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Multi-scale responses of breeding birds to experimental forest management in Indiana, USA

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ABSTRACT

Forest managers frequently must balance timber production and wildlife conservation goals when choosing management approaches. We studied the response of the breeding bird community to silvicultural treatments at multiple spatial scales over a 10-year period in 60–90 year old oak-hickory forests of Indiana, USA. We conducted point count surveys in a 3603-ha study area both before (n = 3 years) and after (n = 6 years) application of silvicultural treatments. Bird responses were analyzed at two spatial scales: management units and individual harvests. At the multi-stand management unit scale, treatments were even-aged management, uneven-aged management, and a no-harvest control. We also analyzed the responses of birds at the spatial scale of individual timber harvests (clearcuts, patch cuts, shelterwood harvests, and single-tree selection). Multi-species *N*-mixture models were used to estimate bird species density and richness at both spatial scales. At the management unit scale, 4 species increased in density following even-aged management (relative to the control), while 1 species (Red-eyed Vireo [*Vireo olivaceus*]) declined. A larger number of species responded both positively (n = 9) and negatively (n = 3) to uneven-aged management. Overall richness was significantly greater in the even- and uneven-aged treatments than in the control. At the harvest scale, only the clearcuts and patch cuts resulted in changes in the density of any species, but a larger number of species were impacted and effect sizes were generally larger in these harvests than at the management unit scale. In the clearcuts, 13 species increased in density relative to the no-harvest control, while 5 species declined. A larger number of species were impacted by patch cut harvests (18 species increasing and 6 decreasing). Overall richness was greatest in the clearcut harvests. At both scales, species that increased were generally those associated with early successional habitat, including the Eastern Towhee (*Pipilo erythrophthalmus*) and Indigo Bunting (*Passerina cyanea*), while species that declined were typically associated with mature forest habitat (e.g., Red-eyed Vireo [*Vireo olivaceus*] and Ovenbird [*Seiurus aurocapilla*]). Harvesting appeared to benefit several species of conservation concern in Indiana, including the Cerulean Warbler (*Setophaga cerulea*) and Black-and-white Warbler (*Mniotilta varia*). Both management treatments appear to be good options for simultaneously conserving bird species diversity (particularly of early-successional specialist species) while meeting other forest management goals. However, the impact of the next phases of the shelterwood harvests remains to be evaluated.

1. Introduction

Increasingly, forest management addresses issues of wildlife conservation in the context of lost or altered habitat (Carey and Curtis, 1996; Lindenmayer et al., 2000; Putz et al., 2001). In parts of the Midwestern United States, for example, forest cover declined >60% following European settlement as land was cleared for agriculture (Evans et al., 2010). In addition to changes in the overall quantity and configuration of forest habitat, forest composition and structure (e.g., seral stage) has been altered. For example, availability of early successional forest habitat in the eastern United States has declined considerably due to forest maturation and fire suppression over the past 7 decades (Trani et al., 2001). Loss of early successional habitat has occurred even as the overall amount of forest habitat available has begun to increase in many parts of the eastern U.S., including a 15% increase in Indiana from 1950 to 2008 (Carman, 2013).

Forest maturation has contributed to designation of several previously common bird species as threatened or of special concern (Backs and Castrale, 2010; DeGraaf and Yamasaki, 2003; Ruhl et al., 2015). Based on North American Breeding Bird Survey data,

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74% of eastern forest bird species that rely on shrubby/early successional habitat are declining (Sauer et al., 2013). Furthermore, 51% of breeding Neotropical migrant species in the Midwestern U.S. rely to some degree on young forest habitats during the breeding season and/or migration (Probst and Thompson, 1996; Rodewald and Brittingham, 2004). Thus, conservation of bird community diversity requires maintenance of a corresponding diversity in habitat structure (Freemark and Merriam, 1986; Vitz and Rodewald, 2006).

Timber harvesting (e.g., clearcutting) typically creates good habitat for shrubland-specialist bird species for 10–15 years (Conner and Adkisson, 1975; Thompson et al., 1992; Annand and Thompson, 1997; Keller et al., 2003; Perry and Thill, 2013). Group-selection harvests or patch cuts also provide habitat for at least a subset of these species (King et al., 2001; Morris et al., 2013). In many cases, mature-forest species may also benefit from harvest openings (Porneluzi et al., 2014; Vitz and Rodewald, 2006). Increased vegetation density in harvest openings results in more concentrated sources of arthropod prey for birds (Keller et al., 2003), and increased fruit availability provides a valuable energetic resource for birds during the post-breeding period prior to fall migration (Vitz and Rodewald, 2007). However, some mature-forest species like the Ovenbird (*Seiurus aurocapilla*) appear to respond negatively to the opening and edge habitat created post-harvest (King et al., 1996; Morris et al., 2013). Additionally, edge habitat created by harvest could promote nest predators, or parasites like the Brown-headed Cowbird (*Molothrus ater*) (Dijak and Thompson, 2000; Perry and Thill, 2013). Partial harvesting techniques (e.g., shelterwoods) may provide a middle ground, promoting a subset of early successional species while maintaining some overstory structure for mature forest birds (Annand and Thompson, 1997; King and DeGraaf, 2000).

To accurately estimate the response of the bird community to silviculture, studies should be relatively long-term, have adequate replication, randomly assign treatments, and include pre- and post-harvest data collection (Sallabanks et al., 2000). In addition, sampling designs should account for imperfect detection when estimating population parameters of interest (e.g., abundance or occupancy), as failure to do so could introduce bias in reported species responses to silviculture (Gu and Swihart, 2004; Kellner and Swihart, 2014). A few studies of bird responses to silviculture in eastern and Midwestern U.S. forests met some or all of these criteria including Morris et al. (2013) in the Missouri Ozarks and Perry and Thill (2013) in the Ouachita Mountains of Arkansas and Oklahoma. However, gaps in our understanding remain; for example, more information is needed at multiple spatial scales about long-term patterns of bird responses to forest management in more mesic eastern forests.

We collected 9 years of data over a 10 year period on bird community responses to replicated, experimentally applied forest management for oak regeneration in deciduous forests of south-central Indiana, USA (Kalb and Mycroft, 2013). We examined bird density for 41 species as well as community richness both before (3 years) and after (6 years) harvesting at two scales: (1) a management unit scale, encompassing multiple stands, to which a treatment (i.e., even-aged, uneven-aged, or no harvest) that included multiple harvest types was applied, and (2) a stand scale, to which an individual harvest (i.e., clearcut, shelterwood, patch cut, single-tree selection, or no harvest) was applied. We applied multi-species *N*-mixture models to account for imperfect detection and improve accuracy of inference (Royle, 2004).

We expected an overall positive response of shrubland and edge species to harvest at both the management unit and individual harvest spatial scales. These effects should be positively correlated with both the total area disturbed by harvest and by the intensity of disturbance (Morris et al., 2013). Thus, at the harvest scale, we expected the greatest changes in shrubland bird density to occur in clearcuts (part of the even-aged treatment), as the smaller openings created by uneven-aged management may be below the threshold required by some early successional species (Askins et al., 2007; Chandler et al., 2009; Shake et al., 2012). However, at the management unit scale, we expected larger changes following uneven-aged management, because a greater percentage of the overall treated area was disturbed than under the even-aged management treatment (see Methods).

In contrast, we predicted that the density of mature-forest birds would be negatively related to the size and intensity of disturbance. However, we expected the absolute magnitude of these responses to be relatively small, since the negative impacts of disturbance should be at least partially offset by mature forest birds using early successional habitat for food and cover during the post-fledging period (Porneluzi et al., 2014; Vitz and Rodewald, 2006). We also expected absolute effect sizes of harvesting at both spatial scales to be greater for early successional birds because prior to harvesting little suitable habitat existed for early successional species, whereas plentiful mature forest habitat remained post-harvest.

At the community level, we expected richness to be greater in managed units as a result of increased habitat heterogeneity (Freemark and Merriam, 1986). More specifically, we predicted that even-aged management would have the highest species richness of any management treatment because it included the most intensive disturbances (clearcuts) with matrix areas that were unharvested (Keller et al., 2003; Porneluzi et al., 2014). Some studies have reported greater richness in shelterwood harvested stands relative to unharvested stands (King and Degraaf, 2000; Newell and Rodewald, 2012). However, the HEE shelterwoods were only in the first phase of the shelterwood harvest (midstory removal). Thus, we predicted a minimal effect of shelterwood harvest at this initial stage for our study (Greenberg et al., 2014).

2. Methods

2.1. Study location

The study was located in the Brown County Hills region of southern Indiana, USA (Homoya et al., 1985) in Morgan-Monroe and Yellowwood State Forests and Brown County State Park (Fig. 1). Together, the state forests and state park comprise >19,000 ha of secondary deciduous forest (Kalb and Mycroft, 2013) that grew on abandoned farmland starting in the early- to mid-1900s (Carman, 2013). The forests are managed for multiple uses including timber production (primarily single-tree selection), recreation, and conservation (Carman, 2013). Topography in the region is characterized by xeric ridges and steep ravines with silt-loam soils (Jenkins and Parker, 1998). In the forest canopy, the dominant species are oaks (*Quercus* spp., especially *Q. alba*, *Q. velutina*, *Q. rubra*, and *Q. prinus*), hickories (*Carya* spp.), and tulip poplar (*Liriodendron tulipifera*), whereas the understory and midstory is primarily composed of shade-tolerants including American beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*) (Jenkins and Parker, 1998; Saunders and Arseneault, 2013). The forests are 60–90 years old with basal areas ranging from 21.7 to 29.9 m^2/ha, and total tree density from 923 to 1527 trees/ha (Saunders and Arseneault, 2013).

In 2006, the Hardwood Ecosystem Experiment (HEE) was established. The HEE was designed to be a long-term, large-scale study of the effects of management for oak regeneration on forest ecosystems (Kalb and Mycroft, 2013). At the beginning of the study, nine management units were designated in the two state forests. The units ranged in size from 303 to 483 ha and were each composed