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Combined long-term effects of variable tree regeneration and timber management on forest songbirds and timber production

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ABSTRACT

The structure of forest stands is an important determinant of habitat use by songbirds, including species of conservation concern. In this paper, we investigate the combined long-term impacts of variable tree regeneration and timber management on stand structure, songbird occupancy probabilities, and timber production in northern hardwood forests. We develop species-specific relationships between bird species occupancy and forest stand structure for canopy-dependent black-throated green warbler (*Dendroica virens*), eastern wood-pewee (*Contopus virens*), least flycatcher (*Empidonax minimus*) and rose-breasted grosbeak (*Pheucticus ludovicianus*) from field data collected in northern hardwood forests of Michigan's Upper Peninsula. We integrate these bird-forest structure relationships with a forest simulation model that couples a forest-gap tree regeneration submodel developed from our field data with the US Forest Service Forest Vegetation Simulator (Ontario variant). Our bird occupancy models are better than null models for all species, and indicate species-specific responses to management-related forest structure variables. When simulated over a century, higher overall tree regeneration densities and greater proportions of commercially high value, deer browse-preferred, canopy tree *Acer saccharum* (sugar maple) than low-value, browse-avoided subcanopy tree *Ostrya virginiana* (ironwood) ensure conditions allowing larger harvests of merchantable timber and had greater impacts on bird occupancy probability change. Compared to full regeneration, no regeneration over 100 years reduces merchantable timber volumes by up to 25% and drives differences in bird occupancy probability change of up to 30%. We also find that harvest prescriptions can be tailored to affect both timber removal volumes and bird occupancy probability simultaneously, but only when regeneration is adequate. When regeneration is poor (e.g., 25% or less of trees succeed in regenerating), timber harvest prescriptions have a greater relative influence on bird species occupancy probabilities than on the volume of merchantable timber harvested. However, regeneration density and composition, particularly the density of *Acer saccharum* regenerating, have the greatest long-term effects on canopy bird occupancy probability. Our results imply that forest and wildlife managers need to work together to ensure tree regeneration density and composition are adequate for both timber production and the maintenance of habitat for avian species over the long-term. Where tree regeneration is currently poor (e.g., due to deer herbivory), forest and wildlife managers should pay particularly close attention to the long-term impacts of timber harvest prescriptions on bird species.

1. Introduction

Variation in forest stand structure can have a strong influence on the use of these habitats by bird species across space and time (MacArthur and MacArthur, 1961; James, 1971; Cody, 1981; Robinson and Holmes, 1982; Urban and Smith, 1989). Silvicultural practices in managed forests are key determinants of forest stand structure, and consequently, of occupancy by birds, including species of conservation concern (Thompson et al., 1995; Matteson et al., 2009). Although the general pattern of different bird species occupying forest stands with different structural characteristics is well recognized (e.g., Sallabanks et al., 2000), the combined impacts of timber harvest practices and variations in tree regeneration success on bird habitat use over many decades (due to

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changes in stand structure) are less clear. We examine these potential long-term impacts here, specifically with regards to a widely used uneven-aged timber management approach.

In uneven-aged timber management, single to small groups of trees are harvested to create forest-canopy gaps in which juvenile, shade-tolerant trees are expected to regenerate. Uneven-aged timber management is so-called because, over many harvests and with adequate regeneration, it results in the creation and/or maintenance of uneven tree-age and tree-size distributions (Nyland, 1998). If this occurs, stand structure can be assumed to be in quasi-equilibrium as removed canopy trees are replaced by younger regeneration cohorts in perpetuity. However, target residual stand structures (basal area, diameter-distribution, etc.) vary by land owner/manager with unclear long-term effects on bird occupancy. Furthermore, adequate regeneration of the same or ecologically and morphologically similar species as those removed is likely critical to the assumption of invariant stand structure. Variable or poor gap-tree regeneration can influence forest stand structure in lower strata immediately and in upper strata over the long term (i.e., many decades), as trees grow into the upper canopy (Woods, 2000). Therefore, in contrast to the immediate and much greater changes in forest structure produced by more intensive practices such as clear-cutting, impacts of uneven-aged management and variable regeneration are more subtle and take longer to manifest themselves, particularly in the overstory.

Several studies have shown that poor regeneration, primarily due to herbivory by white-tailed deer (*Odocoileus virginianus*), can influence bird populations by modifying stand structure (e.g., deCalesta, 1994; McShea and Rappole, 2000; Allombert et al., 2005). These studies mainly focus on understory vegetation, and although many bird species are dependent on structural features in under- and mid-story strata for nesting and foraging, others are more dependent on overstory characteristics (e.g., Annand and Thompson, 1997; Collins, 1983; De Graaf et al., 1985, 1998; Germaine et al., 1997; Goodale et al., 2009). To understand how these overstory specialists are likely to respond to management activities, we also need to evaluate the long-term dynamics of managed forests, as immediate changes in canopy characteristics due to tree removal are followed by expansion of the canopies of trees that remain, and gradual recruitment of understory trees into the canopy.

Many empirical studies examining impacts of forest structure on bird habitat have focused on short-term responses (e.g., less than 10 years post-harvest, Sallabanks et al., 2000; Forsman et al., 2010) because of the costs and logistical challenges of longer-term studies (but see, e.g., Shifley and Kabrick, 2002; Wallendorf et al., 2007 for longer-term empirical studies). Given difficulties of collecting long-term data, computer simulation tools are the primary means to evaluate the long-term effects of changes in management practices and regeneration success (e.g., Marzluff et al., 2002; Larson et al., 2004; Goldstein et al., 2003; Klaus et al., 2005; Shifley et al., 2000, 2006, 2008). For those interested in effects on birds, simulations can provide insight into how changes in timber harvest targets or herbivory rates are likely to influence habitat suitability for species that select breeding territories based on canopy characteristics. Thus, as we pursue goals of ecologically and economically sustainable forest management (e.g., Marzluff et al., 2002), simulations play a key role by allowing long-term impacts on overstory-dependent bird species to be weighed along with other costs and benefits of different management actions.

Previous simulation modeling studies have represented the impacts of variation in regeneration on long-term stand composition and structure explicitly (e.g., Mladenoff and Stearns, 1993; Kobe, 1996). Others have examined different forest types and harvest strategies across decades and centuries with varying degrees of stand-structure representation, from no structure representation (e.g., Goldstein et al., 2003 modeled pine plantations as a function of stand age), through implicit representation (e.g., Shifley et al., 2006 represented stand species and size class – such as sapling and sawlog – for multiple forest types using the LANDIS model) to explicit representation (Marzluff et al., 2002, represented individual trees in conifer-hardwood stands using FVS). Of these, Marzluff et al. (2002) and Shifley et al. (2006) considered impacts on both birds and timber production.

Here, we investigate the combined long-term impacts of variable tree regeneration and uneven-aged timber management on stand structure, bird occupancy probabilities and timber production in northern hardwood forests. Northern hardwood forests in the Great Lakes region of the USA are an ideal ecosystem in which to evaluate these effects as they are managed nearly exclusively by selection silviculture, they provide habitat for many bird species of conservation concern (Matteson et al., 2009), harvest prescriptions vary among managers but often with variation driven by institutional factors rather than long-term expected outcomes (*pers. comm.* informal survey of regional forest managers), and large extents of these forests experience limited regeneration of desirable tree species due to high deer-browse pressure and other factors (Tilghman, 1989; Long et al., 2007; Powers and Nagel, 2009; Matonis et al., in press). In the northern hardwood forests of Michigan we study here, regeneration in areas with abundant deer is often characterized by low stem densities and/or domination by less browse-preferred and usually less commercially valuable tree species such as *Ostrya virginiana* (Mill.) (ironwood) and *Fagus grandifolia* (american beech), whereas areas with fewer deer are characterized by higher stem densities and/or domination by more browse-preferred species, especially commercially valuable *Acer saccharum* (sugar maple). In this paper, we investigate the impacts of different regeneration success rates (0–100% stocked), regeneration species compositions (sugar maple vs. ironwood) and timber harvest prescriptions (different residual stand structure criteria) on bird occupancy probabilities and harvested timber volumes over a century. To do so, we use field data to develop models to describe the relationships between bird occupancy probability and forest structure. We then use these relationships with the USFS Forest Vegetation Simulator and a forest-gap regeneration and growth model. The goal of our work is to improve understanding of the tradeoffs inherent to ensuring habitat for sensitive bird species and maintaining production of forest products.

2. Material and methods

2.1. Study area

Our data were collected in a 4,000 km^2 forested region of the Upper Peninsula of Michigan, USA (see Millington et al., 2010; Matonis et al., 2011). This region is dominated by upland northern hardwood, lowland conifer, aspen and mixed upland forest types juxtaposed in a mosaic across the rolling topography of the Menominee drumlin field. Predominant tree species in these forest cover types are sugar maple in upland northern hardwood stands, *Thuja occidentalis* (northern white-cedar) in lowland coniferous forest stands, and *Populus tremuloides* (trembling aspen) in aspen stands. These forest types provide habitat for numerous wildlife species including white-tailed deer and a diverse assemblage of songbirds (Laurent, 2005; Matteson et al., 2009).

Forest management for timber products is the primary land use in this region, and uneven-aged selection silviculture (both group and single-tree selection) dominates management of the region's northern hardwood stands. Consequently, harvesting and variation in harvesting (e.g., variation in intensity and frequency) are the predominant disturbance-based influences on northern hardwood