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Bird communities of reference and altered mixed-pine forests: Implications for restoring fire-dependent forest ecosystems

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ABSTRACT

Changes have occurred to disturbance regimes that drive composition, structure, and function in many forest ecosystems. In the northern Lake States, USA land use change has impacted fire-dependent mixed-pine forests of red pine (*Pinus resinosa* Ait.) and eastern white pine (*P. strobus* L.). Although restoration is now being conducted on many federal and state forestlands, we currently lack baseline data on wildlife communities. To address the need for such information we sampled 25 reference and 29 altered mixed-pine sites in a wetland-upland landscape mosaic representative of eastern Upper Michigan. We put forward three questions: (1) do bird communities differ between reference sites and altered sites?; (2) what forest compositional and structural attributes are associated with differences in bird communities and how might they be related to fire history?; and (3) how does heterogeneity of natural land cover affect bird communities? Analyses revealed that richness of forest bird species was greater in reference sites ($T = -1.93$, $P = 0.06$), even though reference sites exist within 20-ha patches with less forest and more wetlands compared to altered sites. Bird assemblages also differed between reference and altered sites (Multiple Permutation Procedure, $T = -5.26$, $A = 0.02$, $P \leqslant 0.001$). Eight indicator species were associated with reference sites, and four species were found in altered sites. Although correlations among environmental variables were generally low, they suggested the important role fire played in this ecosystem. Our findings support the hypothesis that mixed-pine ecosystem restoration can be an important management tool in restoring bird communities.

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1. Introduction

Vegetation structure is a major driving force in the use of forest ecosystems by different bird species (MacArthur and MacArthur, 1961). Forest structure and composition are largely driven by landforms, edaphic facets, site quality, availability of seed sources and other propogules, competition, and past disturbances such as fire (Pregitzer et al., 2000; Frelich, 1995). Spatial attributes that characterize the heterogeneity of forests also affect bird communities (Boulinier et al., 1998), with terms such as area sensitivity being coined to describe the influence of patch characteristics on bird species occupancy (Robbins et al., 1989).

Across much of North America and elsewhere, alterations have occurred to natural disturbance regimes that drive forest structure and composition (Nowacki and Abrams, 2008; Schulte et al., 2007). In the northern Lake States, USA for instance, changes to fire regimes have reduced the dominance of mixed-pine forests of red pine (*Pinus resinosa* Ait.) and eastern white pine (*P. strobus* L.) that during pre-EuroAmerican times occupied nearly three million ha (Leahy and Pregitzer, 2003; Stearns and Likens, 2002; Frelich, 1995). In eastern Upper Michigan, extensive wildfires outside the natural range of variability and subsequent fire suppression and forest management have promoted jack pine (*P. banksiana* Lamb.) on many former red pine-dominated sites (Corace et al., 2013; Drobyshev et al., 2008a). These changes in structure and composition have produced ladder fuels that increase the risk of high-severity crown fires in a landscape comprised of ecosystems that

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were historically maintained by low or mixed-severity fires (Drobyshev et al., 2008b). Elsewhere in the northern Lake States, aspen (*Populus* spp.), maple (*Acer* spp.), other deciduous species, and monotypic plantations are now more common on sites that were historically mixed-pine (Fraver and Palik, 2012; Bender et al., 1997).

Like many federal and state agencies, the U.S. Fish and Wildlife Service's National Wildlife Refuge System has policies that foster the restoration of historical conditions (Meretsky et al., 2006). Management is promoting the regeneration of red pine and eastern white pine while reducing the dominance of jack pine (Nyamai, 2013; Corace et al., 2009). These actions are in lock-step with the related fire management concerns that current conditions are more likely to burn in a manner more difficult to manage safely. Consequently, many National Forests in the northern Lakes States are conducting similar treatments (B. Palik, *pers. comm.*). However, mixed-pine restoration is occurring with little knowledge of associated wildlife communities found in reference forests (sites) that provide targets for management actions [in this context, we define reference forests as those that have never been logged (i.e., are virgin), are comprised of native flora, and are maintained by a relatively intact natural disturbance regime, see below]. Theory suggests that reference mixed-pine forests should provide structural conditions which a unique wildlife community, not represented in more altered forests, would favor (Block et al., 2001). However, no tests to validate this assumption have been made even though past work has indicated that mechanical treatments to enhance structure of red pine forests yields different bird communities after three years (Atwell et al., 2008).

While evaluating bird communities of reference and altered mixed-pine sites, we examine potential drivers of bird communities across different forest conditions in a wetland-forest landscape mosaic. We hypothesize that observed differences in forest structure and fire history correspond to different bird communities, but that bird communities are constrained by the spatial attributes of these forest patches and their surrounding land covers.

Specifically, we address the following questions:

1. Do bird communities differ between reference sites and altered mixed-pine sites?
2. What compositional and structural attributes are associated with observed differences in bird communities and how might they be related to fire history?
3. How does heterogeneity of natural land cover affect bird communities?

2. Study area

This study was conducted at the 38,542-ha Seney National Wildlife Refuge (NWR) (N46.271594° W86.057078°), Schoolcraft County, Michigan, USA. Seney NWR lies within the Seney Sand Lake Plain ecoregion (Albert, 1995), itself characterized by having 85% area in public lands (Corace et al., 2012), a low human populations density (~6 people/km), and lacustrine landforms with broad, poorly drained embayments containing beach ridges, swales, dunes, and sandbars. The climate is influenced by its close proximity to both Lakes Superior and Michigan. Average annual precipitation is approximately 81 cm and average annual snowfall is approximately 312 cm. According to the system of Burger and Kotar (2003), 58% of the upland soil types at Seney NWR can support forests of mixed-pine growing with blueberry (*Vaccinium* spp.), sedges (*Carex* spp.), and bracken fern (*Pteridium aquilinum* L.).

The fire history of Seney NWR was reconstructed by Drobyshev et al. (2008b). During drought conditions over the last 300+ years, the mosaic of upland and wetland (peatland) fuels became linked and fire burned across the landscape relatively unchecked, with at least one landscape-scale fire approximately every 60 years. The estimated fire cycle (148 years) in the Seney Wilderness Area of Seney NWR was found to be consistent over the pre-European settlement time period (1707–1860). This observation suggests that currently this part of Seney NWR (in which is contained most of our reference sites) has a fire cycle very close to the long-term average documented before extensive timber harvesting commenced in eastern Upper Michigan. Therefore, this area represents a valuable baseline for other studies of natural mixed-pine forests and a benchmark for restoration efforts. Moreover, because our red pine-dominated reference sites are similar in overstory structure and composition with references sites in Minnesota (Fraver and Palik, 2012) we consider the range of structure and composition that we have documented in past studies (Corace et al., 2013; Drobyshev et al., 2008a,b) to fall within the natural range of variability found in benchmark red pine-dominated ecosystems of the northern Lake States.

Past studies have documented the red pine dominance of our reference sites and the shift in dominance to jack pine on altered sites (Corace et al., 2013; Drobyshev et al., 2008a). Unlike reference sites that have no history of logging, are dominated by a cohort of individuals up to 350 years old, and have a relatively intact fire regime, altered sites have all been logged (often repeatedly, Rist, 2008) and have altered fire regimes due to the proximity of anthropogenic impoundments and active fire suppression (Drobyshev et al., 2008b). Explanations why some sites are reference and some sites are altered rests largely with land use since EuroAmerican settlement (~1860), and especially since refuge establishment (1935). The wetter area of this landscape thwarted attempts to log at the turn of the 20th century as logging with horses and oxen across a wetland was not possible. When Seney NWR was established in 1935 a system of dikes, ditches, and impoundments (pools) were built by supplementing and altering previous (turn-of-the-century) ditching efforts for agricultural purposes. Efforts to create pools for waterfowl started in the eastern portion of the landscape and preceded west until funding ceased in the 1950s. The result was a landscape that was half altered by impoundments, gated gravel roads, and dikes to the east and a landscape that was half untouched by these actions (or other actions) to the west, hence Wilderness Area status starting in 1970 (Losey, 2003; Fig. 1). This resulting pattern of half altered and half reference resulted in different fire patterns due to impounded water, other anthropogenic developments, and active fire suppression on the non-Wilderness portions of the landscape.

3. Materials and methods

3.1. Bird surveys

We conducted unlimited-radius bird point counts within 54 plots also used to quantify forest composition and structure in this and past studies (Corace et al., 2013; Drobyshev et al., 2008a,b): 25 plots represented reference sites and 29 represented altered sites (Fig. 1). All sites were pine-dominated and naturally regenerated. Vegetation plots were randomly located within sites that were selected based on past management history (Rist, 2008). Counts were conducted from each plot center, with all plots being > 250 m from the center of any other plot so as to reduce the likelihood of counting the same bird twice while using unlimited-radius count methods (Ralph et al., 1993). Two point counts for each plot occurred between 6 June and 13 July 2009, a period coinciding with most bird breeding activity in Upper Michigan (Brewer et al., 1991). We observed a minimum interval of two weeks between visits and initiated counts no earlier than 15 min before sunrise (roughly 0545–0600 h), concluding them no later than 1100 h. The second