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Research article

The effect of urban growth on landscape-scale restoration for a fire-dependent songbird

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ABSTRACT

A landscape-scale perspective on restoration ecology has been advocated, but few studies have informed restoration with landscape metrics or addressed broad-scale threats. Threats such as urban growth may affect restoration effectiveness in a landscape context. Here, we studied longleaf pine savanna in the rapidly urbanizing southeastern United States where a habitat-specialist bird, Bachman's sparrow (*Peucaea aestivalis*), is closely associated with savanna vegetation structure and frequent fire. Our objectives were to construct a species distribution model for Bachman's sparrow, determine the relationship between fire and urbanization, quantify the urban growth effect (2010–2090), identify potential restoration areas, and determine the interaction between restoration potential and urban growth by 2050. Number of patches, patch size, and isolation metrics were used to evaluate scenarios. The species distribution model was 88% accurate and emphasized multiscale canopy cover characteristics, fire, and percent habitat. Fires were less common <600 m from urban areas, and this fire suppression effect exacerbated urban growth effects. For restoration scenarios, canopy cover reduction by 30% resulted in nearly double the amount of habitat compared to the prescribed fire scenario; canopy cover reduction resulted in larger patch sizes and less patch isolation compared to current conditions. The effect of urban growth on restoration scenarios was unequal. Seventy-four percent of restoration areas from the prescribed fire scenario overlapped with projected urban growth, whereas the canopy cover reduction scenario only overlapped by 9%. We emphasize the benefits of simultaneously considering the effects of urban growth and landscape-scale restoration potential to promote a landscape with greater patch sizes and less isolation.

1. Introduction

The worldwide trend towards urbanization is projected to lead to 2.5 billion more people living in urban areas by 2050 compared to today (United Nations, 2015). Fundamental consequences of urbanization on natural ecosystems include habitat loss and fragmentation (Chace and Walsh, 2006; Radeloff et al., 2005a) as well as the creation of pervasive wildland–urban interfaces (Radeloff et al., 2005b). Meanwhile, the return of a regular fire regime is a common objective of habitat restoration and ecosystem management, as fires are a major influence on the structure of ecosystems and their biodiversity, but are often suppressed in a variety of human-modified environments (Bond et al., 2005; Hobbs and Huenneke, 1992). Although landscape-scale conservation planning has become common, the threat of future urban growth has rarely been explicitly incorporated with conservation actions such as restoration or management. Of the ecosystems in the United States, the fire-dependent longleaf pine savanna is one of the most critically threatened, as ranked by extent of decline, current rarity, number of threatened or endangered species, and existing threats

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(Noss and Peters, 1995). Longleaf pine (*Pinus palustris*) once covered 37 million hectares, but recent estimates, excluding pine plantations, indicate that it covers only 2–3% of its original expanse (Frost, 2006; Oswalt et al., 2012). Extensive losses occurred beginning in the 1600s and fire suppression quickly became widespread (Frost, 1993). In contrast, pre-European settlement longleaf pine savanna burned at a low intensity every 1–5 years, which facilitated longleaf pine germination as well as maintained savanna structure and composition (Chapman, 1932; Christensen, 2000; Heyward, 1939; Platt et al., 1988). Today, losses of longleaf pine continue as a consequence of urbanization, fire suppression, and conversion to loblolly pine (*Pinus taeda*) plantations (Oswalt et al., 2012). As urban growth occurs, patches of savanna are often left as remnants in a landscape dominated by a matrix of urban and suburban homes (Heuberger and Putz, 2003) or other incompatible land uses. Similar to other fire-dependent ecosystems, fragmentation of pine savanna increases the difficulty in managing multiple small habitat patches with prescribed burning, especially at the wildland–urban interface (e.g., Scheller et al., 2008). For example, smoke management concerns and the perceived increased risk and liability often deter prescribed burning (Moorman et al., 2002). As such, burning near urban interfaces often requires greater time and effort per unit area because patches are often small and this can result in fewer hectares managed in limited burn seasons.

Although restoration has conventionally been assessed at the scale of patches, there has been broad recognition of the importance of a landscape ecology perspective (Leite et al., 2013; Meinke et al., 2009; Perring et al., 2015). This perspective is particularly important where landscapes continue to be altered by humans, such as the rapid urban growth of the southeastern United States (Terando et al., 2014). Landscape-level studies have shown the importance of projected urban growth on species' distributions (e.g., Dorning et al., 2015; Jongsomjit et al., 2013), but few studies have integrated threats with restoration potential (e.g., Meinke et al., 2009). A landscape perspective is especially important for longleaf pine savanna restoration because the range-wide goal is to increase from 1.4 to 3.2 million ha over the next 15 years (America's Longleaf, 2009), and this expansion may be affected by urban growth.

Restoration of longleaf pine savanna seeks to create an open canopy dominated by mature longleaf pines, a reduced mid-story, and lush and diverse herbaceous ground cover. The beneficial effects of frequent fires and tree canopy thinning are well known for longleaf pine specialist birds (Allen et al., 2006; Steen et al., 2013a), reptiles and amphibians (Litt et al., 2001; Steen et al., 2013b), and plant species richness (Kirkman et al., 2004; Veldman et al., 2014). In our study, Bachman's sparrow (*Peucaea aestivalis*) was used to elucidate potential conflicts among a fire-dependent ecosystem, a rapidly urbanizing environment, and cultural aspirations for restoration. Bachman's sparrow habitat closely parallels the characteristics of frequently burned, open canopy longleaf pine savanna. More specifically, Bachman's sparrow are associated with low tree density and canopy cover, an open understory, moderate/dense herbaceous groundcover, and a fire return interval of $\leq$3 years (Dunning and Watts, 1990; Tucker et al., 2004). In comparison to other species, these associations make the species particularly sensitive to habitat degradation in the absence of fire (Plentovich et al., 1998; Provencher et al., 2002). Bachman's sparrow are also influenced by broad-scale habitat (Taillie et al., 2015), and their lack of genetic differences suggest they are adapted to quickly colonize new areas (Cerame et al., 2014), such as restoration sites. Bachman's sparrow is classified as a species of greatest conservation need in North Carolina (NCWRC, 2015), and continentally, is a bird of high conservation concern due to its population size, distribution, threats, and population trend (North American Bird Conservation Initiative, 2016). Other endemic species of the ecosystem do not respond quickly to restoration (e.g., red-cockaded woodpeckers, *Picoides borealis*) or they respond to local conditions which are difficult to map (e.g., wetland plants, amphibians). Furthermore, Bachman's sparrow is a recognized indicator of the herbaceous understory of fire-maintained, open-canopy pine forest by a consortium of federal and state agencies (Pickens et al., in press). The species' habitat associations, colonization ability, and vulnerability to urbanization make the species ideal to investigate how landscape-scale restoration may interact with urban growth effects in future scenarios.

Our objectives were to: 1) develop a species distribution model for Bachman's sparrow, 2) determine the relationship between fire and urbanization, 3) quantify the effect of projected urban growth (2010–2090) on predicted Bachman's sparrow distribution, and 4) develop scenarios to identify potential restoration areas and determine the interaction between restoration potential and urban growth by 2050, including the quantification of how patch size and isolation are predicted to change.

2. Methods

2.1. Study area

The study extent included the historic range of longleaf pine in North Carolina, USA, as defined by Little's geographic range for longleaf pine; Little's ranges for tree species are compiled based on historic forest surveys, herbarium records, and expert knowledge (Climate Change Atlas: Landscape Change Research Group, 2014). Within the study area, America's Longleaf, a collaborative group of public agencies and private organizations, have identified Significant Geographic Areas as focal areas for longleaf pine savanna restoration and management (America's Longleaf, 2009) (Fig. 1). The region included distinct non-longleaf pine, wetland communities; therefore, we initially removed the following land cover

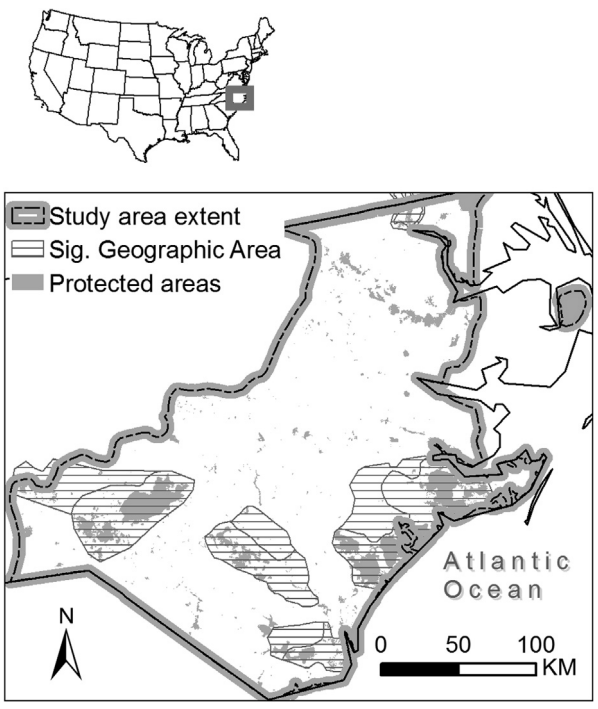

Fig. 1. The study area extent in North Carolina, USA. Significant Geographic Areas are designated as focus areas for longleaf savanna management and restoration.