Habitat Selection, Nest Box Usage, and Reproductive Success of Secondary Cavity Nesting Birds in a Semirural Setting

Laura E. Jardine
Oklahoma City University, Department of Biology, Oklahoma City, OK 73106

Alanah N. Hosford
Oklahoma City University, Department of Biology, Oklahoma City, OK 73106

Shelbi A. Legg
Oklahoma City University, Department of Biology, Oklahoma City, OK 73106

Anthony J. Stancampiano
Oklahoma City University, Department of Biology, Oklahoma City, OK 73106

Abstract: As urban areas continue to grow and erode rural landscapes, it is critical to characterize essential habitats for all wildlife in order to set aside protected areas in an attempt to maintain diversity. We constructed and monitored 30 nest boxes for usage by secondary cavity-nesting birds each year from 2014-2016 at the John Nichols Scout Ranch located in southeast Canadian County, Oklahoma. At each of six sites, five nest boxes were situated along a transect at 15m intervals with a central box located at an abrupt edge between a wooded habitat and a grassland habitat. We measured 77 habitat variables around each nest box at 2 sampling scales, $1m^2$ and $10m^2$. We used these habitat variables and sites in which nesting occurred in a principal components analysis. Eastern Bluebirds and Carolina Chickadees nested in grassland habitats with little to no overhead canopy cover. Carolina Wrens nested in woodland areas with high amounts of litter ground cover and overhead canopy cover. Results at both spatial scales were similar. We used the simplified Morisita index to calculate niche overlap at both spatial scales. Overlap varied substantially depending on sampling scale. *©2016 Oklahoma Academy of Science*

Introduction

As urban areas continue to encroach on rural landscapes, it is often difficult to delineate one land use type from another due to the fragmented nature of urban development and its associated construction (habitat destruction). These dynamic zones between urban and rural landscapes are referred to as semirural. Such areas represent a challenge for birds and other animals that are adapted to native landscapes, as opposed to those adapted to urban settings. Avian abundance in urban and suburban landscapes can be higher than in surrounding rural landscapes, while species diversity in the larger contiguous landscape tends to decrease overall as urban landscapes become dominated by only a few species (Reale and Blair 2005, Saarikivi and Herczeg 2014). Additionally, bird tolerance of human disturbance may increase in some species (Clucas and Marzluff 2012). Urbanization can produce new habitat types resulting in new species' presence, but it also typically reduces the number and size of large habitat patches when compared to rural and semirural areas (Gilbert 1989, Luck and Wu 2002). Many birds require these larger patches for breeding (Vickrey et al. 1994). Semirural areas may represent the last available source of nesting sites for non-urban adapted birds over long, unsuitable urban distances (Wiens 1989, Sanström et al. 2006). Because habitat in urban and suburban areas is hyper-managed relative to rural and semirural areas, characters within the urban and suburban habitats tend to be more uniform. This includes manicured landscapes with similar characters such as tree height, a distinct lack of snags and tree cavities, canopy cover, monocultures, herbaceous vegetation type and height, etc. (Berthier et al. 2012). These more homogeneous habitats preclude occupation and breeding by birds that require specific habitat structure, including secondary cavity-nesting birds (Jackson et al. 2013). As urban areas sprawl into and eventually consume rural areas, it is critical that ecologists have an inventory of species that will most likely be displaced and the specific habitat requirements of these species so that at a minimum, quality remnants of suitable size can be set aside and reserved as refugia.

Studies of cavity-nesting birds have been conducted in both urban and rural areas (Conner and Adkisson 1977, Pogue and Schnell 1994, Jackson et al. 2013, Saarikivi and Herczeg 2014). Most of these studies assess habitat relative to some life strategy such as foraging or reproduction. In this study, we associate nest box selection (reproduction) with habitat sampled in a $1m^2$ and $10m^2$ area around each nest.

Methods

Study Area

The John Nichols Scout Ranch (JNSR, 97-ha) is located in the extreme southeast corner of Canadian County, Oklahoma (35.349987 N, 97.672389 W), and as such is included in the cross timbers physiognomic region (Duck and Fletcher 1945, Oklahoma Department of Wildlife Conservation). The JNSR is bordered on the south by the Canadian River (and Grady County) and to the east by Cleveland County. A 250 hectare housing development is currently under construction less than 1km to the east of JNSR. Various cultivated fields lie between this development and JNSR. Across the river to the south is pasture and cross timber forest. To the west and north is pasture and wheat fields. Habitat types at JNSR include riparian, intermittent streams, woodlands, and mixed-grass prairie. Mowing of camp areas occurs at irregular intervals. The JNSR serves as a summer camp for scouts of all ages. Human occupancy ranges from high (hundreds) to none throughout the year. Occupancy is heavy in the late spring and early summer due to Boy Scout camping and events and tapers down to low or no occupancy through the fall and winter.

Nest Box Monitoring

We established nest boxes at 6 separate sites in the fall of 2013. Nest boxes are constructed of ¾" rough cedar with a finished inner surface. Nest box dimensions are 9" tall x 5½" wide x 5½" deep. The entrance hole has a diameter of 1½" and is located 6½" above the floor of the box. All nest boxes are affixed to an 8ft t-post by a U-bolt at a bottom height of 6ft with the entrance facing due east.

Each site consists of a distinct woodland and a distinct grassland with an abrupt edge (ecotone) between the two. Five of the grassland habitats undergo periodic mowing, but at different frequencies. The woodland areas are not manicured in any way.

We placed one nest box at the abrupt edge between the woodland and grassland habitats. This box was designated as the C (center) box. We placed 2 boxes at 15m intervals into the woodland (C+1 and C+2) and 2 boxes into the grassland at 15m intervals (C-1 and C-2) along a 60m transect set perpendicular to the edge.

We monitored nest boxes for nesting activity on a weekly basis beginning in February and continuing through August of each year from 2014-2016. Nest boxes were classified as being used for reproduction after the nest was complete and egg laying had begun. We removed all nesting materials after fledging or nest abandonment.

Habitat Sampling

We sampled 77 habitat variables using quadrats at 2 spatial scales, $1m^2$ and $10m^2$, around each nest box location. These variables include ground cover, canopy cover, vertical structure, major vegetation type, and various distance measures (Table 1). Cover was measured using a $1m^2$ PVC sampling frame. We measured vertical structure using a 1m rod marked with 1dm increments. We used a convex densiometer to measure canopy cover at the t-post for $1m^2$ and at each of the 4 corners and t-post for the $10m^2$ scale. We recorded the average of these 5 readings as the $10m^2$ canopy cover. Distance measures were made using a Leica Rangemaster 1600-B laser range finder. We measured tree heights using a Suunto PM-5/1520 clinometer. All site transects and individual nest boxes were georeferenced using a Trimble Juno 3B.

Statistical Analysis

We used these habitat variables and nest box usage data in various statistical analyses to provide general descriptive associations between bird species and the habitats that they occupied. Initially, we used the 77 habitat variables in a principal components analysis (PCA) to characterize general trends along habitat gradients from a rectangular data matrix of 30 nest box sites by habitat variables. These data were mean-centered and correlations were calculated among the variables. We then projected standardized data onto eigenvectors extracted from the correlation matrix. In this type of analysis, principal component 1 (PC1) explains the maximum character variance and each subsequent PC explains the maximum remaining variance.

We also constructed a rectangular matrix of nesting bird species by habitat variable averages and subjected this matrix to PCA. Projections of these species onto principal component axes indicates species habitat preferences (Stancampiano and Schnell 2004).

Niche overlap was evaluated at both scales using the simplified Morisita index (Ecological Methodology ver. 7.2). This measure of niche overlap ranges from 0.0 (no resources in common) to 1.0 (complete overlap).

Results

Seventeen clutches were laid at 5 of the 6 transects between March of 2014 and September of 2016. The Greenbriar transect had 6 nests, Bermuda Triangle 4, Council Ring 4, Creaking Cabin 2, and Walnut Grove had 1 nest. Eastern Bluebirds (*Sialia sialis*) utilized 11 boxes and Carolina Chickadees (*Poecile carolinensis*) and Carolina Wrens (*Thryothorus ludovicianus*) nested in 3 boxes each. Eastern Bluebirds and Carolina Chickadees only used boxes in grassland habitat while Carolina Wrens only used boxes in the woodlands (Fig. 1). The mean clutch size and mean number of fledglings was similar for all species (Fig. 2). Carolina Wrens chose wooded areas that were near the abrupt edge. In 2 of the 3 nesting instances they occupied the C+1 nest (closest to the edge). Eastern Bluebirds used the C+2 boxes (furthest from the edge) for 6 of the 11 nestings and Carolina Chickadees used C+2 boxes in 2 out of 3 instances. Nest boxes located at the abrupt edge between woodlands and clearings were not utilized at any of the 6 study sites.

Principal Components Analysis

We constructed a rectangular matrix of 77 habitat variables by 30 nest box sites at both the $1m^2$ and $10m^2$ scale for principal components analysis. Twenty-nine invariant habitat variables were eliminated in the $1m^2$ analysis and 25 were eliminated in the $10m^2$ analysis. The first 3 components in the $1m^2$ PCA explained 37.4% of the total variance in the habitat variables. Projections and character loadings indicate that PC I (19.3% of total variance) represents a gradient from high annual cover and low canopy cover to low annual cover and high canopy cover. This describes the transition from grassland into the woodland at each transect. PC II represents a gradient from sites with rocky and annual ground cover to sites with litter and no cover. Most nest box sites had very low loadings (positive and negative) or high positive loadings for this component.

The first 3 components in the $10m^2$ PCA of habitat variables versus nest box sites explained 35.6% of the total variance in the habitat

Table 1. Habitat variables and variable codes used in principal components analysis.

6-10	CA00-20 - CA81-100	Annual Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
11-15	CL00-20 - CL81-100	Litter Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
16-20	CR00-20 - CR81-100	Rock Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
21-25	CS00-20 - CS81-100	Shrub Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
26-30	CT00-20 - CT81-100	Basal Tree Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
31-35	CM00-20 - CM81-100	Moss Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
36-40	COC00-20 - COC81-100	Overhang Canopy Cover 0-20%, 21-40%, 41-60%, 61-80%, 81-100%
41-47	MHA00-2 - MHAgt10	Mean Annual Height 0-2dm, 2-4dm, 4-6dm, 6-8dm, 8-10dm, >10dm
48-51	MHS00-5 - MHSgt20	Mean Shrub Height 0-5dm, 6-10dm, 11-20dm, >20dm
52-55	MHT00-15 - MHTgt85	Mean Tree Height 0-15dm, 16-40dm, 41-85dm, >85dm
56-59	VegA, VegT, VegS, VegN	Annuals are major vegetation, Trees are major vegetation, Shrubs are major vegetation, No major vegetation
60-63	DHA00-10 - DHAgt30	0-10m distance from human activity, 11-20m distance, 21-30m distance, greater than 30m distance from human activity
64-67	DW00 - 10 - DWgt30	0-10m distance from permanent water source, 11-20m distance, 21-30m distance, greater than 30m distance from permanent water source
68-71	DDH00-10 - DDHgt30	0-10m distance from different habitat, 11-20m distance, 21-30m distance, greater than 30m distance from different habitat
72-78	DT00-5 - DTgt30	0-5m distance to closest tree, 6-10m distance, 11-15m distance, 16-20m distance, 21-25m distance, 26-30m distance, 31-35m distance, greater than 35m distance to closest tree

variables. Projections and character loadings indicate that PC I (17.5% of total variance) represents a gradient from low annual cover, high litter cover, and high canopy cover to sites dominated by annual vegetation that are near a different habitat type (edge). Component II represents a gradient from low annual and high litter cover with moderate overhead canopy

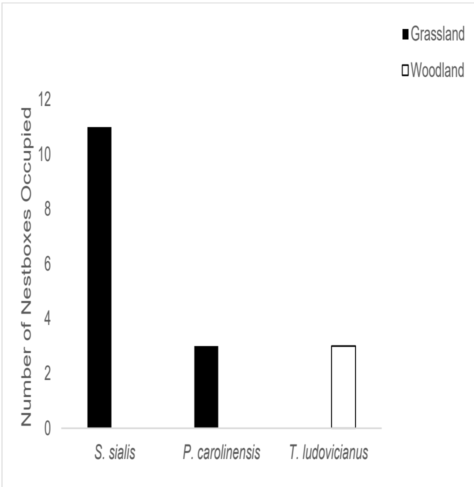

Figure 1. Nest box usage in grassland and woodland per species.

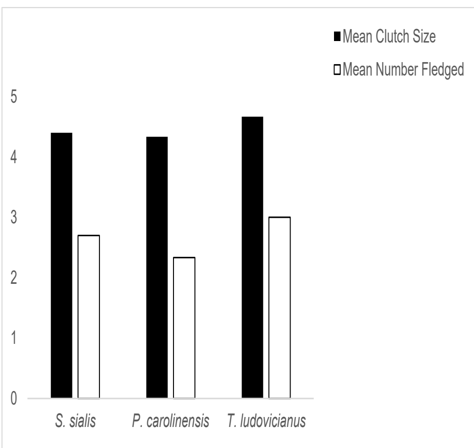

Figure 2. Mean clutch size and mean number of fledglings per species.

cover to sites with very high annual cover and little canopy cover. These 2 components accurately represent the woodland to grassland transition.

We calculated the mean value for each of the 77 habitat variables at both the 1m^2 and 10m^2 scale for each of the 17 nesting sites. Fifty-one invariant habitat variables were eliminated in the 1m^2 analysis and 45 were eliminated in the 10m^2 analysis of the nesting bird species by habitat variables PCA.

In the 1m^2 analysis, the first 2 components explained 100% of the total variance in the habitat variables. Projections and character loadings show that PC I (71.38% of the total variance) represents a gradient from short, intermediate annual cover, presence of shrubs, greater tree density and overhead canopy cover to taller, almost total annual cover, and low canopy cover. Component II represents a gradient from habitat with some rocky cover, abundant litter cover, intermediate height annuals, and relatively longer distances to different habitat type (negative loadings) to habitat with relatively shorter distance to different habitat type and very short annual vegetation (Fig. 3).

The first 2 components of the 10m^2 PCA (nest species by habitat variables) also explain 100% of the total variance in the habitat variables. Component I describes a gradient from habitat with less than 80% annual cover, high litter cover, moderate shrub cover, high tree density and overhead canopy cover to areas with greater than 80% annual cover and little canopy cover. Component II had very few high loading positive loadings, such as low annual vegetation height and low percentage of areas with no ground cover. Negative loadings included habitat with

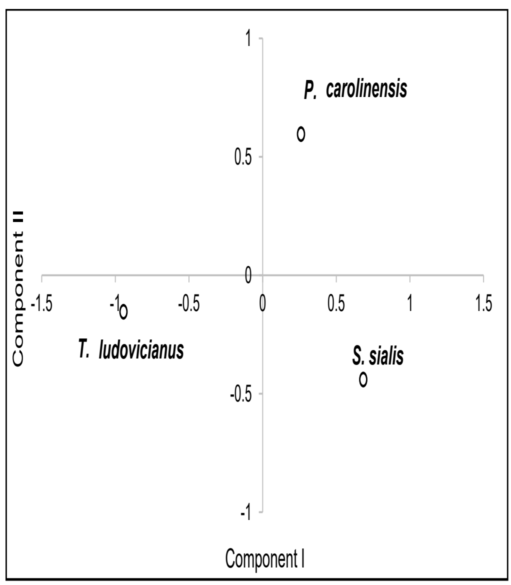

Figure 3. Projections of *T. ludovicianus, P. carolinensis,* and *S. sialis* based on the 1m^2 habitat variables onto principal components I and II.

some shrub cover, moderate areas of no ground cover, and moderate overhead canopy cover (Fig. 4).

Nesting species niche overlap varied widely from the $1m^2$ scale to the $10m^2$ scale analysis (Table 2). At both scales, the 2 species that utilized grassland areas for nesting had a high degree of overlap. At the $1m^2$ scale, both Eastern Bluebirds and Carolina Chickadees had relatively high overlap with Carolina Wrens.

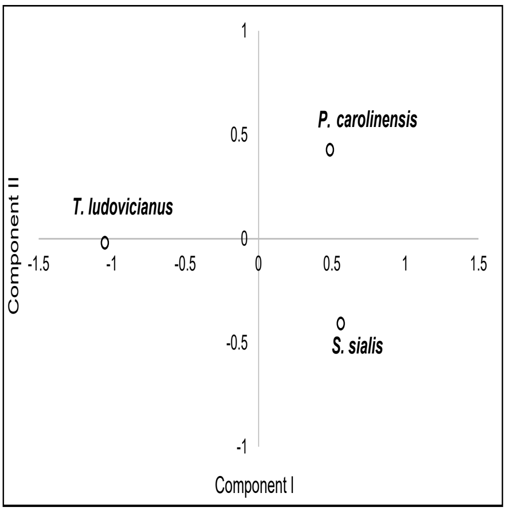

Figure 4. Projections of *T. ludovicianus, P. carolinensis,* and *S. sialis* based on the $10m^2$ habitat variables onto principal components I and II.

However, at the $10m^2$ scale there was reduced overlap between the grassland nesters and Carolina Wrens.

Discussion

Principal components analysis of nesting sites versus habitat variables suggests that these 3 species perceive their habitat in terms of ground cover, vertical structure, horizontal structure, and neighborhood type. The $1m^2$ and $10m^2$ PCA produced very similar results and as such, neither scale provided unique habitat characters that help to reveal habitat preferences. The PCA did, however, support the importance of diversity in habitat and landscape structure in providing quality nesting habitat for multiple species.

Although the $1m^2$ scale niche overlap index suggests substantial overlap among all 3 species, the $10m^2$ scale niche overlap values reveal that overlap drops dramatically between the 2 grassland nesting species and the Carolina Wren. Sampling at an even larger scale to include landscape measurements may reveal additional insight into why habitat that appears similar in structure and composition may not equally support nesting activity. This information is important as developers and city planners consider requirements for incorporating/ preserving native habitats in newly developed areas.

We expected secondary cavity-nesting birds to utilize nest boxes to a greater extent than they did. Based on observations of the avian fauna at JNSR, we also expected a higher diversity of birds using the boxes. Other secondary cavity-nesting birds seen at JNSR, but not utilizing nest boxes include the Tufted Titmouse (*Baeolophus bicolor*) and Bewick's Wren (*Thryomanes bewickii*). Despite JNSR's proximity to encroaching housing development, we only saw House Sparrows and European Starlings in very low numbers, typically only along county roadsides. Additionally, over the course of the study, 4 clutches were abandoned prior to incubation indicating either predation threats or that mated pairs had multiple nests. Although there was no ecotone at any of our sites due to the abrupt edge, we expected C-0 nest boxes (edge effect) to be used at least as frequently as the other boxes. We found the opposite to be true as edge nest boxes were the only location where no boxes were used for nesting over the course of all 3 years.

These facts indicate to us that 1) natural cavities are abundant at this time on JNSR 2) JNSR currently has a sufficient rural buffer around it to minimize invasion by naturalized invasive species such as House Sparrows and European Starlings, commonly associated with urban environments, and 3) with regard to our study, edge effect has little influence when choosing nest box sites for the 3 species. It is

Table 2. Niche overlap between bird species using the simplified Morisita index of overlap.

	1m^2			10m^2		
Species	1	2	3	1	2	3
1 *Sialia sialis*	1.000			1.000		
2 *Poecile carolinensis*	0.987	1.000		0.967	1.000	
3 *Thryothorus ludovicianus*	0.879	0.866	1.000	0.219	0.199	1.000

important to characterize nesting habitat for native species in the absence of competition with these introduced species. This provides a more accurate evaluation of habitat affinities with regard to reproductive adaptations of native species.

Acknowledgments

We would like to thank the Boy Scouts of America Last Frontier Council and Jim Taylor for the use of the John Nichols Scout Ranch. We also thank Troy Woodson, store manager at Lowe's Home Improvement Store #2540 for construction materials. This study was supported, in part, by a 2014 CAIRS OCU Undergraduate Research Grant. We thank the Dean's Office in the Petree College of Arts and Science and the Department of Biology at OCU for use of a field vehicle and financial support of the field crew. This study would not have been possible without field assistance from Cassandra Velasco and Dylan Smith-Sutton.

References

Berthier K, Leippert F, Fumagalli L, Arlettaz R. 2012. Massive Nest-Box Supplementation Boosts Fecundity, Survival and Even Immigration without Altering Mating and Reproductive Behaviour in a Rapidly Recovered Bird Population. PLOS ONE. 7(4): e36028.

Clucas B, Marzluff J. 2012. Attitudes and Actions Toward Birds in Urban Areas: Human Cultural Differences Influence Bird Behavior. The Auk. 129(1):8-16.

Conner R, Adkisson C. 1977. Principal Component Analysis of Woodpecker Nesting Habitat. Wilson Bull. 89(1):122-29.

Duck LG, Fletcher JB. 1945. A survey of the game and furbearing animals of Oklahoma. Oklahoma Biological Survey [Online]. Available from: http://www.biosurvey.ou.edu/duckflt/dfpref.HTM. (Accessed September 11, 2016).

Exeter Software. 2015. Ecological Methodology version 7.2. Exeter Software. Setauket (NY).

Gilbert OL. 1989. *The Ecology of Urban Habitats*. New York (NY). Chapman and Hall.

Jackson AK, Froneberger JP, Cristol DA. 2013. Habitat near nest boxes correlated with fate of eastern bluebird fledglings in an urban landscape. Urban Ecosystems. 16(2):367-376.

Luck M, Wu J. 2002. A gradient analysis of urban landscape pattern: a case study from the Phoenix metropolitan region, Arizona, USA. Landscape Ecol. 17(4):327-339.

Oklahoma Department of Wildlife Conservation. Vegetation Classification Project: Interpretive Booklet [online]. Available from: https://www.wildlifedepartment.com/facts_maps/ecomap/Oklahoma_State-wide_Interpretive_Booklet.pdf. (Accessed September 12, 2016).

Pogue DW, Schnell GD. 1994. Habitat Characterization of Secondary Cavity-Nesting Birds in Oklahoma. Wilson Bull. 106(2):203-226.

Reale J, R Blair. 2005. Nesting Success and Life-History Attributes of Bird Communities Along an Urbanization Gradient. Urban Habitats. 3 (1):1-24.

Saarikivi J, Herczeg G. 2014. Do Hole-Nesting Passerine Birds Fare Well at Artificial Suburban Forest Edges?. Ann Zool Fenn. 51(6):488-494.

Sandström UG, Angelstam P, Mikusiński G. 2006. Ecological diversity of birds in relation to the structure of urban green space. Landscape Urban Plan. 77(1-2):39-53.

Stancampiano AJ, Schnell GD. 2004. Microhabitat Affinities of Small Mammals in Southwestern Oklahoma. J Mammal. 85(5):948-958.

Wiens JA. 1989. Spatial Scaling in Ecology. Funct Ecol. 3(4): 385-397.

Vickery PD, Hunter ML, Melvin SM. 1994. Effects of Habitat Area on the Distribution of Grassland Birds in Maine. Conserv Biol. 8(4):1087-1097.

Submitted September 15, 2016 Accepted November 21, 2016