010 and 2011. We found 26 nests and monitored them every 3–4 days. Fourteen nests were monitored with cameras. We built nest survival models using the covariates of distance to nearest woody edge, crop field, ditch, and road as well as year, camera effect, and field border width. The most explanatory model was constant northern bobwhite nest survival with an estimated daily nest survival $\pm$ SE of 0.9512 $\pm$ 0.0119 (AIC*c* weight = 0.23). Models with covariates suggested similar daily nest survival rates. Four snake and two mammalian predation events were recorded on camera. Distance to edge types and field border width did not appear to influence the outcome of nests in an agriculture-dominated landscape. Thus, landowners and managers in an agriculture-dominated landscape may have flexibility with field border placement and distance to edge type as they relate to nest success.

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Key words: *Colinus virginianus*, field borders, nest predators, nest survival, North Carolina

INTRODUCTION

Northern bobwhites have been declining over the past few decades and these declines are primarily attributed to habitat loss and fragmentation (Vance 1976, Brennan 1991, Hunter et al. 2001, Brennan and Kuvlesky 2005). Field borders, a strip of planted native or volunteer vegetation on the edge of a crop field, have been proposed as a conservation tool to aid in reversing this declining trend. Numerous studies have shown field borders have been beneficial in providing suitable habitat for bobwhites. For example, summer and fall bobwhite abundance increased with establishment of field borders (Bromley et al. 2002, Palmer et al. 2005, Riddle et al. 2008). Additionally, more bobwhite nests were found on farms with field borders than farms without field borders (Puckett et al. 1995).

The effectiveness of field borders as a successful management tool can vary due to characteristics including field border shape, width, or the surrounding landscape context. For example, Riddle et al. (2008) found that northern bobwhite populations increased on farms with both linear and non-linear borders in agriculture-dominated landscapes and only on farms with non-linear field borders in forest-dominated landscapes. Greater avian abundance and richness of overwintering birds were found in wide field borders compared to narrow field borders (Conover et al. 2007), and nearly twice the density of breeding birds was found in wide field borders as opposed to narrow field borders (Conover et al. 2009). Distance to differing edge types is another factor that could impact the effectiveness of a field border in providing adequate habitat, and especially nesting habitat, for northern bobwhites.

Field borders, by definition, are along edges that are adjacent to other features such as woods, roads, and ditches. Many studies have investigated the relationship between edge effects and breeding songbirds but few studies have examined the relationship between edge and breeding northern bobwhites. Increased depredation rates of songbird nests have been observed along field edges (Gates and Gysel 1978, Andren and Anglestam 1988, Marini et al. 1995), potentially making field borders unsuitable for producing high nest success. This could be due to predators using edges for foraging or as travel lanes between different habitats (Bider 1968, Pedlar et al. 1997, Dijak and Thompson 2000). Nest depredation already is a significant source of nest failure for bobwhite populations (Stoddard 1931, DeVos and Mueller 1993, Puckett et al. 1995, Conover 2005), and field borders could increase this risk through negative edge effects.

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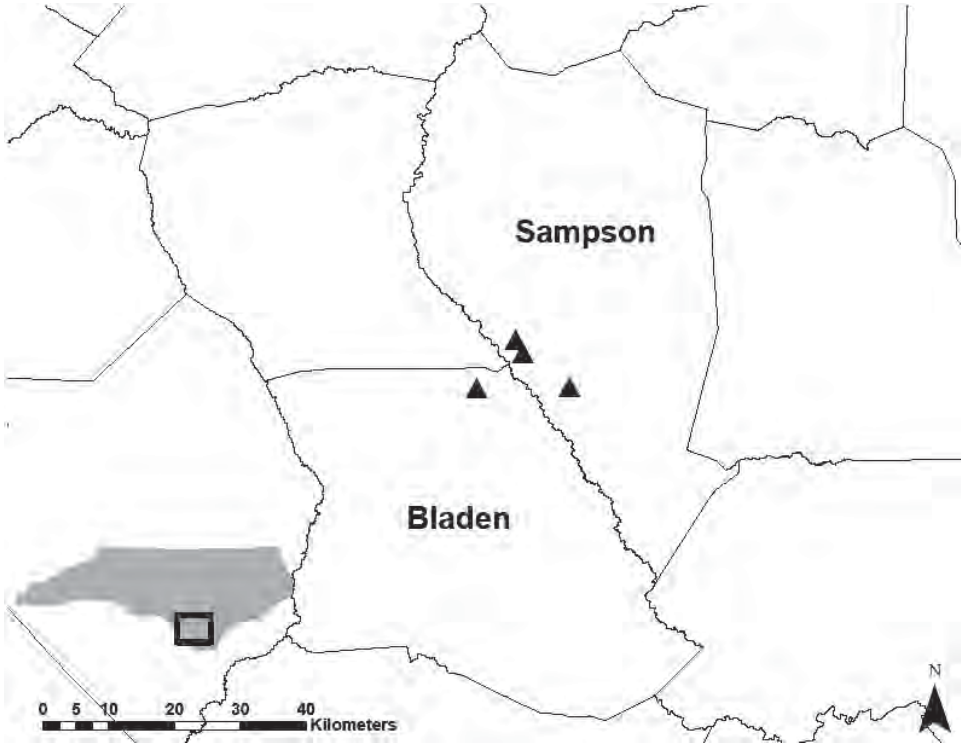

Fig. 1. Locations of farms studied in Bladen and Sampson counties, North Carolina, USA.

The composition of the predator community depends upon the region and habitat. Studies including real and artificial nests have shown that mammals are major nest predators of northern bobwhites (Klimstra and Roseberry 1975, DeVos and Mueller 1993, Hernández et al. 1997, Fies and Puckett 2000, Staller et al. 2005, Rader et al. 2007b). However, Puckett et al. (1995) reported snakes were the primary nest predators on their study farms. Other studies also have found snakes to be important predators of bobwhite nests (Stoddard 1931, Burger et al. 1995, Staller et al. 2005). This could be due to selective snake use of edges as opposed to other landscape features (Weatherhead and Charland 1985, Blouin-Demers and Weatherhead 2001, Sperry et al. 2009). Riddle and Moorman (2010) speculated that black rat snakes (*Elaphe obsoleta*) may be a main predator of songbird nests in southeastern North Carolina based on signs of predation. However, this could not be confirmed because they did not monitor nests with cameras.

The relationship between predators, landscape context, and edge effects needs to be studied further to better manage bobwhite populations (Rollins and Carroll 2001, Burger 2002, Riddle et al. 2008). This is particularly true for managing northern bobwhites in field border habitats as there is a lack of research linking northern bobwhite nest success in field borders to proximity to woody edges and other edge types.

Our objectives were to ascertain: (1) if nests of northern bobwhites in field borders were more likely to fail if they were closer to woody, crop, ditch, and road edges, and (2) if snakes were the primary nest predators of northern bobwhites in field borders. We hypothesized the closer nests were to edge types, the more likely they were to fail. We also hypothesized that snakes were the main nest predator.

STUDY AREA

Our study sites consisted of ~ 77 ha of field borders on four commercial hog farms in Bladen and Sampson counties in southeast North Carolina (Fig. 1). The agricultural land on the farms mainly was used to grow soybeans, corn, and winter wheat. Three of the farms were smaller in size totaling ~ 312 ha and the fourth farm was ~ 1,619 ha.

Field borders were maintained in an early-successional state which distinguishes them from other areas bordering crop fields. Specifically they were disked, mowed, and treated with herbicide when needed to keep them in an early-successional state. About 5 ha of field borders were used for this study on the three smaller farms and ~ 72 ha of field borders on the larger farm. We used only those field borders adjacent to crop fields on at least 1 side and selected 141 linear and 24 non-linear field borders for this study. Linear field borders were spatially arranged around the crop fields, often being on 1 or more sides of a crop field at varying lengths. Linear borders were ~ 0.41 ± 0.34 ha (mean ± SD) in size and varied in length (509.08 ± 305.25 m) and width (9.02 ± 6.40 m). A non-linear field border was an irregularly-shaped field border and averaged 0.80 ± 0.72 ha in size. Most field borders contained marestail (*Conyza canadensis*), dog fennel (*Eupatorium capillifolium*), little bluestem (*Schizachyrium scoparium*), blackberry (*Rubus* spp.), salt myrtle (*Baccharis halimifolia*), and other herbaceous or grassy vegetation. A few non-linear field borders were composed of mostly planted native warm season grasses including big bluestem (*Andropogon gerardii)*, little bluestem, and switchgrass (*Panicum virgatum*).

METHODS

Nest Searching

We separated individual field borders into 2 groups at the beginning of each field season: one comprised of field borders on the larger farm and one of field borders on the 3 smaller farms. Separating the larger farm and the smaller farms into 2 different groups allowed the area of field borders searched on the 3 small farms to be proportional with those searched on the larger farm. This reduced the chance of searching one field border in a farm group more than another. We searched the field borders in each group in a random order. We paired field borders separated by a ditch for searching purposes. We searched each field border at least twice in 2010 and at least 4 times in 2011.

We searched for nests in each field border systematically, using behavioral cues from birds, and opportunistically. We systematically searched each field border thoroughly by walking transects through the entire field border and looking for nests. We also used behavioral cues such as vocalizations and flushes while we were systematically searching or performing other duties. We found nests opportunistically when one was encountered while we were performing activities such as monitoring an active nest or setting up a camera.

We simultaneously searched paired field borders that were separated by a ditch (if applicable). Two people either searched linear borders parallel to the ditch on the same side or on opposite sides of the ditch until each field border was completely searched. Searches in non-linear borders depended on shape of the border. Each person either started on opposite ends of the non-linear field border and walked parallel lines toward each other or both people walked side by side. We recorded the stage of the nest and the number of eggs present for all nests located.

Nest Monitoring

We monitored nests every 3 to 4 days and tried not to destroy vegetation or leave a trail (Martin and Geupel 1993). We recorded the stage of progress at each nest check as well as how many eggs were present, and any other comments relevant to parental behavior and the eggs. This information helped us identify when the young fledged if it was successful.

Camera Set-up

We randomly selected half of all nests found for cameras. We placed a camera at the nest once it was selected during the next designated nest check for that particular farm. The camera setup included a small bullet camera (PC506-IR Color weatherproof infrared camera Supercircuits; Austin, TX, USA), a digital video recorder (DVR, SVAT CVP800 Mini Portable DVR Digital Video Recorder with MPEG4 Compression; SVAT Electronics, Niagara Falls, ON, Canada), and batteries. We attached the camera to a PVC pipe $\sim$ 1.5 m from the nest at the appropriate height based on the amount of surrounding vegetation. We chose the best angle to ensure the camera had a clear view of the nest without destroying vegetation which could make the nest more visible to predators.

We connected a closed-circuit television (CCTV) video/power cable from the camera to the DVR and 2, 12-volt 33-amp hr batteries contained in a sealed bucket. The bucket also contained a voltage regulator and harness which attached the batteries to the DVR and camera. We used 16 gigabyte secure digital (SD) cards throughout the entire season to store the video data collected from each nest. We changed the SD cards and batteries every 3–4 days during routine nest monitoring activities. We placed 2 humidity sponges in the bucket to prevent moisture buildup. We placed the bucket $\sim$ 8 m from the camera and under as much vegetation as possible for concealment and to reduce exposure to the weather. We placed a sheet of burlap over the bucket to provide camouflage and prevent overheating of the bucket contents. We encased the cable in heavy duty piping to prevent exposure from the weather and from being chewed by animals. Nests were recorded continuously at 8 frames/sec on high mega pixel quality with no audio.

Edge Sampling

We recorded the width of the border and distance from each nest to the closest woody, ditch, and crop edge once the outcome of the nest was known. We measured field border width for both linear and non-linear field borders by walking from the nest to both the crop side of the field border and the other side of the field border which was usually a woody, ditch, or road edge. We measured distance to the closest woody edge using a range finder at the nests. We used the measuring tool in ArcGIS to measure the distance to the closest road for every nest.

Data Analysis

We used Program MARK (White and Burnham 1999) to analyze the collected nest data via the daily nest survival option. Specifically, Program MARK uses the number of exposure days, number of nest failures, and the last day a nest was known to be active to estimate daily nest survival. However, unlike traditional methods that use exposure days (e.g., the Mayfield method; Mayfield 1961, 1975), Program MARK allows covariates on individual nests (model development in Dinsmore et al. 2002). We built nest survival models using 7 covariates to test our hypotheses: distance to closest woody, crop, ditch, and road edge as well as field border width, camera effect, and year effect. Each model included one of the covariates. We also included a null model (i.e., one with

Table 1. AIC model results from Program MARK including AIC*c* statistics, point estimates of survival (Ŝ), and standard error. S(.) represents constant nest survival. The other covariates are year effect (S(Year)), camera effect (S(Camera)), distance to closest crop (S(Distance to crop)), distance to closest ditch (S(Distance to ditch)), distance to closest woody edge (S(Distance to woody edge)), distance to closest road (S(Distance to road)), and field border width (S(Field border width)). All data were collected from nests in field borders on farms in Bladen and Sampson counties, North Carolina, USA.

Model description	AIC*c*	AIC*c* Weight	No. Parameters	Deviance	Ŝ	SE
S(.)	89.79	0.23	1	87.77	0.9512	0.0119
S(Year)	90.27	0.18	2	86.23	0.9516	0.0120
S(Camera)	91.08	0.12	2	87.04	0.9508	0.0120
S(Distance to crop)	91.23	0.11	2	87.19	0.9493	0.0125
S(Distance to ditch)	91.31	0.11	2	87.27	0.9540	0.0127
S(Distance to woody edge)	91.53	0.10	2	87.49	0.9521	0.0120
S(Distance to road)	91.81	0.08	2	87.77	0.9511	0.0120
S(Field border width)	91.81	0.08	2	87.77	0.9513	0.0123

constant nest survival) for a total of 8 models. Program MARK uses an information-theoretic approach to facilitate model selection. Daily survival rates and distance summaries are presented as mean ± SE.

We used a Chi-square goodness of fit test ($\alpha > 0.05$) to examine if snakes were the main nest predators. This was done by placing predators caught on camera into three main predator groups (snake, mammalian, and avian) for comparison.

RESULTS

Twenty-six nests were found in 2010 and 2011 for a total of 297 exposure days. Seventeen nests failed during the study. The top 2 models in Program MARK were constant nest survival and year effect, (AIC*c* weight = 0.23 and 0.18, respectively; Table 1). All covariates had betas with 95% confidence intervals that overlapped zero, resulting in little contribution to the slope. Daily nest survival for the constant nest survival model was 0.9512 ± 0.0119, 95% CI = 0.9218-0.9699). The model averaged estimate for daily nest survival was 0.9514 ± 0.0121, 95% CI 0.9211–0.9704).

Average distance to woody edge in relation to nest location was 403.6 ± 271.3 m while average distance to closest crop, ditch, and road was 35.2 ± 4.8, 8.8 ± 18, and 168.5 ± 142.8 m, respectively (Table 2). The average field border width at each nest location was 13.4 ± 16.9 m.

Cameras were placed at 14 nests between 2010 and 2011 (Table 3). Four snake (3 king snake [*Lampropelitis getula getula*] and one unidentifiable snake) and two Virginia opossum (*Didelphis virginiana*) were captured on cameras in predation events ($\chi_2^2 = 4.0$, $P = 0.14$). Eggs in 6 nests monitored with cameras successfully hatched and 2 nests were abandoned.

Table 2. Average, minimum, and maximum distances (m) from nests to closest woody, crop, ditch, and road edges. All data were collected from nests in field borders on farms in Bladen and Sampson counties, North Carolina, USA.

Edge type	Average	Minimum	Maximum
Woody	403.6	13.0	942.0
Ditch	8.8	0.8	87.0
Crop	5.2	0.4	16.0
Road	168.5	8.1	525.0

DISCUSSION

Constant daily nest survival was the most competitive model. There appeared to be considerable model uncertainty because the 7 covariates had little effect on estimation of daily nest survival. Daily nest survival estimates had small SEs and were similar across all models indicating our estimates were stable and that proximity to edges as well as field border width, year effect, and camera effect did not influence the outcome of nests in field borders. We had similar results with indigo bunting (*Passerina cyanea*) and blue grosbeak (*P. caerulea*) on these farms, which suggests a trend among both ground and shrub nesting birds (unpublished data). Our model-averaged daily nest survival estimate for bobwhites (0.9514, 95% CI = 0.9211–0.9704) was similar to mean daily nest survival rates from Burger et al. (1995) and Rader et al. (2007a) which ranged from 0.9458 to 0.9692.

Woody edges, on average, were farther from nests than any of the other 4 edge types, and only 7 of our nests were < 200 m from a woody edge. Therefore, nests tended to be far from woody edges, and predators that come from the woods would have to travel substantial

Table 3. Camera identification of nest outcome from 2010 and 2011 field seasons. All data were collected from nests in field borders on farms in Bladen and Sampson counties, North Carolina, USA.

Outcome	2010	2011	Totals
Predator			
Virginia opossum	1	1	2
King snake	1	2	3
Unidentifiable snake	0	1	1
Abandoned	1	1	2
Successful	2	4	6

distances to depredate a nest. Landscape context may have influenced this distance pattern.

All northern bobwhite nests located during our study were in field borders on the large farm which was in an agriculture-dominated landscape as opposed to field borders on the 3 smaller farms which were in a forest-dominated landscape. Field borders in an agriculture-dominated landscape could be providing more preferable nesting habitat or simply nesting habitat in a more favorable landscape context. This may help explain why Riddle et al. (2008) found that breeding season bobwhite abundance almost doubled on farms in agriculture-dominated landscapes as opposed to forest-dominated landscapes after establishment of field borders.

Nest predation was a more common cause of nest failure than abandonment (56 vs. 44%, respectively). Snakes depredated twice as many nests as other taxa, but this was not statistically significant, likely due to our small sample size with cameras.

Studies have shown different primary predators of northern bobwhite nests and those without cameras have speculated snakes were the main nest predators due to evidence left after depredation (Burger et al. 1995, Puckett et al. 1995). Previous camera studies involving bobwhite nests have shown a variety of primary predators. Staller et al. (2005) found common raccoons (*Procyon lotor*) were the primary nest predator in Florida and Georgia while Rader et al. (2007b) found coyotes (*Canis latrans*) were the primary nest predators in Texas. Fies and Puckett (2000) found striped skunks (*Mephitis mephitis*) most frequently depredated artificial bobwhite nests in Virginia. Hernández et al. (1997) found raccoons were the most frequent predator of artificial nests in Texas. King snakes depredated bobwhite nests 3 times in our study. King snakes were also a frequent predator of songbird nests in a field setting (Thompson et al. 1999), but have not previously been shown to be an important predator of northern bobwhite nests to our knowledge.

Our findings should be viewed with caution as we only had 26 nests in our study and only 14 nests with cameras. Future studies should focus on acquiring a larger sample size to gain a more accurate representation of the predator community in particular areas and to more thoroughly examine distances to difference edge types. The predator community needs to be compared between forest and agriculture-dominated landscapes to examine for differences.

MANAGEMENT IMPLICATIONS

Distance to edges did not appear to influence bobwhite nest success in our study. Thus, landowners and managers appear to have flexibility with field border placement relative to the edge types we considered in an agriculture-dominated landscape. This could allow more field borders to be established without having the concern of whether edge will negatively affect nest success for bobwhites. Establishing more field borders should benefit bobwhite populations and also other wildlife. We found no bobwhite nests on farms in a forest-dominated landscape and recognize our recommendations for field border placement may not apply to that type of landscape.

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