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Relative importance of local and landscape variables on site occupancy by avian species in a pine forest, urban, and agriculture matrix

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ABSTRACT

In the Southeastern USA, planted pine forests are increasingly embedded in a matrix of urban and/or agricultural land. Most avian conservation management in these forests has primarily focused on local (stand) characteristics and less attention has been given to landscape characteristics. We investigated the relative influences of local and landscape variables on site occupancy of 17 avian species in pine forests in urban and agricultural matrices. During May–August 2010 and 2011, we conducted bird surveys and vegetation surveys in stands dominated by loblolly pine (*Pinus taeda*) in the Sandhills Ecoregion of Georgia, USA. We developed 8 single-season occupancy models. An autocovariate was also incorporated to account for spatial autocorrelation. We used three principal components summarizing environmental characteristics at each of three spatial extents (one local and two landscape scales, 500 m-radius circle and 1 km-radius circle surrounding a point) as covariates. Of 17 species, occupancy by 5 species was associated with local vegetation variables and by 8 species with variables at 500 m and/or 1 km landscape scale. Occupancy by forest interior species had a greater association with landscape variables, whereas occupancy by pine–grassland species was related to local variables. Urban development and agricultural land use positively influenced the occupancy of species associated with landscape variables. To improve overall avian diversity, our results suggest that forest management needs to consider both local vegetation characteristics and landscape characteristics, and that the potential habitat value of pine forests in the urban/agricultural matrix should not be ignored.

1. Introduction

In the Southeastern USA, forests are a dominant landscape component, estimated at 40% of total land area (Miller et al., 2009). In particular, loblolly pine (*Pinus taeda*) and shortleaf pine (*Pinus echinata*) forests are among the most prevalent, occupying 55 million acres or ~25% of southern forests (Smith et al., 2009). Most of these forests are plantations, covering ~20% of southern forests (Miller et al., 2009). Although those pine plantations are largely managed for commercial timber, with a growing interest and expectation of stakeholders in wildlife conservation there are increasing efforts to improve the conservation value of pine plantations.

For birds, the majority of pine forest management has been applied at the local level with an emphasis on increasing heterogeneous vegetation structures within a stand (e.g., Melchiors, 1991; Turner et al., 2002; Luck and Korodaj, 2008). While this local level management would improve habitat quality for some species, its effectiveness can be limited without the consideration of the landscape context. The extent of the use of individual space is known to vary greatly among avian species and movements of breeding individuals can occur across a variety of habitat patches (Whitaker and Warkentin, 2010). A suitable landscape matrix could compensate for resources that may be insufficient within a patch or facilitate movements of individuals among patches. Conversely, an unsuitable landscape matrix could impede movements or reduce the quality of the patch by increasing non-native species or predation risk. Thus, landscape characteristics can strongly influence avian species distribution and habitat selection.

Recently, several studies have noted the importance of landscape characteristics to avian species occurrence or richness in pine forests (Mitchell et al., 2001; Loehle et al., 2005; Mitchell et al., 2006). Like structural diversity at a stand level, spatial heterogeneity (e.g., heterogeneous age structure of pine patches) within a landscape is considered an important factor affecting avian richness (e.g., Turner et al., 2002; Mitchell et al., 2006; Luck and Korodaj, 2008). However, those studies were performed at sites

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or points embedded in a matrix dominated by natural and/or planted forests. The Southeast has experienced the highest rate of urbanization in the USA (Smith et al., 2009). In particular, low-density exurban development (or rural residential development) is more dominant than high-density urban development often seen in other regions (Brown et al., 2005). Moderate suburban development that can be considered between exurban and typical suburban also commonly occurs adjacent to cities as a result of urban sprawl. Rapid urbanization with this low or moderate development pattern has drastically changed the agriculture/forest dominant landscape matrix surrounding planted or natural pine forests in several areas in the Southeast, including east-central Georgia. Those pine forests are increasingly embedded in a matrix of both urban development and agricultural land, leading to increases in the complexity of the landscape matrix surrounding the pine forests. In this landscape, effects of landscape characteristics on avian species distributions may be substantial, given that a number of studies conducted in anthropogenic landscapes have found greater explanatory power of landscape variables on avian species compared to local variables (e.g., Donovan et al., 1997; Saab, 1999; Miller et al., 2003). However, little is known about species associations with local or landscape variables in pine forests in urban and/or agricultural matrices and how avian species in pine forests respond to urban development and agricultural land use.

Although a greater association of avian species with landscape variables is expected in anthropogenic landscapes, their association with local or landscape variables can vary depending on the organisms of interest, the community variables of question, or the ecosystems being studied (Graham and Blake, 2001; Hennings and Edge, 2003; Miller et al., 2004). For example, forest-restricted species have been found to be more responsive to local characteristics because they find their compliment of necessary resources within a patch and move less to find resources (Graham and Blake, 2001). Thus, identifying species' association with environmental characteristics at multiple spatial extents (e.g., local level and landscape level) and assessing their responses to the differing characteristics of each scale remain crucial for a successful management plan to enhance avian diversity in pine forests.

In this study, we investigated the relative importance of local and landscape variables on site occupancy of avian species in pine forests along an urban–rural/agriculture–wildland gradient (from moderate to very low level of human land use) in the Sandhills Ecoregion of Georgia, USA. We also explored species responses to those variables, particularly urban development and agricultural land use. To reduce bias and improve inference, we used two recently developed approaches: site occupancy models to account for imperfect detection (MacKenzie et al., 2002) and an autologistic regression model using a spatial autocovariate to account for spatial autocorrelation (Augustin et al., 1996; Klute et al., 2002; Moore and Swihart, 2005).

2. Methods

2.1. Study site

The study was conducted in pine forest remnants (stands or patches) in Fort Gordon and surrounding areas of Fort Gordon in 3 ecoregions (Sandhills, Coastal Plain Red Uplands, and Southern Outer Piedmont) of Georgia, which include 7 counties: Burke, Columbia, Glascock, Jefferson, McDuffie, Richmond, and Warren (Fig. 1). The study areas represent a gradient of urban–rural/agriculture lands: moderate to high urban development in the northeastern part of Richmond County and little development in Fort Gordon; low agricultural land uses and low to moderate urban development in Columbia and McDuffie Counties; and moderate to high agricultural land uses in other counties.

Agricultural land uses in our study areas are dominated by pasture and hay fields. Pine forests are composed mainly of planted loblolly pine. Slash pines (*Pinus elliottii*) or shortleaf pines are mixed with loblolly pines in some areas. Most mature longleaf pines (*Pinus palustris*, >20 years old) are found at Fort Gordon. The ages of pine patches vary across our study sites; however, old pine patches (>75 years) are relatively rare and most pine patches are young and mid-aged (20–75 years). Overstory and midstory of hardwood forest and mixed forest largely consist of sweetgum (*Liquidambar styraciflua*), sassafras (*Sassafras albidum*), black cherry (*Prunus serotina*), flowering dogwood (*Cornus florida*), and oak (*Quercus* spp.). Sparkleberry (*Vaccinium arboreum*) is also commonly found in the midstory. The understory is dominated by yellow jessamine (*Gelsemium sempervirens*), muscadine (*Muscadinia rotundifolia*), greenbrier (*Smilax* spp.), brambles (*Rubus* spp.), blueberry (*Vaccinium* spp.), broomsedge bluestem (*Andropogon virginicus*), low panicgrass (*Dicanthelium* spp.), wiregrass (*Aristida stricta*), and lespedeza (*Lespedeza* spp.).

2.2. Sample patches and points

We selected 20–75-year-old loblolly and longleaf pine patches for sampling, considering the levels of urban development/agricultural land uses and separation distance among patches to minimize spatial dependency. Minimum distance between sampled patches was >300 m at Fort Gordon and >1 km at outside of Fort Gordon. We used the 2009 forest inventory data of Fort Gordon, 2007 digital orthophoto images (National Agriculture Imagery Program, NAIP), 2006 National Land Cover Dataset (NLCD), and ArcGIS version 9.2 to select sample patches. We also used 1998 Digital Orthophoto Quarter Quads (DOQQs) to distinguish pine forest and hardwood forest. However, the number of sample patches within Fort Gordon and outside of Fort Gordon was limited by accessibility related to intensive military training and road condition and by landowner permission, respectively. Pine patches used in our study included stands unmanaged in the recent past (patches located in highly or moderately urbanized areas and some patches in agricultural lands), minimally or moderately managed stands (most patches), and relatively intensively managed stands (several patches in Fort Gordon).

Within a patch, we established one point randomly at least 50–70 m from any edge (road, other types of vegetation or land covers, etc.). We established 94 points in 2010, 4 of which were developed or harvested in 2011. We established an additional 92 points in 2011, but 4 points had prescribed burns after the 1st visit, and thus 178 points were completely surveyed in 2011. All points were >500 m apart from each other, except 2 points separated 450 m in 2010 and 14 points separated 300–500 m in 2011. All points within longleaf pine patches were located at Fort Gordon.

2.3. Bird sampling

We performed bird surveys three times from May through June each year during 2010–2011, using fixed-radius point counts (Ralph et al., 1993). At each point, an observer recorded species seen or heard within a 50 m radius of a sample point for a 10-min duration and also estimated the distance from the species detected to the sample point. One observer in 2010 and two observers in 2011 conducted surveys. In 2011, the observers were rotated between sites to reduce observer effects. We also alternated surveys in order to minimize the effect of time-of-day. Each survey was performed between dawn and 1100 EDT. We did not conduct surveys during periods of rain or high wind (>16 km/hr).