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Long-term avian response to fire severity, repeated burning, and mechanical fuel reduction in upland hardwood forest

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ABSTRACT

Forest restoration, fuel reduction, and wildlife conservation management requires understanding if, and how repeated prescribed fire, fire severity, or mechanical methods can promote goals. We examined breeding bird response to repeated fuel reduction treatments by mechanical understory reduction (twice; Mechanical-only), prescribed burning (four times; Burn-only), or mechanical understory reduction plus burning (then three subsequent burns; Mechanical + Burn). Initial burns were hotter in Mechanical + Burn than Burn-only resulting in heavy tree mortality, canopy openness, thick shrub density, and abundant snags lasting several years. Relative density and species richness of birds increased in Mechanical + Burn within three breeding seasons of high-severity burns, and remained greater throughout subsequent burns. Increases were due to an influx of species associated with young forest conditions, with little change in most mature forest species. Repeated burning in Mechanical + Burn likely impeded forest maturation, allowing many scrub-shrub bird species to persist. Species richness in Burn-only did not differ from any treatment, but modest increases over time were apparent as structural heterogeneity increased with delayed tree mortality. Cavity-nester density was highest in Mechanical + Burn, but remained high even as snags fell to pretreatment levels. Ground-nester density was lower in Mechanical + Burn than Control and Mechanical-only, but ground-nesting species responded differently. Open woodlands were not created by any treatment due to persistent re-sprouting of top-killed trees and shrubs. We note that breeding birds appear to respond similarly to high-severity burns and silvicultural treatments with heavy canopy reduction, offering possible alternatives in managing upland hardwood forests for diverse breeding bird communities.

1. Introduction

Historically, availability of fire-maintained habitats in the Central Hardwood Region, such as savannas and oak woodlands, likely played an important role in the distribution and density of breeding bird species that require different variants of early successional or young forest conditions (Greenberg et al., 2015). Many open, fire-maintained habitats have virtually disappeared as trees encroached and grew to canopy closure after the elimination of frequent burning by Native Americans and (later) Euro-American settlers, and suppression of primarily human-caused wildfires for several decades (Greenberg et al., 2015). Populations of many disturbance-dependent bird species have declined or become locally extirpated as these open conditions have declined or disappeared (Askins, 2001).

Prescribed fire, often in conjunction with other silvicultural methods, is commonly recommended to reduce fuels, promote oak regeneration, improve wildlife habitat, and restore upland hardwood forests to an open oak woodland condition (Waldrop et al., 2016). Yet, many questions remain regarding if, and how forests can be managed to attain these goals. Further, objectives are often vaguely defined, and lack metrics to gauge their achievement. For example, 'wildlife habitat improvement' implies that all 'wildlife' will benefit from a specific

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silvicultural disturbance (Harper et al., 2016). Yet, changes to habitat characteristics caused by fire or other disturbances might benefit some species while adversely affecting others. Critical knowledge gaps identified by forest managers include development of methods to create, maintain, or restore open woodland conditions (Waldrop et al., 2016).

By definition, disturbance-dependent birds are associated with habitats created by disturbances, but many species require specific variants, across a gradient of open structural conditions (Askins, 2001; Hunter et al., 2001; Greenberg et al., 2011, 2015). For example, field sparrows (*Spizella pusilla*) and northern bobwhite (*Colinus virginianus*) require open, grass-dominated habitats with scattered shrubs or young trees, whereas eastern meadowlarks (*Sturnella magna*) require open grasslands. Eastern towhees (*Pipilo erythrophthalmus*) and, at higher elevations chestnut-sided warblers (*Setophaga pensylvanica*), are most abundant in open, brushy, shrub- or stump sprout-dominated areas. Indigo buntings (*Passerina cyanea*) use a wide range of open conditions, as do eastern bluebirds (*Sialia sialis*) if nesting cavities are available. Thus open, shrub- and sprout-dominated young forest conditions created by high-severity disturbances are suitable for many scrub-shrub species (Askins, 2001; Rush et al., 2012), but not for those requiring open conditions with a grass-forb dominated understory. Although no disturbance-dependent species are known open oak woodland obligates (Vander Yacht et al., 2016), many could benefit from increased availability of the open woodland condition (Grundel and Pavlovic, 2007a, 2007b). Forest restoration, fuel reduction, and wildlife conservation efforts require an understanding of how repeated prescribed fire, fire severity, or mechanical methods can be applied to attain goals, and how diverse wildlife species with differing habitat requirements will respond (Driscoll et al., 2010).

We used a Before-After/Control-Impact (BACI; Smith, 2002) approach to experimentally assess how breeding birds responded to repeated fuel reduction treatments by mechanical understory reduction (Mechanical-only), dormant season prescribed burning (Burn-only), or mechanical understory reduction followed a year later by prescribed burning (Mechanical + Burn), in upland hardwood forest. Initial prescribed burns in the Mechanical + Burn treatment resulted in heavy tree mortality and abundant snags due to hotter fires fueled by cut shrubs and small trees remaining on the forest floor for a year prior (high-severity burn). In contrast, prescribed burns in the Burn-only treatment were relatively lower-intensity, and initial tree mortality was low (low-severity burn).

We reported early results after initial treatment implementation (Greenberg et al., 2007), and again after a second prescribed burn in both burn treatments (Greenberg et al., 2013). Our earlier results showed that species richness and relative density (termed density, hereafter) of total breeding birds and several species increased in the high-severity burn within three breeding seasons. Many species showed no response; a few decreased temporarily following some treatments, compared to controls (Greenberg et al., 2007). Few changes were evident after a second burn in either burn treatment, that were not already apparent within a few years of initial treatments (Greenberg et al., 2013). Since then, a third and fourth prescribed burn was conducted in both burn treatments, and a second mechanical understory reduction in the Mechanical-only treatment. Our long-term study with repeated treatment applications provided us an opportunity to examine long-term (16-year) changes in the breeding bird community in response to initial fire severity and repeated fuel reduction treatments, and also evaluate responses in the context of progress toward restoration of an open woodland community.

Based on our earlier results, we predicted (1) repeated burns in the Mechanical + Burn treatment would maintain open, shrubby young forest conditions created by the initial high-severity burns, resulting in sustained higher densities and species of breeding birds; (2) repeated burns in the Burn-only treatment would create canopy gaps as some delayed tree mortality occurred, with an associated increase in breeding bird species richness; (3) density and species richness of birds would be unaffected by repeated understory reductions in the Mechanical-only treatment where the canopy remained intact and shrub recovery was rapid; (4) density of the tree-nester guild would be unaffected by fuel reduction treatments; shrub-nester density would remain higher in Mechanical + Burn, but cavity-nester density would decrease as snag abundance declined, and; ground-nester density would temporarily decrease after each burn in both burn treatments, due to temporary decreases in leaf litter depth.

2. Methods

2.1. Study area

Our study was conducted on the 5841-ha Green River Game Land (35°17′9″N, 82°19′42″W, blocks 1 and 2; 35°15′42″N, 82°17′27″W, block 3) in Polk County, North Carolina. The Game Land was in the mountainous Blue Ridge Physiographic Province of Western North Carolina. Average annual precipitation is 1638 mm and is distributed evenly throughout the year, and average annual temperature is 17.6 °C (Keenan, 1998). Soils were primarily of the Evard series (fine-loamy, oxidic, mesic, Typic Hapludults), which are very deep (> 1 m) and well-drained in mountain uplands (USDA Natural Resources Conservation Service, 1998). The upland hardwood forest was composed mainly of oaks *Quercus* spp. and hickories *Carya* spp. Shortleaf pine (*Pinus echinata*) and Virginia pine (*P. virginiana*) were found on ridgetops, and white pine (*P. strobus*) occurred in moist coves. Forest age within experimental units ranged from about 85–125 years. Predominant shrubs were mountain laurel (*Kalmia latifolia*) along ridge tops and on upper southwest-facing slopes, and rhododendron (*Rhododendron maximum*) in mesic areas. Elevation ranged from approximately 366–793 m. Prior to our first prescribed burns in 2003, none of the sites had been thinned or burned for at least 50 years (D. Simon, personal communication).

2.2. Study design

Our experimental design was a randomized block design with repeated measures over years. We selected three study areas (blocks) within the Game Land. Perennial streams border and (or) traverse all three replicate blocks. Blocks were selected based on size (on the basis of their capacity to accommodate four experimental units each), forest age, cover type, and management history, to ensure consistency in baseline conditions among the treatments. Minimum size of experimental units (four per block) was 14-ha to accommodate 10-ha ‘core’ areas, with 20 m buffers around each. Dirt roads or fire lines separated some of the experimental units but did not traverse any, and wooded trails traversed some experimental units.

Three fuel reduction treatments and an untreated control (Control) were randomly assigned within each of the three study blocks, for a total of 12 experimental units. Treatments were: (1) repeated mechanical felling of all shrubs and small trees ≥ 1.4 m tall and < 10.0 cm diameter at breast height (dbh) with a chainsaw (twice, winter of 2001–2002 and winter of 2011–2012) with cut fuels left scattered on-site (Mechanical-only); (2) repeated dormant season prescribed burns (four times, in February or March 2003, 2006, 2012, 2015) (Burn-only), and; (3) initial mechanical understory reduction (winter of 2001–2002), followed by four dormant season prescribed burns (as for Burn-only, above) (Mechanical + Burn) (Table 1).

During the initial prescribed burns (March 2003), fine woody fuel loading on Mechanical + Burn, where the shrub layer was felled, was approximately double that on Control and Burn-only units. Average fire temperature measured 30 cm aboveground was much hotter in Mechanical + Burn (517 °C) than Burn-only (321 °C); temperatures varied within Burn-only and Mechanical + Burn units, but a higher proportion of Mechanical + Burn units burned at high (601–900 °C)