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Avian community composition associated with interactions between local and landscape habitat attributes

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ABSTRACT

As human demand for ecosystem products increases, managers of landscapes used for commodity production require information about effects of management regimes on biological diversity. Landscape attributes, however, may moderate ecological responses to local-scale conservation and management actions. As a result, uniform application of local management prescriptions may yield variable biodiversity responses. We examined how interactions between local habitat structure and landscape forest cover were associated with avian community composition in the Ouachita Mountains, Arkansas, USA, 1995–1998. We used Bayesian hierarchical models to estimate occupancy for 63 breeding bird species, while accounting for variable detection with data collected from 1941 temporally replicated point count stations. Specifically, we estimated how interactions of four local habitat covariates (canopy cover of mature coniferous and hardwood trees, number of snags, and shrub cover) with percentage of mature hardwood forest at the landscape scale were associated with species occupancy and richness. Average predictive comparisons indicated that snag count and shrub cover had the strongest associations with species richness. Estimated associations for each of the four local forest cover variables was similar across all levels of landscape forest cover, suggesting weak or negligible interactions between these local measures and the landscape covariate. We found little support for our main prediction that local/landscape habitat interactions would be strongest at low levels of landscape forest cover (1–20%). Consequently, we suggest that forest managers consider prescriptions that result in a broad spatial distribution of heterogeneous habitat structural conditions (e.g., variation in understory cover and composition), irrespective of landscape context, to maintain a diverse avian breeding assemblage on landscapes in this region.

1. Introduction

Information on responses of floral and faunal communities to landscape attributes can inform decisions about management of terrestrial ecosystems. Forest landscapes are often managed for multiple objectives such as retaining populations and communities of native organisms, maintaining ecosystem services, and commodity production (Beschta et al., 2004; Perrings et al., 2010). However, management at smaller scales (e.g., patches or stands) over time produces variation in habitat configuration and composition across moderately or heavily modified landscapes (Tittler et al., 2012; Linden and Roloff, 2013). Quantifying cumulative effects of specific management practices on ecological responses is of critical importance, as even modest changes to current practices can provide substantial ecological benefits (Bunnell et al., 1999; Kroll et al., 2012a; Linden et al., 2012; Giovanini et al., 2013).

Landscape structure may moderate ecological responses to local-scale conservation and management actions (e.g., conservation field margins, set-asides, structural retention), and a recent review identified this mechanism (the "intermediate landscape-complexity hypothesis") as one of eight alternative hypotheses to explain how landscape effects influence biological diversity (Tscharntke et al., 2012). Specifically, in landscapes retaining moderate amounts of native vegetation cover (e.g., the dominant historical cover type), local management should yield the largest positive ecological response at the local scale. Conversely, response to local management will be minimal at the local scale in

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landscapes retaining either negligible (management intensity is highest) or high (management intensity is lowest) proportions of native cover types (Fig. 1A). Thus, a local-scale management action (solid line in Fig. 1A) is predicted to yield a larger ecological response than no management (dashed line in Fig. 1A), but local responses should be largest when 1–20% of the landscape (Tscharntke et al., 2005) is composed of a native cover type.

General linear models can be used to evaluate these predictions (Fig. 1B). Ecological response is predicted to be lowest in cleared (retaining <1% of native cover types) landscapes (bottom line) and will change only slightly (the slope will not differ significantly from 0) regardless of local management enhancements (i.e., increasing the covariate value along the *x*-axis). The same is true for complex (retaining >20% cover of native cover types) landscapes (dashed line, Fig. 1B), although the ecological response is always higher (i.e., the terms have different y-intercepts in the model, but the interaction with local management is not significant). However, in simple (1–20% cover of native cover types) landscapes, local management enhancements have a substantial effect on the local response (the interaction between landscape composition and local management terms will be significant).

To evaluate predictions from the intermediate landscape complexity hypothesis, we examined relationships between avian species and community responses and indicators of forest management intensity in Arkansas, USA. Intensive forestry practices typically include clearcutting of existing stands, chemical and/or mechanical site preparation, rapid regeneration of single-species stands, fertilization, and chemical or mechanical control of competing vegetation (Hayes et al., 2005; Brockerhoff et al., 2008). At the local scale, intensive management can modify structural conditions of forests, resulting in single-species plantations, reductions in snag abundance or understory vegetation cover, altered canopy cover, and shortened successional stages (Thompson et al., 1995; Bunnell et al., 1999; Carnus et al., 2006; Linden and Roloff, 2013). As a result, species that rely on structurally complex habitat types and/or longer disturbance intervals may be reduced in distribution and abundance because of reductions in habitat quality and availability (Chambers et al., 1999; Lindh and Muir, 2004; Ellis and Betts, 2011).

Avian species respond strongly to habitat structure and are reasonable candidate taxa to evaluate the intermediate landscape-complexity hypothesis (Hansen et al., 1995; Kroll and Haufler, 2010). We examined how differences in avian species-level occupancy and community richness at sample points (i.e., the "local" scale) varied based on interactions between four local habitat covariates (canopy cover of mature coniferous and hardwood trees, number of snags, and shrub cover, all of which are modified by forest management) and amount of mature hardwood-dominant forest in the landscape (Hunter et al., 1993; Fitzgerald and Pashley, 2000). Oak (*Quercus* spp.) and pine (*Pinus* spp.) dominated pre-settlement forest composition in our study area (Fitzgerald and Pashley, 2000). As a result, we expected amount of mature hardwood-dominant forest in the landscape to decline as pine management intensity increased. We summarized responses of cavity-nesting (CN) species and species of conservation concern (PIF; as defined by Partners-in-Flight in Fitzgerald and Pashley (2000)) separately, given sensitivity of some of these species to increases in forest management intensity (Martin, 1992; Fitzgerald and Pashley, 2000).

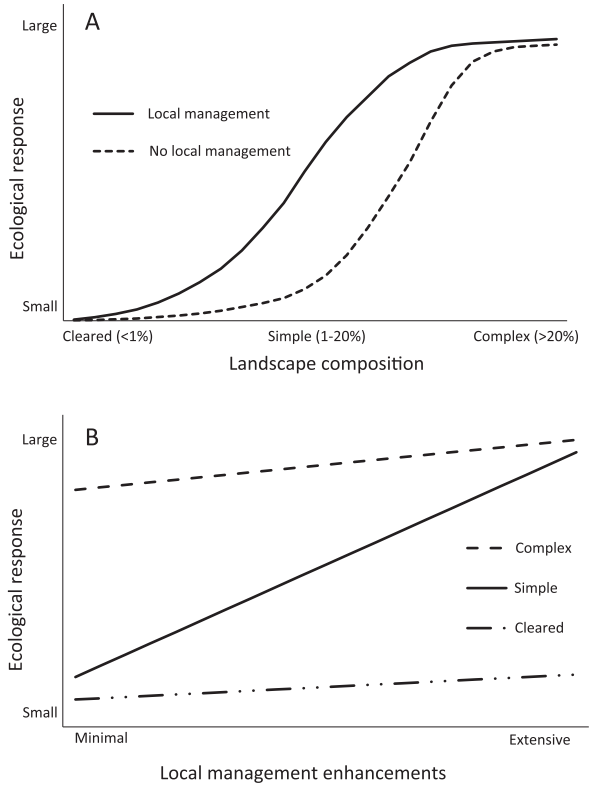

Fig. 1. Hypothetical relationship between an ecological response and local habitat management for three categories (based on percent cover) of landscape composition (A; based on Fig. 6 in Tscharntke et al. (2012)). Predicted relationships from a general linear model for the association of an ecological response with the interaction of local habitat management and landscape composition (B).

2. Methods

2.1. Study area and management prescriptions

We sampled forested plots in four watersheds in the Ouachita Mountains in Garland and Saline Counties, Arkansas, USA. The Ouachita Mountains consisted of east–west oriented ridges and mountains with elevations ranging from 100 to 900 m. Climate was characterized by hot, humid summers and mild winters (Skiles, 1981). The primary forest type throughout the area was mixed pine-hardwood forest with stands of pure hardwood also present. Most pine-dominated forest included some component of hardwoods. This hardwood component was diverse (>32 species) and included oaks (*Quercus* spp.), hickories (*Carya* spp.), maple (*Acer rubra*), and sweetgum (*Liquidambar styraciflua*). Watersheds ranged in size from 1500 to 4000 ha, and were owned and managed by the United States Department of Agriculture Forest Service (USFS) and Weyerhaeuser Company. Forest management prescriptions on Weyerhaeuser lands included clearcutting and planting of loblolly pine (*Pinus taeda*) plantations, whereas various even- and uneven-aged prescriptions were applied to USFS lands. Mature (>50 years old) forest stands with no active management other than fire suppression were a dominant component in three of the watersheds. The four watersheds contained a range of forest cover types and structural conditions (Tappe et al., 2004). Little Glazypeau (LG; 2275 ha) was owned by Weyerhaeuser Company and was managed largely for saw-log production using intensive, short-rotation (~35 years) pine management; Bread Creek watershed (BC; 1535 ha) was managed primarily by USFS using a mix of regeneration treatments, including group selection and single-tree selection; North Alum Creek watershed (NAC; 3960 ha) was of mixed ownership, with about half of the area under Weyerhaeuser Company management and half under USFS management; and South Alum Creek watershed (SAC; 1500 ha) was owned almost entirely by USFS and received minimal management for