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Danielle J. Berger
University of Nebraska-Lincoln, danielle.berger@huskers.unl.edu

Jessica N. Piispanen
University of Wisconsin-Stevens Point

Tim F. Ginnett
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Jason D. Riddle
University of Wisconsin - Stevens Point

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NORTHERN BOBWHITE NEST SITE SELECTION IN FIELD BORDERS

Danielle J. Berger[1]
College of Natural Resources, University of Wisconsin – Stevens Point, Stevens Point WI 54481, USA

Jessica N. Piispanen
College of Natural Resources, University of Wisconsin – Stevens Point, Stevens Point WI 54481, USA

Tim F. Ginnett
College of Natural Resources, University of Wisconsin – Stevens Point, Stevens Point WI 54481, USA

Jason D. Riddle
College of Natural Resources, University of Wisconsin – Stevens Point, Stevens Point WI 54481, USA

ABSTRACT

Field borders are used to supplement early successional habitat critical for northern bobwhite (*Colinus virginianus*) nesting that is lost to modern intensive agricultural practices. The suitability of field border habitat for nesting may be affected by microhabitat characteristics at the site and patch scale and placement relative to various land-cover types at the landscape scale. We sought to determine whether bobwhite select nest locations at site, patch, and landscape scales. We collected microhabitat data (stem density, percent cover, and ground composition) and distance to land-cover type data (woody edge, crop, ditch, and road) from 26 bobwhite nests and 26 control sites in field borders in North Carolina, USA, during 2010 and 2011. We modeled nest site selection by comparing nests with random locations using conditional logistic regression at the site scale and logistic regression at the combined patch–landscape scale. We performed model selection using the small sample Akaike's Information Criterion (AIC_c). The top site-scale model showed that bobwhite selected for the presence of woody cover and avoided open soil at the nest. There was no clear top model at the combined patch–landscape level. In an agriculture-dominated landscape, managers should focus on microhabitat characteristics of field borders to improve suitability for bobwhite nesting.

Northern bobwhite (*Colinus virginianus*) are associated with diverse, patchy landscapes predominated by large, open expanses and abundant woody edge (Rosene 1969, Roseberry and Klimstra 1984, Roseberry and Sudkamp 1998). Within these landscapes, bobwhite require microhabitats supported by the various stages of succession for survival and reproduction (Ellis et al. 1969). However, modern intensive agricultural practices adopted throughout much of the bobwhite's native range have reduced landscape heterogeneity (Warner et al. 2012). The precipitous decline of bobwhite populations over the past several decades (Sauer et al. 2014) can, in part, be attributed to this loss of early successional habitat (Guthery 1997, Hunter et al. 2001, Dimmick et al. 2002, Brennan and Kuvlesky 2005, Veech 2006).

Field borders—herbaceous buffers between cropland and adjacent cover types—may provide supplemental early successional habitat and increase bobwhite abundance in agricultural regions (Smith et al. 2005, Stamps et al. 2008, Doxon and Carroll 2010, Blank et al. 2011, Bowling et al. 2014). Summer and autumn bobwhite abundance was greater on farms in North Carolina, USA, after the establishment of field borders (Bromley et al. 2002, Palmer et al. 2005, Riddle et al. 2008, Bowling et al. 2014). Increases in the number of nesting attempts, improved nest success, or a combination of these 2 aspects of reproduction may be responsible for larger bobwhite populations on farms where field borders are present (Richardson 2016). More bobwhite nests were found on farms where field borders were implemented than on farms where field borders were not present with no difference in nest success between the 2 treatments (Puckett et al. 1995).

The suitability of field border habitat for bobwhite nesting is likely influenced by micro and macrohabitat variables operating simultaneously at multiple scales. Bobwhite avoid bare soil at the nest site throughout their range (Taylor et al. 1999, Townsend et al. 2001, Lusk et

al. 2006, Rader et al. 2007). The vegetation at the nest is generally taller (Taylor et al. 1999, Arrendondo et al. 2007, Rader et al. 2007), denser and composed of more strata (Townsend et al. 2001, Arrendondo et al. 2007, Rader et al. 2007, Collins et al. 2009). Bobwhite seem to favor nesting locations that offer greater concealment than the preponderance of available habitat, but there is little evidence to support that the structure of vegetation differs between successful and unsuccessful nests (Townsend et al. 2001, Rader et al. 2007). Bobwhite have not been observed to exhibit selection for microhabitat variables at a patch scale in association with nesting (Taylor et al. 1999). No studies to date have focused on bobwhite nest placement in field borders relative to land-cover types. However, nest placement near field–forest ecotones, which are common in agricultural landscapes, has been shown to adversely impact success in other species (Gates and Gysel 1978).

None of the previous nest-site selection research was conducted in field borders habitat. Selective pressures that drive nest placement in field borders may differ from the larger, contiguous habitats of prior studies. Nest depredation risk and microclimate stressors are likely intensified in field borders habitat. Increased edge presence in field borders and potential use as travel corridors by predators, facilitated by the linear shape of the habitat and persistence in a disturbed landscape may collectively result in greater depredation risk than contiguous habitat (Shalaway 1985, Camp and Best 1994, Pedlar et al. 1997, Clark and Bogenschutz 1999, Dijak and Thompson 2000). The recruitment potential of field borders may be outweighed by increases in predator density if the habitat has utility for multiple species (Puckett et al. 1995). Microclimate characteristics of field borders may also influence nest placement. The planting or harvest of adjacent crops or accidental application of herbicide could induce thermal stress that would decrease the probability of nest success (Carroll et al. 2015). Bobwhite nesting decisions at multiple scales are likely reflective of both selective pressures.

A better understanding of the interaction between habitat placement within the landscape matrix, microhabitat composition at the patch and nest level, and the relationship of these variables to nest success is critical to continued recovery efforts for bobwhite (Duren et al. 2011). Knowledge of landscape-level effects is of great importance to the implementation of supplemental habitat (Riddle et al. 2008, Bowling et al. 2014) whereas awareness of favorable microhabitat characteristics is essential to field border maintenance (Greenfield et al. 2002). Field border management must be informed because of the significant investment of monetary and technical resources required to create and maintain this supplemental habitat.

Our study sought to model bobwhite nesting decisions in field border habitat at 3 spatial scales. Our objectives were to determine whether, 1) at the site level, microhabitat variables influenced nest placement relative to the immediately adjacent habitat, 2) at the patch level, microhabitat variables influenced utilization of field border for nesting, 3) at the landscape level, distance to various cover types influenced utilization of field border for nesting. We hypothesized that top models at the site and combined patch–landscape scale would include structural and compositional microhabitat parameters that contribute to greater concealment at the nest site. We also hypothesized that the most competitive patch–landscape scale model would demonstrate avoidance of woody edges.

STUDY AREA

We conducted our study on a 1,619-ha Murphy-Brown, LLC., agro-industrial hog farm located in Bladen County, North Carolina, a part of the southeastern Coastal Plain. Our study site consisted of approximately 72 ha of field borders maintained in an early successional shrub–grassland mixed state through a combination of disking, mowing, and selective herbicide application. All field borders were adjacent to a crop field on ≥1 edge. Crop land on the farm was cultivated rotationally on an annual basis between soybeans, corn, and winter wheat. We selected 141 linear and 24 nonlinear field borders for use in this study. Linear field borders separated or defined the periphery of the agricultural fields. Linear borders were approximately 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). Nonlinear field borders were irregularly shaped field corners. They averaged 0.80 ± 0.72 ha in size. The predominant vegetation in the field borders was marestail (*Conyza canadensis*), dog fennel (*Eupatorium capillifolium*), little bluestem (*Schizachyrium scoparium*), blackberry (*Rubus* spp.), salt myrtle (*Baccharis halimifolia*), and other herbaceous or grassy species. The species composition was the result of a mixture of plantings and natural germination after agricultural cessation. A few nonlinear field borders were composed of planted native warm season grasses, including big bluestem (*Andropogon gerardii*), little bluestem, and switchgrass (*Panicum virgatum*).

METHODS

Nest Searching

We searched field borders for bobwhite nests ≥2 times in 2010 and ≥4 times in 2011. During each search rotation, we selected field borders in a random order. However, field borders separated by a ditch were paired for searching to minimize disturbance to the adjoining border. We searched each field border systematically by walking parallel transects and carefully parting the vegetation with sticks to detect the presence of nests. Each observer searched an area equal to their arm length on both sides of the transect. We walked as many transects as was necessary to thoroughly search the entire field border. We intensified our search in areas where behavioral cues, such as bobwhite vocalizations and flushes, indicated likely nest presence. Nests encountered opportunistically while achieving other research objectives were also included in the study. We were alerted to

the presence of one nest through behavioral indicators and encountered another opportunistically over the course of 2 field seasons.

Linear field borders separated by a ditch were searched by a pair of individuals each walking parallel transects on the same side of the channel in wide borders or opposite sides in narrow borders. The search strategy for nonlinear field borders was dependent on the border's overall geometry. Two individuals either started on opposite ends of the field border, walking parallel transects until converging in the center, or both individuals walked side by side canvasing the entirety of the area. If we found a nest, we marked the site approximately 3 m away with flagging tape and recorded the location with a handheld Global Positioning System (GPS) unit. We also marked vegetation that had the characteristic covered dome construct of a bobwhite nest, but only treated these sites as nests if we encountered an egg during the next observational period. We monitored nests periodically until a success, failure, or abandonment outcome could be determined, after which we measured vegetation characteristics and proximity to landscape-level features at each site (Westmoreland and Best 1985, Major 1990, Martin and Geupel 1993, Ralph et al. 1993). We took vegetation measurements within 1 week of observed nest failure with nest and control site measurements in the same field border typically performed on the same day.

Vegetation Sampling

We quantified vegetation characteristics at nest sites, as well as 2 associated random sites within 5–20 m of the nest center to model site-scale selection. We considered a nest site or associated site to include all habitat within a 1-m radius of a central point of interest. We chose associated sites using a random number generator to select an azimuth and random distance between 5 and 20 m from the nest. We took measurements immediately inside the field border edge at the respective azimuth if an associated site fell within an adjacent cover type.

We also randomly selected a control site from the field borders included in our search rotation to model patch selection. We considered a single field border to be synonymous with a patch. Coincidentally, there was no overlap between the field borders that contained control sites and nests within a field season. Between field seasons, there was only a single case where a field border selected as a control in 2010 was found to contain a nest during the subsequent field season. Field borders containing control sites were typically searched both before and after measurements were taken in accordance with the scheduled rotation, providing reasonable certainty of nest absence. Therefore, control sites should be considered representative of field borders where quail did not nest during a respective field season. Similar to the nest site, we measured the attributes of the vegetation at the control site as well as 2 associated sites within 5–20 m of the initial location. We averaged the measures of the control site and associated sites to produce a general characterization of field border habitat.

We selected the control site by first randomly choosing a field border and then arbitrarily designating a location within that field border constrained by border dimensions. We selected the location of the control site in linear field borders using 2 randomly generated distances corresponding to the length and width, but not exceeding the maximum length and width of the field border. Starting from the primary point of access for the field border, we walked the length-associated distance down the crop edge, then entered the width-associated distance into the border and took vegetation measurements at this point. In nonlinear field borders, we treated the edge adjacent to the crop field as the border's length. We walked a random distance along this edge beginning at the terminus closest to our point of searching access. We defined the width of the border as the maximum length of a perpendicular transect drawn from this point to the opposite side of the border.

At all nests, control sites, and associated sites we assessed ground composition (i.e., woody plants, grass, open soil, leaf litter, and herbaceous), percent cover (an estimate of visual obscurity of the nest), and stem density of woody plants. We recorded ground composition using a 1-m × 1-m quadrat centered on the point of interest. We classified elements within the square frame as woody plants, grass, open soil, leaf litter, or herbaceous vegetation, and described the composition using 5% intervals with the total for all coverage classes summing to 100%. We characterized percent cover and stem density using a Robel pole with 15 0.1-m sections centered on the site of interest (Robel et al. 1970). An observer standing approximately 3 m from the pole estimated percent cover per section at 5% intervals, adjusting position accordingly to ensure readings were taken at eye-level. We also quantified the density of woody stems by counting the number of woody stems touching each of the 15 sections of the Robel pole. We measured both percent cover and stem density at 3 separate random azimuths and averaged percent cover across the azimuths and 15 sections of the Robel pole to produce a single value for the site.

Edge Sampling

We measured the distance to land-cover types (woody edge, crop, ditch, and road) from the center of both nest and control sites. We assessed distance to crop and ditch with a tape measure stretched from the site of interest to its intersection with the nearest edge of the cover type. We could not determine the proximity of nest and control sites to the closest woody edge or road with the same measurement technique because of the scale of our study area. Instead, we ascertained the distance to nearest woody edge, defined as the edge of a forest or hedge row with trees, using a range finder held over the center of the nest or control site. We used the measuring tool in ArcGIS (Version 9.3; ESRI, Redlands, CA, USA) and satellite imagery to determine the distance to the closest road. We also used this technique to determine distance to woody edge if obstructions in our line of site prohibited use of a range finder.

Table 1. Akaike's Information Criterion corrected for small sample size (AIC$_c$) and weight (w_i) for site scale models of differences in vegetation variables between northern bobwhite nests and associated random sites in field borders, North Carolina, USA, 2010–2011.

Model description	K	AIC$_c$	ΔAIC$_c$	w_i
Woody + open soil	3	40.852	0.000	0.527
Global	6	42.857	2.005	0.193
Open soil	2	44.113	3.261	0.103
Open soil + herbaceous	3	44.155	3.303	0.101
Open soil + grass	3	45.389	4.537	0.055
Woody	3	47.718	6.866	0.017
Woody + herbaceous	2	51.550	10.698	0.003
Grass	3	53.604	12.752	0.001
% cover	2	59.747	18.895	0.000
Herbaceous	2	60.461	19.609	0.000
Grass + herbaceous	2	60.590	19.738	0.000

Statistical Analysis

To model nest site selection at the site level, we used conditional logistic regression to compare variables measured at the actual nest site to the 2 associated random sites. To model nest site selection at a combined patch–landscape level, we used logistic regression to compare variables measured at the nest sites with the averages of the control sites and 2 associated sites. We performed model selection using the small-sample Akaike's Information Criterion (AIC$_c$). In each case the tested models included a global model, all single-variable models, and all 2-variable combinations of cover types. We excluded stem density as a parameter because of a high degree of multicollinearity with woody vegetation. Sum constraints also resulted in a lack of independence among the quadrat data response variables so we chose to eliminate leaf litter from the final analyses because we perceived it to be the cover type with the least biological relevance for our study location.

RESULTS

We located 26 bobwhite nests during the 2010 and 2011 field seasons. We also assessed an additional 26 control sites within field borders that did not contain nests during the respective field season. The top site-scale model included open soil and woody parameters (Table 1). Beta values indicate that bobwhite selected against open soil at the nest site (β = −0.2233, SE = 0.0865), but favored a greater presence of woody vegetation (β = 0.0507, SE = 0.0250). Open soil was present in the top 5 models and appears to be the strongest predictor of nest placement (Relative Importance Value = 0.979; Table 1). The next 2 models included woody cover as a parameter, indicating its secondary significance as a predictor of habitat suitability for nesting (Relative Importance Value = 0.740; Table 1). Open soil was also the strongest single variable model behind the top and global models, followed by woody cover (Table 1). Nests had a median of 5% open soil and a range (R) of 25% compared with 10% open soil (R = 47.5%) at associated sites (Table 2).

Table 2. Median (M), range (R) for ground cover, percent cover and stem density (%) of northern bobwhite nests and the average of adjacent random sites in field borders, North Carolina, USA, 2010–2011.

Ground cover	Nest		Adjacent site	
	M	R	M	R
Woody plants	0.0	80	1.25	55.0
Grass	22.5	75	12.50	72.5
Open soil	5.0	25	10.00	47.5
Herbaceous	25.0	70	26.25	50.0
Percent cover	48.39	55.89	46.39	54.39

The distribution of the open soil variable at the nest site was strongly left-skewed with an absence of open soil from 8 of the nest locations. Nests had a median of 0% woody cover (R = 80%) compared with 1.25% at random sites (R = 55%), which initially seems to contradict the trend of the model betas (Table 2). However, like open soil, the distribution of the woody cover variable was strongly left-skewed with 14 of the 26 nests we encountered having no woody vegetation. The maximum percentage of woody cover observed at an adjacent subplot was 55%, while 4 nests had >60% woody cover. There was model uncertainty at the combined patch–landscape level (Table 3).

DISCUSSION

Bobwhite nest placement within field border habitat was influenced solely by microhabitat characteristics at the site level. Bobwhite selected nesting locations with less open soil and more woody cover than adjacent

Table 3. Akaike's Information Criterion corrected for small sample size (AIC$_c$) and weight (w_i) for combined patch–landscape models of differences in vegetation variables and distance to land-cover types between northern bobwhite nests and random control sites in field borders, North Carolina, USA, 2010–2011.

Model description	K	AIC$_c$	ΔAIC$_c$	w_i
Open soil + herbaceous	3	69.446	0.000	0.206
Woody + grass	3	69.467	0.021	0.204
Grass + open soil	3	70.762	1.316	0.107
Open soil	2	71.331	1.885	0.080
Global	10	71.417	1.970	0.077
Herbaceous	2	72.124	2.678	0.054
Woody + open soil	3	72.493	3.047	0.045
Grass	2	72.647	3.201	0.042
Grass + herbaceous	3	72.828	3.382	0.038
Woody + herbaceous	3	73.762	4.316	0.024
Road	2	73.990	4.544	0.021
Woody edge	2	74.066	4.620	0.021
Distance	5	74.169	4.723	0.019
Vegetation	6	74.337	4.891	0.018
Ditch	2	74.554	5.108	0.016
Crop	2	75.217	5.771	0.012
Woody	2	76.039	6.593	0.008
% cover	2	76.072	6.626	0.008

habitat. Bobwhite in our study may have avoided nests with abundant open soil because these sites did not provide adequate concealment from predators. Conversely, bobwhite may have selected for nesting locations with a greater presence of woody vegetation because increased concealment reduced depredation risk. Overall concealment at the nest site, represented by the percent cover parameter in our model set, was a poor predictor of site selection in our study. This may indicate that the cover types bobwhite favored or avoided may have specific structural characteristics or use values that are of greater importance than the total amount of vegetation.

Avoidance of open soil at the nest is the only ground cover attribute that is consistently important throughout the bobwhite's range. Taylor et al. (1999), Townsend et al. (2001), Lusk et al. (2006), and Rader et al. (2007) observed bobwhite selection against bare ground at the nest site in contiguous grassland, rangeland, and Conservation Reserve Program (CRP) field habitats. Each of these studies attributed the avoidance of open soil to selection for greater concealment at the nest site. However, the presence of open soil at the nest site may have a differential impact on survival throughout the bobwhite's range. Townsend et al. (2001) found that bobwhite nests with less open soil had a greater probability of success; whereas Lusk et al. (2006) observed that although bobwhite selected for less open soil at the nest, bare ground exposure was positively correlated with nest success. Lusk et al. (2006) attributed their findings to human alteration of bobwhite habitat on rangelands that may have uncoupled selection criteria from the anticipated benefit of greater nest success. We assumed that bobwhite avoidance of open soil at nests in field borders was driven by increased survival probability, but selection criteria may also be divorced from success at our field site because field borders are highly disturbed, man-made habitats. Further exploration of the relationship between ground cover classes and nest success in field border habitat is necessary to determine whether selective pressures have become uncoupled from nest success.

Structural characteristics of vegetation at the nest that increase concealment may be of greater importance to bobwhite than specific cover types. We attributed bobwhite selection for the presence of greater woody vegetation at the nest to increased concealment. However, bobwhite selection for microhabitat characteristics must be driven by a secondary factor other than total concealment because percent cover at the nest was comparable to random sites. Bobwhite may have selected for structural attributes of woody species including height, distribution of cover, or concealment of the nest from an aerial perspective. While different cover types may serve a similar function across the bobwhite's range, it is possible that woody species most adequately fill this role in our study area. Functional tradeoffs of vegetation would also explain the absence of woody vegetation from over half of our nest sites and secondary importance in our model set. Woody cover may have desirable structural attributes for nesting but vegetation with similar structural qualities may serve as an adequate substitute if woody cover is not available. No similar tradeoffs exist for open

soil, which may explain why it was the strongest predictive parameter. We did not measure structural characteristics directly and those that could be derived from Robel pole data were masked by averaging the data for site comparisons.

Woody cover was only found to be a predictor of nest site selection in a narrow portion of the bobwhite's range in northern Texas and Oklahoma until our findings (Townsend et al. 2001, Lusk et al. 2006). Other authors attributed the relationship between the Townsend and Lusk studies to the value of a particular woody species because the vegetation composition of both study locations was similar (Rader et al. 2007). Although our study site is found at a similar latitude, the plant community in our field border habitat had very little overlap with these previous studies, contradicting the species value hypothesis. Regional similarities in the predator community may have resulted in similar patterns of cover type selection. Factors unrelated to nest predation but reliant on nest vegetation structure, such as nest microclimate, also would be subject to similar selective pressures and may be tied to climatological similarities at comparable latitudes. Any similarities between these two disparate regions of the bobwhite's range are merely speculative and further research is needed to determine whether there is any relationship between the importance of woody vegetation at nest sites in both areas.

Microhabitat characteristics that influenced nesting decisions within a field border did not determine which field borders bobwhite utilized for nesting, defined for the purposes of our study as patch selection. Model uncertainty at the patch scale was likely representative of the homogeneity of vegetation in all borders included in our study. Similar ground composition between borders did not predicate patch selection because all habitat was equally suitable for nesting. Our results were comparable to Taylor et al. (1999), who noted the absence of patch selection on contiguous rangelands.

Bobwhite utilization of field borders for nesting was also not influenced by distance to land-cover types, defined as landscape scale selection. Piispanen and Riddle (2012) were unable to show that nest placement relative to land-cover types conferred any nest survival advantage. Therefore, nest placement with respect to land-cover types may not have been observed because it does not contribute to reproductive fitness at our study site.

Although model uncertainty at the combined patch–landscape scale indicated that microhabitat variables and distance to land-cover types were similar between all field borders in our study, bobwhite did not utilize all borders for nesting. Nonuse is likely a consequence of some variable our study failed to capture. Bobwhite may have avoided some field borders because they were unsuitable for nesting. For example, bobwhite would likely not have nested in habitat supporting a large population of predators. Field borders may have been suitable for nesting but dispersal to the habitat was restricted by some feature of the agricultural landscape. There also may not have been a great enough abundance of bobwhite at our study site to utilize all of the habitat suitable for nesting. We found 9 nests during the 2010 field season and 17

Table 4. Mean distance to landscape features (m) of northern bobwhite nests and control sites in field borders, North Carolina, USA, 2010–2011.

Feature	Nest		Control site	
	$\bar{x}$	SE	$\bar{x}$	SE
Woody edge	401.77	53.60	296.64	47.66
Crop	4.93	0.92	3.72	0.81
Ditch	8.35	2.98	4.53	0.97
Road	169.25	27.91	249.46	47.35

nests during the subsequent summer. This dramatic increase in nest initiations may indicate underutilization of habitat resources available for nesting. However, further research is needed to determine why bobwhite are not utilizing all seemingly suitable field borders for nesting.

Negative edge effects resulting from proximity to woody cover types observed in other species may not have influenced nest placement on our study site because of broader landscape context (Gates and Gysel 1978, Andren and Anglestam 1988, Marini et al. 1995, Woodward et al. 2001, Sperry et al. 2009). The average nest in our study was approximately 400 m from the nearest woody edge (Table 4). Weatherhead et al. (2010) did not observe edge effects for nesting birds in a field environment within 74 m of a woody edge, <25% of the distance observed in our study. The average control location in our study was nearly 300 m from the closest woody edge, indicating that all available nesting habitat may be sufficiently far from woody edges in an agriculture-dominated landscape to avoid the increased predation risk associated with woody edges. Piispanen and Riddle (2012) did not observe any bobwhite nests in field borders on farms in a forest-dominated landscape. This observation supports the findings of Duren et al. (2011), which noted that bobwhite select against both highly fragmented early successional habitat and agricultural lands juxtaposed with forest edge. Although field borders may have less influence on bobwhite occupancy rates than landscape composition (Bowling et al. 2014), the nesting habitat they provide may contribute to increases in local abundance. Within a suitable landscape, field borders placement may be flexible and prove to be a valuable conservation tool to maximize bobwhite abundance.

MANAGEMENT IMPLICATIONS

Field-border management practices should encourage some presence of woody vegetation and minimize the amount of open soil. Within an agricultural landscape, field border placement may be flexible. The construction of additional field-border habitat does not appear to be constrained by proximity to various land-cover types. However, the relationship between our study variables and nest success may warrant further investigation to determine whether selective pressures have become uncoupled in field border habitat.

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