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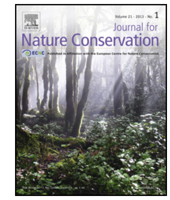

Habitat availability for multiple avian species under modeled alternative conservation scenarios in the Two Hearted River watershed in Michigan, USA

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ABSTRACT

Due to differences in the responses of species to changing landscape patterns, developing a conservation plan with an optimal outcome of supporting contrasting habitat needs can be difficult. Landscape scenario modeling can provide a means to compare alternative conservation strategies and can reveal tradeoffs of managing for one objective versus another. In order to evaluate the impacts of alternative conservation strategies in a 53,653 ha landscape in Michigan's Upper Peninsula, four scenarios of alternative conservation strategies were modeled 100 years into the future using the VDDT®/TELSA® spatial model suite, and habitat availability was evaluated for five target bird species of local conservation concern under each scenario. The target species were *Dendroica fusca* (Blackburnian Warbler), *Picoides arcticus* (Black-backed Woodpecker), *Dendroica kirtlandii* (Kirtland's Warbler), *Buteo lineatus* (Red-shouldered Hawk), and *Scolopax minor* (American Woodcock). Scenarios were ranked based on relative performance of three habitat metric results (total primary habitat area, average size of habitat patches, and average distance to the nearest neighboring habitat patch) for each species. The final overall rank for each scenario was generally related to harvest intensity; the scenario with the smallest total area of even-aged management ranked the highest. Ranks were not consistent across all response variables. Relative species sensitivity was also evaluated, and the ranks did not match expectations, with the more habitat generalist species showing the highest sensitivity and the most specialist species showing the lowest. The approach here provides a means of projecting and comparing potential long-term impacts of alternative landscape strategies on diverse wildlife habitats. These results, when considered with budget considerations and species' habitat area and population goals, can assist local managers and stakeholders in conservation planning by identifying tradeoffs and compromises aimed at optimizing protection for a variety of target species.

Introduction

As conservation strategies increasingly span large geographic areas and often involve multiple land owners, it is important to understand and anticipate impacts of various management strategies over broad spatial and temporal scales in order to achieve resource and conservation goals (Jin et al. 2010; Price et al. 2012; Shifley et al. 2008; Zollner et al. 2008). For example, the unit area, intensity, and return interval of forest management activities affect the availability of habitat for wildlife species by influencing stand composition and landscape pattern (Jin et al. 2010; Scolozzi & Geneletti 2011; Shifley et al. 2006; Zollner et al. 2008). The ability to project, visualize, and assess the impacts of alternative scenarios of management activities and natural disturbances could benefit the understanding of how long-term forest management strategies affect biodiversity and could aid in conservation planning.

Loss and fragmentation of habitat are two of the greatest threats to biodiversity in forest landscapes (Ohman et al. 2011), and the importance of fragmentation, edge effects, and corridors for species survival and reproductive success have been widely discussed in scientific literature (Knowlton & Graham 2010; Venier et al. 2007). In conservation and metapopulation theories, it is generally accepted that larger and more connected patches can support greater species richness as well as population abundance and

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persistence than smaller, isolated ones (Prugh et al. 2008). Larger patch sizes may reduce a population's probability of extinction by supporting larger population sizes, enabling greater colonization rates, and reducing edge effects and predator invasions (Etienne et al. 2004; Shanahan et al. 2011). Greater patch connectivity may enhance dispersal success, colonization, and population interchange, especially for rare and specialist species in degraded or fragmented landscapes (Davies et al. 2000; Knowlton & Graham 2010; Shanahan et al. 2011). Consequently, conservation plans should consider not only the amount and quality but also the spatial configuration of suitable habitat in the landscape, including properties such as patch size, shape, and connectivity (Larson et al. 2004; Rittenhouse et al. 2007; Shifley et al. 2006; Venier et al. 2007).

Due to the differences in species' responses to landscape patterns, planning an optimal strategy in the face of contrasting habitat needs can be difficult (Gottschalk et al. 2010; Monkkonen et al. 2011; Watts et al. 2010; Zollner et al. 2008). This difficulty explains the tendency of researchers to perform single-species habitat or population assessments or use landscape pattern metrics as proxies for multiple species representation (Edenius & Mikusinski 2006; Nicholson & Possingham 2006; Venema et al. 2005). A suite of species which are sensitive to differing threats can represent the diversity of spatial, compositional, and functional attributes that are of conservation concern in a landscape (Edenius & Mikusinski 2006; Mace et al. 2007; Scolozzi & Geneletti 2011). Landscape modeling may reveal which species among a suite of species, in terms of habitat availability, might be more sensitive to alternative management strategies or landscape changes and therefore may require special or urgent consideration in management planning.

Considering the vast amount of time and resources needed for long term monitoring at broad spatial and temporal scales, landscape simulation models and GIS technologies offer a convenient method of evaluating potential effects of long-term management strategies in landscapes and enable a more timely flow of information to inform management decision making (Ferrier & Drielsma 2010; Jin et al. 2010; Shifley et al. 2006, 2008; Zollner et al. 2008). In recent years, several spatially explicit landscape modeling programs have been developed, used in forest planning, and reviewed (Barrett 2001; Jin et al. 2010; Larson et al. 2004; Mladenoff 2004; Scheller & Mladenoff 2007; Shifley et al. 2008). These models have the ability to simulate forest successional dynamics over long time periods and project future conditions of the landscape. When local knowledge from various stakeholders is incorporated into the modeling through a collaborative process, more plausible outcomes may be realized (Price et al. 2012).

The ability to model alternative scenarios and analyze future landscapes provides a means of assessing potential changes in habitat availability and comparing the potential effectiveness of conservation strategies. Such comparisons could benefit managers who are interested in the impacts of their decisions, provide insight into how and where habitat management could be improved, and allow more adaptive planning.

Our partners at The Nature Conservancy (TNC) were particularly interested in comparing the long-term conservation effectiveness of working forest conservation easements and fee simple ownership of land in the Two Hearted River watershed, a 53,653 ha forested landscape in Michigan's Upper Peninsula. The purpose of working forest conservation easements is to keep land productive while preventing subdivision and fragmentation of land, thus being beneficial for habitat conservation. Since property is not fully purchased, easements are a less costly strategy up front than fee simple acquisition, potentially allowing conservation efforts and resources to be more broadly distributed across a landscape (Silbernagel et al. 2011). They provide tax relief to the land owners and generally allow resource extraction (e.g. sustainable timber harvesting), thus contributing to the local economy. However, they require long-term monitoring and enforcement and may carry added transaction costs of working with multiple landowners and unique ecological conditions (Fishburn et al. 2009; Merenlender et al. 2004). It is not known whether easements can provide the same level of biodiversity protection as acquiring land under fee simple ownership (Fishburn et al. 2009; Merenlender et al. 2004), which may also require continuous human and financial resources to manage the land into the future. Without long-term ecological monitoring, the effectiveness of these strategies, or any conservation strategies that attempt to balance resource extraction with conservation, remains unclear, and there is little evidence that can inform future acquisitions and help gain public and financial support in favor of certain strategies (Rissman et al. 2007; Silbernagel et al. 2011).

To evaluate the potential long-term impacts of four alternative conservation scenarios on habitat availability for five diverse bird species of concern in the Two Hearted River watershed, we performed habitat assessments on the spatial output of 100-year forest landscape models. The scenarios represented current-day management as well as three alternative hypothetical management strategies across the landscape, each informed by the management goals and practices of major forest landowners in the area (Fig. 1). The four scenarios were: A) current management scenario (Current scenario), B) no conservation action (NCA) scenario, C) working forest conservation easement scenario (Easement scenario), and D) ecological forestry scenario (Ecological scenario). Each scenario simulated different amounts, intensities, and general spatial characteristics of forest harvest activities. The Ecological scenario contained the greatest area of TNC managed land, and we expected this scenario to be the most beneficial for target species because of its emphasis on restoration and conservation of native and old-growth habitat, cooperative and broad-scale nature of management, and low amount of even-aged timber harvest. The NCA scenario, on the other hand, contained the largest area of industrially managed private lands, and we expected it to be the least beneficial for target species due to its nature of having a high amount of productivity-driven even-aged harvest, as well as a great number of land owners acting independently in the landscape, resulting in spatially fragmented management. In the Easement scenario, current-day TNC fee title lands were instead placed under a working forest conservation easement, which allows even-aged harvest but restricts subdivision of land and thus provides a spatially aggregated management outlook. We expected this scenario to be more beneficial than the NCA scenario, but not as beneficial as the Ecological or Current scenarios.

In an attempt to identify an optimal scenario, we developed a scoring system to rank scenario outcomes based on three metrics of habitat availability: 1) total area of habitat, 2) average size of habitat patches, and 3) average distance to nearest neighboring habitat patches for each target species. We hypothesized that 1) all of the habitat metric response variables would be significantly influenced by scenarios representing alternative management strategies over 100 years; 2) scenarios with smaller total area of even-aged timber harvest would provide the most beneficial habitat conditions for species overall; and 3) species that have more specific habitat requirements such as a limited number of preferred cover types, a large patch size requirement, or require proximity to additional necessary habitat elements would be the most sensitive to alternative scenarios.

Methods

Study Area and Scenario Modeling

The "Forest Scenarios" project team, based at the University of Wisconsin at Madison, has built a set of spatial landscape