Forest Ecology and Management 402 (2017) 272–284

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Decade-long bird community response to the spatial pattern of variable retention harvesting in red pine (*Pinus resinosa*) forests

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ARTICLE INFO

Keywords:
Avian
Biodiversity
Complexity
Ecological forestry
Forest management
Minnesota

ABSTRACT

Structural complexity is widely recognized as an inherent characteristic of unmanaged forests critical to their function and resilience, but often reduced in their managed counterparts. Variable retention harvesting (VRH) has been proposed as a way to restore or enhance structural complexity in managed forests, and thereby sustain attendant biodiversity and ecosystem function. Here we examined the decade-long response of diurnal breeding birds to a VRH experiment that, for the first time, incorporated both overstory and shrub layer treatments in red pine (*Pinus resinosa*) dominated forests in Minnesota, USA. Overstory treatments included dispersed retention, aggregated retention achieved by cutting small (0.1 ha) gaps, aggregated retention achieved by cutting large (0.3 ha) gaps, and an uncut control. A shrub layer treatment of ambient or reduced shrub density was also implemented as a split-plot design in each harvest treatment. We found a consistent increase in bird species richness and abundance with all retention harvest treatments over time compared to the control; species richness was also significantly greater in the large gap-aggregated treatment compared to dispersed and small gap-aggregated retention harvests. Among guilds, foliage-gleaning and shrub- and tree-nesting birds exhibited the strongest positive response to retention harvesting. Species associated with early-successional habitat, forest edges, and shrubs responded most positively to VRH including Chestnut-sided Warbler (*Setophaga pensylvanica*) and American Restart (*S. ruticilla*), although late-successional species such as Blackburnian Warbler (*S. fusca*) and Black-throated Green Warbler (*S. virens*) also showed positive response. We found few differences due to shrub reduction, and only at the species level: Ovenbird (*Seiurus aurocapilla*) and American Redstart were more abundant in the ambient shrub treatment, whereas Brown Creeper (*Certhia americana*), Veery (*Catharus fuscenscens*), and Chipping Sparrow (*Spizella passerina*) were more abundant with a reduced density of shrubs. Results through the first 10 years following harvest revealed differences in bird response to both VRH and shrub treatment, suggesting that management can result in forested landscapes with bird communities that are species rich, diverse, and abundant.

1. Introduction

Structural complexity—the amount, condition, size distribution, and arrangement of different structural attributes—is critical for sustaining forest ecosystem function and resilience, but is often greatly simplified in managed forests when compared to their unmanaged counterparts (Franklin et al., 1997; Puettmann et al., 2009). For example, forests of the northern Great Lakes region of North America today are widely recognized as much simpler in structure than their pre-Euro-American counterparts due to the loss of conifers, large trees, and spatial heterogeneity (Crow et al., 2002; Friedman and Reich, 2005; Schulte et al., 2007; Fraver and Palik, 2012), components that contribute to structural complexity. Declines in structural complexity have been linked to increased risk and severity of pest outbreaks (Raffa et al., 2008); altered carbon, water, and nutrient cycles (Fisk et al., 2002; Guo and Gifford, 2002); and loss of biodiversity (Schulte et al., 2005).

Variable retention harvesting (VRH) can be used to enhance the structural complexity of managed forests, thereby creating conditions that may resemble those found after natural disturbances (Gustafsson et al., 2012; Lindenmayer et al., 2012). Grounded in an understanding of natural disturbance and associated biological legacies (Franklin et al., 2007; Lindenmayer and Franklin, 2002; Lindenmayer et al., 2012), VRH approaches silviculture from the perspective of what is retained, rather than what is removed, and can be variously implemented to meet different management goals: for instance, the

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http://dx.doi.org/10.1016/j.foreco.2017.07.053
Received 10 November 2016; Received in revised form 28 July 2017; Accepted 29 July 2017
Available online 08 August 2017

proportion of overstory retained or the specific species, size, or spatial arrangement of retained forest elements can be varied. Previous studies of VRH have documented impacts of amount of retention and its spatial pattern on microclimate conditions (Peck et al., 2012), forest growth (Palik et al., 2014), and post-harvest biodiversity (Baker et al., 2013), as well as resource availability (Boyden et al., 2012), understory plant community composition (Roberts et al., 2016), and spatial patterns of plants within the forest understory (Halpern et al., 2012). Understanding the response of forest taxa beyond trees has been less well researched, but is important where the maintenance of biodiversity is a fundamental management goal.

Structural complexity has long been recognized as important to birds and other wildlife, and forest bird communities tend to respond positively to increased heterogeneity in both horizontal and vertical planes (MacArthur and MacArthur, 1961; Willson, 1974; Robinson and Holmes, 1982; Whelan, 2001). While studies on bird community response to VRH have generally revealed a positive association between the amount of overstory retained and bird abundance and species richness (Norton and Hannon, 1997; Lance and Phinney, 2001), few studies have investigated bird response to the spatial configuration of retained trees; specifically, dispersed versus aggregated retention. Leaupin et al. (2004) found negligible bird response to different patterns of harvest up to two summers following timber removal. Atwell et al. (2008) found that retention harvesting had a positive effect on bird species richness and abundance three summers after harvest; however, no differences were associated with the spatial pattern of retention nor did birds respond to shrub layer reduction.

To better understand longer-term responses of forest birds to VRH, our study extended to 10 years post-harvest the experiment examined by Atwell et al. (2008) in a red pine (*Pinus resinosa*) forest in north central Minnesota, USA (Palik and Zasada, 2003). These VRH treatments were implemented to assess responses to variation in the spatial pattern of retained overstory trees and reduced abundance of woody shrubs in the understory. There is a growing body of research from this experiment, including work on seedling disease and mortality (Ostry et al., 2012), tree physiological processes (Powers et al., 2008, 2009a, 2009b, 2010, 2011), early survival and growth of seedlings in gaps (Peck et al., 2012), individual seedling mortality and diameter and height growth (Montgomery et al., 2013), resource availability (Montgomery et al., 2010; Boyden et al., 2012), and biomass growth (Palik et al., 2014). Here we present decade-long responses of diurnal breeding birds to VRH in red pine forests.

Based on existing knowledge of bird response to horizontal and vertical heterogeneity of forest structure (MacArthur and MacArthur, 1961; Willson, 1974; Robinson and Holmes, 1982; Whelan, 2001), we hypothesized the bird community would respond to changes in overstory, shrub density, and time since treatment. We expected greater levels of horizontal heterogeneity, as caused by aggregation of retained trees, because of increased spatial variability of light (Boyden et al., 2012). Removal of shrubs in the context of this experiment greatly reduced the vegetation cover and thus substantially reduced vertical heterogeneity. We expected time to impact stand heterogeneity in this experiment because both horizontal and vertical heterogeneity increase with post-harvest vegetation response. In terms of guild responses, we expected no differences due to our treatments among ground nesters, and we otherwise hypothesized that within the 10-year timeframe of this study:

- Overstory removal to have a negative impact on the abundance of cavity nesters and bark gleaners due to loss of nesting and foraging substrates with harvesting, but no substantial differences due to spatial pattern of retention;
- Overstory removal to have a positive impact on the abundance of aerial foragers due to an increase in air space surrounding remaining overstory trees, but no substantial differences due to spatial pattern of retention; and,
- Overstory and understory shrub removal to have an initial negative impact on the abundance of tree and shrub nesters, and foliage gleaners by removing potential nesting or foraging substrates, but also that these guilds would increase with time thereafter due to increased heterogeneity associated with forest regrowth. We expected a greater level of response among these guilds with greater levels of spatial aggregation for the reasons outlined above.

We expected treatment responses to be variable among bird species, with individual species responses consistent with guild status according to Ehrlich et al. (1988), as outlined above. For example, we hypothesized we would record lower numbers of bark-gleaning woodpeckers in the treatments versus controls because of the loss of snags and foraging substrates with logging. Similarly, we expected to record a higher abundance of aerially foraging flycatchers in treatments versus the control because of increases in air space surrounding retained overstory trees.

2. Methods

2.1. Study area and experimental design

Our study area is located on the Chippewa National Forest in north central Minnesota, USA. Mean annual temperature for this region of Minnesota is 3.9 °C and mean annual precipitation is 70.0 cm (MRCC, 2006). Study sites are located in a matrix of upland forest, bogs, and lakes and on glacial contact and outwash landforms with deep sandy soils and low topographic relief (< 10 m variation; Albert, 1995). Prior to treatment, study stands were predominantly even-aged and red pine comprised approximately 91% of basal area (Palik et al., 2003). Northern red oak (*Quercus rubra*), eastern white pine (*P. strobus*), trembling aspen (*Populus tremuloides*), bigtooth aspen (*P. grandidentata*), paper birch (*Betula papyrifera*), balsam fir (*Abies balsamea*), red maple (*Acer rubra*), white spruce (*Picea glauca*), bur oak (*Q. macrocarpa*), and black spruce (*P. mariana*) were also present, individually comprising < 0.01–2.8% of total basal area. Total basal area of study stands averaged 36 m^2/ha for trees with a diameter at breast height (DBH) greater than 10 cm.

The experiment used a randomized complete-block, split-plot design. Four blocks, each approximately 64 ha in size, were divided into four approximately 16-ha stands with three VRH treatments and an unharvested control randomly assigned to each block and crossed with a shrub layer treatment. VRH treatments included dispersed retention, which resembled a traditional shelterwood cut of evenly-spaced retained trees, aggregated retention achieved by cutting small (0.1 ha) gaps and retaining trees between the gaps, and aggregated retention achieved by cutting large (0.3 ha) gaps, again leaving trees between the gaps (Fig. 1; Palik et al., 2014). Treatments were cut between 15 August 2002 and 15 April 2003 to a basal area of approximately 17 m^2/ha. Areas of advance tree regeneration were protected and resultant basal area of each tree species remained similar to pre-harvest (Palik et al., 2003). To facilitate seedling planting, shrubs were cut with a mechanized brush cutter in mid- to late spring of 2002 across the entire stand of each VRH treatment. In spring 2003, each VRH treated stand was hand planted with red pine, eastern white pine, and jack pine (*Pinus banksiana*) seedlings at density of ~1200 trees/ha. In 2003–07, 2009, 2011, shrubs were again manually cut on one half of each treated stand but left intact (ambient) on the other half. These treatments targeted shrubs (mostly *Corylus* spp.), prolific sprouting tree species (e.g., aspens), and semi-woody herbaceous species (e.g., *Rubus* spp.) (Palik et al., 2014).