CONSERVING A CHARISMATIC GRASSLAND SPECIES IN ILLINOIS: THE BARN OWL

BY

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THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Natural Resources and Environmental Sciences
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2015

Urbana, Illinois

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ABSTRACT

As a result of the precipitous loss of grasslands and savannas that the Midwestern U.S. has experienced, populations of many species native to this habitat have declined. One such species is the barn owl, *Tyto alba*, which is threatened or endangered in 5 states. The conversion of grasslands into agricultural or developed areas has cost barn owls both suitable foraging habitat and nest sites. To mitigate this loss and support barn owl populations, many states, including Illinois, have installed nest boxes in or near grassland habitat. Many of these boxes were never monitored to document their success. Adding to the uncertainty of the barn owl population in Illinois is their secretive, nocturnal nature. Since owls that nest outside of nest boxes are rarely discovered, an effective large scale survey method is needed. My goals for this project were to describe barn owl use of nest boxes, learn how they selected their nest sites, determine factors correlated with nest survival, and test playback surveys as a method of detection. To this end, I checked all known nest boxes in Illinois and monitored active nests until they fledged or failed. I then compared land cover at occupied and unoccupied nest boxes. To determine a response rate for barn owls to broadcasted calls, I conducted nighttime playback surveys close to active nests. I found that barn owl occupancy of nest boxes was positively related to percent cover of grassland and negatively related to percent cover of corn and soybeans with 2 km. Daily survival rate was also positively related to grass cover. Barn owls responded to active playback surveys at a rate of 48.8%, irrespective of time of night, date, or age of the nest. This information is intended to assist biologists in the process of monitoring, managing, and evaluating the status of barn owls in Illinois, with the ultimate goal being the recovery and delisting of the species.

ACKNOWLEDGMENTS

I would like to thank my advisor, T.J. Benson, for all his patient guidance, feedback, and help with statistics. I feel extremely fortunate to have been his graduate student. I would also like to thank my committee members, Mike Ward and Jeff Walk, for their feedback. I thank my field assistants, Sky Bischoff-Mattson and Jay Card for all their hard work. I also thank the other members of the Benson lab. To Val, Tyson, Jake, and Scott I offer my gratitude for making me feel welcome and helping me settle into the graduate program when I first arrived at the U of I. I thank Tyson and Scott for helping me gather, assemble, and troubleshoot my field equipment; Jake, Tyson, and Tara for making trips into the field with me; and Scott, Val, and Tim for sharing statistical knowledge and SAS/R coding.

I would like to thank my funding sources, the Illinois Department of Natural Resources (IDNR) and U.S. Fish and Wildlife Service through the Federal Aid in Wildlife Restoration Program (project W-168-R) as well as the Champaign County Audubon Society and the Illinois Ornithological Society. I thank Terry Esker, Bob Lindsay, Michelle Simone, Mark Phipps, Bob Shelby, and Leroy Harrison of IDNR for providing field assistance, sharing data, and facilitating access to study sites. I would especially like to thank Terry Esker for the many trips he took into the field with me and the countless hours he spent installing new nest boxes and updating the database.

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CHAPTER 1

GENERAL INTRODUCTION

Across North America, tallgrass prairies and oak savannas have declined substantially since European settlement. In many states, as little as 0.1% of tallgrass prairies and 0.02% of oak savannas remain (Nuzzo 1986, Samson and Knopf 1994). Most of these ecosystems have been replaced by woody encroachment, development, or agriculture (Colvin 1985, Nuzzo 1986, Coppedge et al. 2001). As a result, many grassland species have become threatened or extinct (Samson and Knopf 1994). This trend is particularly evident with grassland birds in the Midwestern U.S., whose populations have declined faster than any other group of birds in the United States (Warner 1994, Herkert 1995, Samson and Knopf 1996, Coppedge et al. 2001). In Illinois, grassland bird populations are estimated to have declined between 24 and 91% between 1969 and 1991 (Samson and Knopf 1994).

For cavity-nesting birds, another limiting factor may be a shortage of nest sites (Drapeau et al. 2009, Franco et al. 2013). While snags and open manmade structures have traditionally provided these sites, snags become scarce as landscapes have largely been converted to row-crop agriculture and many old buildings with suitable nests sites have been removed from the landscape or replaced with newer buildings that are not suitable for nesting (Bagne et al. 2008). To compensate for this shortage of nest sites, nest boxes for cavity-nesting birds have been installed in a variety of habitats. These nest boxes are used regularly and they commonly produce successful clutches. Nest boxes can stabilize or increase bird populations that have been limited by a lack of nest sites (Mummert et al. 2002, Lambrechts et al. 2012, Franco et al. 2013).

The barn owl, *Tyto alba pratincola*, is a species of grasslands and savannas that has declined throughout the Midwestern U.S. for several decades (Tate 1981). As of 2015, the barn owl was listed as endangered in 4 states and at risk, threatened, or a species of special concern in 7 additional states. This decline is primarily due to habitat and nest site loss (Colvin 1985). Farming methods formerly included grasslands such as pastures, hayfields, meadows, and fallow fields, but there has been a shift towards converting these areas to row crops (Colvin 1985). These crop fields do not support healthy populations of voles (*Microtus* spp.) and other small mammals, which are the preferred prey of barn owls (Colvin 1985).

Nesting sites have been lost at a high rate in many areas that would be otherwise suitable for barn owls (Hindmarch et al. 2012). Although they nest in natural cavities such as hollow snags and cliff ledges, they also regularly use manmade structures, including barns, grain bins, silos, abandoned houses, and nest boxes. Nest boxes have been shown to increase populations at locations where nest sites are limited (Marti et al. 1979). Barn owls frequently use nest boxes and successfully fledge young from them, perhaps at an even greater rate than they fledge from natural cavities or structures without nest boxes (Johnson 1994). In Illinois, these nest boxes were originally placed in existing structures, such as barns and silos. However, this strategy limited box installation to areas that already contained these buildings, and many of the structures that housed nest boxes have collapsed or been demolished in recent years. If these building are replaced, it is often with closed structures that are not accessible to birds. Older wooden barns usually had several openings to the outside and had suitable nest sites such as ledges and lofts. Newer barns are usually made of metal and lack these openings. Recently, the Illinois Department of Natural Resources (IDNR) has shifted to installing free standing pole-mounted nest boxes. If these boxes are used successfully by barn owls, land managers will gain flexibility in their nest box placement options.

Beyond potentially enhancing populations, nest boxes provide a means for assessing the population status for an otherwise difficult to monitor species. Given their secretive and nocturnal nature, barn owl presence and abundance can be challenging to evaluate. Barn owls, like other raptors, maintain large territories, which results in low population density. Systematic searches are impractical and expensive, and traditional surveys like the Breeding Bird Survey are not effective for counting nocturnal birds. Since nests in natural cavities or on private property are rarely found or reported, nest boxes increase the number of known, documented barn owl nests which can be easily monitored.

Another possible method of assessing barn owl presence and abundance is conspecific playback surveys. Playback surveys are an effective means of surveying many secretive species, including marsh birds, owls, and diurnal raptors (McLeod and Andersen 1998, Barnes and Belthoff 2008, Soehren et al. 2009). I was unable to find any previous studies conducted in the United States that addressed the effectiveness of playback surveys with barn owls, though three studies from Spain and Africa that suggested playbacks may increase detection rates (Zuberogoitia and Campos 1998, Stevens 1999, Siverio et al. 1999).

To aid in the recovery of barn owl populations and provide guidance for future efforts intended to conserve this species, I examined use and reproductive success in nest boxes. I sought to identify the landscapes that have the greatest probability of successful establishment of barn owls and reproductive success. I also wanted to find out whether pole-mounted boxes, which do not require preexisting structures and can be placed in suitable grass-dominated landscapes, are a viable option. I did this by comparing their rate of use and success with nest boxes in barns. In order to develop a methodology to detect barn owls in new areas, I conducted experimental nighttime playback surveys near active nests to determine the response rate of breeding barn owls. A greater understanding of barn owl vocalization may provide a mechanism for assessing the presence or absence of barn owls at larger scales.

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CHAPTER 2: FACTORS ASSOCIATED WITH BARN OWL NEST SITE SELECTION AND NEST SURVIVAL

ABSTRACT

Barn owl populations have decreased in the Midwestern U.S. in recent years, and they are listed as threatened or endangered in several states, including Illinois. This is largely due to the loss of grassland and savanna habitat to increased row cropping and development, as well as a likely decrease in suitable nesting substrates. To deal with the problem of nest site scarcity, many states, including Illinois, have initiated nest-box programs. However, monitoring of these nest boxes has been intermittent. I aimed to better estimate the state's barn owl population, fully document their use of nest boxes and factors associated with nest-box use, and find factors associated with nest survival in Illinois. To ascertain factors associated with box occupancy, I examined the landscape composition and structure at barn owl nest sites and unoccupied boxes. I found that barn owls more commonly nested in boxes with more grassland cover and less corn and soybean cover within a 2 km radius. Nest boxes in southern Illinois were used more frequently than those in the northern half of the state and pole-mounted boxes were used with equal or greater frequency than boxes associated with buildings. Nest survival was most strongly associated with grassland cover near the nest box. Placing pole-mounted boxes in landscapes with large amounts of grass cover, particularly in southern Illinois, will likely provide the best approach for recovering, and ultimately delisting, barn owls in Illinois.

INTRODUCTION

North American tallgrass prairies have declined by as much as 99.9% in some states since 1830, when homesteaders first began to settle in the Midwestern U.S. (Samson and Knopf 1994). During this time period, all but 0.02% of Midwestern oak savannas also disappeared

(Nuzzo 1986). The major causes of this grassland and savanna loss include agricultural intensification (Colvin 1985) and encroachment of woody plants as a result of fire suppression (Nuzzo 1986, Coppedge et al. 2001).

Remaining grasslands and savannas are generally degraded due to their use for agricultural purposes and fragmentation. As a result, many species of birds and mammals that were once common in prairies are now endangered or extinct (Samson and Knopf 1994). Grasslands birds, including several endemic species, have been particularly negatively impacted by these changes (Warner 1994, Herkert 1995, Coppedge et al. 2001). This avian community has declined faster than any other group of birds in the U.S. (Samson and Knopf 1996). In Illinois, grassland birds are estimated to have declined between 24 and 91% between 1969 and 1991 (Samson and Knopf 1994), and birds nesting in small remaining grassland fragments may experience decreased breeding success (Herkert et al. 2003).

Another problem that may restrict bird populations is a shortage of nest sites. Nest sites may be a limiting factor for cavity-nesting bird populations in areas where suitable snags are scarce (Drapeau et al. 2009, Franco et al. 2013). Snags have limited lifespans, including in areas with prescribed burning (Bagne et al. 2008), and snags on private property are often removed for safety and aesthetic reasons. To address this shortage of nest sites, nest boxes are routinely used for some cavity-nesting bird species. In many cases, these boxes are widely used for breeding by target species, and can stabilize or increase bird populations that have been limited by a lack of nest sites (Mummert et al. 2002, Lambrechts et al. 2012, Franco et al. 2013). Examples of bird populations that have been quickly revived by widespread nest box programs include the wood duck and the American kestrel (Hawkins and Bellrose 1940, Smallwood et al. 2009).

The barn owl, *Tyto alba pratincola,* has declined throughout the Midwestern U.S. for several decades (Tate 1981), primarily due to habitat and nest-site loss (Colvin 1985). Exposure to DDT may have also negatively impacted their populations in the mid-20th century (Newton et al. 1991). Barn owls are grassland and savanna species that depend on large open areas to hunt for their prey, mainly small rodents (Gubanyi et al. 1992). Formerly, farming methods included pastures, hayfields, meadows, and fallow fields, which function largely as grasslands, but there has been a shift towards converting these areas to row crops, primarily corn and soybeans (Colvin 1985). In landscapes dominated by these row crops, habitat for the barn owls' preferred prey, voles (*Microtus* spp.), is lost, thereby rendering these fields inadequate as foraging areas (Colvin 1985). As of 2015, the barn owl was listed as endangered in 5 states and at risk, threatened, or a species of special concern in 7 additional states.

Barn owl nesting sites have been lost at a high rate in many areas (Hindmarch et al. 2012). Barn owls require relatively large cavities in which to nest, which can be scarce. Loss of nesting sites can cause owls to abandon the surrounding area, even when alternative nest sites are available (Ramsden 1998). Although barn owls nest in natural cavities such as hollow snags and cliffs, they also commonly use manmade structures, including nest boxes. Barn owls have been demonstrated to readily use and successfully fledge young from nest boxes, perhaps at an even greater rate than they fledge from natural cavities or structures without nest boxes (Johnson 1994). Moreover, nest boxes have been shown to increase local populations at locations where nest sites are limited (Marti et al. 1979, Johnson 1994). In some cases, the quick occupation of newly installed nest boxes reinforced the theory that barn owls in these areas were cavity limited. However, despite their utility, the traditional placement of nest boxes in existing structures, such as barns, has restricted their deployment on many landscapes. Beyond potentially enhancing populations, nest boxes also provide a mechanism for assessing population status and trends for an otherwise difficult to monitor species.

In addition to the challenges posed by habitat loss and the availability of nest sites, numerous factors, including weather and anthropogenic mortality, can limit barn owl populations. Deep snow can make finding food difficult and can lead to die-offs during harsh winters in northern locations (Stewart 1952, Marti and Wagner 1985, Altwegg et al. 2006). Collisions with cars can cause high rates of mortality (Boves and Belthoff 2012), and heavy vehicle traffic can prevent barn owls from using areas with suitable habitat (Hindmarch et al. 2012). In some areas, ingestion of pesticides may have a negative effect on breeding success (Mendenhall et al. 1983).

To aid in the recovery of barn owl populations and provide guidance for future efforts intended to conserve this species, I set out to examine use and reproductive success in nest boxes. I sought to identify the landscapes that have the greatest probability of breeding by barn owls and reproductive success. Since other studies found that barn owl populations were limited by nest site availability, I looked for evidence of this phenomenon in Illinois. I also examined whether pole-mounted boxes, which are not constrained to placement in preexisting structures, are used for successful breeding by barn owls.

METHODS

Study Area

In 2013 and 2014, there were 275 and 305 nest boxes, respectively, known by the Illinois Department of Natural Resources (IDNR) to be installed in 53 counties in Illinois (Fig. 1). I visited several different styles of nest box, including wooden (166) and plastic boxes (105) mounted in barns (132) or on free-standing poles (139). The plastic boxes placed in barns and poles were purchased (Barn Owl Box Company, Pittsburgh, PA), whereas wooden boxes were constructed. Most nest boxes (93%) were in the southern half of the state, and almost all sites with documented breeding activity before my field work began were in Gallatin, Jackson, Johnson, Perry, Pope, Pulaski, and Union counties in far-southern Illinois. Additional breeding sites had been found previously in Bond, Christian, Clinton, Effingham, Franklin, Hamilton, Lawrence, Marion, Montgomery, and Wayne counties. Few nests in natural cavities or in structures without nest boxes were known, as they are difficult to find and seldom reported by landowners. Fewer than 50 such nests were reported to the IDNR between 1986 and 2012.

Nest monitoring

I checked every nest box with known locations at least once between March and July of each year. I did not check new nest boxes that were installed during or after the year's breeding season. The field seasons began on March 25, 2013 and March 17, 2014. Sites south of Marion County were checked at least twice to maximize the probability of detecting nest attempts.

I revisited active nests in southern Illinois about every 2 weeks until they fledged or failed. This interval seemed appropriate given the long incubation and nestling periods (~30 days of incubation plus ~64 days until fledging; (Smith et al. 1974). I continued to check these nest sites after the conclusion of nesting attempts to maximize detection of new nesting attempts. Although multiple clutches are thought to be uncommon in temperate climates (Marti el al 2005) they have been documented (Witmer and Patrick 1987, Marti 1994, Walk 1999). During the fall and winter of 2013-2014, I checked for evidence of fall or winter breeding by making monthly visits to two sites with high rates of nest box occupancy in Perry and Jackson County in southern Illinois.

Nest checks were done mainly with a pole-mounted camera (Huebner and Hurteau 2007). The camera, mounted on a 6.1-m tall telescoping pole, sent a live image to a monitor on the ground. Although intensive monitoring of barn owl nests has not been shown to have serious negative consequences such as nest abandonment (Taylor 1991), our use of a pole-mounted camera minimized disturbance during each nest check and increased our efficiency in checking nests. In many cases, the incubating owl did not flush and I did not attempt to force it to do so. Consequently, I was not always able to quantify the nest contents. In cases where the nests could not be reached with the camera (e.g., nests more than 6 m above the ground), I accessed nest boxes with a ladder. In addition to checking box contents, I surveyed the area surrounding each nest box for fresh owl pellets, feces, and owl feathers.

Quantifying landscape context

To identify factors associated with nest-box use and assist in identifying locations for future nest-box deployment, I quantified landscape attributes of all boxes using the most recent land cover data from the National Agricultural Statistics Service (NASS 2014) in ArcMap 10.1 (ESRI 2012). A study of radio-tagged barn owls in Nebraska found individuals within 1.3 km of their nests 95% of the time (Gubanyi et al. 1992), and studies in other regions have found home ranges varying from a 0.9 km to 1.5 km radius (Bunn et al. 1982, Hegdal 1984, Michelat 1991); I increased to a 2-km radius to accommodate for the potential for larger home ranges (Colvin 1985). Although I focused on a 2-km radius surrounding nest boxes, I also examined landscape variables within 1, 1.3, 3, and 4 km of nest sites. While the results from all buffers were qualitatively and quantitatively similar, they were strongest with a 2-km buffer.

The NASS data have 30-m resolution and are compiled yearly. Because the nests are initiated in the late winter before crops have been planted, I analyzed each year's nests with the previous year's crop data. I used the Geospatial Modeling Environment (Beyer 2012) to calculate percentages of ground-cover types within the buffered nesting areas. I focused on corn, soybeans, open water, developed area, deciduous forest, and grassland/pasture, because these were the most common cover types or were thought to be biologically important for owl habitat use, and I excluded rare cover types (e.g. oats, fallow fields). Grassland and pasture were separate land-cover categories in the 2012 NASS dataset, but in 2013 they were combined. For consistency, and because these types of land-cover are similar in their suitability for barn owl foraging, I combined them in 2012 to make the variable 'grass.' I also included alfalfa hay and 'other hay' in this variable, since hayfields may be used by foraging owls (de Bruijn 1994). I kept corn and soybeans as separate variables due to their different structures, which may have different implications for barn owl use.

I calculated the distance of each box from the nearest road and highways, and the total length of roads and highways within the 2.0 km buffer. I acquired road data through ArcMap, in conjunction with Tele Atlas North America (Tele Atlas). Roads in this layer were classified as 'freeway or other major road', 'major road less important than a freeway', 'other major road', 'secondary road', 'local connecting road', or 'important local road'. I used all classifications in calculating the distance to a road or the total length of roads within 2 km. For calculating the distances to and total length of highways, I used all categories except for 'important local road', since many busy local highways were listed as secondary or local connecting roads.

<u>Statistical analyses</u>

I examined differences in variables between occupied and unoccupied nest boxes using a general linear mixed model (Table 1) (SAS PROC MIXED; Littell et al. 2006). I also examined factors associated with the presence of barn owl nests using a generalized linear mixed model with a binomial distribution and logit link function (SAS PROC GLIMMIX; Littell et al. 2006). I examined fixed effects of landscape variables as well as northing (latitude), box location (pole-mounted vs. barn), box type (wood vs. plastic) height, and previous occupancy, and incorporated a random effect of box identification to account for the potential non-independence of having values for nest status at many boxes for both 2013 and 2014 (n = 244).

I evaluated candidate models for barn owl nest site selection (Table 2) using Akaike's Information Criterion adjusted for small sample size (AIC_c) (Burnham and Anderson 2002). I created single-variable models for each major land cover type and nest box type (barn vs. pole-mounted) along with models with additive effects of the most common land use types. I evaluated correlations among explanatory variables; very few were strongly correlated (correlation coefficient ≥ 0.7), and I did not include these variables in the same models. Some variables were moderately correlated due to the nature of the land-cover data, particularly corn cover with northing, soybean cover and grass cover. I also made models to examine the interactive effect of latitude with grass and corn cover. Using a similar set of candidate models (Table 3), I also examined the influence of landscape and box-level factors on nest survival using the logistic exposure method (Shaffer 2004). I calculated daily survival rates of nests for different levels of land cover, and extrapolated these rates to 94 days, to estimate nest survival. To calculate standard errors of the nest survival estimates, I used the Delta method (Powell 2007).

RESULTS

In two years of barn owl box monitoring, I checked 271 boxes in 49 counties throughout Illinois. I found 82 (34 in 2013; 48 in 2014) nests at 58 locations with an additional 21 nests reported in trees, grains bins, or other structures (Fig. 1). Nests were found in 19 counties in

2013 and 17 in 2014, 24 counties in years combined. There were 6 second clutches in 2013 and one in 2014. Of the second nesting attempts in 2013, 5 occurred after the owl pair had successfully fledged their first clutch, and one was after their first clutch failed. In 2014, the second attempt was after their first attempt failed. There were no known pairs in 2014 that successfully raised more than one brood; at least 3 second nesting attempts were successful in 2013.

In 2014, there was an increase in the number of nest boxes that were used in large tracts of public land, including Prairie Ridge State Natural Area in Jasper and Marion Counties (0 in 2013, 6 in 2014), Pyramid State Park in Perry County (6 in 2013, 13 in 2014), Burning Star 5 in Jackson County (3 in 2013, 5 in 2014), and the World Shooting Complex in Randolph County (3 in 2013, 4 in 2014). At Pyramid and Burning Star, every nest box on those properties had barn owl nests in 2014. Overall, 29 nests in 2014 were at sites that did not have nests in 2013, while 19 nests were in boxes that were also occupied in 2013. At least 5 boxes that have had nests for the past two or more years were empty in 2014.

In addition to barn owl nests, I also found 40 American kestrel nests, 16 rock pigeon nests, 15 European starling nests, 3 tree or barn swallow nests, 3 wood duck nests, 47 nests of unknown small birds, 2 nests of unknown raptors, and 1 black vulture nest. The unknown small birds were likely European starlings as well. I found one roosting eastern screech-owl and 1 eastern bluebird. In boxes that lacked predator guards, I found 4 squirrels, 1 cat, and 7 raccoons. Evidence of raccoons was present in other boxes as well, mainly in barn boxes. I discovered a black rat snake in one plastic pole-mounted box with a standard predator guard; agitated kestrels were flying around the box, suggesting that the snake may have depredated their nest.

In 2013, 10 nests were initiated between 5 February and 1 March. In 2014, only one nest was initiated in February (27 February). The average estimated initiation date for first nesting attempts was 16 March in 2013 ± 34.67 days (SD) and 30 March in 2014 ± 23.14 days (SD). In each year, there were a small number of nests that were initiated in the late summer (the last known initiations were approximately 20 Aug 2013 and 10 Jul 2014).

The best-ranked model for predicting the presence of a barn owl nest was grass and corn cover within 2 km (Table 2). Grass and corn cover significantly differed between occupied and unoccupied nest boxes, as did total road length and distance from highway (Table 1). Cover of forest, developed open space, and open water did not differ between occupied and unoccupied boxes, nor did total highway length or distance from the nearest road, whereas cover of all development and soybeans were marginally significant. Northing was not significantly different between occupied and unoccupied sites, but it had a very large standard error. Based on summed AIC weights, the most important variable for predicting nest presence was grassland cover within 2 km ($\Sigma w_i = 1.00$; Fig. 2). Corn and soybean cover were negatively associated with barn owl nest presence (Figs. 3, 4). Northing had a lesser, but important, influence; nests were more likely in southern rather than northern Illinois (Fig. 5). Nest box type did not have an effect on site selection (Fig. 6). Despite differing significantly between occupied and unoccupied boxes, neither total road length nor distance from highway were strongly supported by AIC_c model rankings.

In 2013, the number of eggs laid was between 3 and 8 with an average clutch size of 5.22 ± 1.91 (SD) eggs (*n* = 34). In 2014, the number of eggs laid was between 3 and 9 with an average clutch size of 5.19 ± 1.51 eggs (*n* = 48). 46 of 72 nests with known outcomes were observed to successfully fledge young (63.9%), 18 of 28 for 2013 (64.3%) and 28 of 44 for 2014 (63.6%).

Approximately 170 nestlings fledged from these nests. For all nesting attempts with known outcomes, a mean of 2.36 ± 1.95 (SD) chicks were fledged (*n* = 72) per nesting attempt. For successful nests, 3.69 ± 0.99 chicks were fledged per nest (*n* = 37). In 2013, the average number of chicks fledged per nesting attempt was 2.52 ± 2.14 for all nests (*n* = 34), and 4.00 ± 1.06 for successful nests (*n* = 18). In 2014, the average number of chicks fledged per nesting attempt was 2.19 ± 1.83 for all nests (*n* = 48), and 3.48 ± 0.87 for successful nests (*n* = 28).

Of the monitored nests that failed, 22 appeared to fail due to starvation or abandonment (including 2 cases when one of the adults was found dead or injured), 3 were probably depredated, and 1 was probably due to public disturbance. All known predation events occurred in 2013 in wooden pole mounted boxes that lacked predator guards. After predator guards were added prior to the 2014 breeding season; barn owls successfully nested in them in 2014. Nest failures occurred at both the egg (*n* = 8) and nestling stage (*n* = 18). There were 10 nests with unknown outcomes.

The top-ranked models for nest survival were the additive effects of corn and grass cover (Table 3). Corn and grass cover were both positively associated with nest daily survival rate. There appeared to be some support for the variable northing, with nest survival increasing at northerly locations. Soybean cover and road or highway variables appeared to be unimportant predictors of nest survival. Nest box height, nest box style, date, and initiation date were also not important for nest survival. Daily survival rate ranged from 0.9880 to 0.9987 (mean = 0.9962) with increasing grass cover within 2 km. This daily survival rate translates into a 32.3% chance of a nest surviving to fledging in an area with no grass, and an 88.9% chance of nest success with 70% grass cover within 2 km (Fig. 7).

DISCUSSION

I found that the percent cover of grassland within a 2-km radius of nest boxes was the most influential factor for both barn owl nest site selection and nest survival. Preserving, restoring, and managing healthy grasslands should be a main focus for barn owl conservation, and it is in these habitats that site managers should install nest boxes.

The positive effect of grassland cover on both barn owl nest site selection and nest survival likely reflects the availability of voles, their main prey species (Phillips 1951, Colvin and McLean 1986). The strong effect of grassland cover likely indicates an effect of both grassland patch size and number of patches. Although I did not quantify patch size, larger grassland patches may be more easily discovered by barn owls in search of a nest site, or may support more healthy prey populations. The strong negative impact of crop cover, especially corn, is likely due to poor foraging in these areas. Vole populations are low in row-cropped fields relative to grasslands (Lyman 2012, Heisler et al. 2013). Moreover, corn fields are difficult for owls to enter, particularly when the corn is tall (Arlettaz et al. 2010). Row crops may also be harmful to owls due to pesticides (Mendenhall et al. 1983).

The high rate of use of nest boxes at large grassland sites in Perry, Randolph, and Jackson Counties and the rapidity with which barn owls began to occupy them suggests that barn owls were limited by a shortage of nest sites at these locations. In order to support breeding barn owl populations, installation and continuing maintenance of nest boxes is necessary in many areas. The construction of the nest boxes (plastic vs. wood) had no effect on barn owl nest site selection or survival, and pole-mounted boxes were used at least as often and had comparable nest survival to barn boxes. Wooden boxes may be an attractive option for site managers due to their relatively low cost. Pole-mounted nest boxes are simple to install and can be placed in open grassland landscapes that lack buildings in which to install barn boxes.

In the only other study known to characterize landscape-level variables surrounding barn owl nests in the United States, a study in Nebraska characterized barn owl habitat as being made up of 47 to 81.9% cropland, 16.5 to 49% grassland, and less than 5% woodland within a 1.3 km radius of active nests (Gubanyi et al. 1992). I found much wider ranges of these variables within 2 km of active barn owl nests, with up to 83% forest, 94% total cropland, and as little as 1% grassland. While barn owls prefer grassland habitat, they are sometimes found in locations that are seemingly less suitable. Owls living in such locations likely travel farther than that those with optimal territories to forage (Hegdal 1984).

Pole-mounted nest boxes are easy to install and can be placed in open landscapes that lack structures in which to install barn boxes. Even though pole-mounted boxes provide increased flexibility for nest-box placement, efforts should be taken to make boxes predator resistant. Without predator guards, pole-mounted boxes may serve as ecological traps. In my study, predation that was presumed to be caused by raccoons was eliminated between 2013 and 2014 by installing predator guards. Predator resistant nest boxes provide safe nesting sites with high rates of nesting success. The clutch size and number of young fledged per successful nest that I observed were similar to other studies conducted in the Midwestern and northeastern U.S. (Radley and Bednarz 2005). I did not monitor enough nests in natural cavities to compare nest success rates between natural cavities and nest boxes, but other studies have documented greater success rates in nest boxes than in natural cavities (Gubanyi et al. 1992). This is believed to be due to lower predation rates and increased protection from weather.

Although I examined the influence of a number of different attributes of nest boxes, there are several additional attributes that warrant further attention. Anecdotally, it appeared that larger boxes may be preferred, although this is based off of a small sample size (4 boxes). It is also possible that larger cavities or nest boxes result in larger clutches (Marti et al. 2005). The largest brood that fledged during my study, 7 nestlings, was in a large tree cavity in Franklin County in 2013; this many barn owls would not fit in standard nest boxes. Nonetheless, my data did not contain sufficient variation to evaluate the effect of box size, and more large boxes would need to be installed to examine this hypothesis. This trend has also been described by other researchers (Marti et al. 2005).

Likewise, there were numerous unmeasured factors that may have influenced barn owl nest survival. Small mammal populations, parasite load, general health of adults, breeding experience of adults, and human disturbance are likely important drivers of nest survival. At developed sites, anthropogenic noise may affect both use and reproductive success. Although proximity to highways did not seem to affect nest survival in this study, barn owls experience high mortality from vehicle collisions in some areas (Boves and Belthoff 2012). Because inexperienced fledglings may be more susceptible to vehicle mortality, placing owl boxes far from high traffic areas is recommended.

Winter weather may be especially problematic for barn owls because they are not particularly well insulated relative to other owls in temperate areas (Massemin and Handrich 1997) and are not adept at hunting in deep snow (Marti and Wagner 1985). The northern parts of their range contain suitable grassland habitat, but the colder climate may limit populations. Potential nesting habitats on the edges of the barn owl's range may also have lower populations because they will be reached by fewer dispersers. This may explain both the pattern of decreased nest box use in northern parts of Illinois, and differences in breeding initiation and success I observed between years. The winter prior to my second field season was harsher than the prior winter. The winter of 2014 had higher than usual snowfall and colder temperatures (Weather Underground). Due to the colder temperatures in the second winter season, the snow stayed on the ground for about 7 days longer than it did in the previous year. Accordingly, the second breeding season had later nest initiation and slightly lower productivity. Although I did not conduct small mammal trapping, it is possible that vole populations were also depressed by the harsher winter and either food supply during the breeding season or the condition of breeding owls was negatively affected.

In most years before 2014, there were nests reported in northern Illinois. There were 5 such nests in 2013, but no nests were reported north of Bond and Fayette Counties in 2014. The winter of 2014 was far harsher in northern Illinois than it was in the southern part of the state. Many areas experienced average temperatures that were 10° F lower and more than double the amount of snowfall (Weather Underground). It is possible that owls that previously nested farther north traveled south for breeding in response to the harsh winter. This may partially explain the increase in use of southern owl boxes in 2014.

Due to the nature of the land-cover data, it was unavoidable that the explanatory continuous variables used were correlated with each other. No correlation coefficient was greater than 0.7 when tested, but there was nevertheless an effect on the data. This made it difficult to separate effects of individual variables and may have led to confusing results, such as the positive impact of corn on daily survival rate.

There are remaining questions about the life history of barn owls in Illinois that future studies may address. A study measuring adult survival and site fidelity could show if the same owl pairs are occupying nest boxes in consecutive years. Research on owls' foraging movements may show how they use different landscapes and illuminate "hot spots" of foraging activity. These specific preferred land-cover types could then be selected for placement of new nest boxes. A study on the survival and dispersal of young barn owls could yield recruitment rates for Illinois' barn owl population. Studying barn owls during the non-breeding season may show their winter movement patterns, including their reaction to major weather events and their behavior as they select their nest site. Small mammal trapping at different nesting sites may show fluctuations in the owls' food supply and shed light on changes in owl populations and causes of mortality. Despite these remaining information gaps, my current results suggest that placing pole-mounted nest boxes in landscapes with sufficient grass cover, particularly in areas where large natural cavities are scarce, will help facilitate barn owl recovery efforts.

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TABLES AND FIGURES

Table 1. Summary statistics for each landscape variable within a 2 km radius of nest boxes that were occupied or unoccupied by breeding barn owls in Illinois, 2013 and 2014.

	Occupied				Unoccupied					
Model	Mean	SE	Min	Max	Mean	SE	Min	Max	*F*	*p*
Proportion land cover										
All development	0.06	0.01	0.00	0.44	0.05	0.00	0.00	0.65	3.51	0.06
Corn	0.11	0.01	0.00	0.57	0.21	0.01	0.00	0.69	13.08	0.0004
Developed open space	0.05	0.00	0.01	0.13	0.05	0.00	0.01	0.19	0.62	0.43
Forest	0.24	0.02	0.00	0.83	0.23	0.01	0.00	0.93	1.18	0.28
Grassland	0.32	0.02	0.01	0.72	0.22	0.01	0.01	0.61	30.24	<0.0001
Open water	0.05	0.01	0.00	0.54	0.03	0.00	0.00	0.53	0.06	0.81
Soybeans	0.15	0.01	0.00	0.47	0.19	0.01	0.00	0.53	3.22	0.07
Distance from highway (m)	5182.3	455.0	74.8	17990.6	4462.6	187.6	32.4	17500.8	5.59	0.02
Distance from road (m)	1330.8	103.9	0.2	3696.3	1217.5	49.3	6.4	4081.6	0.00	0.94
Highway length (m)	1408.1	269.0	0.0	16496.5	1595.9	124.7	0.0	15403.6	0.49	0.49
Road length (m)	3493.8	391.3	0.0	24995.5	3828.3	159.7	0.0	18200.5	6.24	0.01
Nest box height (m)	4.2	0.2	3.0	17.5	4.2	0.1	1.9	17.5	0.01	0.94
Northing	4220499	9059	4129344	4620737	4272312	5855	4109502	4567828	0.23	0.63

Table 2. Relative support for candidate models explaining barn owl nesting activity in nest boxes (n = 271) in Illinois in 2013 and 2014. Landscape variables were extracted from a 2-km radius surrounding nest boxes.

Model	k	AIC_c	ΔAIC_c	w_i
Grass + Corn	3	333.62	0.00	0.57
Corn + Northing + Grass	4	335.27	1.65	0.25
Grass + Northing	3	337.42	3.80	0.09
Grass	2	338.77	5.15	0.04
Grass × Northing	4	339.83	6.21	0.03
Grass + Soybeans	3	340.80	7.18	0.02
Corn	2	347.19	13.57	0.00
Highway distance	2	347.65	14.03	0.00
Soybeans + Corn	3	348.36	14.74	0.00
Corn + Northing	3	349.12	15.50	0.00
Corn × Northing	4	349.90	16.28	0.00
Northing	2	355.40	21.78	0.00
Box type[a]	3	357.27	23.65	0.00
Box location[b]	3	357.58	23.96	0.00
Null	1	358.25	24.63	0.00
All development	2	358.39	24.77	0.00
Soybeans	2	358.55	24.93	0.00
Box type × box location	4	359.05	25.43	0.00
Developed open space	2	360.05	26.43	0.00
Road length	2	360.17	26.55	0.00
Open water	2	360.20	26.58	0.00
Nest box height	2	360.22	26.60	0.00
Forest	2	360.24	26.62	0.00
Road distance	2	360.25	26.63	0.00
Highway length	2	360.27	26.65	0.00

[a] Plastic or wooden nest box.

[b] Pole or building mounted.

Table 3. Relative support for candidate models explaining barn owl nest daily survival rate in Illinois in 2013 and 2014. Landscape variables were extracted from a 2-km radius surrounding nest boxes.

Model	k	AIC_c	ΔAIC_c	w_i
Grass + corn	3	141.92	0.00	0.69
Grass	2	146.59	4.67	0.07
Corn	2	147.19	5.27	0.05
Northing + grass	3	147.86	5.94	0.04
Corn + northing	3	148.67	6.75	0.02
Northing	2	148.85	6.93	0.02
Null	1	149.15	7.23	0.02
Initiation date	2	150.04	8.12	0.01
Highway length	2	150.37	8.44	0.01
Soybeans	2	150.48	8.56	0.01
Nest box height	2	150.53	8.60	0.01
Day of year	2	150.61	8.68	0.01
Developed open space	2	150.63	8.71	0.01
Distance from highway	2	150.77	8.85	0.01
All development	2	151.06	9.14	0.01
Distance from road	2	151.08	9.16	0.01
Road length	2	151.17	9.25	0.01
Nest box type[a]	3	151.86	9.94	0.00
Nest box location[b]	3	152.64	10.72	0.00

[a] Plastic or wooden nest box.

[b] Pole or building mounted.

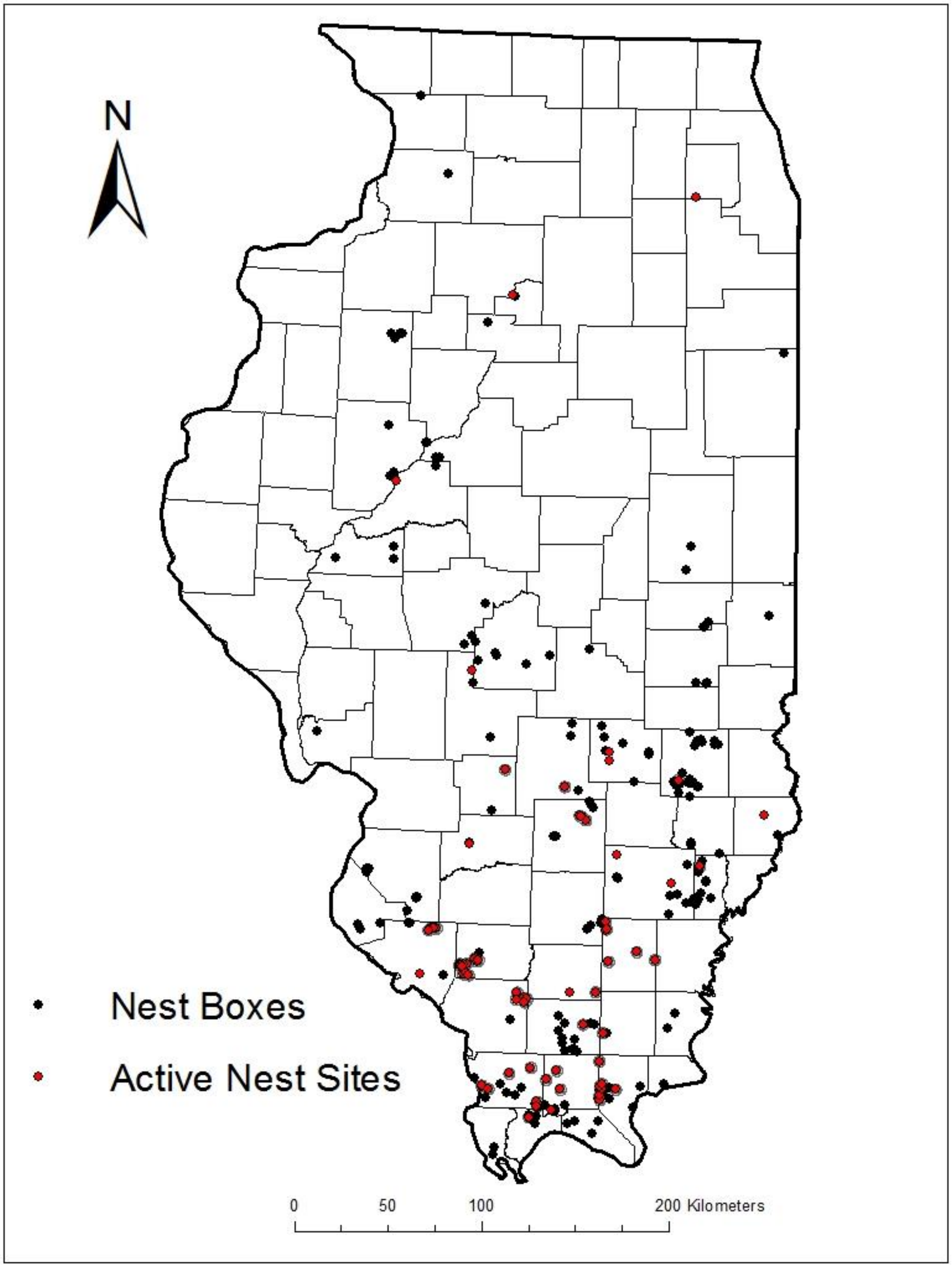

Fig. 1. Distribution of barn owl nest boxes and active nests in Illinois, 2013—2014.

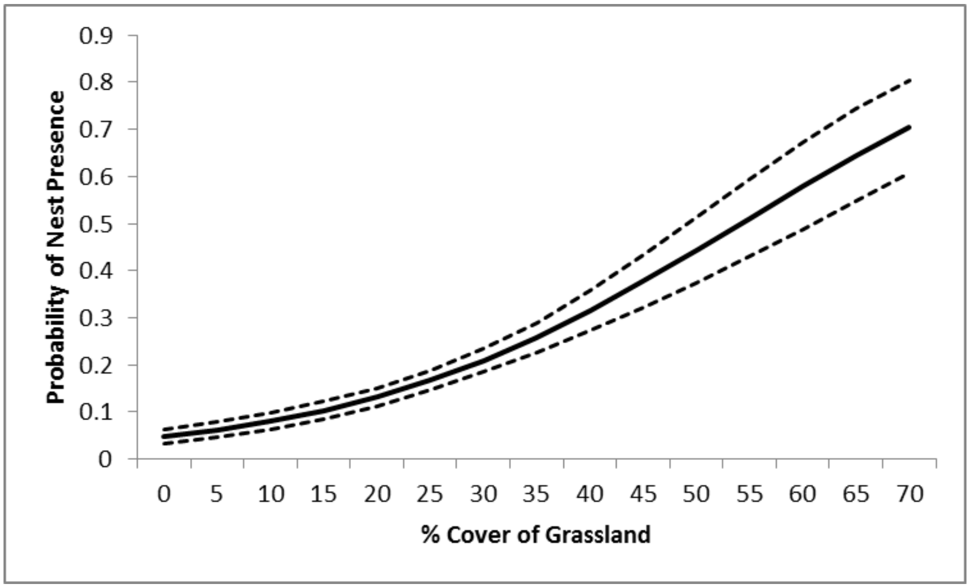

Fig. 2. Estimated probability (±SE) of barn owl breeding activity as a function of grassland cover in the 2 km surrounding a nest box in Illinois in 2013 and 2014.

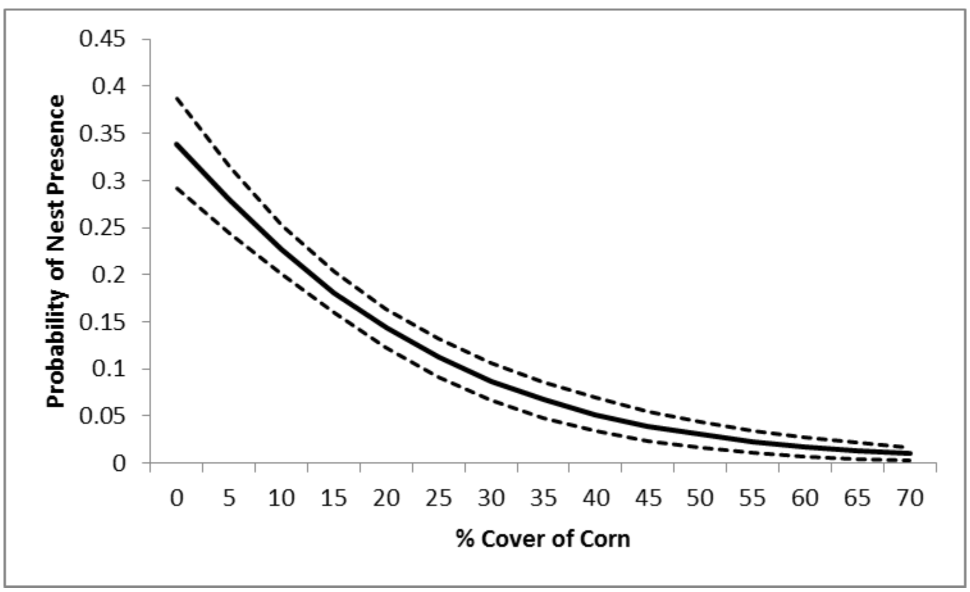

Fig. 3. Estimated probability (±SE) of barn owl breeding activity as a function of corn cover in the 2 km surrounding a nest box in Illinois in 2013 and 2014.

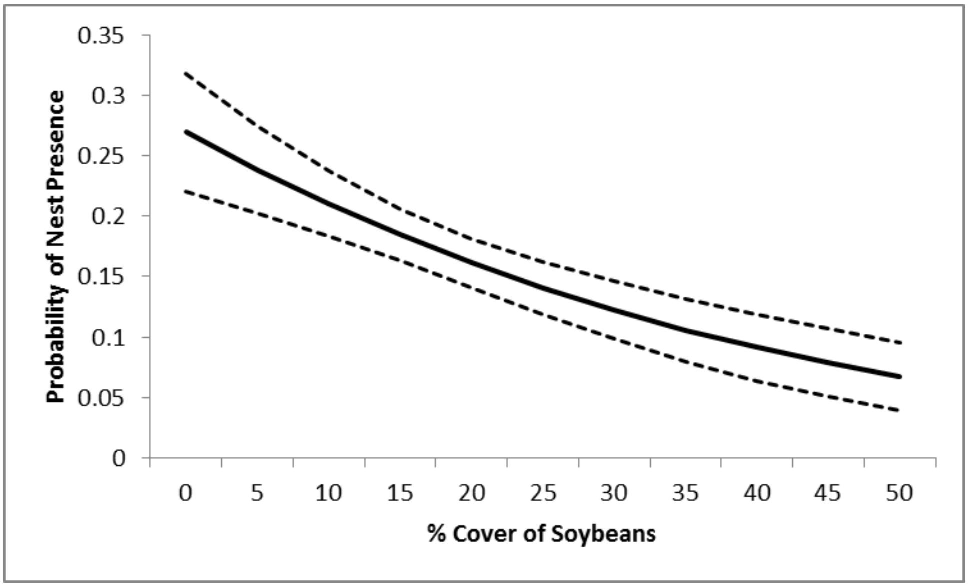

Fig. 4. Estimated probability (±SE) of barn owl breeding activity as a function of soybean cover in the 2 km surrounding a nest box in Illinois in 2013 and 2014.

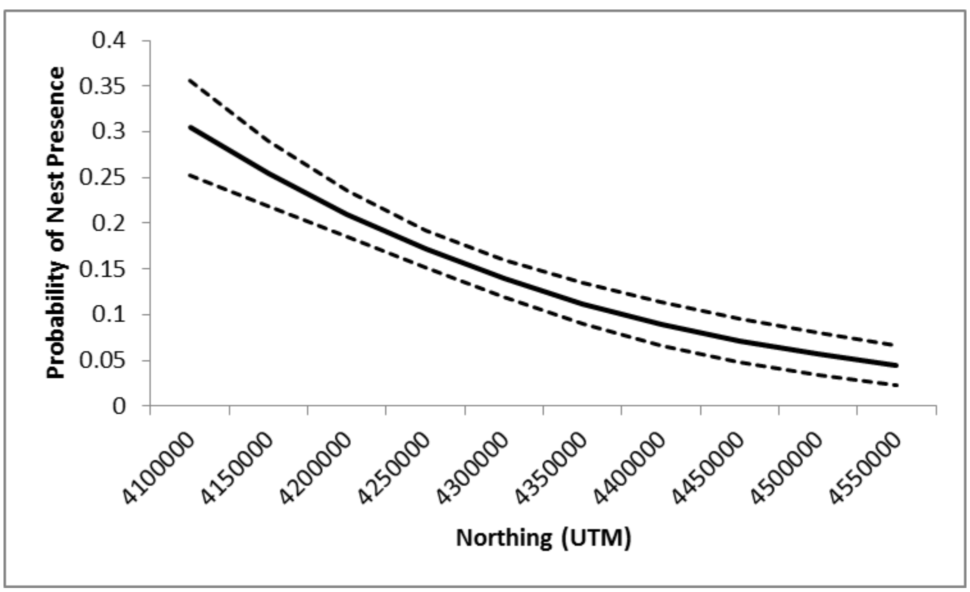

Fig. 5. Estimated probability (±SE) of barn owl breeding activity as a function of northing in Illinois in 2013 and 2014.

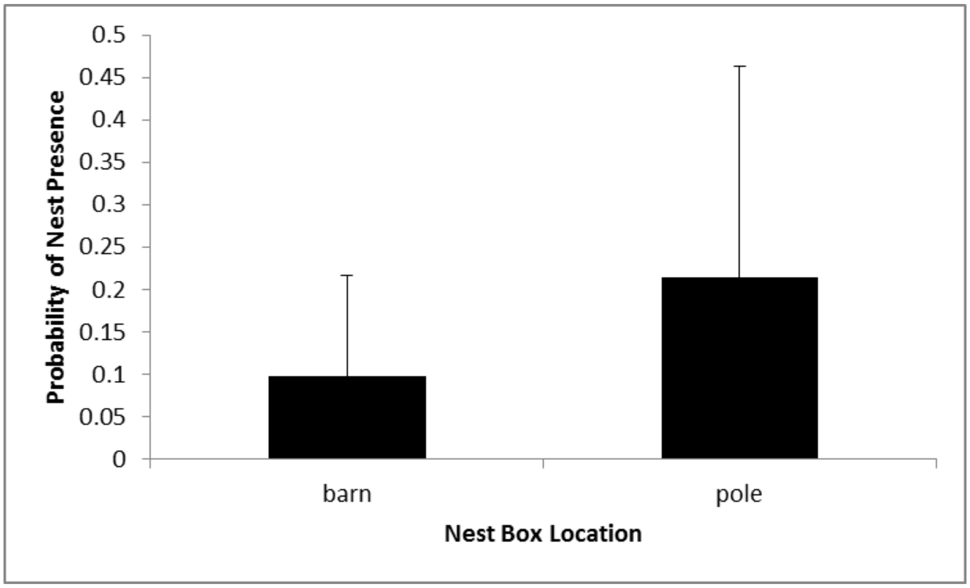

Fig. 6. Estimated probability (±SE) of barn owl breeding activity as a function of nest box location in Illinois in 2013 and 2014.

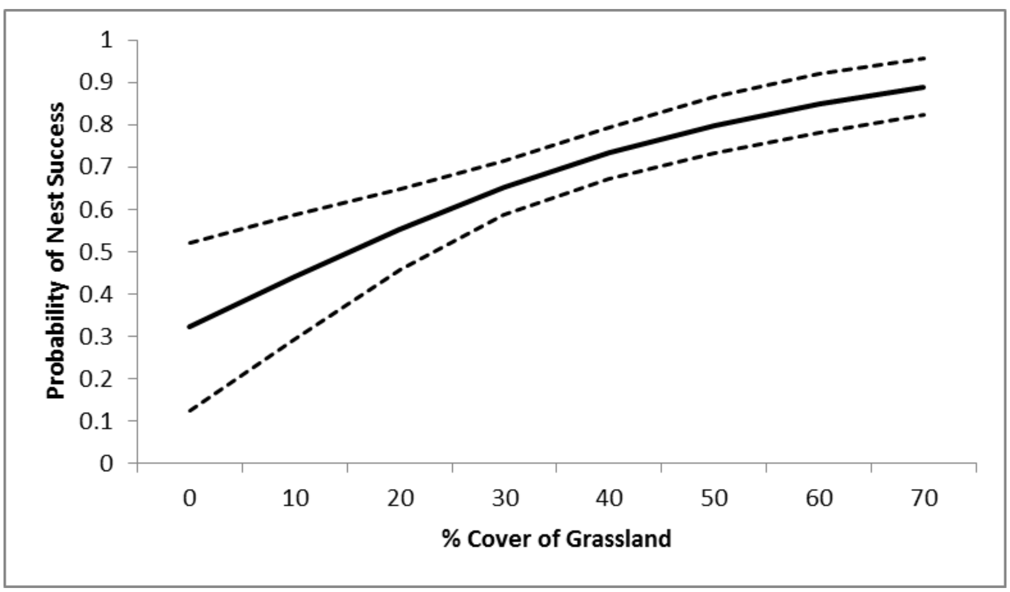

Fig. 7. Estimated probability of barn owl nest success (±SE) as a function of grassland cover in the 2 km surrounding a nest site in Illinois in 2013 and 2014.

CHAPTER 3: RESPONSES OF BARN OWLS TO NIGHTTIME PLAYBACK SURVEYS

ABSTRACT

It is challenging to evaluate populations of raptors because of their low population densities and secretive breeding behavior. Barn owls are particularly difficult to monitor given their nocturnal nature and irregular vocalization patterns. In an effort to help develop more effective survey protocols for locating breeding barn owls and for monitoring barn owl populations, I examined factors influencing barn owl responses to playback surveys. I found that barn owls responded to active playback surveys near known nests on 48.8% of occasions. These results suggest that playback surveys may be an effective approach for large-scale efforts to determine areas where barn owls are breeding, or for monitoring population trends.

INTRODUCTION

Raptors are difficult to survey because of their large territories, low population densities, and secretive behavior (Fuller and Mosher 1981, Forsman and Solonen 1984, Barnes and Belthoff 2008). Consequently, large-scale monitoring programs that work well for many landbird species often perform poorly for tracking changes in raptor populations (Marti et al. 2005). Because systematic searches are generally impractical, expensive, and time-consuming, many biologists have turned to playback surveys to help detect and monitor birds of prey (Fuller and Mosher 1981, McLeod and Andersen 1998, Barnes and Belthoff 2008).

Monitoring owl populations is especially challenging given their nocturnal nature. Barn owls are a prime example; in addition to being nocturnal and having large territories (Hegdal 1984), they vocalize infrequently, especially when they are not breeding (Marti et al. 2005). In the Midwestern U.S., barn owls are relatively rare and are listed as a species of conservation concern in most states (Marti et al. 2005). Monitoring their nests is currently the best known approach for assessing barn owl populations, but methods for finding new nest sites and less expensive methods for monitoring populations are needed. Knowing areas where barn owls occur will help biologists manage lands for them more effectively and ensure that the proper protections are in place.

Playback surveys have been effectively used to survey for owls (McGarigal and Fraser 1985, Zuberogoitia and Campos 1998), but past studies have had varying degrees of success using conspecific playbacks to detect barn owls (Sara 1989, Siverio et al. 1999). The response of owls to playbacks may be influenced by numerous factors, including population density (Sorace 1987, Stevens et al. 1999), weather (Zuberogoitia and Campos 1998), and stage of breeding (Stevens et al. 1999). Consequently, any effort to use playbacks for monitoring should evaluate and account for these potential sources of variation. In an effort to examine the potential utility of playbacks for locating breeding barn owls and for monitoring populations of this species, I set out to determine factors influencing response rates of breeding barn owls to playback surveys.

METHODS

Study Area

In 2013 and 2014, I checked 271 nest boxes for breeding barn owls in 53 counties in Illinois. I checked each box at least once between March and July of each year, and found 82 nests (34 in 2013; 48 in 2014) at 58 unique locations, 45 of which were on public lands and 13 on private property. Of the 45 sites on public land, 33 sites were both within a 2 hour drive of my field station and safely accessible at night; I selected these 33 nest sites for playback surveys.

Playback surveys

I conducted surveys when barn owls were confirmed to be breeding in these boxes, between 15 April and 24 July in 2013 and 2014. I conducted each survey from a randomly selected point 250 m from each nest box based on the audible range to human observers when the sounds were played at maximum volume on our equipment; I assume that barn owls could detect the sound from greater distances. Surveys were conducted between sunset and 1:00 AM and consisted of five minutes of passive listening followed by either a five-minute playback period or five additional minutes of passive listening. Playbacks were randomly assigned, and the five minute period was split into two minutes and thirty seconds of playbacks followed by an equivalent period of passive listening. Surveys were conducted in three sample rounds, approximately 2-3 weeks apart, and the order in which nests were surveyed was randomized for each round. I visited each nest twice per round; once for an active playback survey, and once for passive listening.

Surveys were conducted using barn owl calls from the Macaulay Sound Library (Kellogg 1956, Keller 1990, Vyn 2006). I used a mix of territorial, advertising, and warning vocalizations to attempt to illicit a response (Bunn et al. 1982, Conway and Simon 2003). To broadcast these calls, I used a FoxPro Wildfire II model wildlife caller (FOXPRO Inc, Lewistown, PA). I counted detections during surveys only if they occurred within approximately 20 m of the observer. Once a nest became inactive, I discontinued surveys at that site. Additional data collected during each survey included wind speed (Beaufort scale), temperature, cloud cover, moon phase, ambient noise level, and time after sunset (Takats and Holroyd 1997). Surveys were not conducted during high winds or rain, as this could hinder my ability to hear responses (McGarigal and Fraser 1985, Gerhardt 1991).

Statistical analyses

I examined differences in variables between surveys where barn owls were detected and those where they were not detected using a general linear mixed model (Table 4) (SAS PROC

MIXED; Littell et al. 2006). I examined factors influencing barn owl detections using a generalized linear mixed model with a binomial distribution and logit link function (SAS PROC GLIMMIX; Littell et al. 2006). I investigated the effects of whether a playback had been conducted along with breeding stage (mated pair, eggs, eggs and nestlings, nestlings only, or fledglings), date, cloud cover, moon phase, time after sunset, and temperature. To account for the potential influence of population density, I also considered models with the number of other active nests within 1, 2, and 3 km buffers around each nest. I incorporated a random effect of box identification to account for the potential non-independence of surveying individual nests multiple times. I summarized the number of surveys conducted during different states of cloud cover, moon phase, and stage of development of the nest (Table 5). Candidate models were evaluated using AIC_c (Burnham and Anderson 2002). I considered 23 candidate models with additive and interactive combinations of variables (Table 6).

RESULTS

I conducted 44 surveys, 27 with playbacks and 17 silent controls, at 13 sites in 2013, and 100 surveys, 55 with playbacks and 45 silent controls, at 29 sites in 2014. Nine boxes were surveyed during both years. Owls were detected on 29.2% of surveys (27.2% in 2013, in 30.0% 2014), including 40 of 82 playback surveys and 2 of 62 passive surveys. Responses to playbacks ranged from a single silent fly-by to 3 or 4 adult owls circling, hovering, and calling repeatedly. The most common response was a single, vocal owl that circled the observer. Owls were detected during 1 control period in 2013 and 3 in 2014 (2 were detected during the passive period prior to playback surveys). During 14 control periods, I detected barn owls in the area but judged that they were farther that 20m away, so I did not count these as detections. These uncounted detections were usually begging calls from the nest or distant calls (>50m away) from foraging adults. Owls responded to the active playbacks throughout the breeding season of 2013, but during the third round of playbacks in 2014, I received only one response out of 13 active playbacks.

The most important factor for predicting barn owl detection was whether playback was conducted (Σw_i=1.0; Table 6). Playback made a clear difference in detection probability; the probability of detection with an active playback was 0.484 ± 0.075 (SE) and the probability of detection during a silent survey was 0.011 ± 0.012 (SE) (Fig. 8). Date was also significant; detections were more likely earlier in the breeding season (Fig. 9). While the raw data suggests that the probability of a response is greater with increased time after sunset, this model was only weakly supported by AIC_c and the 95% confidence interval for the parameter included zero. The 95% confidence intervals of the parameter estimates for year, nest density, and temperature also included zero.

DISCUSSION

Playback surveys show promise as a means to detect barn owl presence in areas where their status is unknown, and may facilitate standardized monitoring efforts. Surveys may be more effective if they are conducted in the early part of the breeding season. The lack of effect of other explanatory variables suggests that barn owls should respond to playbacks at a consistent rate, regardless of variables such as nest stage, moon illumination, cloud cover, population density, or the time of night. This provides biologists flexibility in planning surveys.

Even though barn owls are known to defend areas against conspecifics, the extent of this defense behavior is not fully understood. In densely populated areas, their territories overlap and they appear to be tolerant of conspecifics. Most barn owls do not strongly defend their foraging grounds, but they will protect their nest structures (Taylor 1994). In Utah, an aggregated group of breeding barn owls only defended areas within 4.5-9 m of their nests, perhaps because of the large costs associated with defending large foraging areas (Smith et al. 1974). However, vocalization in response to intruders may be an important defensive strategy (Bunn et al. 1982) and barn owls have been observed to respond more strongly to playbacks in more densely populated areas (Sorace 1987, Stevens et al. 1999).

Though time after sunset was not strongly supported in the AIC_c analysis, I would caution that my surveys only occurred between sunset and 1:00 AM and I cannot make inferences about potential responses before or after this time. Nonetheless, I would not recommend starting surveys before it is completely dark, as the earliest response I recorded was 34 minutes after sunrise, at 8:46 pm, and 90% of responses occurred an hour or more after sunset. Although the sampling date model was only weakly supported by AIC_c, I would suggest confining playback sampling to dates when most owls are assumed to be in the early stages of breeding (March to May). I did not observe an effect of population density on response to playbacks, despite observed effect in past studies (Sorace 1987, Stevens et al. 1999), perhaps because of lower overall densities in Illinois.

Even though I was focusing specifically on boxes where barn owls were known to be breeding, owls did not respond on about half of playback surveys. Small video cameras were installed at a subset of boxes (n = 5) where playbacks were conducted in 2014. Based on 3 video observations from the time period when active playback surveys were conducted, I observed that one incubating owl ignored the playback on one survey, and on another survey one owl stayed at the nest, feeding nestlings, while two owls responded. The third adult in this instance may have been unmated or from another nesting pair at the same site. At another site, I observed an adult take a brief break from feeding its nestlings to investigate the playback before returning to the nest. Although the reasons for response or lack of response are unknown, these observations suggest that even when present in the box, barn owls do not necessarily respond to playbacks.

Overall, playback surveys improve barn owl detections in areas where their presence has not been confirmed. Additional work is needed to determine the maximum distance from which barn owls will regularly respond to playbacks. Likewise, I do not know whether there was an influence of the call types used during playback, the age or sex of the barn owls represented in the recordings (Navarro et al. 2005), or the potential for habituation to playbacks. Additionally, the potential effectiveness of playback surveys during the non-breeding season is unknown. From past research, I would expect this response rate to be lower than when the owls are breeding (Zuberogoitia and Campos 1998). Once the limits of this approach are better known, this may be an effective survey method for detecting owls on managed lands, estimating their abundance, and monitoring population trends.

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TABLES AND FIGURES

Table 4. Summary statistics for numerical variables describing conditions during playback surveys for breeding barn owls in Illinois, 2013 and 2014.

	Response				No Response					
Variable	Mean	SE	Min	Max	Mean	SE	Min	Max	*F*	*p*
1 km nest density	0.24	0.07	0	1	0.20	0.04	0	1	0.09	0.76
2 km nest density	1.81	0.24	0	5	1.43	0.14	0	5	0.13	0.72
3 km nest density	2.14	0.24	0	5	1.87	0.14	0	5	0.48	0.49
Day	146.40	4.06	104	204	158.67	2.67	111	204	7.31	0.01
Temperature (°F)	65.25	1.58	40	78.98	67.49	0.69	48	78.98	2.74	0.10
Minutes after sunset	125.31	8.38	34	262	108.03	5.85	9	255	0.63	0.43

Table 5. Number of surveys for categorical variables describing conditions during playback surveys for breeding barn owls in Illinois, 2013 and 2014.

	Response	No Response
% Cloud cover		
0 to 25%	22	51
26 to 50%	6	13
51 to 75%	6	10
76 to 100%	8	24
Moon phase		
Not visible	7	24
Crescent	13	22
Half	6	13
Gibbous	7	23
Full	9	21
Breeding stage		
Mated pair	2	0
Eggs	11	24
Eggs and nestlings	5	7
Nestlings	17	47
Fledglings	7	25

Table 6. Relative support for candidate models explaining breeding barn owl detections during playback surveys in Illinois in 2013 and 2014.

Model	k	AIC_c	ΔAIC_c	w_i
Playback conducted	2	128.72	0.00	0.24
Playback + time after sunset	3	129.05	0.33	0.21
Playback × 2km density	4	129.65	0.93	0.15
Playback × 3km density	4	130.13	1.41	0.12
Playback × time after sunset	4	131.05	2.33	0.08
Playback × year	4	131.20	2.48	0.07
Playback × 1km density	4	131.46	2.74	0.06
Playback × date	4	131.99	3.27	0.05
Playback + breeding stage	7	133.65	4.93	0.02
Playback × breeding stage	12	138.96	10.24	0.00
Date	2	168.80	40.08	0.00
Temperature	2	173.48	44.76	0.00
Time after sunset	2	173.65	44.93	0.00
Null	1	174.07	45.35	0.00
2 km density	2	174.67	45.95	0.00
Breeding stage	6	174.87	46.15	0.00
3 km density	2	175.44	46.72	0.00
Clouds	5	176.08	47.36	0.00
Breeding stage + time after sunset	7	175.39	46.67	0.00
Year	2	176.08	47.36	0.00
1 km density	2	176.08	47.36	0.00
Breeding stage + date	7	176.78	48.06	0.00
Moon phase	6	180.19	51.47	0.00

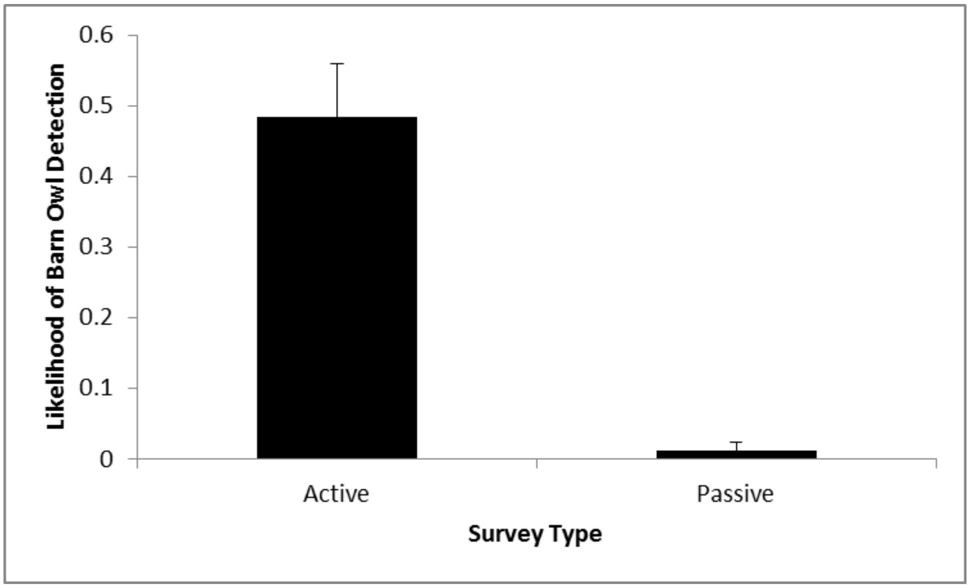

Fig. 8. Estimated probability (±SE) of barn owl detection during playback surveys as a function of survey type in Illinois in 2013 and 2014.

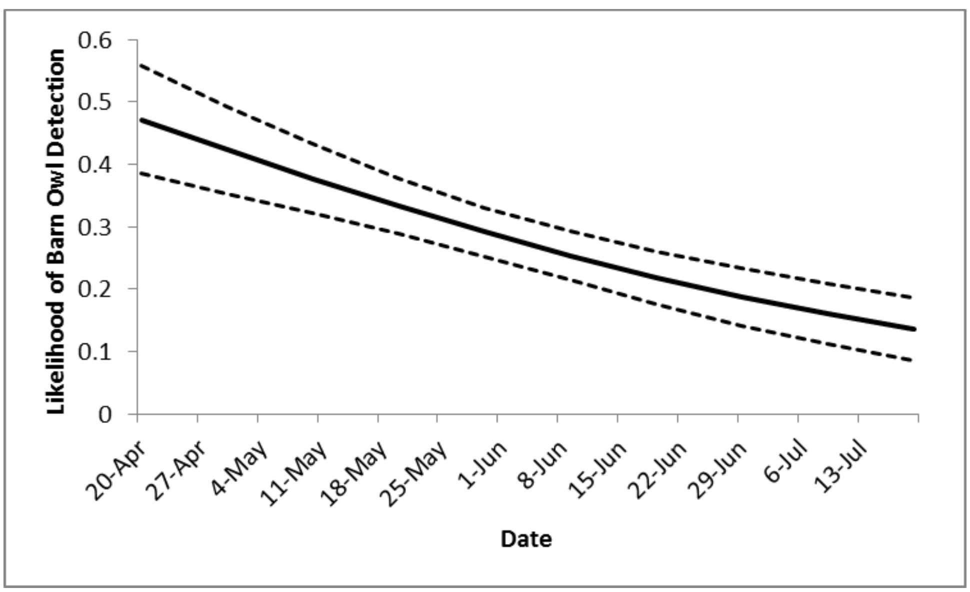

Fig. 9. Estimated probability (±SE) of barn owl detection during playback surveys as a function of date in Illinois in 2013 and 2014.

CHAPTER 4: GENERAL CONCLUSION

The main purpose of my research was to determine factors associated with barn owl use of nest boxes, survival of barn owl nests, and barn owl detections on standardized surveys. The primary conclusions of the second chapter were that barn owls were most likely to breed in nest boxes in areas with more grass and less corn and soybean cover within 2 km of the box. Cover of forest, open water, and development were not strong predictors of barn owl nest presence. The amount of and proximity to roads and highways also were not strongly correlated with barn owl nest presence. I found that the type of nest box (barn box vs. pole-mounted) did not affect barn owl use or nest daily survival rate. Percent cover of grass within 2 km of the nest had a positive relationship with daily survival rate of nests.

The main conclusion of Chapter 3 was that breeding barn owls responded to broadcasted barn owl calls about 48% of the time, but were only detected 2.8% of the time when no calls were broadcast. Responses were greatest earlier in the breeding season. Other explanatory variables such as time after sunset, moon phase, age of the nest, and temperature had no measurable impact on the probability of detecting barn owls during the surveys. This suggests that playback surveys may be an effective tool for detecting barn owls, especially early in their breeding season.

Overall, my research suggests that the preservation and restoration of grasslands is important for maintaining suitable habitat for barn owls. Nest boxes in grass-dominated landscapes were more likely to contain breeding barn owls and to successfully fledge young. Large grasslands were more likely to support multiple pairs of barn owls, but they were also found nesting in highly disturbed environments that were close to small grassland patches. Predator resistant pole-mounted nest boxes were used readily by barn owls in open grasslands.

Importantly, land managers can place pole-mounted nest boxes in any potential barn owl habitat without being limited by on the presence of preexisting structures, as was the case with traditional barn-mounted boxes. By placing nest boxes in grass-dominated landscapes, managers can likely maintain or increase barn owl populations, an important goal in most Midwestern states where barn owls have become uncommon and listed as species of concern. Moreover, playback surveys may be an effective method for locating previously undetected breeding barn owls or for monitoring trends in barn owl populations.

APPENDIX A

NEST CAMERAS

In 6 plastic pole-mounted nest boxes at Pyramid State Park, the Sparta World Shooting Complex, and Burning Star 5 Mine, I placed small video cameras. Each camera was powered by one deep-cycle marine battery. The battery and digital video recorder were then secured in a locked plastic box. These were installed in boxes that were active in 2013, after the owls vacated them. I presumed that some, if not all, of these boxes would be active during the next breeding season so that continuous data could be collected on the breeding owls. From these recordings, I hoped to collect data on the frequency of feeding visits by the adults, survival rate of nestlings, and predation events.

Five out of six nest boxes with cameras had barn owl nests in them in 2014: Perry 4 and Perry 6 at Pyramid State Park, Jackson 1 and Jackson 2 at Burning Star 5, and Randolph 9 at the World Shooting Complex in Sparta. Randolph 7, also at the shooting complex, did not have a nest this year. In total, I recorded about 9233 hours and 21 minutes of footage from all 6 boxes, though mechanical failures caused large gaps in the coverage. One camera stopped working, and most of the DVR units would occasionally shut off after recording for 2 or 3 days, possibly due to heat. There were also problems with cameras becoming dirty or misdirected when owls and nestlings leaned on them. I suspect that the camera's night vision sensor was visible to the owls at night, since they frequently inspected the cameras up close when it was dark. When the nestlings became large, it was not possible to get information on feeding visits by the adults since the chicks crowded to the front of the box, obscuring the camera view. Most of the video files were either viewed fully or scanned for activity.

Jackson 1: Footage began September 25, 2013. Throughout the fall, occasional nighttime visits by barn owls were recorded. Often only one owl would enter the box for an hour or two and rest, but sometimes a pair entered. Pairs would often engage in mutual grooming before napping. Weeks would go by without owls entering the box. No owl was ever present in the box during daylight hours, only night. I observed no prey items with the owls. Recording was stopped from 11/15/13 to 1/16/14 and from 2/5/14 to 4/16/14. In mid-April, the nest had already been initiated and the female was incubating eggs. The nest was recorded until July 1, just before the fledglings left the box permanently. In the last days of footage, the young owls make their first short flights before returning to the box.

Jackson 2: Recording began on 1/16/14 and was stopped between 3/20/14 and 4/10/14. Occasional nighttime visits were made by single owls during the winter. When recording resumed, a pair was in a pre-breeding stage in the box. They copulated twice on the first day and the nest appeared to be initiated on the next day. While the female was incubating, the male fed her approximately every 30 minutes. I could not say this with complete certainty since the male never entered the box, but this was the frequency with which the female went to the front of the box at night before returning to the eggs. The owl pair only tended the nest for four days before it was abandoned on 4/15 for no apparent reason. The incubating owl had frequently moved off the eggs and even left the box for periods before abandoning the nest. An owl slept in the box the next day, but did not incubate. After that, single or paired owls made short night visits to the box through April, then activity ceased after May 3. Recording continued until 7/6/14.

Perry 4: This was the earliest nest to be started; I estimate the date at 2/27/14. During the fall (10/29/13 to 11/18/13), a barn owl pair made frequent night visits to the box, grooming each other, sleeping, and even appearing to copulate at times. A male kestrel briefly entered the box as well. When recording resumed at 3/23/14, the female was incubating eggs or very young chicks. Small nestlings were visible on camera by 4/8/14. The male made food carries to the female, who tore the rodents up and fed them to the chicks throughout the day. Once she had torn several pieces off, she would swallow what remained. Feeding was sporadic; it was sometimes hourly, but sometimes hours passed between feeding. Feeding visits were less frequent on rainy days; rain was visible dripping into the box. Recording continued until the DVR failed just before the chicks fledged. The last day of recording was 5/21/14.

Perry 6: The camera started recording this nest on 9/25/13. At this time, the box was active with a late second clutch. Recording continued through the fall, capturing the fledglings' first flights on 10/29/13. There were still owls returning to the box as of 11/11/13, the last day of fall recording, but it is unknown whether these were fledglings or the original adults, who continued to use the box during the winter. This pair slept in the box during the day as well as visiting it at night, which was unique. Spring recording started on 4/8/14, at which point the owls had been incubating for almost a month. The nest was recorded until the camera went bad on 5/12/14, which was a month before the nest fledged.

Randolph 7: No owls nested in this box in 2014, but one barn owl investigated the box in April. A European starling also entered the box several times to remove pieces of mulch. In late May, a starling nested in the box. This box was recorded intermittently from 4/9/14 to 6/5/14; the DVR frequently failed to record.

Randolph 9: Recording began on 4/16/14. The female had been incubating for about 3 weeks on this date. She was surrounded by whole dead mammals, which she occasionally ate throughout the day. This DVR unit also suffered frequent failures, causing gaps in the coverage. During one such gap, the camera became pointed at the corner of the box so that it was harder to see the contents. I was not able to fix this while the box was still active. I recorded feeding visits, including times when the adult tried to feed whole voles to the nestlings, who would not accept them, though they were large enough to swallow them. After several tries, the adult would tear the food into pieces to feed them. One chick appeared to die around 5:30 am on 5/26/14 due to unknown causes. It is possible that the parasite load of this nest was too high; small insects were frequently seen crawling on the adult and nestlings. The second nestling died the next morning, around 8:30 or 9:00, also due to unknown causes. The adult returned that night, so the nest was not abandoned. After about 10 days, a barn owl pair started using the box regularly at night. In late June, they copulated and a new nest was initiated on July 5. The female adult slept in the box during the two days before she laid the first egg. The nest was recorded until 7/6/14.

Some barn owl behaviors occurred in multiple boxes, including the following observations. First visits to the nests by adults were usually just after 8:00 pm each night. Barn owls used boxes as rest stops while hunting at night during the nonbreeding season. It was less common for them to roost in boxes during the day when they were not breeding. The boxes were also used for copulation. Pole-mounted plastic nest boxes leaked when it rained, and this could be improved.

No predation events were captured. Four nests fledged successfully, one failed due to suspected disease or parasites. A new nest was initiated where the original one failed almost six weeks after the first failed. Pre-breeding activity was evident in the days before the first egg was laid.