DEPREDATION PATTERNS AND NEST SUCCESS FOR BOBWHITE AND SONGBIRD POPULATIONS ON FIELD BORDERS IN NORTH CAROLINA

By

Jessica N. Piispanen

A Thesis
Submitted in partial fulfillment of the requirements of the degree
MASTER OF SCIENCE
IN
NATURAL RESOURCES (WILDLIFE)

College of Natural Resources
UNIVERSITY OF WISCONSIN
Stevens Point, Wisconsin

August 2012
APPROVED BY THE GRADUATE COMMITTEE OF

Dr. Jason D. Riddle, Committee Chair
Assistant Professor of Wildlife

Dr. Tim F. Ginnett
Professor of Wildlife

Dr. Michael J. Hansen
Professor of Fisheries

Dr. Theodore R. Simons
Professor of Biology and Forestry
North Carolina State University
EXECUTIVE SUMMARY

Many bird species have been experiencing declines across their ranges due to habitat loss. Northern bobwhites (*Colinus virginianus*) and early succession songbirds have lost habitat from fragmentation, urbanization, fire suppression, and large-scale farming practices (Vance 1976, Brennan 1991, Askins 1993, Brawn et al. 2001, Hunter et al. 2001, Brennan and Kuvlesky 2005, Sauer et al. 2011). Field borders have been implemented in many states as a way of providing early succession habitat for these birds and other wildlife. A field border is a strip of planted or volunteer vegetation around a crop field that is maintained in early succession.

Bobwhite and early succession songbird populations increase with the establishment of field borders (Puckett et al. 1995, Marcus et al. 2000, Bromley et al. 2002, Palmer et al. 2005, Riddle et al. 2008, Conover et al. 2009). However, additional work is needed to determine if field borders are beneficial to birds by providing quality nesting habitat, thereby increasing nest success. Quality nesting habitat can depend on surrounding landscape features such as edges. Predators could be using edges more intensely than other landscape features for foraging or travelling (Gates and Gysel 1978, Durner and Gates 1993, Marini et al. 1995, Dijak and Thompson 2000), thereby resulting in lower nest success. Field borders may reduce nest success because they juxtapose many different edge types in addition to row crops including woods, ditches, and roads. A variety of predators use edges and field borders. One of these, the black rat snake (*Elaphe obsolete*), was suspected of being the main nest predator of two songbirds, blue grosbeaks (*Passerina caerulea*) and indigo buntings (*Passerina cyanea*), on some farms (Riddle and Moorman 2010). However this was never confirmed as cameras were not
placed on nests to accurately identify predators. Few studies have examined predator communities in field borders (but see Gillis 2000).

My study had two primary objectives. My first objective was to determine whether northern bobwhite, blue grosbeak, and indigo bunting nests in field borders were more likely to fail if within close proximity to edge types such as woods, row crops, ditches, and roads. My second objective was to determine if snakes, such as the black rat snake, were the main nest predator for each of our focal species.

My study sites included 178 field borders (totaling 77 ha) along the edges of row crop fields on four industrial hog farms owned and operated by Murphy-Brown, LLC. Three of the farms totaled approximately 312 ha in size and were located in a forest-dominated landscape. The fourth farm was approximately 1619 ha in size and was in an agriculture-dominated landscape. I searched each field border for nests of my three focal species at least twice during summer 2010 and four times during summer 2011. I recorded nest location, the number of eggs, nest stage, and other relevant information such as condition of the nest and its contents and whether the male or female was present. I monitored each nest every 3 to 4 days until it either failed or successfully fledged. I set up cameras on half of each of my focal species’ nests. The camera setup included three main components: a small bullet camera, a digital video recorder (DVR), and two 12-V 33- A hour batteries. I changed batteries and 16 gigabyte secure digital (SD) cards every 3 to 4 days during nest checks.

I used Program MARK to estimate daily nest survival rates for each species. Specifically, I built models to estimate the effect of 7 different covariates: distance to closest woody, row crop, ditch, and road edges, field border width, year, and a camera
effect. I placed predators caught on camera into three groups: snake, avian, and mammalian. I then used a Chi-square goodness of fit test ($\alpha > 0.05$) to determine the relative importance of these three nest predator groups.

I found a total of 26 northern bobwhite nests, 29 blue grosbeak nests, and 12 indigo bunting nests in two field seasons. The top three models in Program MARK for northern bobwhites were constant nest survival, year effect, and camera effect (AICc weights = 0.23, 0.18, and 0.12, respectively). The top three models for blue grosbeaks were constant nest survival, field border width, and distance to the nearest ditch (AICc weights = 0.22, 0.17, and 0.15, respectively). The top three models for indigo buntings were distance to nearest crop, distance to nearest road, and constant nest survival (AICc weights = 0.52, 0.41, and 0.02, respectively). All of the covariates had slope betas with 95% confidence intervals that overlapped zero indicating that none of the covariates exerted a strong influence on the nesting success of any of our focal species. In other words, I found no edge effect in relation to nest success for any bird species because no variables were significantly related to nest success.

I set up cameras at 14 northern bobwhite nests, 14 blue grosbeak nests, and 5 indigo bunting nests. I recorded 4 snake (3 king snakes (*Lampropeltis getula getula*) and one unidentifiable snake) and 2 Virginia opossum (*Didelphis virginiana*) depredation events at northern bobwhite nests ($P = 0.1353$). I recorded 2 unidentifiable mammalian, 3 unidentifiable snake, and one avian depredation events ($P = 0.3620$) for blue grosbeaks. I recorded 3 black rat snake depredations ($P = 0.0498$) for indigo buntings.

Lack of edge effects on my focal species nest success may have been influenced by landscape-level patterns. All northern bobwhite nests and all but 2 blue grosbeak
nests and 3 indigo bunting nests were found on field borders in an agriculture-dominated landscape rather than a forest-dominated landscape. This resulted in the average distance from the nest to the closest woody edge being relatively large for northern bobwhites (403.6 m ± 271.3 SE), blue grosbeaks (363.5 m ± 239.4 SE), and indigo buntings (152.1 m ± 194.0 SE). In addition, distance to the closest road was relatively large while distances to the closest row crop and ditch were small because all field borders were next to a row crop on one side and most had a ditch on the other side.

Snakes were the most frequent nest predator for all of my species, but were only statistically significant for indigo buntings. Specifically, black rat snakes were the main nest predator for indigo buntings. This may be related to the closer proximity of indigo bunting nests to woody edges compared to the other two species.

Landowners and farm managers appear to have little restrictions on where they can place field borders with respect to the four edges studied (woody, row crop, ditch, road) and nest success of my three focal species. Therefore, in agriculture-dominated landscapes, landowners and farm managers should focus more on adding field border acres and less on where these acres are placed on a farm. Future studies should focus on gaining a larger sample size for each focal species in field borders in each landscape. Indigo bunting and blue grosbeak nests were found in ditches in both landscapes, but were not included in my analysis because I did not consider ditches as part of a field border. Therefore, studies also should focus on songbird nest success and prevalence of nests in ditches compared to those in field borders. In a forest-dominated landscape, a comparative study should examine whether songbirds prefer to nest on the forest edge, field borders, or ditches.
LITERATURE CITED


Riddle, J. D., and C. E. Moorman. 2010. The importance of agriculture-dominated landscapes and lack of field border effect for early succession songbird nest


ACKNOWLEDGEMENTS

I would like to thank my advisor Dr. Jason Riddle for his guidance and friendship. His constant supply of advice and support, his infinite patience, and his humorous jokes were always very much appreciated. I also thank my committee members Dr. Tim Ginnett and Dr. Michael Hansen for their support and guidance.

I would like to thank my technicians Alixandra Godar, Danielle Berger, Andy Richardson, and Sara Wendt for all of their hard work, dedication, and patience with many long days in the field.

All of the faculty and staff as well as my fellow graduate students at UWSP helped tremendously with all of their assistance and support during this project. In particular, I thank the Fish and Wildlife Cooperative Research Unit at North Carolina State University and the Fish Cooperative Research Unit at UWSP for all of their logistical support.

I would like to thank Ted Simons, John Wettroth, and others at NCSU for designing and building the regulators and harnesses used as part of my camera set up. I also thank Ted, who is on my committee, for his technical help and general advice throughout this project. Thank you to Jim Tuszka from UWSP for helping me decipher what parts and cables would make for an efficient camera set up. I thank Scott Roepke for his help with the construction of the PVC pipes used for mounting the cameras.

I thank Tommy Hughes, Mark Jones, Michael Champion, and others at the North Carolina Wildlife Resources Commission (NCWRC) for all of their help. I especially thank Tommy Hughes for giving us permission to stay at the Suggs Mill Pond cabin both field seasons. I also thank Benjy Strope with NCWRC for all of his logistical help,
advice, and support throughout the entire project. I thank Murphy Brown, LLC. for allowing us to use their farms and especially Dawn Williamson for assisting us with the logistics of gaining access to the farms, as well as all the farm managers for their assistance. I especially thank our funding source, the North Carolina Department of Justice’s Environment Enhancement Grants Program for without them this project would not have been possible.

Finally I would like to thank all my wonderful friends and family for always supporting and believing in me and my crazy love for the outdoors. Specifically, I give many, many thanks to my dad and mom, Brian and Gail, for their infinite love and support in allowing me to pursue my dreams, and my brother, Bennett, for always being there with a word of encouragement or a laugh.
# TABLE OF CONTENTS

EXECUTIVE SUMMARY .............................................................................................. iii

ACKNOWLEDGMENTS .................................................................................................... x

LIST OF TABLES ........................................................................................................... xiv

LIST OF FIGURES ......................................................................................................... xvi

PREFACE ........................................................................................................................ xvii

CHAPTER I: DEPREDATION PATTERNS AND NORTHERN BOBWHITE NEST SUCCESS IN FIELD BORDERS
Abstract .......................................................................................................................... 1
Introduction ..................................................................................................................... 2
Study Area ...................................................................................................................... 5
Field Borders ................................................................................................................ 5
Methods ......................................................................................................................... 6
Nest Searching .............................................................................................................. 6
Nest Monitoring ........................................................................................................... 7
Edge Sampling ............................................................................................................. 7
Camera Set Up ........................................................................................................... 8
Data Analysis ............................................................................................................... 9
Results .......................................................................................................................... 9
Discussion .................................................................................................................... 10
Management Implications ......................................................................................... 12
Acknowledgments ....................................................................................................... 12
Literature Cited ........................................................................................................... 13

CHAPTER II: PREDATION AND THE IMPORTANCE OF DISTANCE TO DIFFERENT EDGE TYPES ON SONGBIRD NEST SUCCESS IN FIELD BORDERS
Abstract ....................................................................................................................... 25
Introduction .................................................................................................................. 26
Study Area .................................................................................................................... 28
Field Borders .............................................................................................................. 29
Methods ....................................................................................................................... 29
Nest Searching ............................................................................................................ 29
Nest Monitoring ......................................................................................................... 31
Edge Sampling .......................................................................................................... 31
Camera Set Up .......................................................................................................... 32
Data Analysis ............................................................................................................. 33
Results ....................................................................................................................... 33
Discussion ................................................................................................................... 35
Management Implications ......................................................................................... 38
Acknowledgments ....................................................................................................... 38

xii
Literature Cited

.................................................................

.. 39
LIST OF TABLES

CHAPTER I

Table 1. AIC model selection results from Program MARK including AICc statistics, number of parameters, deviance, point estimates of survival (\(\hat{S}\)) and standard errors from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. \(S(.)\) represents the constant nest survival model. The other models account for year effect (\(S(\text{Year})\)), camera effect (\(S(\text{Camera})\)), distance to closest crop (\(S(\text{Distance to crop})\)), distance to closest ditch (\(S(\text{Distance to ditch})\)), distance to closest woody edge (\(S(\text{Distance to woody edge})\)), distance to closest road (\(S(\text{Distance to road})\)), and field border width (\(S(\text{Field border width})\)). .......................................................... 21

Table 2. The betas for the slope along with standard errors and 95% Confidence Intervals from Program MARK from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. The other models account for year effect (\(S(\text{Year})\)), camera effect (\(S(\text{Camera})\)), distance to closest crop (\(S(\text{Distance to crop})\)), distance to closest ditch (\(S(\text{Distance to ditch})\)), distance to closest woody edge (\(S(\text{Distance to woody edge})\)), distance to closest road (\(S(\text{Distance to road})\)), and field border width (\(S(\text{Field border width})\)). ................. 22

Table 3. Average, minimum, and maximum distances (m) for nests to closest woody, crop, ditch, and road edges on field borders on four farms in Bladen and Sampson counties, North Carolina, USA, 2010 and 2011.............................................................. 23

Table 4. Camera results of the number of depredations in total and by year from 2010 and 2011 breeding seasons on field borders on four farms in Bladen and Sampson counties, North Carolina, USA. ........................................................................................................................................ 24

CHAPTER II

Table 1. AIC model selection results for blue grosbeaks including AICc, AICc weight, numbers of parameters, and deviance as well as point estimates of survival (\(\hat{S}\)) and standard errors from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. Constant nest survival is represented by \(S(.)\). The other models account for distance to closest woody edge (\(S(\text{Distance to woody edge})\)), distance to closest ditch (\(S(\text{Distance to ditch})\)), distance to closest crop (\(S(\text{Distance to crop})\)), distance to closest road (\(S(\text{Distance to road})\)), field border width (\(S(\text{Field border width})\)), year effect (\(S(\text{Year})\)), and camera effect (\(S(\text{Camera})\)). ........................................................................................................ 47
Table 2. The betas for the slope for blue grosbeaks along with standard errors and 95% Confidence Intervals from Program MARK from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. The other models account for 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)).

Table 3. AIC model selection results for indigo buntings including AICc, AICc weight, number of parameters, and deviance as well as point estimates of survival (Ŝ) and standard errors from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. S(.) represents constant nest survival. The other models account for distance to closest woody edge (S(Distance to woody edge)), distance to closest crop (S(Distance to crop)), distance to closest ditch (S(Distance to ditch)), distance to closest road (S(Distance to road)), field border width (S(Field border width)), camera effect (S(Camera)), and year effect (S(Year)).

Table 4. The betas for the slope for indigo buntings along with standard errors and 95% Confidence Intervals from Program MARK from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. The other models account for 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)).

Table 5. Average, minimum, and maximum distances (m) for closest woody, crop, ditch, and road edges for blue grosbeaks and indigo buntings on field borders on four farms in Bladen and Sampson Counties, North Carolina, USA, 2010 and 2011.

Table 6. Number of nest depredations recorded on camera for each group of predators for blue grosbeaks and indigo buntings from 2010 and 2011 breeding seasons on field borders on four farms in Bladen and Sampson counties, North Carolina, USA.
LIST OF FIGURES

CHAPTER I

Figure 1. Farm locations in Bladen and Sampson Counties, North Carolina, USA. ....... 20

CHAPTER II

Figure 2. Farm locations in Bladen and Sampson Counties, North Carolina, USA. ....... 46
PREFACE

The chapters of this thesis were written using the format of the 7th National Quail Symposium (Chapter 1) and The Wildlife Society Bulletin (Chapter 2) and are written for submission using their submission guidelines. Therefore any duplication of material and citations within chapters is intentional. A version of Chapter 1 has been accepted for peer-reviewed publication in the Proceedings of the 7th National Quail Symposium.
CHAPTER I:

DEPREDATION PATTERNS AND NORTHERN BOBWHITE NEST SUCCESS IN FIELD BORDERS

ABSTRACT Northern bobwhite (*Colinus virginianus*) populations have declined because of habitat loss and fragmentation. Field borders provide habitat for northern bobwhites and other wildlife that depend on early-succession habitat. However, the proximity of field borders to woods and other edge types may result in increased bobwhite nest depredation. My primary objective was to determine if northern bobwhite nest survival in field borders was inversely related to proximity to various edges such as woody, row crop, ditch, and road. I also considered effects of year, camera presence, and field border width on nest success. My secondary objective was to determine if snakes were the primary nest predator via 24-hour video camera surveillance. I searched for and monitored northern bobwhite nests on 77 ha of field borders on farms in both agriculture-dominated and forest-dominated landscapes in southeast North Carolina during the summers of 2010 and 2011. I found 26 nests and monitored them every 3-4 days. All nests were in an agriculture-dominated landscape. I monitored fourteen nests with cameras. I built nest survival models using covariates of distance to nearest woody, row crop, ditch, and road edges, and year, camera, and field border width effects. The most explanatory model was constant northern bobwhite nest survival with an estimated daily nest survival of 0.9512 (± 0.0119 SE; AICc weight=0.23). Models with covariates suggested similar daily nest survival rates to the constant model. Four snake and two mammalian depredation events were recorded on camera. Distance to edges and field border width did not influence nest success in an agriculture-dominated landscape.
Therefore, landowners and managers in an agriculture-dominated landscape may have considerable flexibility in where they implement field borders on their farms.

**KEY WORDS** *Colinus virginianus*, field borders, nest depredators, nest survival, North Carolina

**INTRODUCTION**

Declines in northern bobwhite populations over the past few decades have been 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. Field borders are part of both federal and state-level incentive programs for farmers.

At the federal-level, the Farm Bill includes several conservation incentive programs to encourage farmers to manage edges of agricultural fields as wildlife habitat in return for monetary compensation. One of these programs is the Conservation Reserve Program (CRP; United States Department of Agriculture USDA 2003), which provides over thirty different natural plantings to improve wildlife habitat (Clark and Reeder 2007). The Habitat Buffer for Upland Birds (CP33) is a CRP field border option that allows either planted native or volunteer vegetation specifically for improving habitat quality for bobwhite and early succession songbirds (USDA 2004). Field borders are established along crop field margins such as the field-woods interface, between adjoining fields, or between a crop field and other edge types such as a road or a ditch. In addition to increasing habitat for bobwhites and early succession songbirds, borders provide
additional benefits of improving water quality and preventing erosion (Burger et al. 2006).

At the state-level, the North Carolina Wildlife Resources Commission (NCWRC) developed the Cooperative Upland Habitat Restoration and Enhancement (CURE) program in 2000. Similar to CRP, CURE provides early succession habitat establishment and management in the form of field borders on predominately private lands and to a lesser extent on state wildlife management areas (Cobb et al. 2002). However, CURE is more selective than CRP with regard to lands that may be enrolled. CURE enrolls farms based on surrounding landscape features and specifically targets areas with the greatest management potential for bobwhites (Cobb et al. 2002).

Numerous studies have shown that field borders provide 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).

Effectiveness of field borders can vary with field border shape, width, or surrounding landscape. For example, northern bobwhite populations increased on farms with both linear and nonlinear borders in agriculture-dominated landscapes and on farms with nonlinear field borders in forest-dominated landscapes (Riddle et al. 2008). Avian abundance and richness of overwintering birds were greater in wide field borders than narrow field borders (Conover et al. 2007) and breeding bird density was nearly 2-times higher in wide field borders as opposed to narrow field borders (Conover et al. 2009). Another factor that could impact the effectiveness of a field border in providing adequate
habitat, and especially nesting habitat, for northern bobwhites could be its distance to various edge types.

By definition, field borders are located along edges that are adjacent to other features such as forests, ditches, and roads. Although edge effects on breeding songbirds have been well studied, edge effects on breeding northern bobwhites have received less attention. 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 is a significant source of nest failure for bobwhite populations (Stoddard 1931, DeVos and Mueller 1993, Puckett et al. 1995, Conover 2005) and there are a variety of predators that could depredate nests.

Predator community structure depends on region and habitat. Studies including both real and artificial nests have shown that mammals are a major nest predator of northern bobwhites (Klimstra and Roseberry 1975, DeVos and Mueller 1993, Hernandez et al. 1997, Fies and Puckett 2000, Staller et al. 2005, Rader et al. 2007a). However, snakes were the primary nest predator on farms in at least one study (Puckett et al 1995). Other studies have found that snakes are important predators of bobwhite nests (Stoddard 1931, Burger et al. 1995, Staller et al. 2005), perhaps because snakes use edges more than other habitats (Weatherhead and Charland 1985, Blouin-Demers and Weatherhead 2001, Sperry et al. 2009). Based on predation evidence left at songbird nests in southeastern North Carolina, Riddle and Moorman (2010) speculated that black rat snakes (Elaphe
obsolete) may be a main predator of bird nests. However, they could not confirm this because they did not monitor nests with cameras.

To better manage bobwhite populations, the relationship between predators, landscape, and edge effects should be studied further (Rollins and Carroll 2001, Burger 2001, 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.

My primary objective was to determine if nests of northern bobwhites in field borders are more likely to fail if they are closer to woody edges as well as other edge types such as row crops, ditches, and roads. A secondary objective was to determine if snakes, such as the black rat snake, are primary nest predators of northern bobwhites in field borders. I hypothesized that nests closer to edges would more likely fail than nests farther from edge. I also hypothesized that snakes, such as black rat snakes, would be primary nest predators.

STUDY AREA

Study sites consisted of about 77 ha of field borders located on four commercial hog farms in Bladen and Sampson counties in southeast North Carolina (Fig. 1). The hog farms are owned by Murphy-Brown, LLC. The agricultural land on the farms was mainly used to grow a rotation of soybeans (Glycine max), corn (Zea mays), and winter wheat (Triticum aestivum). Three of the farms were smaller in size, totaling approximately 312 ha, and the fourth larger farm was approximately 1619 ha.

Field borders. — Field borders were maintained in an early successional-state, which distinguishes them from other areas bordering crop fields, by diskng, burning, and
treating with herbicide when needed. About 5 ha of field borders were used for this study between the three smaller farms and about 72 ha of field border on the larger farm. I used only those field borders that were adjacent to crop fields on at least one side.

I used 141 linear and 24 nonlinear field borders. On average, a linear border was about 0.41 ha ± 0.34 (mean ± standard deviation) in size and varied in length from 24 m to 1,821 m (mean 509.08 m ± 305.25) and in width from 3 m to 52 m (mean 9.02 m ± 6.40). Nonlinear field borders were irregularly shaped field borders that averaged 0.80 ha (± 0.72) in size. Most field borders were composed of marestail (*Coryza canadensis*), dog fennel (*Eupatorium capillifolium*), little bluestem (*Schizachyrium scoparium*), blackberry (*Rubus sp.*), salt myrtle (*Baccharis halimifolia*), and other herbaceous or grassy vegetation. A few of the nonlinear field borders were composed of mostly planted native warm season grasses, such as big bluestem (*Andropogon gerardii*), little bluestem, and switchgrass (*Panicum virgatum*).

**METHODS**

*Nest Searching.*— I separated individual field borders into two groups at the beginning of each field season: one on the larger farm and one on the three smaller farms. Separating the larger farm from the smaller farms enabled the acreage searched on the three small farms to be proportional to acreage searched on the larger farm. This reduced the chance of searching one field border in a farm group more than another. The order in which I searched field borders in each group was randomly chosen. I paired field borders separated by a ditch for searching purposes to reduce disturbance to the neighboring field border and save time. In 2010, I searched each field border 2-3 times and in 2011, I searched each field border 4-5 times.
I searched each field border systematically, using behavioral cues from the birds, and opportunistically. Using the systematic approach, I searched each field border thoroughly by walking the entire field border. If I saw a male or female bird flush while systematically searching, I searched the general area with greater intensity. I also used bobwhite vocalizations to locate their nests. I found nests opportunistically while I was monitoring active nests or setting up cameras (see below).

To search linear borders, two people either searched parallel to the ditch on the same side or on opposite sides of the ditch until each field border was completely searched. Depending on the shape of particular nonlinear field borders each person either started on opposite ends of the habitat area and walked parallel lines toward each other or both people walked side by side. Once a nest was found, I recorded the stage of the nest and the number of eggs present.

*Nest Monitoring.*—I monitored nests every 3 to 4 days. As I walked to and from the nest, I tried to leave vegetation as undisturbed as possible and not leave a trail (Martin and Geupel 1993) to reduce attracting predators to the nest.

When I checked a nest, I recorded the stage of progress (i.e. egg laying, incubation, nestlings), number of eggs present, and any other observations relevant to parental behavior and the clutch. If the nest was successful, this information helped to estimate when the nest fledged. A nest was considered successful if it hatched one or more young.

*Edge Sampling.*—I measured width of the field border and distance to the closest woody, row crop, and ditch edges after the outcome of the nest was known either using a range finder or measuring tape. I measured field border width for both linear and
nonlinear field borders by walking with measuring tape from the nest to both the crop side of the field border and the opposite side of the field border; usually a wood, ditch, or road edge. I measured distance to closest woody edge using a range finder at the nest. I used the measuring tool in ArcGIS (Version 9.3, ESRI, Redlands, California, USA) to measure distance to the closest road for every nest.

Camera Set up.— I placed cameras randomly on half of all nests found to document depredation events. After a nest was selected, I placed a camera on the nest during the next designated nest check for that farm within 3 to 4 days of finding the nest.

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 two 12-V 33-A hour batteries. I attached the camera to a PVC pipe about 1.5 m from the nest at an appropriate height based on the amount of surrounding vegetation. More specifically, I positioned the camera with a clear view of the nest without destroying vegetation that could make the nest more visible to predators.

I connected a closed-circuit television (CCTV) video/power cable from the camera to the DVR and two batteries that were contained in a sealed 5-gallon bucket. In addition to batteries, the bucket contained a voltage regulator and harness that attached the batteries to the DVR and camera. I used 16 gigabyte secure digital (SD) cards throughout the season to store video data collected from each nest. I changed SD cards and batteries every 3-4 days during routine nest monitoring activities. I placed two humidity sponges in the bucket to prevent moisture buildup. I placed the bucket about 8
m away from the camera under as much vegetation as possible for concealment and to reduce exposure from weather. I placed a sheet of burlap over the bucket to provide camouflage and prevent overheating of the bucket contents. I encased the cable in heavy duty piping to reduce exposure from weather and animals. I recorded nests continuously at 8 frames per second on high megapixel quality with no audio.

_Data Analysis._— I used Program MARK (White and Burnham 1999) to analyze nest data via the daily nest survival option which uses the number of exposure days, the number of failed nests, and the last day a nest was known to be active to calculate the daily nest survival rate (DSR). Program MARK differs from traditional methods that use exposure days (e.g., the Mayfield method; Mayfield 1961, 1975) because it allows covariates on individual nests (see model development in Dinsmore et al. 2002). Program MARK then uses Akaike’s information criterion with a correction for small sample sizes (AICc) to facilitate model selection via an information-theoretic approach. I built nest survival models with and without distance to closest woody, crop, ditch, and road edges and field border width, camera effect, and year effect as covariates.

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

**RESULTS**

I found a total of 26 nests in 2010 and 2011 of which 16 failed. There was a total of 297 exposure days. The top three models in Program MARK were constant nest survival, year effect, and camera effect (AICc weights = 0.23, 0.18, and 0.12,
respectively; Table 1). All covariates had slope betas with 95% confidence intervals that overlapped zero, resulting in little contribution to the slope (Table 2). Daily nest survival for the constant nest survival model was 0.9512 (± 0.0119 SE, 95% CI 0.9218 - 0.9699). The model averaged estimate for daily nest survival was 0.9514 (± 0.0121 SE, 95% CI 0.9211 – 0.9704).

Nests were located an average of 403.6 m (± 271.3  SE) from the nearest woody edge, 5.2 m (± 4.8) from the nearest row crop, 8.8 m (± 18.3) from the nearest ditch, and 168.5 m (± 142.8) from the nearest road (Table 3). The average field border width at nests was 13.4 m (± 16.9).

Cameras on 14 nests in 2010 and 2011 (Table 4) captured 4 snakes (3 king snakes (Lampropeltis getula getula) and one unidentifiable snake), 2 Virginia opossum (Didelphis virginiana), and no avian predators ($X^2 = 4.0, P = 0.14$). Six nests monitored with cameras successfully fledged and 2 were abandoned.

**DISCUSSION**

Our results showed that constant nest success survival was the most competitive model. The 7 covariates had little effect on the estimation of daily nest survival. Daily nest survival estimates were similar across all models indicating the outcome of nests in our field borders was not influenced by the various edges as well as field border width, year effect, and camera effect. Our model averaged daily nest survival estimate (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. (2007b) which ranged from 0.9458 to 0.9692.

On average, nests were farther from woody edges than any of the 4 edge types. Only 7 of our nests were less than 200 m from a woody edge. Because nests were
relatively far from woody edges, predators coming from woody areas would need to travel large distances in order to depredate a nest. Landscape context may have influenced this distance pattern. All of the northern bobwhite nests I found during my study were located 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. Agriculture-dominated landscapes could be providing better landscape context for nesting which results in more birds during the summer months. Indeed, Riddle et al. (2008) found that summer bobwhite abundance almost doubled on farms in agriculture-dominated landscapes as opposed to forest-dominated landscapes when field borders were established.

Nest depredation was a more common cause of nest failure than abandonment (56% vs. 44%, respectively). Depredation rates between the three predator groups were not different. This could be due primarily to our small sample size with cameras.

This is the first study to our knowledge to demonstrate that king snakes are important nest predators of northern bobwhites. Thompson et al (1999) found that king snakes were frequent predators of songbird nests in a field setting. A variety of studies have shown different primary predators of northern bobwhite nests. Studies without cameras have speculated that snakes were the main nest predators due to evidence left after the depredation (Burger et al. 1995, Puckett et al. 1995). Previous camera studies have shown a variety of primary predators. For example, Staller et al. (2005) found raccoons were the primary nest predator in Florida and Georgia while Rader et al. (2007a) found coyotes were the primary nest predators in Texas. Fies and Puckett (2000) found striped skunks most frequently depredated artificial bobwhite nests in Virginia.
Hernandez et al. (1997) found raccoons were the most frequent predator of artificial nests in Texas. Because the predator community and primary nest predators of northern bobwhites vary regionally, more studies should use cameras across the bobwhite’s range to more accurately understand predators of northern bobwhite nests.

Our results should be viewed with some caution until a larger sample is obtained. Future studies should focus on acquiring a larger sample to more thoroughly examine nest success in relation to distance to edge and to accurately represent the predator community in that area. Bobwhite nest success in forest and agriculture-dominated landscapes especially should be compared. Artificial nests also could be used to understand of the relationship between distance to edge and bobwhite nest success in agriculture-dominated and forest-dominated landscapes.

**MANAGEMENT IMPLICATIONS**

Because distance to edges does not appear to influence bobwhite nest success in an agriculture-dominated landscape, our results suggest that landowners and managers may be able to place field borders any distance from edge types in agriculture-dominated landscapes. This could allow more field borders to be established without negatively affecting nest success for bobwhites. Planting more field borders will benefit bobwhite populations and other wildlife. Because our study found no bobwhite nests on farms in forest-dominated landscapes, we cannot make recommendations for field border placement in that landscape context.

**ACKNOWLEDGEMENTS**

I want to thank the faculty and staff at the College of Natural Resources at the University of Wisconsin-Stevens Point. I thank the Cooperative Fish and Wildlife
Research Unit at North Carolina State University and the Cooperative Fish Research Unit at University of Wisconsin-Stevens Point. I also thank my field technicians D. J. Berger, A. J. Godar, A. D. Richardson, and S. R. Wendt for all of their dedicated work in the field. I also thank T. K. Hughes, M. D. Jones, and B. M. Strope from the North Carolina Wildlife Resources Commission and M. D. Williamson from Murphy-Brown, LLC for their logistical support and advice. I want to thank T. R. Simons, J. M. Wettroth, and J. M. Tuszka for helping in the construction of my camera set up. I also thank the North Carolina Department of Justice for funding this project.

LITERATURE CITED


Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner and Sons, New York, New York, USA.


Figure 1. Farm locations in Bladen and Sampson Counties, North Carolina, USA.
Table 1. AIC model selection results from Program MARK including AICc statistics, number of parameters, deviance, point estimates of survival (\( \hat{S} \)), and standard errors from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. S(.) represents the constant nest survival model. The other models account for 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)).

<table>
<thead>
<tr>
<th>Model Description</th>
<th>AICc</th>
<th>AICc Weight</th>
<th>No. Parameters</th>
<th>Deviance</th>
<th>( \hat{S} )</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>S(.)</td>
<td>89.79</td>
<td>0.23</td>
<td>1</td>
<td>87.77</td>
<td>0.9512</td>
<td>0.0119</td>
</tr>
<tr>
<td>S(Year)</td>
<td>90.27</td>
<td>0.18</td>
<td>2</td>
<td>86.23</td>
<td>0.9516</td>
<td>0.0120</td>
</tr>
<tr>
<td>S(Camera)</td>
<td>91.08</td>
<td>0.12</td>
<td>2</td>
<td>87.04</td>
<td>0.9508</td>
<td>0.0120</td>
</tr>
<tr>
<td>S(Distance to crop)</td>
<td>91.23</td>
<td>0.11</td>
<td>2</td>
<td>87.19</td>
<td>0.9493</td>
<td>0.0125</td>
</tr>
<tr>
<td>S(Distance to ditch)</td>
<td>91.31</td>
<td>0.11</td>
<td>2</td>
<td>87.27</td>
<td>0.9540</td>
<td>0.0127</td>
</tr>
<tr>
<td>S(Distance to woody edge)</td>
<td>91.53</td>
<td>0.10</td>
<td>2</td>
<td>87.49</td>
<td>0.9521</td>
<td>0.0120</td>
</tr>
<tr>
<td>S(Distance to road)</td>
<td>91.81</td>
<td>0.08</td>
<td>2</td>
<td>87.77</td>
<td>0.9511</td>
<td>0.0120</td>
</tr>
<tr>
<td>S(Field border width)</td>
<td>91.81</td>
<td>0.08</td>
<td>2</td>
<td>87.77</td>
<td>0.9513</td>
<td>0.0123</td>
</tr>
</tbody>
</table>
Table 2. The betas for the slope along with standard errors and 95% Confidence Intervals from Program MARK from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. The other models account for 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)).

<table>
<thead>
<tr>
<th>Model Description</th>
<th>Beta</th>
<th>Standard Error</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>S(Year)</td>
<td>0.6592</td>
<td>0.5204</td>
<td>-0.3608</td>
<td>1.6793</td>
</tr>
<tr>
<td>S(Camera)</td>
<td>-0.4416</td>
<td>0.5141</td>
<td>-1.4492</td>
<td>0.5659</td>
</tr>
<tr>
<td>S(Distance to crop)</td>
<td>-0.0525</td>
<td>0.0658</td>
<td>-0.1814</td>
<td>0.0764</td>
</tr>
<tr>
<td>S(Distance to ditch)</td>
<td>0.0189</td>
<td>0.0293</td>
<td>-0.0406</td>
<td>0.0744</td>
</tr>
<tr>
<td>S(Distance to woody edge)</td>
<td>-0.54E-03</td>
<td>0.99E-03</td>
<td>-0.0025</td>
<td>0.0014</td>
</tr>
<tr>
<td>S(Distance to road)</td>
<td>0.12E-03</td>
<td>0.0017</td>
<td>-0.0032</td>
<td>0.0034</td>
</tr>
<tr>
<td>S(Field border width)</td>
<td>0.57E-03</td>
<td>0.0194</td>
<td>-0.0374</td>
<td>0.0386</td>
</tr>
</tbody>
</table>
Table 3. Average, minimum, and maximum distances (m) for nests to closest woody, crop, ditch, and road edges on field borders on four farms in Bladen and Sampson counties, North Carolina, USA, 2010 and 2011.

<table>
<thead>
<tr>
<th>Edge Type</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woody</td>
<td>403.6</td>
<td>13.0</td>
<td>942.0</td>
</tr>
<tr>
<td>Ditch</td>
<td>8.8</td>
<td>0.8</td>
<td>87.0</td>
</tr>
<tr>
<td>Crop</td>
<td>5.2</td>
<td>0.4</td>
<td>16.0</td>
</tr>
<tr>
<td>Road</td>
<td>168.5</td>
<td>8.1</td>
<td>525.0</td>
</tr>
</tbody>
</table>
Table 4. Camera results of the number of depredations in total and by year from 2010 and 2011 breeding seasons on field borders on four farms in Bladen and Sampson counties, North Carolina, USA.

<table>
<thead>
<tr>
<th>Predator</th>
<th>2010</th>
<th>2011</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opossum</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>King snake</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Unidentifiable snake</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Abandoned</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Success</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>
CHAPTER II:

PREDATION AND THE IMPORTANCE OF DISTANCE TO DIFFERENT EDGE TYPES ON SONGBIRD NEST SUCCESS IN FIELD BORDERS

ABSTRACT Field borders along field edges have been promoted as a management tool to benefit early-succession songbirds and other wildlife. However, if predators use field borders and the edges they juxtapose for traveling and foraging they might reduce the nesting success of songbirds nesting in those habitats. My primary objectives were to determine if indigo bunting (Passerina cyanea) and blue grosbeak (Passerina caerulea) nests in field borders were more likely to fail when in close proximity to woody, row crop, ditch, and road edges, and if snakes were the primary nest predator. I searched for and monitored focal species nests (n=41) on 77 ha of field borders on farms in agriculture-dominated and forest-dominated landscapes in southeastern North Carolina during breeding seasons in 2010 and 2011. I placed cameras (n=19) on nests to identify predators. I used Program MARK to estimate daily survival rate (DSR) with covariates for distance to nearest woody, row crop, ditch, and road edges, and the effects of field border width, year, and the presence of a camera. Distances to the four edge types did not significantly influence nest success for either species. The model averaged DSR was 0.9657 (± 0.0090 SE) and 0.8846 (± 0.0444 SE) for blue grosbeaks and indigo buntings respectively. Snakes were the most frequent nest predator for both species, but this was only statistically significant for indigo buntings ($X^2_2=6.00, P=0.0498$). Given that proximity to edges does not appear to influence nest success, landowners can place field borders on farms without affecting nest success of blue grosbeaks and indigo buntings in an agriculture-dominated landscape.
KEY WORDS: blue grosbeak, field borders, indigo bunting, nest success, North Carolina

INTRODUCTION

Early succession songbird populations have been declining over the past few decades primarily due to habitat loss (Askins 1993, Hunter et al. 2001, Sauer et al. 2011). Habitat loss has resulted from fire suppression, urbanization, fragmentation, and a shift to large-scale agricultural practices (Vance 1976, Askins 2000, Brawn et al. 2001, Brennan and Kuvlesky 2005).

Field borders have been promoted as a potential conservation solution to reverse population declines by providing more habitat for early succession songbirds. A field border is a strip of native or volunteer vegetation located along the edge of a crop field. In addition to providing habitat for wildlife, field borders also reduce erosion and increase water quality (Best 2000). Field borders have been promoted at both federal and state-levels. At the federal-level, the Conservation Reserve Program (CRP) offers the CP33 field border option, also known as the Habitat Buffer for Upland Birds, which is specifically designed to provide habitat for northern bobwhite and early succession songbirds (USDA 2004). At the state-level, North Carolina developed the Cooperative Upland Habitat Restoration and Enhancement (CURE) program, which is similar to CRP by helping farmers to provide wildlife habitat as field borders, but is more specific in which farms are enrolled in the program. Through CURE, farm enrollment is based on surrounding landscape features that have the greatest potential management impact on northern bobwhite (Cobb et al. 2002).
Field borders are beneficial for early succession birds by providing habitat at various times of year. For example, some sparrow species densities in winter were greater on farms with field borders than those without (Marcus et al. 2000, Smith et al. 2005). In spring and summer, species richness and density of birds were greater on field borders than non-field borders, which generally lack non-crop vegetation (Conover et al. 2009). Finally, farms with field borders had a higher nest density and greater nesting bird diversity than farms without field borders (Bromley et al. 2002).

In addition to being next to a crop field, field borders may be located along edges with other features such as forests, ditches, and roads. Field edges sometimes increase depredation rates (Gates and Gysel 1978, Andren and Anglestam 1988, Marini et al. 1995), which could be related to higher predator activity along edges (Suarez et al. 1997). Predators use edges to search for food and to travel between habitats (Bider 1968, Durner and Gates 1993, Pedlar et al. 1997, Dijak and Thompson 2000). In particular, edges near agricultural fields can produce a higher rate of nest failure than other types of edges (Suarez et al. 1997, Shake et al. 2011). Many nest failures are the result of nest depredation (Ricklefs 1969, Best 1978, Martin 1992, Conover 2005).

Snakes are a common depredator of songbird nests (Eichholz and Koenig 1992, Thompson and Burhans 2003, Weatherhead et al. 2010). More specifically, black rat snakes (*Elaphe obsolete*) have been shown to be an important nest predator (Thompson et al. 1999, Thompson and Burhans 2003) perhaps because of their preferential use of edges over other landscape features (Weatherhead and Charland 1985, Durner and Gates 1993, Blouin-Demers and Weatherhead 2001, Sperry et al. 2009).
Identification of predators at nests has often been by evidence left at the nest after depredation. However, such indirect evidence can misidentify nest predators (Hernandez et al. 1997, Fies and Puckett 2000, Pietz and Granfors 2000). In contrast, cameras have been used to accurately identify predators, prevent misdiagnoses of nest fate (Pietz and Granfors 2000), and more accurately represent the local predator community.

My primary objective was to determine if blue grosbeak and indigo bunting nests in field borders were more likely to fail if located closer to woody, crop, ditch, and road edges. Another objective was to determine if snakes, such as black rat snakes, were primary nest predators of the focal species. I hypothesized that nests closer to edges would more likely fail and that black rat snakes were the primary nest predators of both blue grosbeak and indigo buntings. Knowing the relationship between songbird nest success in field borders and distance to woody, row crops, ditches, and road edges will allow wildlife biologists to recommend placement of field borders. Blue grosbeaks (*Passerina caerulea*) and indigo buntings (*Passerina cyanea*) were chosen for this study because they were commonly found on farms in North Carolina and were used in a study in the same area by Riddle and Moorman (2010). Black rat snakes may have been the main nest predator of these two songbirds, but this could not be confirmed because cameras were not used at nests to identify predators (Riddle and Moorman 2010).

**STUDY AREA**

Study sites consisted of 77 ha of field borders on four farms in Bladen and Sampson counties in southeast North Carolina (Figure 1). These were commercial hog farms owned and operated by Murphy-Brown, LLC. About 5 ha of field border acres were divided between the three smaller farms with 72 ha of field borders on the larger
farm. Agricultural land on farms mainly grew a rotation of corn (*Zea mays*), soybeans (*Glycine max*), and winter wheat (*Triticum aestivum*).

*Field borders.*— Field borders were maintained in early succession by disking, burning, and spraying as needed. We only used field borders that adjoined a crop field on at least one side which excluded field borders adjacent to pastures or hay fields.

My study included linear and nonlinear field borders. Linear field borders (n=141) were positioned on one or more sides of a crop field and varied in size, length, and width. The average linear field border was about 0.41 ha ± 0.34 (mean ± standard deviation) in size and varied in length from 24 m to 1,821 m (mean 509.08 m ± 305.25) and in width from 3 m to 52 m (mean 9.02 m ± 6.40). Nonlinear field borders (n=24) were irregularly shaped, positioned on at least one side of a crop field, and averaged about 0.80 ha ± 0.72 in size. The primary vegetation in field borders was marestail (*Conyza canadensis*), dog fennel (*Eupatorium capillifolium*), blackberry (*Rubus sp*), salt myrtle (*Baccharis halimifolia*), and native warm season grasses such as big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and switchgrass (*Panicum virgatum*).

**METHODS**

*Nest searching.*— I separated field borders into two groups at the beginning of each field season. One group included field borders from the large farm and the second group included field borders from the three smaller farms. I made this separation so the borders on the large farm and the borders on the three small farms were searched proportionally to each other. I randomly determined the order in which the field borders would be searched throughout the field season in each of the two groups. I searched field
borders separated by a ditch simultaneously to save time and reduce disturbance to nests and the neighboring field border. I searched each field border 2-3 times in 2010 and at least 4-5 times in 2011.

I searched field borders using three techniques: systematic, behavioral, and opportunistic. A systematic search entailed walking transects in each field border until I searched it completely. If I saw behavioral cues from the birds, such as carrying food or nesting material while I was systematically searching the field border, I would suspend the systematic search to follow the birds to the nests. I also used other behavior cues to locate nests including persistent chipping, fluttering of wings, or other distraction mechanisms, and attempting to lead me away from a nest. After I found the nest, I returned to the location where the bird was first seen and finished systematically searching the field border. I also found nests opportunistically while I was changing camera batteries, checking a nest, or performing other field activities.

When searching linear field borders, two people either searched in the same field border parallel to the crop edge or on opposite sides of the ditch (if applicable) until the field border was searched completely. The shape of nonlinear field borders determined how they were searched. Each person either started on opposite ends of the nonlinear field border and walked towards each other or they walked side-by-side until the entire field border was searched.

When I found a nest, I completed a nest sheet which included information about nesting species, location (field border and farm), stage of the nest, number of host eggs in the nest, and other relevant comments.
**Nest monitoring.**—I performed nests checks every 3–4 days until the outcome of the nest was known. I took several precautions to reduce my influence on predation events (Ralph et al. 1993) because there can be a positive correlation between frequent observer visits and increased rates of nest depredation (Westmoreland and Best 1985, Major 1990). First, when a nest was checked, I used a mirror to look into the nest. I did this to avoid disturbing the young, attracting predators to the nest, or making the nest more visible to predators by disrupting surrounding vegetation. Second, as I walked to and from the nest I pretended to look into surrounding vegetation to make fake (dummy) nest checks to avoid attracting attention to the actual nest.

Each time I checked a nest, I recorded the stage of the nest (i.e. egg laying, incubation, and nestling) along with the number of host eggs and other observations related to parental behavior and condition of the young. This information was important to determine when the nest fledged if a camera was not placed at the nest. A nest was considered successful if one or more young fledged.

**Edge Sampling.**—After the outcome of the nest was known, I measured the width of the field border and distance to the closest woody, row crop, and ditch edges either using a range finder or a measuring tape. I measured field border width for both linear and nonlinear field borders by walking with a measuring tape from the nest to both the crop side of the field border and the opposite side of the field border: usually a ditch, road, or wood edge. I measured the distance to closest woody edge using a range finder at nests. I used the measuring tool in ArcGIS (Version 9.3, ESRI, Redlands, California, USA) to measure distance to the closest road for every nest.
Camera set up.— I set up cameras on half of both indigo bunting and blue grosbeak nests. I randomly selected nests that would receive a camera and placed a camera on the nest during the next designated nest check.

The camera setup included three main components: 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 two 12-V 33-A hour batteries. I attached the camera to a piece of PVC pipe and placed it about 1.5 meters from the nest at an appropriate height based on the height of the nest and surrounding vegetation. I chose the best camera angle with a clear view of the nest without removing surrounding vegetation. This lack of destruction prevented the nest from potentially becoming more susceptible to predators.

I attached the camera to a closed-circuit television (CCTV) video/power cable that ran through a hole in a sealed 5 gallon bucket. I placed a coupling in the hole and sealed it with thread seal tape and silicone caulking to prevent water and dirt from entering the bucket. I connected the cable to the DVR which then connected to a voltage regulator/harness and batteries. I used 16 gigabyte secure digital (SD) cards to record video footage. I changed SD cards and batteries during nest checks every 3-4 days. Each nest was recorded continuously at 8 frames per second on high megapixel quality with no audio.

I took several precautions to prevent damage to the camera equipment. I placed two humidity sponges into the bucket to prevent moisture from building up and short-circuiting the equipment. I also securely placed a sheet of burlap over the bucket to
provide additional camouflage and protection from heat. I covered the CCTV cable with heavy-duty flexible piping to prevent exposure to weather and being chewed or damaged by animals.

Data Analysis.— I used Program MARK (White and Burnham 1999) to estimate the daily nest survival rate (DSR) data for each species. 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 DSR. Traditional methods use exposure days (e.g., the Mayfield method; Mayfield 1961, 1975), however Program MARK allows covariates on individual nests (see model development in Dinsmore et al. 2002). Program MARK uses Akaike’s information-theoretic approach with the correction for small sample sizes ((AICc) Akaike 1972, Burnham and Anderson 2002) to aid in model selection. We built 7 nest survival models using a different covariate in each model: distance to closest woody, row crop, ditch, and road edges and field border width and effects of year and camera. A constant daily nest survival model was included in the set.

Predators caught on camera were placed into one of three predator groups: snake, mammalian, and avian. To determine if snakes were the main nest predators, we used a Chi-square goodness-of-fit test ($\alpha > 0.05$).

RESULTS

I found 9 blue grosbeak nests in 2010 and 20 in 2011 with a total of 449 exposure days. A total of 16 nests failed between the two years. The top three models for blue grosbeaks were constant nest survival, field border width, and distance to the nearest ditch (AICc weights = 0.22, 0.17, and 0.15, respectively) (Table 1). Nest success was not significantly related to any covariates because all covariates had slope betas with 95%
confidence intervals that overlapped zero (Table 2). DSR for the constant nest survival was 0.9651 (± 0.0086 SE, 95% CI 0.9438-0.9785). The model averaged DSR using all models was 0.9657 (± 0.0090 SE, 95% CI 0.9428-0.9796).

I found 8 indigo bunting nests in 2010 and 4 in 2011 with a total of 94 exposure days. Eight nests failed between the two years. The top three models for indigo buntings were distance to nearest crop, distance to nearest road, and constant nest survival (AICc weights = 0.52, 0.41, and 0.02 respectively) (Table 3). DSR for the distance to nearest crop model was 0.8733 (± 0.0499 SE, 95% CI 0.7401-0.9434). All covariate slope betas except for the top two had 95% confidence intervals that overlapped zero (Table 4). However, because there was so much variance in the Ŝ of the top two models, their 95% confidence intervals for Ŝ overlap point estimates for all other models. The model averaged DSR was 0.8846 (± 0.0444 SE, 95% CI 0.7578-0.9495).

For blue grosbeaks, average distance was 363.5 m (± 239.4 SE) to closest woody edge, 5.2 m (± 4.4 SE) to the closest row crop, 4.8 m (± 11.7 SE) to the closest ditch, and 209.6 m (± 138.7 SE) to the closest road (Table 5). The average field border width was 16.2 m (± 45.3 SE).

For indigo buntings, the average distance was 152.1 m (± 194.0 SE) to closest woody edge, 4.6 m (± 4.0 SE) to the closest row crop, 41.6 m (± 99.7 SE) to the closest ditch, and 197.0 m (± 190.4 SE) to the closest road (Table 3). The average field border width was 10.6 m (± 7.1 SE).

Cameras were set up at a total of 14 blue grosbeak nests in 2010 and 2011 (Table 6). In 2010 I recorded 2 unidentifiable mammalian depredation events and 2 nests successfully fledged. In 2011 I recorded 3 unidentifiable snake and one avian
depredation events. One nest failed due to farm equipment. Four camera-monitored nests successfully fledged and one outcome was unknown because of a camera malfunction. The three main predator groups (snake, mammalian, and avian) had similar depredation frequencies ($X^2 = 2.03, P = 0.3620$).

In 2010 and 2011 cameras were placed on 5 indigo bunting nests (Table 6). In 2010 I recorded 2 black rat snake depredations. One nest was partially depredated by a corvid resulting in one nestling being thrown out of the nest but it did not ultimately lead to nest failure. One nest successfully fledged. One black rat snake depredation was recorded in 2011 and one outcome could not be determined due to a camera malfunction. The three main predator groups had different depredation frequencies ($X^2 = 6.00, P = 0.0498$) with snakes being the main nest predator.

**DISCUSSION**

I found that distance to edge had little effect on DSR for either blue grosbeaks or indigo buntings. This was because for each of the species, slope betas had 95% confidence intervals that overlapped zero or point estimates of $\hat{S}$ had 95% confidence intervals that overlapped each other. Other studies have found similar relationships between daily nest survival and distance to woody edge, in which nests located closer to edges were not always at greater risk of nest depredation in forest-field edges (Robinson and Wilcove 1994, Marini et al. 1995, Weatherhead et al. 2010), but this is not always the case (Gates and Gysel 1978, Andren and Anglestam 1988, Marini et al. 1995, Suarez et al. 1997, Shake et al. 2011).

For both species, the average closest distance from a nest to a ditch or crop field was fairly small. This could be because each field border juxtaposed a crop field on at
least one side and most field borders juxtaposed a ditch on the other side. Distances to closest woody and road edges were much larger on average. This could be because all but two blue grosbeak nests and three indigo bunting nests were located on field borders in an agriculture-dominated landscape and that most of the field borders themselves were in an agriculture-dominated landscape.

Because this is the first study to my knowledge examining distances to various edge types in relation to nest success in field borders for blue grosbeaks and indigo buntings, there are no comparative results from past studies. There also are limited studies comparing distance from a nest to other features such as row crops, ditches, and roads. There are numerous studies that have examined edge effects from the closest woody edge but there is a lack of studies that have had nests that were greater than 500 m from a woody edge. Multiple studies found all their nests less than 150 m from a field-forest edge in multiple types of forest and field habitats (Gates and Gysel 1978, Chasko and Gates 1982, Yahner 1991, Woodward et al. 2001) with the largest distance from a nest to woody edge being 500 m (Vickery et al. 1992). Nonetheless, these studies produced mixed results regarding whether they found an edge effect. For both my species, the average distance was over 150 m to the closest woody edge. Weatherhead et al. (2010) found that the average distance to a forest edge for indigo bunting nests in two types of forest and field habitats was about 74 m and observed no edge effect. This was less than half of the average distance to closest woody edge for indigo bunting nests (152m) in my study and may explain my lack of edge effect as well.

My model averaged DSR for blue grosbeaks was 0.9657 (± 0.0090 SE) and for indigo buntings was 0.8846 (± 0.0444 SE). Few studies have recorded DSR for blue
grosbeaks. However, Shake et al. (2011) reported a similar DSR of 0.96 for blue grosbeaks in early succession forested riparian buffers. In a variety of studies examining DSR in indigo buntings, rates varied between different habitat types. DSR was 0.961 in shrublands (Woodward et al. 2001), 0.949 in early succession forested riparian buffers (Shake et al. 2011), and 0.950 in clearcut and shelterwood treatments (Annand and Thompson 1997). In forests DSR ranged from 0.911-0.937 (Twedt et al. 2001, Brawn 2006) and in old fields it ranged from 0.940-0.952 depending on whether the nest had a camera or not (Thompson et al. 1999). Among all nests found in two types of forest and fields DSR was 0.948 in one study (Weatherhead et al. 2010). Our DSR for indigo buntings was smaller than all of those reported in the other studies.

I found that snakes were the most frequent nest predator for both indigo buntings and blue grosbeaks though only statistically significant for indigo buntings. Past studies have found similar results with indigo buntings when using cameras (Thompson et al. 1999, Thompson and Burhans 2003). For example, snakes were the main nest predator of indigo buntings recorded by cameras in old fields in Missouri (Thompson et al. 1999). Snakes were 3 times more likely to depredate a nest in an old field than in a forest, with 33 of 46 nests in fields being depredated by snakes (Thompson and Burhans 2003).

We had a relatively small sample size for both of our species. However, similar patterns of lack of edge effects have been found for northern bobwhites on the same farms in North Carolina (Piispanen and Riddle, in press). Similar findings of no edge effect across 3 species with different life histories and nesting habits suggest a strong pattern and consistent effects of field borders.
MANAGEMENT IMPLICATIONS

Landowners and managers have flexibility to choose where they place field borders in relation to the four edge types studied because distance to woody, ditch, road, and row crop edge do not seem to influence the outcome of indigo bunting and blue grosbeak nests. Based on our small sample size of nests in field borders in the forest-dominated landscape, our recommendation applies more to farms in an agriculture-dominated landscape. Future studies should focus on gaining a larger sample size to determine if edge affects nesting birds differently on field borders in both forest-dominated and agriculture-dominated landscapes. Continuing to identify landscape features influencing nest success will allow biologists to make better management recommendations in relation to nest success in field borders.

ACKNOWLEDGMENTS

I would like to thank the faculty and staff at the College of Natural Resources at the University of Wisconsin-Stevens Point. I thank the Cooperative Fish and Wildlife Research Unit at North Carolina State University and the Cooperative Fish Research Unit at University of Wisconsin-Stevens Point. I also thank our field technicians D. J. Berger, A. J. Godar, A. D. Richardson, and S. R. Wendt for all of their dedicated work in the field. I also thank T. K. Hughes, M. D. Jones, and B. M. Strope from the North Carolina Wildlife Resources Commission and M. D. Williamson from Murphy-Brown, LLC for their logistical support and advice. I thank T. R. Simons, J. M. Wettroth, and J. M. Tuszka for helping in the construction of my camera set up. I also thank the North Carolina Department of Justice for funding this project.
LITERATURE CITED


Blouin-Demers, G., and P. J. Weatherhead. 2001. Habitat use by black rat snakes 

Brawn, J. D. 2006. Effects of restoring oak savannas on bird communities and 
populations. Conservation Biology 20:460-469.

Brawn, J. D., S. K. Robinson, and F. R. Thompson, III. 2001. The role of disturbance in 
the ecology and conservation of birds. Annual Review of Ecology and 
Systematics 32:251-276.


borders and mesomammal reduction on northern bobwhite and songbird 
abundance on three farms in North Carolina. Page 71 in S. J. DeMaso, W. P. 
Kuvlesky, Jr., F. Hernandez, and M. E. Berger, editors. Quail V: Proceedings of 
the Fifth National Quail Symposium. Texas Parks and Wildlife Department, 
Austin, Texas, USA.

York, USA.

corridor in an oak-hickory forest region. Wildlife Monograph 82:3-41.

Cobb, D. T., T. L. Sharpe, D. Sawyer, and D. O. Baumbarger. 2002. Integrating early-
succesional wildlife and habitats into North Carolina’s 21st century landscape.


Figure 1. Farm locations in Bladen and Sampson counties, North Carolina, USA.
**Table 1.** AIC model selection results for blue grosbeaks including AICc, AICc weight, numbers of parameters, and deviance as well as point estimates of survival (\(\hat{S}\)) and standard errors from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. Constant nest survival is represented by \(S(.)\). The other models account for distance to closest woody edge (\(S(\text{Distance to woody edge})\)), distance to closest ditch (\(S(\text{Distance to ditch})\)), distance to closest crop (\(S(\text{Distance to crop})\)), distance to closest road (\(S(\text{Distance to road})\)), field border width (\(S(\text{Field border width})\)), year effect (\(S(\text{Year})\)), and camera effect (\(S(\text{Camera})\)).

<table>
<thead>
<tr>
<th>Model Description</th>
<th>AICc</th>
<th>AICc Weight</th>
<th>No. Parameters</th>
<th>Deviance</th>
<th>(\hat{S})</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(S(.))</td>
<td>102.12</td>
<td>0.22</td>
<td>1</td>
<td>100.11</td>
<td>0.9651</td>
<td>0.0086</td>
</tr>
<tr>
<td>(S(\text{Field border width}))</td>
<td>102.69</td>
<td>0.17</td>
<td>2</td>
<td>98.66</td>
<td>0.9677</td>
<td>0.0106</td>
</tr>
<tr>
<td>(S(\text{Distance to ditch}))</td>
<td>102.86</td>
<td>0.15</td>
<td>2</td>
<td>98.83</td>
<td>0.9656</td>
<td>0.0088</td>
</tr>
<tr>
<td>(S(\text{Year effect}))</td>
<td>103.55</td>
<td>0.11</td>
<td>2</td>
<td>99.52</td>
<td>0.9653</td>
<td>0.0086</td>
</tr>
<tr>
<td>(S(\text{Distance to road}))</td>
<td>103.76</td>
<td>0.10</td>
<td>2</td>
<td>99.73</td>
<td>0.9653</td>
<td>0.0086</td>
</tr>
<tr>
<td>(S(\text{Distance to crop}))</td>
<td>103.92</td>
<td>0.09</td>
<td>2</td>
<td>99.89</td>
<td>0.9649</td>
<td>0.0086</td>
</tr>
<tr>
<td>(S(\text{Distance to woody edge}))</td>
<td>104.06</td>
<td>0.08</td>
<td>2</td>
<td>100.03</td>
<td>0.9653</td>
<td>0.0086</td>
</tr>
<tr>
<td>(S(\text{Camera effect}))</td>
<td>104.12</td>
<td>0.08</td>
<td>2</td>
<td>100.09</td>
<td>0.9651</td>
<td>0.0086</td>
</tr>
</tbody>
</table>
Table 2. The betas for the slope for blue grosbeaks along with standard errors and 95% Confidence Intervals from Program MARK from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. The other models account for 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)).

<table>
<thead>
<tr>
<th>Model Description</th>
<th>Beta</th>
<th>Standard Error</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>S(Field border width)</td>
<td>0.0161</td>
<td>0.0286</td>
<td>-0.0400</td>
<td>0.0723</td>
</tr>
<tr>
<td>S(Distance to ditch)</td>
<td>0.0331</td>
<td>0.0417</td>
<td>-0.0487</td>
<td>0.1148</td>
</tr>
<tr>
<td>S(Year effect)</td>
<td>-0.4349</td>
<td>0.5863</td>
<td>-1.5840</td>
<td>0.7142</td>
</tr>
<tr>
<td>S(Distance to road)</td>
<td>-0.0010</td>
<td>0.0016</td>
<td>-0.0042</td>
<td>0.0022</td>
</tr>
<tr>
<td>S(Distance to crop)</td>
<td>0.0268</td>
<td>0.0592</td>
<td>-0.0892</td>
<td>0.1428</td>
</tr>
<tr>
<td>S(Distance to woody edge)</td>
<td>3.2E-03</td>
<td>0.0011</td>
<td>-0.0019</td>
<td>0.0026</td>
</tr>
<tr>
<td>S(Camera effect)</td>
<td>-0.0749</td>
<td>0.5132</td>
<td>-1.0809</td>
<td>0.9310</td>
</tr>
</tbody>
</table>
Table 3. AIC model selection results for indigo buntings including AICc, AICc weight, number of parameters, and deviance as well as point estimates of survival (\( \hat{S} \)) and standard errors from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. \( S(.) \) represents constant nest survival. The other models account for distance to closest woody edge (\( S(Distance\ to\ woody\ edge) \)), distance to closest crop (\( S(Distance\ to\ crop) \)), distance to closest ditch (\( S(Distance\ to\ ditch) \)), distance to closest road (\( S(Distance\ to\ road) \)), field border width (\( S(Field\ border\ width) \)), camera effect (\( S(Camera) \)), and year effect (\( S(Year) \)).

<table>
<thead>
<tr>
<th>Model Description</th>
<th>AICc</th>
<th>AICc Weight</th>
<th>No. Parameters</th>
<th>Deviance</th>
<th>( \hat{S} )</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>S(Distance to crop)</td>
<td>35.35</td>
<td>0.52</td>
<td>2</td>
<td>31.21</td>
<td>0.8733</td>
<td>0.0499</td>
</tr>
<tr>
<td>S(Distance to road)</td>
<td>35.84</td>
<td>0.41</td>
<td>2</td>
<td>31.70</td>
<td>0.8940</td>
<td>0.0398</td>
</tr>
<tr>
<td>S(.)</td>
<td>41.90</td>
<td>0.02</td>
<td>1</td>
<td>39.86</td>
<td>0.9149</td>
<td>0.0289</td>
</tr>
<tr>
<td>S(Distance to ditch)</td>
<td>42.45</td>
<td>0.02</td>
<td>2</td>
<td>38.31</td>
<td>0.9182</td>
<td>0.0302</td>
</tr>
<tr>
<td>S(Distance to woody edge)</td>
<td>43.02</td>
<td>0.01</td>
<td>2</td>
<td>38.88</td>
<td>0.9140</td>
<td>0.0295</td>
</tr>
<tr>
<td>S(Field border width)</td>
<td>43.53</td>
<td>0.01</td>
<td>2</td>
<td>39.39</td>
<td>0.9173</td>
<td>0.0291</td>
</tr>
<tr>
<td>S(Camera)</td>
<td>43.62</td>
<td>0.01</td>
<td>2</td>
<td>39.47</td>
<td>0.9097</td>
<td>0.0310</td>
</tr>
<tr>
<td>S(Year)</td>
<td>43.97</td>
<td>0.01</td>
<td>2</td>
<td>39.83</td>
<td>0.9151</td>
<td>0.0289</td>
</tr>
</tbody>
</table>
**Table 4.** The betas for the slope for indigo buntings along with standard errors and 95% Confidence Intervals from Program MARK from field borders on four farms in Bladen and Sampson counties in North Carolina, USA, 2010 and 2011. The other models account for 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)).

<table>
<thead>
<tr>
<th>Model Description</th>
<th>Beta</th>
<th>Standard Error</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>S(Distance to crop)</td>
<td>-0.5549</td>
<td>0.2591</td>
<td>-1.0627</td>
<td>-0.0471</td>
</tr>
<tr>
<td>S(Distance to road)</td>
<td>-0.0081</td>
<td>0.0031</td>
<td>-0.0141</td>
<td>-0.0020</td>
</tr>
<tr>
<td>S(Distance to ditch)</td>
<td>0.0062</td>
<td>0.0066</td>
<td>-0.0067</td>
<td>0.0190</td>
</tr>
<tr>
<td>S(Distance to woody edge)</td>
<td>0.0021</td>
<td>0.0023</td>
<td>-0.00234</td>
<td>0.0066</td>
</tr>
<tr>
<td>S(Field border width)</td>
<td>0.03819</td>
<td>0.0605</td>
<td>-0.0805</td>
<td>0.1569</td>
</tr>
<tr>
<td>S(Camera)</td>
<td>-0.4599</td>
<td>0.7430</td>
<td>-1.9163</td>
<td>0.9964</td>
</tr>
<tr>
<td>S(Year)</td>
<td>-0.1285</td>
<td>0.7676</td>
<td>-1.6330</td>
<td>1.3760</td>
</tr>
</tbody>
</table>
Table 5. Average, minimum, and maximum distances (m) for closest woody, crop, ditch, and road edges for blue grosbeaks and indigo buntings on field borders on four farms in Bladen and Sampson Counties, North Carolina, USA, 2010 and 2011.

<table>
<thead>
<tr>
<th>Edge</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue grosbeak</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woody</td>
<td>363.5</td>
<td>3.2</td>
<td>949.0</td>
</tr>
<tr>
<td>Ditch</td>
<td>4.8</td>
<td>0.2</td>
<td>65.0</td>
</tr>
<tr>
<td>Crop</td>
<td>5.2</td>
<td>0.3</td>
<td>19.8</td>
</tr>
<tr>
<td>Road</td>
<td>209.6</td>
<td>6.3</td>
<td>600.0</td>
</tr>
<tr>
<td>Indigo bunting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woody</td>
<td>152.1</td>
<td>2.0</td>
<td>507.0</td>
</tr>
<tr>
<td>Ditch</td>
<td>41.6</td>
<td>0.0</td>
<td>338.0</td>
</tr>
<tr>
<td>Crop</td>
<td>4.6</td>
<td>1.4</td>
<td>15.3</td>
</tr>
<tr>
<td>Road</td>
<td>197.0</td>
<td>17.0</td>
<td>599.0</td>
</tr>
</tbody>
</table>
Table 6. Number of nest depredations recorded on camera for each group of predators for blue grosbeaks and indigo buntings from 2010 and 2011 breeding seasons on field borders on four farms in Bladen and Sampson counties, North Carolina, USA.

<table>
<thead>
<tr>
<th></th>
<th>Snake</th>
<th>Mammalian</th>
<th>Avian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue grosbeak</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Indigo bunting</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>