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Bird conservation potential of fire and herbicide treatments in thinned pine stands

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ABSTRACT

Fire-maintained pine (*Pinus* spp.) forests, characterized by a diverse herbaceous layer, sparse midstory layer, and a dominant pine overstory, once covered approximately 30 million ha in the southeastern United States. Fire suppression, landscape changes, and land management changes have contributed to reduced suitability of many pine stands for fire-dependent species, including many avian species in regional decline. However, intensively managed loblolly pine (*P. taeda*) stands treated with prescribed fire and herbicide could help restore or maintain fire-dependent communities within working landscapes. Therefore, we investigated avian responses to combinations of prescribed fire and herbicide (imazapyr) treatments within a matrix of intensively managed pine stands in east-central Mississippi, USA. We used a randomized complete block design of 6 mid-rotation, thinned pine stands (blocks) each with 4 treatments (control, burn only, herbicide only, burn + herbicide) assigned to 10-ha experimental units. We applied imazapyr herbicide (Arsenal®) during fall 1999 and burned units during winter every 3 years, beginning in 2000. We conducted avian point counts from year pre-treatment (1999) through 9 years post-treatment (2000–2008) and summarized annual vegetation structure and composition. We used 34 of 64 observed avian species for analyses using mixed models, repeated measures ANCOVA. Across the 9-year post-treatment study period, fire and imazapyr differentially affected avian communities with our combination treatment (fire + imazapyr) favoring high-priority, open pine bird species most. However, remaining treatments (burn only, imazapyr only, controls) provided additional vegetation gradients for species preferring greater structure diversity or canopy coverage. Our results indicated that fire and herbicide treatments can maintain vegetation structure attractive to a bird community of high-conservation value, while concurrently meeting economic and sustainable forestry goals. Although primarily managed for economic gain, intensively managed forests can provide suitable habitat conditions for avian species of conservation concern helping land managers meet biodiversity objectives.

1. Introduction

Historically, nearly 30 million ha of longleaf pine (*Pinus palustris*) forests occurred from the Gulf Coastal Plain to the eastern shore of the southeastern United States (Frost, 1993). Other pine species, including slash (*P. elliotii*), loblolly (*P. taeda*), and shortleaf (*P. echinata*), followed a gradient of declining fire tolerance inland from the Lower Coastal Flatwoods to the Upper Coastal Plain and Piedmont. Despite lightning-ignited fires, anthropogenic fire was a main cause of forest fires within these regions (Landers et al., 1995; Masters et al., 1995). However, alterations to fire frequency and extensive human settlement have changed pine-dominated forests over time (Carroll et al., 2002; Stanturf et al., 2002), allowing hardwood encroachment into former pine savannahs once characterized by a diverse herbaceous layer, sparse midstory layer, and a dominant pine overstory.

Planted pine occupies approximately 15.8 million ha in the southeastern United States (Wear and Greis, 2012). Short-rotation, intensive management of pines typically includes 25–32 year rotations, clearcutting followed by site preparation and tree planting, stand establishment vegetation management, 1–2 commercial thins, and fertilization. Intensively managed forest landscapes provide ecosystem benefits such as wildlife habitat, protection of water quality, and carbon sequestration while creating a mosaic of successional stages (Vogt et al., 1999; Wigley et al., 2000; Miller et al., 2009; Demarais et al., 2017). Within pine plantation matrices, mature forest remnants are often limited to streamside management zones (Wigley and Melchiors, 1994; Blinn and Kilgore, 2001). However, conservation efforts could focus on adjacent, frequently disturbed pine stands that may favor disturbance-

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dependent or –tolerant species of concern (i.e., species associated with early seral vegetation associations) which may increase landscape biodiversity (Rundel et al., 1998; Turner et al., 2001; White and Jentsch, 2001).

Prescribed fire during the dormant season provides a management tool capable of maintaining open pine conditions in intensively managed pine stands but with lower risk of crown scorch and less-variable climatic conditions compared to growing-season prescribed fires (Wade and Lunsford, 1989; Robbins and Myers, 1992; Iglay et al., 2014). Dormant-season prescribed fires reduce fuel loads, alter aboveground vegetation structure, and scarify seeds but may not kill roots of midstory hardwood trees (Wade and Lunsford, 1989; Waldrop et al., 1992; Iglay et al. 2010b; Iglay et al., 2014). Therefore, prolific re-sprouting from undamaged root stocks can be common post-burn (Komerak, 1965; Waldrop et al., 1992; Sparks et al., 2002; Iglay et al. 2014).

Smoke management issues, liability concerns, and a limited number of burning-degree days have contributed to greatly reduced use of fire in pine-dominated ecosystems in the southeastern United States. These factors necessitate alternative silviculture tools, such as selective herbicides, when burning is infeasible (Brennan et al. 1998; Burger et al. 1998; Haines et al., 2001; Wigley et al., 2002). Because of fire's unique ability to alter ecosystems, exclusive use of alternative silvicultural tools such as selective herbicides may never capture fully the biodiversity of historic pyric-ecosystems. The primary purpose of herbicide application in mid-rotation pine plantations is hardwood competition control (Iglay et al., 2014), and imazapyr in the form of either Arsenal AC® (BASF Corporation, Research Triangle, NC; BASF Corporation, 2006) or in combination as Arsenal AC® + Escort® (E. I. du Pont Nemours and Company, Wilmington, DE) is the most commonly applied herbicide in the southeastern United States (Shepard et al., 2004). However, past research primarily focused on wildlife responses to prescribed fire or herbicides and information comparing avian diversity responses to fire and selective herbicides has only recently begun to emerge (Singleton et al., 2013; Sladek et al., 2008).

Avifauna typically respond to vegetation changes such as those associated with imazapyr application and/or prescribed fire (Guynn et al., 2004; Sladek et al., 2008; Wagner et al., 2004). In intensively managed pine stands, shifts in food and cover availability associated with both treatments tend to favor early-successional and grassland species such as increased seed availability and shrub cover (Bendell, 1974; Dickson, 1981). Birds preferring dense midstory vegetation are not favored as midstory vegetation is reduced and consequent vegetative structure can benefit shrub and ground-nesting birds (Bendell, 1974; Brennan et al., 1998; Burger et al., 1998; Dickson, 1981; Wilson et al., 1995). Increased richness and abundance of shrub and grassland bird species have been observed post-burn (Dickson 1981), but only some herbicide-treated forest stands in Oklahoma, USA had greater bird species richness (Schulz et al., 1992). Nevertheless, declining detections of early-successional and shrub breeding birds across the United States in the Breeding Bird Survey (0.67% per year, 1966–2004) and in the southeastern United States (0.99% per year, 1966–2004; Sauer et al., 2005) support the need for disturbance-dependent plant communities for avian conservation (Burger, 2005; Engstrom et al., 1984; Saab and Powell, 2005).

Although past research suggests similarities between bird responses to fire and imazapyr, concurrent, experimental comparisons of independent and combined treatments are lacking (McInnis et al., 2004). Herbicide research has focused mostly on site preparation (Shepard et al., 2004) and management regimes applied on non-industrial timberlands (Edwards et al., 2004; Howell et al., 1996; McInnis et al., 2004; Mixon et al., 2009; Singleton et al., 2013; Sladek et al., 2008). Therefore, to better understand effects of prescribed fire and herbicide treatments in post-thinned, commercial pine stands, we investigated long-term response of the avian community to repeated, dormant-season prescribed fire and a single imazapyr treatment, alone and in combination, in mid-rotation pine plantations. We represented vegetation response with vegetation characteristics presented as desired ecological states of open pine priority systems in the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative's (GCPOLCC) Integrated Science Agenda. The GCPOLCC described open pine woodland and savanna as floristically rich, low basal area, and open canopy forests (Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative, 2012). It is possible that mid-rotation fire and imazapyr treatments could contribute to the GCPOLCC's open pine objectives within working landscapes (Iglay et al., 2014; Iglay et al., 2010a, 2010b). We predicted that treated plots (e.g., fire and/or herbicide) would harbor greater bird diversity and abundance than control (thinned only) plots, especially for bird species of high conservation priority.

2. Materials and methods

2.1. Study area

Our study occurred in the Interior Flatwoods (Pettry, 1977) and Upper Coastal Plain of east-central Mississippi in Kemper County, Mississippi, USA. Except for stream bottoms, the overall landscape was relatively flat topography with elevation < 55 m (Harper, 1943). Subtropical climate conditions included mean annual temperatures of 17.4 °C (11.2–23.7 °C) and mean annual precipitation of 149 cm (100–177 cm; National Oceanic and Atmospheric Administration, 2009). Early accounts of forest composition described a mixture of loblolly pine and hardwoods in open, frequently burned forests (Adair, 2005; Bourne, 1904; Lowe, 1913). Original harvest of old growth forests occurred between 1912 and 1941 (Perkins, 1973), followed by conservation selective cutting from 1941–1967 and intensive pine management since 1962 via clearcuts followed by mechanical and/or chemical site preparation and planting of loblolly pine (McKee, 1972). Exclusion of fire and intensive forestry across > 70% of the study area since the early 1990s has generally promoted pine stands composed of overstory pine and midstory hardwood tree species including oaks (*Quercus* spp.), hickories (*Carya* spp.), sweetgum (*Liquidambar styraciflua* L.), black-gum (*Nyssa sylvatica* Marsh.), and eastern red cedar (*Juniper virginiana* L.; Chapman, 1931; Monk, 1968). The 9600-ha landscape containing our research plots had intensively managed pine stands of various ages (70%), mature mixed pine-hardwood stands (17%), hardwood stands (10%) primarily in riparian areas (streamside management zones for water quality protection), and non-forested areas (3%).

2.2. Study design

We chose 6 mid-rotation (18–22 years) pine stands, managed by Weyerhaeuser Company on rotations of 25–32 years, from among available stands with similar management histories and meeting the following criteria: (1) large enough to include four buffered 10-ha experimental units, (2) thinned 2–5 years before our study, and (3) little acreage (< 3%) in streamside management zones. Chosen stands (ranging from 159 to 210 ha per stand) had 25-year site indexes of 19.7–23.9 m ($\bar{x}$ = 22.7 m). These stands had been commercially thinned to ~296 pine trees/ha, 2–5 years before project initiation, and were fertilized immediately post-thin and again in winter 2001 with diammonium phosphate (127–283.5 kg/ha, $\bar{x}$ = 153.4 kg/ha) and/or urea (381–448 kg/ha, $\bar{x}$ = 222.8 kg/ha). At project initiation, stem density (all tree species ≥1.3 cm DBH) was 372–714 stems/ha among stands ($\bar{x}$ = 527.69 stems/ha, σ = 107.66). Predominant understory vegetation (76% total biomass) at time of treatment included sawtooth blackberry (*Rubus argutus* Link, 13%), Japanese honeysuckle (*Lonicera japonica* Thunb., 11%), *Panicum* spp. (9%), *Vitis* spp. (8%), poison ivy [*Toxicodendron radicans* (L.) Kuntze, 7%], slender woodoats [*Chasmanthium laxum* (L.) Yates, 6%], *Smilax* spp. (5%), sweetgum (5%) and American beautyberry (*Callicarpa Americana* L.), *Quercus* spp.,