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Influence of residual forest patches on post-fire bird diversity patterns in jack pine-dominated ecosystems of northern Lower Michigan

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ABSTRACT

Stand-replacing fires are part of the natural disturbance regime that maintain jack pine (*Pinus banksiana* Lamb.) forests of northern Lower Michigan. Currently, the occurrence and extent of wildfire is much reduced relative to the past and young jack pine plantations specifically managed for Kirtland's warbler (*Setophaga kirtlandii* Baird) are a prominent feature on the landscape. Stringers, or patches of residual pre-fire forest, are a unique feature left behind after wildfires which are not often accounted for in plantation management. In this study, we examined the ecological value of stringers from an avian biodiversity perspective by comparing bird assemblages found within stringers to those in the surrounding forest (non-stringers). Our objective was to answer two research questions: (1) do stringers have unique bird communities relative to the surrounding vegetation (forest or plantation)?; and (2) how much of the variation in bird communities can be explained by differences in vegetation structure and composition between stringers and non-stringers? We conducted breeding and non-breeding season point counts and used abundance data to compare bird species found within stringers and non-stringers at seven sites grouped by time since disturbance. Species richness was significantly higher ($P = 0.01$) in the stringers when the non-stringers were 30–40 years old, with 32 species discovered in the stringers and 29 species in the non-stringers. During the breeding season, bird assemblages differed between stringers and non-stringers when the non-stringers were <12 years old (multi-response permutation procedures; $T = -10.11$, $A = 0.07$, $P = <0.00$), but no differences were observed when non-stringers were 30–40 years old or >40 years old. Non-breeding bird communities differed between stringers and non-stringers only when the non-stringer was a recently planted (<5 years old) plantation ($T = -2.15$, $A = 0.09$, $P = 0.02$). Differences in bird assemblages appear to be driven by the vegetation structure of stringers and non-stringers where fires were recent, but increasing similarity in vegetation structure occurs with time since fire; over time the importance of stringers for avian biodiversity is reduced. Our results suggest that stringers are important for bird communities, especially in recently disturbed areas, and that these biological legacies should be considered where jack pine management attempts to emulate natural patterns and processes.

1. Introduction

Across the xeric, sandy outwash plains of northern Lower Michigan (NLM) jack pine (*Pinus banksiana* Lamb.)-dominated ecosystems predominate (Whitney, 1986, 1987). Stand-replacing crown fires are part of the historic natural disturbance regime that maintains these ecosystems (Whitney, 1986, 1987; Frelich, 2002). Currently, the occurrence and extent of wildfire is much reduced relative to the past and young jack pine plantations are a prominent feature on the landscape.

Natural disturbances, like wildfire, leave behind organisms, structures, and other remnants of the previous vegetation. These "biological legacies" add structural, compositional, and functional heterogeneity within the disturbance perimeter and may act as refugia for many species by providing critical cover and food sources not available in disturbed areas (Franklin et al., 2000). Wildfire behavior in jack pine systems often produces long, nar-

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row, unburned strips of the pre-fire vegetation arranged parallel to the direction of fire spread (Kashian et al., 2012). These unburned strings of trees (hereafter termed "stringers") provide heterogeneity on a landscape historically shaped by stand-replacing wildfires (Kashian et al., 2012). While the value of stringers has not been studied in the broader context of biodiversity maintenance in jack pine-dominated ecosystems of NLM, they have been shown to comprise nearly 10% of the post-fire area and have relatively long-term persistence on the landscape (Kashian et al., 2012). As suggested by Kashian et al. (2012), stringers provide important structural diversity in an otherwise even-aged, relatively homogeneous area of regenerating jack pine and thus may offer refugia for birds, insects, and small mammals that otherwise do not use the adjacent disturbed area. Several studies have shown that patches of remnant, pre-disturbance forests are important for bird communities in forested landscapes, including aspen (*Populus* spp.) clearcuts in Minnesota (Merrill et al., 1998), the Cascades region of the Pacific Northwest (Hansen et al., 1995), red pine (*Pinus resinosa* Ait) forests in Minnesota (Atwell et al., 2008), jack pine forests in Ontario, Canada (Venier and Pearce, 2005), the boreal forest of western North America (Schieck and Song, 2006), and the mixed eucalypt (*Eucalyptus* spp.) forests of south-east Australia (Robinson et al., 2014).

Many jack pine-dominated ecosystems of NLM are managed as breeding habitat for the Federally Endangered Kirtland's warbler (*Setophaga kirtlandii* Baird), which breeds in young (5–20 years old) jack pine. Jack pine requires fires for regeneration, and mid-20th century fire suppression therefore greatly reduced the availability of Kirtland's warbler habitat and the species was listed pursuant to the *Endangered Species Act* (Probst, 1986). In an effort to increase the amount of young jack pine coverage necessary for Kirtland's warbler breeding habitat, state and federal land managers currently harvest mature jack pine and regenerate these sites by planting 2-yr old jack pine seedlings in an "opposing wave pattern" (Probst, 1986, 1988). Trees are typically planted at 1.2 m intervals in rows of alternating "waves" that are 1.8 m apart to create elliptical openings (Houseman and Anderson, 2002). The result is a uniform arrangement of densely planted jack pines separated by small (<1 ha) openings in which Kirtland's warbler forage (Probst, 1986; Kepler et al., 1996) and a stand structure significantly different than that created naturally by wildfire (Spaulding and Rothstein, 2009). Specifically, stringers are often unaccounted for in management, even though they are a unique and common feature left behind after stand-replacing wildfires in this region (Kashian et al., 2012).

In step with the general concepts of ecological forestry (Seymour and Hunter, 1999; Franklin et al., 2007), efforts are underway in the Great Lakes Region to manage jack pine ecosystems within the limits of the natural disturbance patterns and processes so that better outcomes of biodiversity conservation can be achieved (Corace et al., 2009, 2010; Corace and Goebel, 2010). This can be accomplished through silvicultural plans that emulate the patterns of natural disturbances of the region, including the return interval, severity, the spatial patterns of the disturbance, and the biological legacies left behind (Seymour and Hunter, 1999). Stringers are common features of naturally disturbed jack pine-dominated ecosystems and are naturally persistent throughout the fire return interval (Kashian et al., 2012). However, the role of stringers in overall stand and landscape-level biodiversity is unknown as few multi-taxa studies have been conducted in jack pine plantations produced for Kirtland's warbler.

The overall objective of this research was to examine the biodiversity value of stringers from an avian perspective by examining the interactions between stringers and surrounding jack pine forests or plantations in NLM. Specifically, we investigated the following research questions: (1) Do stringers have unique bird communities relative to the surrounding vegetation (forest or plantation) and is there seasonal variation?; and (2) how much of the variation in bird communities can be explained by differences in vegetation structure and composition between stringers and non-stringers? Bird communities were analyzed in sites with wildfire-generated stringers to determine the natural range of variability in bird diversity patterns in jack pine-dominated forests of NLM. Bird communities within an anthropogenically created stringer surrounded by a plantation were analyzed to determine if unharvested forest within plantations contribute to avian diversity. Understanding bird diversity patterns in naturally disturbed jack pine-dominated forests of NLM will provide some general principles to guide mangers in better mimicking natural patterns within plantations managed for Kirtland's warbler habitat. We hypothesize that stringers will increase overall avian species diversity within jack pine-dominated forests of NLM, especially in recently disturbed sites.

2. Methods

2.1. Study sites

All field work was conducted in the Highplains Subsection (VII.2) of the Northern Lacustrine-Influenced Lower Michigan Section (VII) as described by Albert (1995). The Highplains Subsection has the most severe climate of NLM due to its inland location, high elevation, and northern latitude. Late spring freezes are common in the area and the annual precipitation is between 71 and 81 cm. The subsection consists mainly of broad outwash plains with excessively drained sand or sand mixed with gravel.

Stringer locations were determined following the methods of Kashian et al. (2012). Aerial photographs of each site were analyzed to determine stringer locations and stringer area. We defined stringers from the surrounding forest or plantation by locating contiguous areas of mature trees within a burn perimeter. Boundaries between stringers and non-stringers were drawn where the edge of the stringer meets the burned area. Kashian et al. (2012) describes the natural range of variability of stringers in jack pine-dominated ecosystems of NLM. While stringers are variable in size and shape across our sample sites, for this study we required that all stringers and non-stringers be a minimum of 100 m wide.

The primary research areas were two sites within the U.S. Fish and Wildlife Service's Kirtland's Warbler Wildlife Management Area (KWWMA): Muskrat Trail and Leota. Sampling was conducted during the non-breeding (December–March) and breeding season (May–August). Muskrat Trail includes an anthropogenically produced stringer that represents a remnant of the tract harvested in 2008. The remaining acreage at this site was planted with jack pine seedlings in 2009. The Leota site was burned by a wildfire in 1977 that left stringers from the previous mature jack pine-red pine stand. Field work was also conducted during the breeding season at five additional wildfire sites. These sites included some of those examined by Kashian et al. (2012) and included Damon (burned in 1967), St. Helen (1967), Mack Lake (1980), No Pablo (2000), and Hughes Lake (2006) (Fig. 1, Table 1). These sites were chosen because they were known to have stringers, were geographically isolated from one another, and because they include a range of times since fire or harvesting. At each of the seven sites we sampled birds and vegetation structure at a minimum of three points located in the stringer and three in the surrounding forest/plantation (non-stringer). For the purposes of this work, we categorized Damon and St. Helen as "mature" sites (>40 years post-disturbance that created the stringer), Leota and Mack Lake as "intermediate age" sites (>30 years post-disturbance), and No Pablo, Hughes Lake, and Muskrat Trail as "recently disturbed" sites