Journal of Raptor Research

Advancing the science, conservation, and understanding of birds of prey

Journal of Raptor Research 58(4):1–16
doi: 10.3356/jrr2393

Barn Owl (*Tyto alba*)† Habitat Suitability, Nest Box Occupancy, and Management Implications Based on Kentucky Surveys 2010–2022

Kate G. Slankard,[1*] Andrea Darracq,[2] and James O. Barnard[1]

[1]*Kentucky Department of Fish and Wildlife Resources, 1 Sportsman's Lane, Frankfort, KY 40601 USA*
[2]*Murray State University, Department of Biological Sciences, 2112 Biology Building, Murray, KY 42071 USA*

ABSTRACT.—Barn Owls (*Tyto alba*) are a species of conservation interest, but management of nesting populations can require significant effort. To focus management activities, we conducted analyses of statewide survey data collected for Barn Owl nests ($n = 515$) and roosts ($n = 145$) in Kentucky, USA, from 2010–2022. Nest and roost sites included natural (e.g., trees, rock shelters) and human-made (e.g., barns, attics, hunting blinds, silos, etc.) structures and nest boxes ($n = 270$) installed on various substrates. Using data related to land cover, agricultural features, and other habitat-related variables, we examined factors influencing Barn Owl site occupancy by creating habitat suitability models. Additionally, we assessed changes in nest box occupancy over time and the factors that influenced nest box occupancy. The Shannon habitat diversity index and number of buildings within 75 m were the most important variables for habitat suitability throughout the study area, though the proportion of hay/pasture/grassland within 625 m and distance to an area intensively managed for Barn Owls were important regionally. Barn Owl nest box occupancy increased over the course of our study, likely due to management efforts. Owls were more likely to occupy nest boxes if they were installed on tall feed silos, retired utility poles, or barns. Moreover, nest boxes installed at sites where we observed owl pairs (prior to installation) were more likely to become occupied and used sooner than nest boxes installed opportunistically. Future management should focus on installing nest boxes for known pairs, on unused feed silos, on retired utility poles on reclaimed surface mines, and near areas intensively managed for the species.

KEY WORDS: Tyto furcata; *ensemble modeling*; *feed silo*; *Kentucky nest monitoring*; *natural nest site*; *nest box installation*; *nest survey*; *population management.*

IDONEIDAD DEL HÁBITAT, OCUPACIÓN DE CAJAS NIDO E IMPLICACIONES PARA LA GESTIÓN DE *TYTO ALBA* BASADAS EN CENSOS REALIZADOS EN KENTUCKY ENTRE 2010 Y 2022

RESUMEN.—*Tyto alba* es una especie de interés para la conservación, pero la gestión de las poblaciones que anidan puede requerir un esfuerzo significativo. Para encaminar las actividades de gestión, analizamos los datos de censos estatales de nidos ($n = 515$) y dormideros ($n = 145$) de *T. alba* realizados en Kentucky entre 2010 y 2022. Los nidos y dormideros incluían estructuras naturales (e.g., árboles, refugios rocosos) y estructuras hechas por humanos (e.g., graneros, buhardillas, escondites de caza, silos, etc.), así como cajas nido ($n = 270$) instaladas en varios sustratos. Utilizando datos relacionados con la cobertura del suelo, características agrícolas y otras variables relacionadas con el hábitat, examinamos los factores que influyen en la ocupación de estos sitios por parte de *T. alba* mediante la creación de modelos de idoneidad del hábitat. Además, evaluamos los cambios en la ocupación de cajas nido a lo largo del tiempo y los factores que influyeron en la ocupación de las mismas. El índice de diversidad de hábitat de Shannon y el número de edificios dentro de un radio de 75 m fueron las variables más importantes para

*Corresponding author: kate.slankard@ky.gov
† This species' name has been recently changed to American Barn Owl (*Tyto furcata*).

la idoneidad del hábitat en toda el área de estudio, aunque la proporción de heno/pastos/praderas en un radio de 625 m y la distancia a un área gestionada intensivamente para *T. alba* fueron importantes a nivel regional. La ocupación de cajas nido por parte de *T. alba* aumentó a lo largo de nuestro estudio, probablemente debido a los esfuerzos de gestión. Las lechuzas tenían más probabilidades de ocupar las cajas nido si se instalaban en silos de alimentación altos o en postes fuera de servicio. Además, las cajas nido instaladas donde ya se sabía que existían parejas reproductoras con anterioridad a la instalación tenían más probabilidades de ser ocupadas antes, comparadas con aquellas instaladas de manera oportunista. La gestión futura debería centrarse en instalar cajas nido para parejas conocidas, en silos de alimentación no utilizados, en postes fuera de servicio en minas de superficie recuperadas y cerca de áreas gestionadas intensivamente para la especie.

[Traducción del equipo editorial]

INTRODUCTION

The Barn Owl (*Tyto alba*) is a charismatic species, often viewed as beneficial by landowners for rodent control (Wendt and Johnson 2017, Martin 2009). However, Barn Owls' tendency to rely on human-made structures and natural cavities can cause problems related to nest site competition, predation, nest destruction, and disturbance (Andrusiak 1994, Marti 1994, Slankard 2022). Thus, over the past 50 yr, Barn Owls have drawn conservation interest throughout portions of North America due to population declines in several states (Burtner 2010, Marti et al. 2020, Wingert 2015, Meilink 2018). Possible causes for these declines have been identified and examined, including habitat loss, vehicle collisions, variability in prey populations, predation, clean farming practices, pesticides, and limited nest site availability (Stewart 1980, Colvin 1985, Martin et al. 2010, Boves and Belthoff 2012, Slankard et al. 2019).

Due to local conservation concern, the Barn Owl was included as a species of greatest conservation need in Kentucky's State Wildlife Action Plan (Kentucky Department of Fish and Wildlife Resources [KDFWR] 2005). In 2006, KDFWR began a project installing Barn Owl nest boxes on Wildlife Management Areas (WMAs) with open land cover. Disappointingly, most of these nest boxes remained vacant for the next few years. At the time, very little was known about the status of the species in Kentucky. Therefore, to inform conservation efforts, KDFWR conducted a statewide Barn Owl survey in 2010. Biologists documented twenty-seven Barn Owl nest locations and eight locations where owls were present but not breeding during that effort. After the 2010 inventory, KDFWR prioritized the Barn Owl survey on a 3-yr interval and began efforts to ensure each known pair of Barn Owls had a reliable nesting location by cooperating with private landowners to install nest boxes. Consideration in nest box placement was given to deterrence of mammalian predators, protection from weather and human disturbance, and convenience for the landowner (i.e., avoiding unwanted mess). The Barn Owl survey was repeated in 2013, 2016, 2019, and 2022.

Efforts to model or describe North American Barn Owl occupancy or habitat suitability relative to land cover have been conducted in southwestern Missouri (Meilink 2018), southern Idaho (Regan et al. 2018), and Napa Valley, California (Wendt and Johnson 2017). Recent studies in Kentucky have focused on spatial tracking of wild and captive-raised birds (Chien and Ritchison 2011, Slankard et al. 2021) and pesticide exposure (Slankard et al. 2019). Nest box occupancy and management recommendations for North American Barn Owls, including nest box design, installation height and orientation, have been reported within the high-density populations of Napa Valley, California, and Florida (Martin 2009, Huysman 2019). However, until recently, studies providing management guidance for the likely lower-density populations of the midwest and mid-south were sparse. Thus, until enough data were collected during KDFWR's triennial surveys to fuel local adaptive management, nest site management of Barn Owls in Kentucky was informed by studies conducted in the 1980s in Ohio (Colvin et al. 1985). Additional information on nest box projects in Missouri and Illinois was released midway through our study, which also helped inform our management approaches (Wingert 2015, Meilink 2018).

Barn Owl populations are likely to require management to avoid declines (Watts 2003, Walk et al. 2010). Because management for the species can be intensive, requiring the support of numerous private landowners, specially trained staff, ample funding, and long-term effort, our general goal for this analysis was to evaluate the successes and failures of this project thus far to better direct future conservation actions. Our unusual approach emphasized finding established breeding pairs nesting on any structure and providing them with nest boxes. Thus, our first

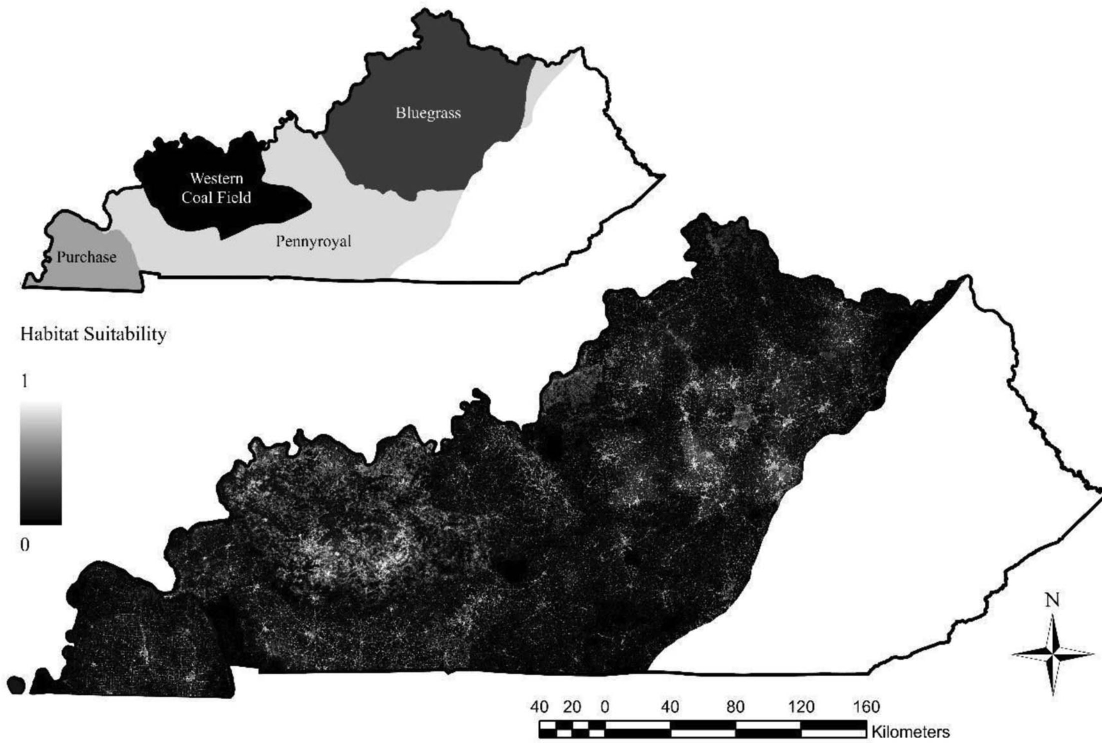

Figure 1. Barn Owl nesting habitat suitability map based on ensemble occupancy models completed for the Bluegrass, Pennyroyal, Purchase, and Western Coal Field physiographic regions in Kentucky, USA. Lighter shades indicate higher habitat suitability.

objective was to evaluate the tactics used between 2010 and 2022 in Kentucky's Barn Owl nest box project and develop management recommendations. Many Barn Owl studies have focused on, and continue to focus exclusively on monitoring nest boxes (e.g., Wingert 2015, Meilink 2018, Huysman 2019), and the inclusion of non-nest box data makes our nest dataset noteworthy. Our second objective was to create a regional, scale-optimized spatial model predicting suitable Barn Owl nesting habitat in Kentucky. Third, we used this model to extrapolate feasibility-based management goals and qualitatively predict where increased management may spur future population growth. Overall, these objectives allowed us to summarize knowledge gained from 12 yr of Barn Owl nest monitoring in Kentucky and suggest future approaches for conservation action.

METHODS

Study Area. Although our survey efforts covered the whole state, all the nesting Barn Owls we recorded were in western and central Kentucky. Thus, for our statistical analyses, we focused on the regular breeding range for Barn Owls in Kentucky by excluding the primarily forested regions east of the Cumberland Plateau (Fig. 1).

Field Data Collection. KDFWR biologists conducted statewide surveys in 2010, 2013, 2016, 2019, and 2022. Survey efforts focused on locating as many Barn Owl nests and roosts as possible. Because Barn Owls can nest year-round in Kentucky, biologists recorded survey data throughout the entire calendar year, though most sites were checked between 1 March and 30 July to focus on the peak months of nesting activity (Slankard et al. 2022).

Nest boxes can provide not only additional or higher quality nest sites, but a distinct place for researchers to survey for owls (Colvin et al. 1985). The number of nest boxes greatly increased over the course of our project, and we consistently monitored nest boxes during each inventory to provide an index of abundance. However, to better understand the status of the entire population and to avoid biasing habitat suitability model results to nests/roosts in nest boxes, we did not limit observations to nest boxes (Møller 1994, Lambrechts et al. 2012).

During each survey, KDFWR personnel searched potential nesting and roosting structures (nest boxes, barns, silos, vacant houses, etc.) on both public and private lands for evidence of use by Barn Owls. We focused searches in areas where Barn Owl sightings and nests had been recently reported or previously documented. News releases, social media posts, articles in an Amish/Mennonite newspaper, radio interviews, and television segments on local access channels resulted in many new reports from the public that we investigated. Wildlife rehabilitators also provided locations where they encountered Barn Owls. As time allowed, we also conducted opportunistic searches of structures near known nesting pairs. We obtained landowner permission to search all structures on private land. We recorded nest and roost locations in a central database.

We considered nest locations and attempts as "confirmed" when at least one of the following criteria was directly observed by KDFWR personnel or, rarely, documented in a landowner's photograph or video: (1) one or two adult Barn Owls observed at a nest site with eggs or incubation behavior; (2) one or more Barn Owl nestling(s) or recently fledged young at or in the immediate vicinity of a nest site; (3) one or more adult Barn Owls seen delivering food to a nest site; (4) one or more adult Barn Owls at a nest site with calls of nestling Barn Owls heard. Because nest sites could be used multiple times in one year, we assigned observations a nest attempt number (i.e., 1, 2, 3) each time we observed (or assumed due to the presence of nestlings) there was a new clutch of eggs at the site.

Barn owls nesting in Kentucky are assumed to be nonmigratory and usually remain on site year-round, though different locations may be chosen for roosting seasonally (Slankard et al. 2022). We also recorded roosting (nonbreeding) Barn Owls during the surveys. When a roosting owl was found, we searched nearby suitable nesting structures for nests. If we did not locate a nest at any point during the calendar year, we recorded the location as a roost site.

To minimize disturbance, we checked most sites via a nest inspection camera on an extendable pole (https://www.ibwo.org/camera.php). We had limited time for nest monitoring during the fall and winter. However, we did make sporadic attempts to monitor for fall and winter nesting, especially when landowners reported related behaviors or when we were present at sites for nest box installations.

Nest Box Installations. Between 2006 and 2022, KDFWR and cooperators installed 270 Barn Owl nest boxes (Supplemental Material Fig. S1; design available at: https://fw.ky.gov/Wildlife/Documents/BarnOwlBoxes.pdf). We installed 92 of these nest boxes opportunistically on public lands in open environments, and 178 on private lands for nesting Barn Owls that needed a safer or more permanent nest site.

Between 2010 and 2022, KDFWR's efforts to install nest boxes on private lands focused on maximizing the productivity of existing Barn Owl nests. Earlier surveys recorded many unreliable nest sites, leading to low nest success. For example, we initially found many nests in precarious locations where nestlings could fall out before fledging (e.g., shallow barn eave) or be easily depredated by ground predators (e.g., silo floors). We also first discovered several nests when they were destroyed (e.g., hollow trees were cut or blown down, grain bins were filled/cleaned, or old barns were demolished). We installed nest boxes for existing Barn Owl pairs on various substrates, many of which the owls used during previous nesting attempts: barns, other buildings, trees, elevated hunting blinds, tall feed silos, or grain bins. On occasion, we installed nest boxes on retired utility poles if no other suitable structure was available. We attempted to install the nest box as close as possible to the previous nest site, while considering deterrence of ground predators, avoidance of human disturbance and vegetation near the nest box entrance, and convenience for the landowner (i.e., avoiding unwanted mess). We generally installed nest boxes at a height of 4.6 m or greater, although we installed a few nest boxes at heights as low as 3.7 m due to lack of other options. Lastly, we considered directional orientation, with a preference for facing the nest box entrance north or east.

Nest Box Occupancy Analyses. Given some nest boxes were installed more recently and immediate occupancy of boxes is unlikely, when considering nest occupancy we excluded nest boxes that were unoccupied from our analyses based on the average time to occupancy of nest boxes ($\bar{x} = 3.6$ yr). Thus, we excluded nest boxes if they were installed in the years 2019 to 2022. We also did not include unoccupied nest boxes in the analysis if they were destroyed within 4 yr following placement. Following these removals, our analysis included 242 nest boxes. We considered nest boxes occupied if we recorded a roost or nest within the box at any point during 2010–2022.

We calculated nest box usage across the five main survey years based on the total number of nest boxes available within each year. We considered nest boxes installed before 30 March within a year available to the birds within that year and we did not consider nest boxes recorded as destroyed within a survey year as available within that year.

We expected to find more Barn Owls near to Amish and Mennonite communities due to smaller farm and field sizes, alternative farming practices, and the willingness of these landowners to host the species as a means of natural pest control. Thus, we evaluated the influence of the distance to Amish/Mennonite communities on whether a nest box was ever occupied, as well as the management status (whether the box was located on a WMA managed for Barn Owls or not), reason for nest box placement (whether the box was installed for a known nesting pair or not), and the structure supporting the nest box (hereafter nest box structure; e.g., barn, pole, silo, etc.). Additionally, for nest boxes that were occupied at least once ($n = 128$), we assessed the influence of these independent variables on the probability that a nest box would be occupied again in future years following initial occupancy (hereafter future occupancy), the time between nest box placement and when a nest was occupied (hereafter time to occupancy), and, for nests available on the landscape for more than three survey years, the number of times a nest was occupied out of the total survey years the nest box was available. To account for the geographic breadth of Amish/Mennonite communities, we categorically quantified the distance to Amish/Mennonite communities (<10 km or >10 km) from each nest box using the *near* tool in ArcGIS Pro. We chose this distance based on the 19 nests we recorded on Amish/Mennonite properties, which were on average 10 km from mapped community points. We used generalized linear models (GLMs) implemented within Program R to assess the influence of each covariate on whether a nest box was ever occupied, future occupancy, time to occupancy, and the number of times each nest box was used. We used a binomial distribution for two dependent variables (ever occupied and future occupancy) and a Poisson distribution for two dependent variables (time to occupancy and the number of times each nest box was occupied). We added an offset term to the GLM for the number of times each nest box was occupied to account for the number of times the nest box was available to be occupied. For each dependent variable, we ran a GLM that considered the independent effects of box structure, a GLM that included the interactive influence of Amish/Mennonite community distance and management status, and a GLM that included the interactive effects of region and the reason for nest box placement. A Bonferroni correction was applied to all *P*-values.

Species Distribution Modeling. We built multiscale habitat suitability models for the nest and roosts combined using four modeling approaches implemented within the package *biomod2* (Thuiller et al. 2023) and Program R version 4.1.3 (R Core Team 2022). These models included three regression-based models (GLMs), generalized additive models [GAM], and multiple adaptive regression splines [MARS]), and maximum entropy [MaxEnt]). Kentucky contains diverse ecosystems and land use varies substantially across the state. Specifically, Kentucky includes seven level III ecoregions and Barn Owl nest/roost locations occurred within four of these ecoregions (Woods et al. 2002). The Purchase region contained expansive row crop agricultural lands as well as a few large tracts of publicly owned upland and bottomland forest; the Western Coal Field region contained extensive reclaimed strip mine land, as well as row crop agricultural areas and publicly owned bottomlands; the Pennyroyal region contained publicly owned forest, row crop agricultural areas, pastured cattle operations, and other agricultural operations including some areas with abundant enrollment in federal conservation cost share programs; and the Bluegrass region contained pastured cattle and horse operations, small farmsteads, and Kentucky's two largest urban centers, Lexington and Louisville. Given this complexity, we built models separately for the Purchase ($n = 34$), Western Coal Field ($n = 66$), Pennyroyal ($n = 128$), and Bluegrass ($n = 86$) physiographic regions and also completed a combined model with all nests/roosts ($n = 314$).

We considered a suite of 12 variables related to landscape topography and composition (Table S1). After evaluating correlations between covariates, between nine and 11 scale-optimized covariates were included within our final models (Table S2). Details on covariate selection, tests for spatial autocorrelation, and background point creation are provided in the Supplemental Material. Before model implementation, we used a spatial blocking approach to obtain training and validation subsets of our data. Specifically, we subset the data into five, spatially separated folds within the Program R package *blockCV* (Valavi et al. 2019). We assigned the blocks randomly using a block size of 11.6 km. We used the first four folds for cross-validation during model training and set aside the fifth fold for model evaluation.

We used the standard *biomod2* formatting options for each regional and the combined model. After running the models separately, we built a weighted average model for each separate modeling approach and an ensemble model that was a combination of the four modeling approaches. We did not include model runs within the final averaged single models or ensemble model if the area under the receiver operating characteristic curve (AUC-ROC) or true skill statistic (TSS) associated with the validation data set within each fold was <0.7 (Allouche et al. 2006). We evaluated the final model outputs using the TSS, AUC-ROC, and the Continuous Boyce Index associated with our evaluation data set (Hirzel et al. 2006). We assessed covariate contributions to the individual and ensemble model within *biomod2* and considered a variable important if it was greater than the mean importance value (IV) for all covariates within each model combined. For variables with an IV greater than the mean, we calculated response curves in *biomod2* using a modification of the evaluation strip method proposed by Elith et al. (2005).

Management Goals. To obtain a crude estimate of how many Barn Owl pairs could be sustained within the four physiographic regions we used a TSS thresholding method to categorize the habitat suitability predictions into "suitable" and "unsuitable" (Liu et al. 2013, 2016). From this, we calculated the amount of area deemed suitable in each region. For a lower estimate of occupancy, we divided the total area available in each region by the average home range size of Barn Owls reported across four studies (approximately 491 ha; Byrd 1982, Hegdal and Blaskiewicz 1984, Byrd et al. 1986, K. Slankard unpubl. data). However, this measure does not account for spatial overlapping of Barn Owl pairs, which does occur. Thus, we also used published estimates of Barn Owl densities from Spain of 3.6 pairs/10 km^2 (Martínez and López 1999) to create an upper estimate of how many Barn Owl pairs could be sustained within each region. Given that our map is specific to predicting the location of nests and roosts, as opposed to Barn Owl foraging habitat, it is likely both estimates are conservative. We also used the 2022 survey data to assess how many unique Barn Owl locations were observed relative to the amount of suitable area in each region and on state-owned public lands. Finally, to set a management goal for our project, we calculated the number of potential Barn Owl pairs each region would support if 15% of the available suitable area was occupied simultaneously.

Table 1. The number of unique nest and roost locations within each physiographic region observed during each triennial Barn Owl survey conducted 2010–2022 in Kentucky, USA.

Type	2010	2013	2016	2019	2022	Total[a]
Bluegrass						
Nests	12	12	15	13	26	58
Roosts	4	6	3	5	14	27
Total	16	18	18	18	40	76
Pennyroyal						
Nests	6	14	27	35	67	97
Roosts	1	3	6	14	9	30
Total	7	16	33	49	76	113
Purchase						
Nests	3	9	10	9	12	26
Roosts	2	0	5	6	3	14
Total	5	9	15	15	15	33
Western Coal Field						
Nests	6	13	25	20	31	55
Roosts	1	2	4	6	5	17
Total	7	15	29	25	36	61
Combined						
Nests	27	48	77	77	136	236
Roosts	8	11	18	31	31	88
Total	35	58	95	107	167	283

[a] Note: These total numbers account for unique locations that were replaced by nest boxes during future surveys and nests and roosts observed at the same location across survey years.

RESULTS

Field Surveys. During 2010–2022, we documented 515 nesting attempts in the following structures: nest box (227), barn (37), house attic (22), house chimney (9), other type of building (61), tall feed silo (53), grain bin (21), elevated hunting blind (28), dead tree (5), live tree (43), rock shelter, (3) and bridge (6). This total reflects nest boxes installed on all structure types. Of these nesting attempts, we recorded 382 during triennial survey years and 133 opportunistically between survey years. We observed two nesting attempts within the same year at 19 locations. We also recorded 145 roosts during 2010–2022. During the triennial Barn Owl surveys, we documented 236 and 88 unique nests and roosts, respectively, at 283 unique locations (Table 1). Of these locations, 80% were located on private property. Between survey years, we located 31 previously undocumented unique roost/nest locations.

Nest Box Analysis. Nest box occupancy rates increased during each consecutive survey from 2010 through 2022 (Fig. 2). Overall, 51.2% of nest boxes were occupied at least one time during the study (Table 2). Nest box occupancy was influenced

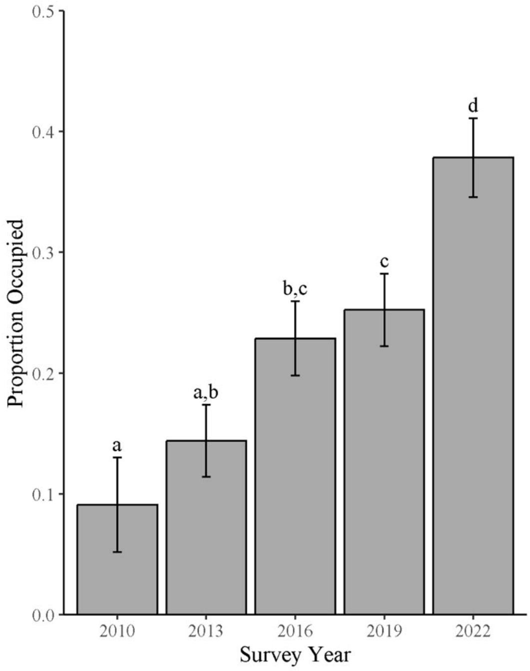

Figure 2. Observed values (±SE) of the proportion of occupied nest boxes observed during each triennial statewide Barn Owl survey conducted between 2010 and 2022 in Kentucky, USA. The number of nest boxes available increased over the course of the project (2010: n = 55; 2013: n = 139; 2016: n = 188; 2019: n = 210; 2022: n = 222). Letters indicate statistical differences in occupancy between years.

by management status, the distance to an Amish/Mennonite community, region, reason for nest box placement, and nest box structure. In unmanaged areas, nest boxes were 1.5 times more likely to be occupied if they were within 10 km of an Amish/Mennonite community ($\bar{x}$ = 0.71, SE = 0.08) compared to nest boxes >10 km from an Amish/Mennonite community ($\bar{x}$ = 0.47, SE = 0.04; β = −1.01, SE = 0.43, Z = −2.34, P = 0.04). Conversely, on managed lands, nest boxes <10 km from an Amish/Mennonite community ($\bar{x}$ = 0.24, SE = 0.09) were three times less likely to be occupied compared to nest boxes >10 km from an Amish/Mennonite community ($\bar{x}$ = 0.73, SE = 0.06; β = 2.14, SE = 0.57, Z = 3.76, $P \leq 0.001$).

Overall and in the Bluegrass region, boxes established where existing Barn Owls were present were two times more likely to be occupied than boxes established where there were no known Barn Owl pairs (all regions: β = 1.42, SE = 0.42, Z = 3.41, $P \leq$ 0.01; Bluegrass: β = 1.58, SE = 0.45, Z = 3.53, P = 0.01). Nest boxes installed for existing pairs also tended to be more likely to be occupied in the Pennyroyal region (β = 1.72, SE = 0.59, Z = 2.94, P = 0.09). However, there was no effect of the reason for box placement on occupancy in the Purchase or Western Coal Field regions. The occupancy of nest boxes was similar across all regions when nest boxes were installed where existing pairs of Barn Owls were present. However, when nest boxes were established in areas where there were no known Barn Owl pairs, occupancy of nest boxes in the Western Coal Field region was 3.25 times greater than in the Bluegrass region (β = −2.30, SE = 0.51, Z = −4.49, $P < 0.001$; Fig. S2).

Nearly all nest boxes installed on tall feed silos/grain bins became occupied (Fig. 3, Fig. S1). The probability of a nest box on a silo/grain bin being occupied was between 3.7 and 11 times greater than on metal poles and live trees, respectively (metal poles: β = 3.50, SE = 1.00, Z = 3.51, P = 0.01; live trees: β = 4.80, SE = 1.04, Z = 4.59, $P <$ 0.001; Fig. 3). Nest boxes installed on retired wood utility poles had the second greatest probability of being occupied, though the probability did not differ from any building types. However, occupancy probabilities of nest boxes installed on live trees were 6.5 and 7.6 times lower than nest boxes installed on barns and retired wood utility poles, respectively (barns: β = −2.55, SE = 0.77, Z = −3.32, P = 0.03; utility poles: β = −2.96, SE = 0.80, Z = −3.69, $P < 0.01$; Fig. 3).

Table 2. Barn owl nest box occupancy observed within each physiographic region during triennial surveys conducted between 2010 and 2022 in Kentucky, USA.

Metric	Bluegrass	Pennyroyal	Purchase	Western Coal Field	Total
Available boxes	113	67	17	51	248[a]
% Occupied[b]	33.6	64.2	70.6	72.5	51.2

[a] Some nest boxes were not included because they were not available to owls during the time period of our survey (i.e., they were destroyed or installed after 1 March 2022).

[b] Percentage of nest boxes occupied at least one time during 2010–2022.

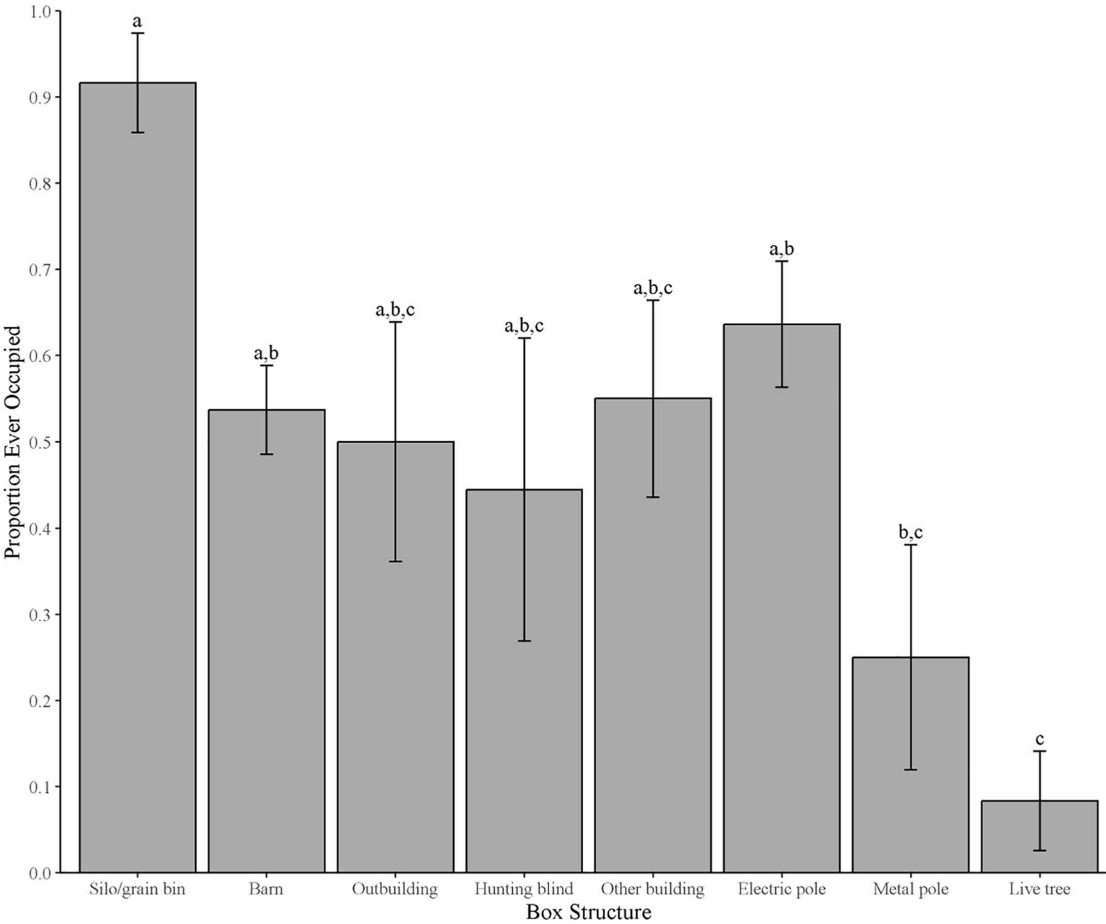

Figure 3. Observed values (±SE) of the proportion of Barn Owl nest boxes ever occupied relative to the type of box structure in Kentucky, USA. Letters indicate statistical differences.

Time to occupancy was related to management status and the distance to an Amish/Mennonite community, region, reason for nest box placement, and nest box structure. Time to occupancy was lower in unmanaged areas ($\bar{x}$ = 3.1 yr, SE = 0.30) compared to managed areas ($\bar{x}$ = 4.6 yr, SE = 0.5; β = −0.57, SE = 0.13, $Z = -4.52$, $P < 0.0001$). There was no difference in the time to occupancy between nest boxes <10 km ($\bar{x}$ = 5.2 yr, SE = 1.5) and >10 km ($\bar{x}$ = 4.6 yr, SE = 0.52) from an Amish/Mennonite community in managed areas (β = 0.14, SE = 0.20, $Z = 0.72$, $P = 0.94$). However, in unmanaged areas nest boxes installed within 10 km of an Amish/Mennonite community ($\bar{x}$ = 2.1 yr, SE = 0.4) were occupied approximately 1.3 yr before boxes >10 km from an Amish/Mennonite community ($\bar{x}$ = 3.4 yr, SE = 0.36; β = 0.48, SE = 0.16, $Z = 2.98$, $P < 0.01$).

Overall the time to occupancy was 2.2 times longer when boxes were placed in areas with no known Barn Owl pairs ($\bar{x}$ = 2.5 yr, SE = 0.22) compared to areas with existing pairs of Barn Owls ($\bar{x}$ = 5.4 yr, SE = 0.53; β = 0.55, SE = 0.16, $Z = 3.49$, $P <$ 0.001). This pattern was largely driven by the Bluegrass region, as the time to occupancy was not related to the reason for box placement in other regions ($P > 0.05$). However, time to occupancy was 3.7 times greater in the Bluegrass region for nest boxes established where no known Barn Owl pairs were present compared to boxes established where there were existing Barn Owl pairs (β = 1.30, SE = 0.17, $Z = 7.71$, $P < 0.0001$). Time to occupancy ($\bar{x}$ = 2.5 yr, SE = 0.2) was similar across all regions when boxes were installed where there were existing Barn Owl pairs. However, when nest boxes

Table 3. The importance values (IV and relative contributions [%]) of covariates included in ensemble species distribution models used to assess Barn Owl (*Tyto alba*) habitat suitability in the Bluegrass, Pennyroyal, Purchase, and Western Coal Field physiographic regions separately and combined in Kentucky, USA. Bold font indicates a significant predictor and dashes indicate the variable was not included in the model set after correlations between predictor variables were evaluated.

	Combined		Bluegrass		Pennyroyal		Purchase		Western Coal Field	
Variable	IV	%	IV	%	IV	%	IV	%	IV	%
Amish	0.0037	0.3	0.0076	0.7	0.0135	1.3	**0.1375**	15.5	0.0275	2.9
Building	**0.6210**	47.3	**0.7486**	71.0	**0.6239**	58.8	**0.4289**	48.4	**0.1439**	14.2
Cattle	0.0123	0.9	0.0674	6.4	0.0461	4.3	—	—	0.0384	4.4
Cultivated	0.0118	0.9	0.0086	0.8	0.0776	7.3	0.0322	3.6	0.0022	0.3
Developed	—	—	—	—	0.0098	0.9	0.0456	5.1	0.0275	3.3
Elevation	0.0539	4.1	0.0399	3.8	0.0280	2.6	0.0175	2.0	0.0454	5.6
Forest	0.0745	5.7	0.0447	4.2	0.0735	6.9	0.0596	6.7	0.0454	6.0
Grass/hay/pasture	0.0311	2.4	—	—	0.0586	5.5	0.0071	0.8	**0.1949**	27.3
Managed	0.0288	2.2	0.0599	5.7	—	—	—	—	**0.1804**	34.8
Roads	0.0217	1.7	0.0096	0.9	—	—	—	—	—	—
SHDI	**0.4341**	33.1	0.0586	5.6	**0.1294**	12.2	**0.1105**	12.5	**0.2432**	71.9
Slope	0.0204	1.6	0.0099	0.9	—	—	0.0480	5.4	—	—
Mean	0.1194		0.1055		0.1178		0.0985		0.0949	

were placed in areas with no known Barn Owl pairs, the time to occupancy in the Bluegrass region was approximately 3.5 times greater compared to nest boxes established in the Pennyroyal and Western Coal Field regions (Pennyroyal: $\beta = 0.85$, SE $= 0.21$, $Z = 4.03$, $P < 0.01$; Western Coal Field: $\beta = 0.99$, SE $= 0.15$, $Z = 6.83$, $P < 0.0001$; Fig. S2).

There was no relationship between any variables considered and the proportion of times a nest box was used. Moreover, there was no relationship between the reason for box placement and future occupancy within any region. Future occupancy did not differ across regions when boxes were established where there was a known pair of Barn Owls. However, when established in areas where no known Barn Owls were present, future occupancy was approximately 4.3 times greater in the Western Coal Field region compared to the Bluegrass region (Future occupancy: $\beta = 2.53$, SE $= 0.80$, $Z = 3.17$, $P = 0.04$; Fig. S2).

Species Distribution Models. Generally, the ensemble model performed similarly or better than other modeling techniques (Table S3). Thus, we present results of the ensemble model for the combined and all regional models. Our model indicated areas of high suitability for Barn Owls are concentrated in the Western Coal Field, the southeastern portion of the Bluegrass, the Western Pennyroyal, and the southeastern and central portion of the Purchase region (Fig. 1). Moreover, the proportion of the Western Coal Field classified as suitable Barn Owl habitat was approximately two and four times greater than the Purchase region and the Pennyroyal and Bluegrass regions, respectively. Overall, 6370 km^2 were classified as suitable Barn Owl habitat throughout the four physiographic regions.

The two variables of greatest importance in the combined model were buildings and the Shannon habitat diversity index (SHDI) at the 75 m scale (Table 3, Fig. 4). Relationships between SHDI and Barn Owl habitat suitability were also present in the Pennyroyal, Purchase, and Western Coal Field models, but weaker (Fig. 4). In addition to building count and SHDI, Barn Owl suitability was influenced by the distance to Amish/Mennonite communities in the Purchase region model and by the distance to managed areas and the proportion of grass/hay/pasture in the Western Coal Field region model (Table 3, Fig. 4).

Management Goals. The number of unique Barn Owl locations per km^2 of suitable area was lowest in the Western Coal Field region and greatest in the Pennyroyal region. A small percentage of public lands were classified as suitable, though additional pairs could be sustained within public lands in the Western Coal Field region. Based on our model, between 1297 and 2293 Barn Owl pairs could potentially be sustained across the four physiographic regions (Table 4). During the triennial Barn Owl surveys, the maximum number of nests and roosts we documented was 167 in 2022 (Table 1). Assuming each nest and roost was a distinct Barn Owl pair, this peak count only represented 7.6–12.8% of the potential number of pairs that

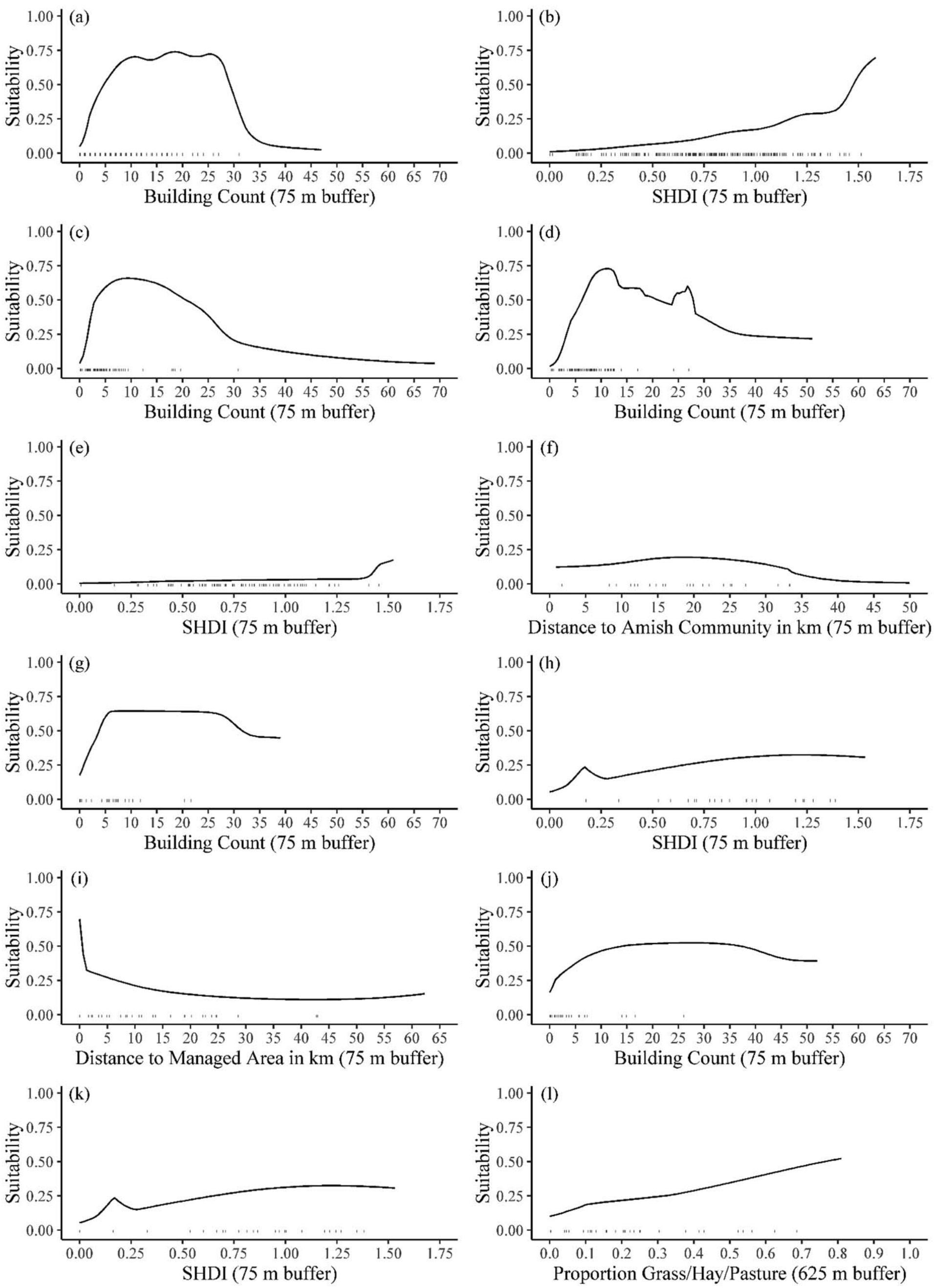

Figure 4. Response curves for the most important environmental variables associated with ensemble occupancy models completed to quantify Barn Owl nesting habitat suitability in the various physiographic regions in Kentucky, USA: (a, b) combined model, (c) Bluegrass, (d, e) Pennyroyal, (f–h) Purchase, and (i–l) Western Coal Field.

Table 4. The amount of suitable Barn Owl habitat regionally and in public areas, the percentage of the regions and public areas within each region considered suitable, the number of unique owl locations per km^2 of suitable area, an estimate of area used by Barn Owls within each region and public areas within each region, and high and low management targets for Barn Owls regionally and combined in Kentucky, USA.

Suitable Habitat	Bluegrass	Pennyroyal	Purchase	Western Coal Field	Combined
Regional					
Total suitable area (km^2)	1563	1594	649	2564	6370
% Suitable	5.9	5.5	9.9	20.6	8.6
Unique locations/km^2	0.03	0.05	0.02	0.01	0.03
Est. of area used (km^2)	196	372.4	73.5	176.4	818.3
Public areas					
Total suitable area (km^2)	15	7	2	153	177
% Suitable	0.9	0.5	0.4	6.0	2.8
Unique locations/km^2	0.62	0.69	0.42	0.12	0.19
Est. of area used (km^2)	44.1	24.5	4.9	88.2	161.7
Management targets					
Potential pairs (low est.)	318	325	132	522	1297
15% Target	48	49	20	78	195
Difference from 2022	8	−27	5	42	28
Potential pairs (high est.)	563	574	234	923	2293
15% Target	84	86	35	138	344
Difference from 2022	44	10	20	102	177

could be supported in the state. As a feasible goal, if 15% of suitable area was occupied, the potential number of pairs the state could support is estimated to be between 195 and 344.

DISCUSSION

Lessons Learned from Management. We placed a significant emphasis on maximizing the productivity of existing Barn Owl pairs since 2010 and this approach has brought our project increased success in terms of nest box occupancy. Using this approach is probably most important when working in regions where Barn Owl habitat is sparsely distributed on the landscape. For instance, in the Bluegrass region, the proportion of area classified as suitable was low and nest boxes installed where there were no known Barn Owl pairs were far less likely to become occupied or became occupied more slowly than those installed where Barn Owls were known to be present. Thus, the benefit relative to conservation investment is likely to occur earlier if increasing the productivity of known pairs is the focus of nest box installations in areas with limited or fragmented Barn Owl habitat. In fact, using a more targeted approach for nest box installations is likely reasonable regardless of Barn Owl density, because there was no difference in the time to occupancy across regions when nest boxes were established where there were existing Barn Owl pairs.

The Western Coal Field region had the highest proportion of area considered suitable and there was also no effect of the reason for box placement on occupancy in this region. Unlike the Bluegrass region, opportunistic installation of nest boxes was successful in the Western Coal Field region, and most of this occurred on one large, intensively managed area with a substantial amount of suitable area available. Peabody Wildlife Management Area (WMA) is located within this region and supports more known Barn Owl nests/roosts per hectare than any other area in the state (0.69 occupied nest boxes per 100 ha in 2022, with nests as close as 0.6 km). This area is composed of reclaimed strip mine land and is used by several grassland raptors including Northern Harriers (*Circus hudsonius*), American Kestrels (*Falco sparverius*), and Short-eared Owls (*Asio flammeus*; Slankard et al. 2018). Human-made structures and natural cavities are scarce on this landscape due to the slow succession of vegetation after mine reclamation. Thus, we installed nest boxes there on retired utility poles at high densities (further discussed below). A high abundance of contiguous open land and minimal human disturbance likely allow for a high Barn Owl density in this area. Additionally, habitat suitability in our model increased as the distance to managed areas decreased for the Western Coal Field ecoregion. This suggests Peabody WMA and nearby areas may function as a source population and should be viewed as a stronghold for the species in Kentucky.

Our discovery of new nest sites outside of known nesting areas depended heavily on reports from the public during our surveys. There is no doubt public awareness about our project increased over the course of the study, leading to increased reporting over time. However, we do think the increasing nest box occupancy and overall nest/roost counts recorded over the course of this project represent consistently greater numbers of Barn Owls within our study area. Because nest boxes were consistently monitored throughout the project, the increase in relative abundance (box occupancy) we observed likely reflects an increase in actual abundance. We opted not to separate opportunistic installations from installations made for known pairs when assessing the increase in nest box occupancy because it is difficult to be certain a site is unoccupied prior to an opportunistic installation. We also chose to pool this data because we found no significant differences in the proportion of times a nest box was used between opportunistic installations and installations made for known pairs in any region. In addition, an increase in species abundance was also supported anecdotally by increasing numbers of Barn Owls being found by chance during surveys, reported by birdwatchers, taken in by rehabilitators, and found dead on Kentucky roadsides (K. Slankard unpubl. data).

Nest site availability is assumed to be a limiting factor for Barn Owl populations (Marti et al. 1979, Johnson 1994). However, several researchers have questioned the utility of nest boxes, and some have suggested they may act as ecological traps (Gehlbach 1994, Møller 1994, Klein et al. 2007). Although we think nest boxes should be placed with care and consideration of the predators in the area, the increase in available nest boxes during our study appears to have boosted Barn Owl populations. We generally installed nest boxes where Barn Owl nest sites were destroyed, where we found nests on the ground in tall feed silos (which were vulnerable to mammalian predation), when nest sites led to failed fledging due to limited space, or when long-term landowner tolerance of the initial nest site was unlikely. We lack sufficient nest success data for before and after nest box installations to show nest success was directly boosted by our efforts, but we surmise nestling/fledgling survival increased because of our efforts and fueled species abundance. Providing nest boxes near a known population also successfully increased nest numbers in Utah (Marti et al. 1979). Additionally, we found value in working with landowners to install nests boxes in places that were convenient for them. Barn Owl nests can result in an unwelcome mess on farm equipment, outdoor living space, or other property. Thus, we often strategized installing nest boxes in a location that would be most likely to avoid conflict in the long term.

Nest boxes on tall feed silos and grain bins (n = 24) had the greatest occupancy rate (Fig. S1). Although silos and grain bins were pooled for analysis, most (88%) of these installations were on the interior wall of unused tall concrete (84%) and metal silos (4%). In fact, all of the nest boxes on the interior of silos became occupied and the only nest box on a silo that was never occupied was installed on the exterior surface. Because installing nest boxes in silos requires specialized tools and strenuous labor, nearly all silo nest boxes were installed for existing pairs. As a result, there is some bias in our results, as nest boxes installed for existing pairs had a higher rate of occupancy. Nonetheless, we think nest boxes installed in tall feed silos would have a high rate of occupancy if installed opportunistically near areas with known nesting populations because we anecdotally found a high incidence of Barn Owl pellets in unoccupied tall feed silos (K. Slankard unpubl. data). In addition, existing pairs nesting on the ground of the tall feed silos moved into provided nest boxes on subsequent attempts 100% of the time, which likely indicates a preference for this type of installation. Marti et al. (1979) also reported a high success rate with attracting Barn Owls to nest boxes installed in abandoned silos in Utah.

Nest boxes installed on retired wood utility poles had the second greatest probability of becoming occupied. The major advantage to this installation type is that nest locations can be provided in land cover types where natural cavities and human-made structures are scarce. The strength and durability of utility poles (as opposed to 10-cm × 10-cm wooden posts or metal poles) also provide better protection from weather damage and ease of ladder access for nestling banding and box maintenance. Installing nest boxes on active power infrastructure requires special permission from the utility company and is often discouraged for powerline maintenance reasons (KDFWR 2018). Thus, we used retired poles obtained from power companies and sunk into the ground with large equipment.

Nest boxes installed on barns and other buildings were also quite successful, especially in attracting existing pairs. On the other hand, nest boxes on trees had the lowest occupancy rate, as they were often colonized and chewed by eastern gray squirrels (*Sciurus carolinensis*). As a result, we abandoned this tactic mid-study. For all installation types, a perch or small platform placed in front of the nest box entrance was important for preventing nestling falls and premature fledging (Meaney et al. 2021, Charter and Rozman 2022).

Practical Use of Species Distribution Model. The SHDI was important in the combined and three of the regional models. This likely represents this species' tendency to nest near edges of cropland, pasture, and shrubland, or within areas composed of a mixture of these land cover types. Similarly, land cover diversity also influenced the home range size of Barn Owls in Italy (Sechaud et al. 2022). In contrast to other studies (Hindmarch et al. 2012, Regan et al. 2018), the location of roads and highways was unimportant in our habitat suitability model. We included the building count in our model, which unsurprisingly showed a bimodal relationship in most regions, demonstrating this species' preference for rural landscapes and nesting within human structures. We expected to find a relationship between Barn Owl habitat suitability and the proportion of grass/hay/pasture in the combined model for the whole study area, as in Illinois (Wingert 2015). Instead, we only found a positive linear relationship in the Western Coal Field region. Additionally, our results differed from a point count survey in Idaho, which associated Barn Owl occupancy with crop coverage (Regan et al. 2018). Given these differences, Barn Owl occupancy relative to landscape variables may vary quite a bit across the species' North American range.

We attempted to map several additional variables that we believe influence the distribution of Barn Owls in Kentucky but were met with some challenges. Barn Owl numbers tend to be high near Amish and Mennonite communities, likely due to alternative farming practices and the willingness of these landowners to host the species as a means of natural pest control. We attempted to explore this relationship statistically and we did find an association with habitat suitability in the Purchase region, as well as a shorter time to nest box occupancy in unmanaged areas near to Amish/Mennonite communities (Fig. 4). However, we were surprised that this variable was not significant in other analyses. Mapping Amish and Mennonite communities is a challenge and the georeferenced data layer we created was flawed. Many communities were represented by a single address, despite their footprint likely spanning several square kilometers. The creation of better data layers for these communities would be time intensive but may be worthwhile to evaluate the association of multiple grassland/farmland bird species with these communities (Wilson et al. 2015).

Another variable we wanted to consider was the presence of tall concrete feed silos on the landscape. Many Barn Owls nested in unused, tall, concrete feed silos and the density of these on the landscape may influence abundance. These silos (generally 4.9–7.3 m in diameter and 15–21 m tall) are typically associated with dairy farms constructed between 1930 and 1980 (Macintire 2009), but data layers for dairies or silos are nonexistent and constructing them from public agency data is difficult due to privacy concerns. Remote sensing may be useful for locating these structures on the landscape, if needed for future study.

Most Barn Owl studies focus exclusively on monitoring nest boxes (Wingert 2015, Meilink 2018, Huysman 2019), so the inclusion of non-nest box occupancy data makes our dataset unusual. Barn Owl habitat selection is likely influenced by nest site availability. Our model was designed to predict locations where Barn Owls nest or roost and not overall habitat use. Barn Owls certainly use areas outside of our predicted suitable area, but we generated the models based on nest/roost locations so the resulting map could inform our nest box installations and nest survey efforts. Thus, our estimates of the potential pairs that could be supported within suitable areas are conservative. In fact, estimates of area used per pair on public areas in all regions, aside from the Western Coal Field region, exceeded the area deemed as available and we assume this is because they use areas outside of those mapped as suitable.

Management Goals. During the triennial Barn Owl surveys, the maximum number of nests we documented was 136 (Table 1). This peak count represented only 5.9–10.5% of the potential number of pairs that could be supported in the state (1297–2293; Table 4). We opted to set our management goal based on feasibility rather than population stability for two reasons. First, we lacked parameters from local populations to support a population viability analysis. Further study may be warranted to set goals based on population viability. Second, a goal of 100% occupancy is unlikely to be attainable, as funding and staff time are limited and not all landowners are willing to host Barn Owls on their property. However, based on our experiences, we estimate that 15% of landowners may be willing to support Barn Owls. Further, a management goal must be practical, and managing over 500 nest boxes would be logistically difficult without more staff. Thus, we have set Kentucky's goal at 15% occupancy of suitable nest areas, and a potential number of pairs between 195 and 344.

Population limiting factors for Barn Owls seem to differ regionally, with either suitable nest sites or foraging habitat thought to be the more significant limiting factor (Marti et al. 1979, Colvin 1985, Johnson 1994). Based on our results, we surmise it is not necessarily the availability of nest sites limiting Kentucky's population, but the availability of higher quality nest sites. Our model is intended to help managers and researchers prioritize efforts to install nest boxes, and it indicates that Kentucky hosts over 5000 km^2 of suitable area for Barn Owls where the species has yet to be documented. For prioritizing future efforts, public lands offer stable land ownership and habitat conditions. Our analysis indicated additional pairs could be sustained within public lands in the Western Coal Field region; the current overall owl density is low for this region, reflecting abundant suitable area that could be prioritized for future nest box installations. However, outside of the Western Coal Field region, unoccupied suitable public land is limited, and only a small percentage (2.8%) of public lands were classified as suitable overall (Table 4). This highlights the need to work on private lands to achieve management goals, especially within the Bluegrass, Pennyroyal, and Purchase ecoregions. Continuing work to provide newly located pairs with high quality nest sites in these regions is likely to be successful. However, our model can also be used to prioritize areas for nest box installations to boost overall nest numbers and geographic range. Areas with larger, contiguous suitable areas should be targeted with the goal of boosting population size and persistence (Fahrig and Merriam 1994). As the population increases, prioritization using the model will help ensure the project remains practicable.

The management objectives for this species undoubtedly vary across a landscape as broad as our study area. Agricultural practices and associated structures, the presence of reclaimed surface mines, and landscape features such as large tracts of forest and floodplains all influence the distribution of this species and that is why we combined habitat suitability modeling with our nest box occupancy analysis. Doing so helps to scale management priorities to the regional level within our broad study area. Although targeting existing pairs for nest box installations may seem an obvious tactic, it has seldom been implemented on a large scale elsewhere. Our results show a more targeted approach can support population growth, especially in the early phase of management of low-density populations. Habitat modeling can further prioritize conservation action and help to set management goals. Updates on this project are available at: https://fw.ky.gov/Wildlife/Pages/Barn-Owls-in-Kentucky.aspx.

SUPPLEMENTAL MATERIAL (available online). Detailed methods on species distribution modeling. Table S1: A description, the source, and original resolution of the raster or feature shapefile associated with each covariate used for Barn Owl species distribution models. Table S2: The radius of the buffers for each covariate used to build scale-optimized Barn Owl species distribution models for the physiographic regions of Kentucky. Table S3: The continuous Boyce index, area under the receiver operating characteristic curves (AUC-ROC), and true skill statistics (TSS) for the ensemble, generalized additive (GAM), generalized linear (GLM), multiple adaptive regression splines (MARS), and maximum entropy (MaxEnt) models completed to assess Barn Owl habitat suitability regionally and combined in Kentucky. Figure S1: Photograph of a nest box installed on the interior wall of a tall concrete feed silo. Figure S2: The proportion of Barn Owl nest boxes ever occupied, time to occupancy, future occupancy, and proportion of times occupied relative to the interaction between the reason for box placement (existing pair or no known pair) and physiographic region in Kentucky.

ACKNOWLEDGMENTS

A project of this scope would not have been possible without the support of many cooperators and private landowners. KDFWR would like to acknowledge the numerous private landowners who have allowed their land to host this species. For their privacy, we do not mention landowner names here. We would also like to acknowledge wildlife rehabilitators Western Kentucky Raptor Center, Liberty Nature Center, Raptor Rehabilitation of Kentucky, and Back Too the Wild for providing information on Barn Owls. We appreciate Vernon Zimmerman and James Shirk for helping to spread the word about our project to Amish and Mennonite communities. Finally, we are grateful to those at KDFWR who helped with this project: Jarrod Arnold, Kasie Bradley, Christine Casey, Sarah Christian, Clay WMA staff, Curt Devine, Tom Edwards, Bill Lynch, Wes McFaddin, Michael Patton, Peabody WMA staff, Ryan Taylor, Angel Smallwood, Eric Williams, Yellowbank WMA staff, and Thomas Young. Gary Sprandel, Daniel Vichitbandha, Trey Prather, and Daren Jones provided technical support for the Barn Owl database and data layers. We also acknowledge the efforts of two anonymous reviewers and JRR Associate Editor Jessi Brown.

LITERATURE CITED

Allouche, O., A. Tsoar, and R. Kadmon (2006). Assessing the accuracy of species distribution models: Prevalence, kappa and the true skill statistic (TSS). Journal of Applied Ecology 43:1223–1232.

Andrusiak, L. A. (1994). Nesting and roosting habitat and breeding biology of the Barn Owl (*Tyto alba*) in the lower mainland of British Columbia. MS thesis. University of British Columbia, Vancouver, BC, Canada.

Boves, T. J., and J. R. Belthoff (2012). Roadway mortality of Barn Owls in Idaho, USA. Journal of Wildlife Management 76:1381–1392.

Burtner, A. (2010). Conservation potential of Barn Owls (*Tyto alba*) in Pennsylvania. MS thesis. Duke University, Durham, NC, USA.

Byrd, C. L. (1982). The home range, habitat and prey utilization of the Barn Owl (*Tyto alba*) in South Texas. Ph. D. dissertation. Texas A&M University, College Station, TX, USA.

Byrd, M. A., C. P. Rosenburg, and K. Terwilliger (1986). Barn Owl Investigations, Annual Report. Virginia Dept. of Game and Inland Fisheries, Richmond, VA, USA.

Chien, J., and G. Ritchison (2011). Post-release movements, behavior and survival of captive-raised Barn Owls in central Kentucky. Kentucky Warbler 87:1–8.

Colvin, B. (1985). Common Barn Owl population decline in Ohio and the relationship to agricultural trends. Journal of Field Ornithology 56:224–235.

Fahrig, L., and G. Merriam (1994). Conservation of fragmented populations. Conservation Biology 8:50–59.

Gehlbach, F. R. (1994). Nest-box versus natural-cavity nests of the Eastern Screech-Owl: An exploratory study. Journal of Raptor Research 28:154–157.

Hegdal, P. L., and R. W. Blaskiewicz (1984). Evaluation of the potential hazard to Barn Owls of Talon (brodifacoum bait) used to control rats and house mice. Environmental Toxicology and Chemistry 3:167–179.

Hindmarch, S. F., E. A. Krebs, J. E. Elliott, and D. J. Green (2012). Do landscape features predict the presence of Barn Owls in a changing agricultural landscape? Landscape and Urban Planning 107:255–262.

Hirzel, A. H., G. Le Lay, V. Helfer, C. Randin, and A. Guisan (2006). Evaluating the ability of habitat suitability models to predict species presences. Ecological Modelling 199:142–152.

Huysman, A. E. (2019). Ecosystem services after a major ecological disturbance: Did Barn Owl (*Tyto alba*) nest box occupancy and hunting habitat selection change in response to Napa Valley fires? MS thesis, Humboldt State University, Arcata, CA, USA.

Johnson, P. N. (1994). Selection and use of nest sites by Barn Owls in Norfolk, England. Journal of Raptor Research 28:149–153.

Kentucky Department of Fish and Wildlife Resources (KDFWR) (2005). Kentucky's Comprehensive Wildlife Conservation Strategy. Kentucky Department of Fish and Wildlife Resources, Frankfort, KY, USA. http://fw.ky.gov/kfwis/stwg/.

Kentucky Department of Fish and Wildlife Resources (KDFWR) (2018). Barn Owl Nest Box Construction and Installation. Kentucky Department of Fish and Wildlife Resources, Frankfort, KY, USA. https://fw.ky.gov/Wildlife/Documents/BarnOwlBoxes.pdf.

Klein, A., T. Nagy, T. Csorgo, and R. Matics (2007). Exterior nest-boxes may negatively affect Barn Owl (*Tyto alba*) survival: An ecological trap. Bird Conservation International 17:273–281.

Lambrechts, M. M., K. L. Wiebe, P. Sunde, T. Solonen, F. Sergio, A. Roulin, A. P. Møller, B. C. Lopez, J. A. Fargallo, K. Exo, G. Dell'Omo, et al. (2012). Nest box design for the study of diurnal raptors and owls is still an overlooked point in ecological, evolutionary and conservation studies: A review. Journal of Ornithology 153: 23–34.

Liu, C., G. Newell, and M. White (2016). On the selection of thresholds for predicting species occurrence with presence-only data. Ecology and Evolution 6:337–348.

Liu, C., M. White, and G. Newell (2013). Selecting thresholds for the prediction of species occurrence with presence-only data. Journal of Biogeography 40:778–789.

Macintire, W. (2009). A Survey of Historic Sites in Rural Marion and Washington Counties, Kentucky. Kentucky Heritage Council State Historic Preservation Office, Frankfort, KY, USA. https://heritage.ky.gov/Documents/RHDImaster.pdf.

Marti, C. D. (1994). Barn Owl reproduction: Patterns and variation near the limit of the species' distribution. The Condor 96:468–484.

Marti, C. D., A. F. Poole, L. R. Bevier, M. D. Bruce, D. A. Christie, G. M. Kirwan, and J. S. Marks (2020). Barn Owl (*Tyto alba*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.brnowl.01.

Marti, C. D., P. W. Wagner, and K. W. Denne (1979). Nest boxes for the management of Barn Owls. Wildlife Society Bulletin 7:145–148.

Martin, J. M. (2009). Are Barn Owls biological controllers of rodents in the Everglades Agricultural Area? Ph.D. dissertation. University of Florida, Gainesville, FL, USA.

Martin, J. M., L. C. Branch, R. N. Raid, and S. C. Beyeler (2010). Temporal instability of agricultural habitat reduces reproductive success of Barn Owls (*Tyto alba*). The Auk 127:909–916.

Martínez, J. A., and G. López (1999). Breeding ecology of the Barn Owl (*Tyto alba*) in Valencia (SE Spain). Journal of Ornithology 140:93–99.

Meaney, K. M., D. E. Peacock, D. Taggart, and J. Smith (2021). Rapid colonisation, breeding and successful recruitment of eastern Barn Owls (*Tyto alba delicatula*) using a customised wooden nest box in remnant mallee cropping areas of Southern Yorke Peninsula, South Australia. Wildlife Research 48:334– 344.

Meilink, S. A. (2018). Nesting success and habitat preference of the Barn Owl (*Tyto alba*) in southwest Missouri. MS thesis. Missouri State University, Springfield, MO, USA.

Møller, A. P. (1994). Facts and artefacts in nest-box studies: Implications for studies of birds of prey. Journal of Raptor Research 28:143–148.

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Regan, T., C. J. W. McClure, and J. R. Belthoff (2018). Assessing patterns of Barn Owl (*Tyto alba*) occupancy from call broadcast surveys. Wildlife Biology 2018: wlb.00411. doi:10.2981/wlb.00411.

Sechaud, R., K. Schalcher, B. Almasi, R. Buhler, K. Safi, A. Romano, and A. Roulin (2022). Home range size and habitat quality affect breeding success but not parental investment in Barn Owl males. Scientific Reports 12:6516. doi:10.1038/s41598-022-10324-7.

Slankard, K. G., J. O. Barnard, and M. D. Patton (2022). Barn Owl Inventory Report. Unpublished technical report. Kentucky Department of Fish & Wildlife Resources, Frankfort, KY, USA.

Slankard, K. G., D. L. Baxley, and G. L. Sprandel (2018). The impacts of native grassland restoration on raptors and their prey on a reclaimed surface mine in Kentucky. Northeastern Naturalist 25:227–290.

Slankard, K. G., C. L. Gaskill, L. M. Cassone, and C. M. Rhoden (2019). Changes in detected anticoagulant rodenticide exposure in Barn Owls in Kentucky, USA, in 2012–2016. Journal of Wildlife Diseases 55:432–437.

Slankard, K. G., M. D. Patton, L. F. Taylor, and J. O. Barnard (2021). Two case studies satellite tracking the dispersal of juvenile Barn Owls (*Tyto alba*). Journal of Raptor Research 55:115–118.

Stewart, P. A. (1980). Population trends of Barn Owls in North America. American Birds 34:698–700.

Thuiller, W., D. Georges, M. Gueguen, R. Engler, F. Breiner, B. Lafourcade, and R. Patin (2023). biomod2: Ensemble platform for species distribution modeling. R package version 4.2-4. https://CRAN.R-project.org/package=biomod2.

Valavi, R., J. Elith, J. J. Lahoz-Monfort, and G. Guillera-Arroita (2019). *blockCV*: An R package for generating spatially or environmentally separated folds for k-fold cross-validation of species distribution models. Methods in Ecology and Evolution 10:225–232.

Walk, J. W., A. Mankowksi, T. L. Esker, M. Cole, and M. G. Alessi (2010). The Illinois Barn Owl Recovery Plan. Illinois Department of Natural Resources, Springfield, IL, USA. https://dnr.illinois.gov/content/dam/soi/en/web/dnr/espb/documents/illinoisbarnowlrecoveryplannovember2010.pdf.

Watts, B. D. (2003). An Evaluation of Nest Box Use by Barn Owls and the Initiation of a New Box Program on Coastal Marshlands in Virginia. Center for Conservation Biology Technical Report. College of William and Mary, Williamsburg, VA, USA.

Wendt, C. A., and M. D. Johnson (2017). Multi-scale analysis of Barn Owl nest box selection on Napa Valley vineyards. Agriculture, Ecosystems and Environment 247:75–83.

Wilson, A., B. Lonabocker, and M. Zagorski (2015). Online mapping tools for geolocating Amish settlements. Journal of Amish and Plain Anabaptist Studies 3:201–211.

Wingert, A. K. (2015). Conserving a charismatic grassland species in Illinois: The Barn Owl. MS thesis. University of Illinois Urbana-Champaign, Urbana, IL, USA.

Woods, A. J., J. M. Omernik, W. H. Martin, G. J. Pond, W. M. Andrews, S. M. Call, J. A. Comstock, and D. D. Taylor (2002). Ecoregions of Kentucky. US Geological Survey, Reston, VA, USA.

Received 28 November 2023; accepted 28 July 2024
Associate Editor: Jessi L. Brown