Effects of Fuel Reduction Treatments on Breeding Birds in a Southern Appalachian Upland Hardwood Forest[1]

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Abstract

In the past, fires set by American Indians and settlers shaped much of the southern Appalachian forest by reducing the shrub layer and maintaining an open understory. Since the 1930's, fire exclusion has allowed the development of a thick shrub layer and accumulation of woody debris. This fuel buildup contributes to the potential for wildfire in many ecosystems. Recently, the need for fuel reduction, using techniques such as prescribed fire or mechanical treatments, has received national attention. However, the impacts of such habitat manipulations on breeding birds are not well understood, especially in southern hardwood ecosystems. As part of the multidisciplinary National Fire and Fire Surrogate Research Project, we compared the effects of three fuel reduction techniques and controls on breeding birds, using 50m point counts in four, 14-ha treatments within each of three replicate blocks at the Green River Game Land, Polk County, North Carolina. Treatments were: (1) prescribed burning (B), (2) mechanical felling of shrubs and small trees (M), (3) mechanical felling + burning (MB), and (4) controls (C). Breeding birds were surveyed using point counts during 2001-2004. Mechanical understory felling treatments were conducted in winter 2001-2002, and prescribed burning in spring 2003. Hence, bird responses to all four treatments were compared only for 2003 and 2004. After prescribed fire (2003), leaf litter depth decreased in B and MB, and snag densities and canopy openness increased in MB. Shrub cover was significantly lower in all fuel reduction treatments than in C. Total breeding bird abundance was similar among treatments each year except 2003, when it was higher in C than M. Species richness was similar among treatments except in 2004 when it was higher in MB. Shrub forager abundance was highest in C in 2003, and higher in C than in B during 2004. The abundance of shrub nesters was also lower in B and M than in MB in 2004. Responses were most evident at the species level. Most species showed no detectable response to treatments. During 2003 Worm-eating Warbler abundance was lower in MB than C or M, and, in 2004, it was lower in both B and MB than C or M. Hooded Warblers were more abundant in C than any fuel reduction treatments during 2003 and 2004. Indigo Buntings, which are associated with open habitats, were most abundant in MB during 2004. Fuel reduction treatments affected individual bird species differently, and responses appeared to be associated with changes in habitat structure. To fully understand how fire and fire surrogates for fuel reduction affect breeding bird communities, post-fire surveys of birds and vegetation structure must continue for several years.

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Introduction

In the past, fires set by American Indians and settlers shaped much of the southern Appalachian forest by reducing the shrub layer and maintaining an open understory (Lorimer 1993). Fire was used first by American Indians to improve conditions for travel and game, and later by settlers to improve hunting conditions and pasturage for livestock (see Lorimer 1993). Ayres and Ashe (1905) reported fire scars on 80% of trees in a systematic survey of 6.5 million acres of the southern Appalachian region. Fire scar evidence in the Great Smoky Mountains indicated that the fire return interval there was $\leq$ 10 years prior to 1940 (Harmon 1982).

Beginning in the 1930's, forest fires began to be viewed as destructive, and were suppressed or excluded where possible (Lorimer 1993). Fire exclusion promoted the buildup of fuels, such as woody debris and ericaceous shrubs, enhancing the likelihood of wildfire. Today, prescribed burning is again employed, now as a forest management tool for ecosystem restoration, oak regeneration, understory control, and fuel reduction, to reduce the likelihood of wildfire. Mechanical methods to reduce the forest understory are also used in lieu of prescribed fire when burning is not feasible or practical. Yet the effects of fire and fire surrogates for fuel reduction on breeding birds is poorly known, especially in the southern Appalachians.

In 2000, the National Fire and Fire Surrogate Study (NFFS) was initiated by the Joint Fire Science Program to research impacts of fuel reduction treatments on multiple components of forested ecosystems across the U.S. (Youngblood et al. 2005). The Green River Game Land in Polk County, NC was selected to represent the southern Appalachian upland, hardwood forest ecosystem in the NFFS study during 2001. This site was added to the original study through funding from the National Fire Plan. As part of the national NFFS, we studied community and species-level responses of breeding birds to three fuel reduction treatments (prescribed burning, mechanical understory removal, and mechanical understory removal + prescribed burning) and controls in the southern Appalachians.

The influence of vertical and horizontal vegetation structure on bird communities is well established (MacArthur and MacArthur 1961, Mauer et al. 1981). However, species differ in their habitat requirements, and might be expected to respond differently to changes in habitat attributes that are created by forest management activities. Several studies report higher bird species richness, diversity, and density in sites that were disturbed by management activities compared to mature undisturbed forest (Annand and Thompson 1997, Baker and Lacki 1997). Several bird species require habitat that has been recently disturbed by fire or by large-scale, high-intensity disturbance (Klaus et al. 2005). However, the abundance and nesting success of some ground and shrub nesting species may decline where the shrub or leaf litter layer is reduced or removed through mechanical means (Rodewald and Smith 1998) or by burning (Aquilani et al. 2000, Artman et al. 2001).

Other than understory reductions, fuel reduction treatments may affect habitat attributes by increasing light levels and primary productivity, which in turn may increase food resources for breeding birds by promoting higher insect densities and fruit production (Blake and Hoppes 1986). Prescribed fire may additionally create snags (Van Lear 2000), which benefit cavity nesters, such as woodpeckers (Lanham and Guynn 1996, Saab et al. 2004, Giese and Cuthbert 2003).

Other studies examine how burning alone or other silvicultural practices affect breeding birds. However, to our knowledge, none compare the effects of three commonly used understory reduction techniques on breeding bird communities and species using a replicated experimental design. Land managers need to know how different fuel reduction methods affect breeding birds to better manage populations and communities in conjunction with forest management. Our objectives were to determine whether and how breeding bird communities and individual species respond to fuel reduction treatments by prescribed burning and/or mechanical understory removal. Specifically, we examine differences in total bird abundance and species richness, foraging and nesting guilds, and individual species among three fuel reduction treatments and controls in the southern Appalachians before--and for two breeding seasons after--all treatments were implemented.

Methods

Our study was conducted on The Green River Game Land in Polk County, North Carolina. The Game Land lies entirely within the mountainous Blue Ridge Physiographic Province of Western North Carolina. Soils are primarily of the Evard series (fine-loamy, oxidic, mesic, Typic Hapludults) which are very deep and well-drained in mountain uplands (USDA Natural Resources Conservation Service 1998). There are also areas of rocky outcrops in steeper terrain. Forest stands are composed mainly of oaks (*Quercus* spp.) and hickories (*Carya* spp.). Shortleaf (*Pinus echinata*) and Virginia (*P. virginiana*) pines are found on ridgetops, and white pine (*P. strobus*) occurs in moist coves. Elevation ranges from approximately 366-793m.

We selected three study areas (blocks) within the Game Land. First and second order streams bordered and/or traverse all three replicate blocks. Study blocks were selected based upon stand size (large enough to fit all four treatments), stand age, cover type, and management history, to insure consistency in baseline conditions among the treatments. Stand ages varied from 80 to 120 years (Waldrop 2001). Minimum treatment size (four within each block) was 14 ha to allow for 10-ha treatment "core" areas, with 20m buffers around each. None of the sites had been thinned during the past ten years and none had been burned in at least five years. Oaks dominated all sites. Other dominant species included pignut hickory (*C. glabra*), mockernut hickory (*C. tomentosa*), and shortleaf pine (*P. echinata*). Generally, thick shrub layers occurred along ridge tops and on upper southwest-facing slopes. Predominant shrubs were mountain laurel (*Kalmia latifolia*) and rhododendron (*R. maximum*).

Three treatments and an untreated control (C) were randomly assigned to each of the three study blocks. Treatments were: (1) fuel reduction by mechanical understory felling (M), (2) fuel reduction by prescribed burning (B), and (3) fuel reduction by mechanical understory felling + prescribed fire (MB). Mechanical understory felling treatments were conducted during winter 2001-2002. The understory thinning was conducted using chainsaws, and included all mountain laurel, rhododendron, and trees >1.8 meters tall and <10.0 cm in diameter at breast height (dbh). Fuels were not removed from the site due to the high cost of operating in steep terrain. Prescribed burns were conducted in B and MB treatments on March 12 or 13, 2003. One block was burned by hand ignition using spot fire and strip-headfire techniques. The other blocks were ignited by helicopter using a spot fire technique. The objectives of prescribed burning were to remove the shrub layer and create a few snags for wildlife habitat.

We censused bird communities using three 50m radius (0.785 ha area) point counts spaced 200m apart in each treatment (Ralph et al. 1993). Each point was surveyed for 10 minutes during three separate visits between 15 May and 30 June during 2001-2004. Point counts were conducted within four hours of sunrise. All birds that were seen or heard were recorded. We rotated the times for point counts among the three visits to each treatment to avoid time-of-day biases. Bird abundance for each treatment was calculated by averaging across the three visits and the three censuses for each year, and extrapolating the average number per point count to number per ha. Species richness was calculated for each treatment by summing the number of species detected during all three visits and point counts each year.

We measured post-treatment habitat features during the first growing season after treatment implementation (2002 for M, 2003 for B, C, and MB). Snag ($\geq$10 cm dbh) density and percent cover of shrub species $\geq$1.4m high were measured within ten, 0.05-ha (10x50m) plots that were spaced systematically within each treatment. Leaf litter depth was measured at three locations along each of three randomly oriented, 15m transects originating at gridpoints that were spaced at 50m intervals throughout treatment areas. Canopy openness was measured at two randomly selected points within each treatment during summer (leaf on) 2003 using a spherical densiometer held at breast height.

We used one-way, ANOVAs (SAS 1990) in a complete randomized block design for each year separately (because treatments were implemented incrementally) to examine differences among the four treatments in total bird abundance, species richness, abundance of select, common species (if n > 30 detections during the four-year study period), and the abundance of birds in nesting and foraging guilds. Each species was assigned a single nesting (ground, shrub, tree, and cavity) and foraging (ground, shrub, and tree) guild (adapted from Hamel 1992). For vegetation analyses, we used ANOVAs to determine post-treatment differences in snag ($\geq$10 cm DBH) density, percent tall ($\geq$1.4m ht) shrub cover, leaf litter depth (Waldrop 2001), and canopy openness. Percentage data (shrub cover and canopy openness) was square-root arcsine transformed for analyses. We used least squares means tests to determine significant differences among treatments. We considered $P < 0.10$ as statistically significant due to high among-site variability in bird detections.

Results

Fire intensities varied within and among sites, but were generally moderate to high. Flame lengths of one to two meters occurred throughout all burn units but reached up to five meters in localized spots where topography or intersecting flame fronts contributed to erratic fire behavior. Loading of fine woody fuels in MB sites was essentially double that of C and M sites due to felling of the shrub layer. Measured temperatures were generally below 120^{o}C in B sites but often exceeded 800^{o}C in MB sites.

Both snag density and canopy openness were higher in MB than the other treatments in 2003 after all treatments had been implemented (*table 1*). Tall ($\geq$1.4m ht) shrub cover was

Table 1—*Mean ($\pm$SE) post-treatment number of snags (per ha), percent cover of tall (>1.4m ht) shrubs, percent canopy openness, and leaf litter depth (cm) in three treatments: burned (B), mechanical understory felling (M), mechanical understory felling followed by burning (MB), and controls (C) (n = 3 each), Green River Game Land, Polk County, NC. P-values represent block effects (P_{Block}) and treatment effects ($P_{Treatment}$). Differences among treatments were determined by least squares means tests, and are denoted by different letters within rows.*

Feature	*Treatment*				P_{block}	$P_{treatment}$
	B	C	M	MB		
Snags/ha	72.7$\pm$19.0^{A}	68.0$\pm$9.0^{A}	52.7$\pm$4.4^{A}	152.0$\pm$25.3^{B}	0.74396	0.0309
Canopy openness (%)	2.6$\pm$1.1^{A}	1.6$\pm$0.4^{A}	3.0$\pm$0.8^{A}	12.8$\pm$5.0^{B}	0.2047	0.0280
Shrub cover (%)	4.7$\pm$2.8^{A}	20.0$\pm$3.9^{B}	1.4$\pm$0.2^{A}	0.2$\pm$0.2^{A}	0.5763	0.0078
Litter Depth (cm)	0.9$\pm$0.1^{A}	4.2$\pm$0.5^{B}	5.5$\pm$ 0.2^{C}	0.5$\pm$ 0.1^{A}	0.1389	<0.0001

significantly lower in all fuel reduction treatments (B, M, and MB) than in C *(table 1)*. Leaf litter depth was significantly lower in both burned treatments (B and MB) than in either unburned treatment, and was slightly greater in M than C *(table 1)*. No block effects were detected for habitat measurements.

We detected 45 breeding bird species within our point counts during the four year study period. Total breeding bird abundance was similar among treatments each year except 2003 when it was higher in C than in M *(fig. 1)*. Species richness was similar among treatments except in 2004, when it was higher in MB than in other treatments

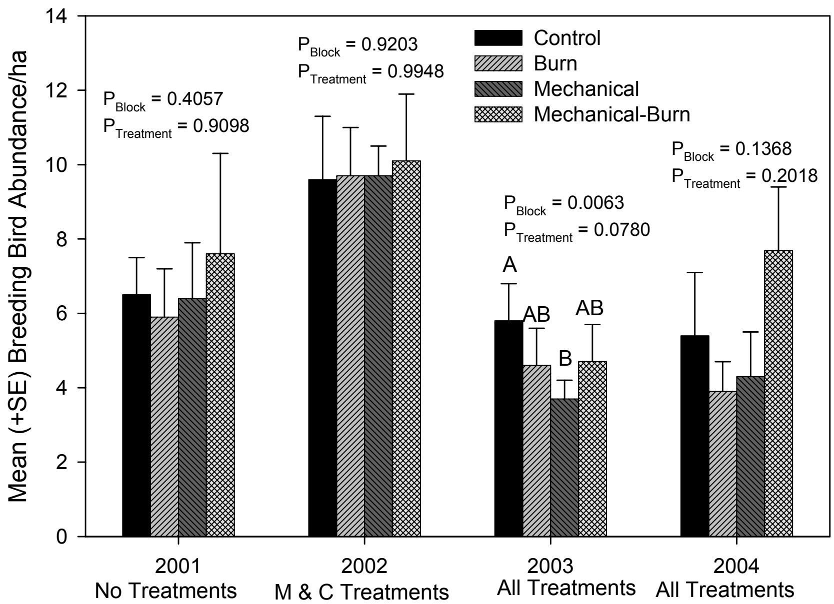

Figure 1—Mean (+SE) total abundance of breeding bird species in 3 treatments: burned (B), mechanical understory felling (M), mechanical understory feeling followed by burning (MB), and controls (C) (n=3 each), Green River Game Land, Polk County, NC. Treatments were not yet implemented in 2001 (pretreatment); in 2002 only (C) (including C and B) and M (including M and MB) were implemented; in 2003 and 2004 all four treatments were implemented. P-values represent block effects (P_{Block}) and treatment effects ($P_{Treatment}$). Significant differences among treatments within years were determined by least square means tests and are denoted by different letters.

(*fig. 2)*. The abundance of ground and tree foragers did not differ among treatments in any year *(fig. 3)*. However, shrub forager abundance was lower in all fuel reduction treatments immediately after understory reductions (in 2003), and lower in B than C in 2004 *(fig. 3)*. Shrub nester abundance was similar among treatments in all years except 2004, when it was higher in MB than in B or M *(fig. 3)*. The abundance of tree, ground, and cavity nesters did not differ among treatments in all years.

Responses to fuel reduction techniques were most evident at the species level. Most species, including those associated with closed canopy forest, showed no response to treatments. For example, Tufted Titmice (*Baeolophus bicolor*) and Blue-headed Vireos (*Vireo solitarius*) were common and showed no response to fuel reduction treatments during the study period *(table 2)*. Red-eyed Vireos (*Vireo olivaceous*) showed a short-term

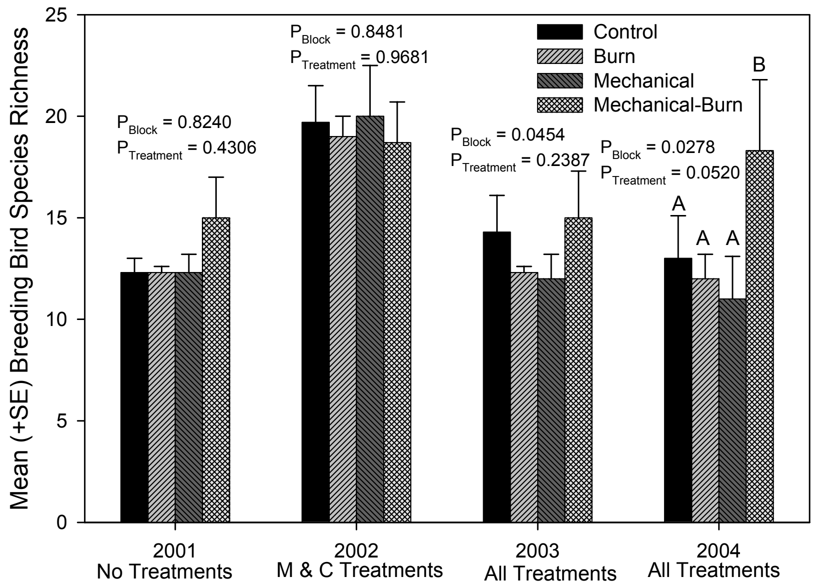

Figure 2—Mean (+SE) breeding bird species richness in 3 treatments: burned (B), mechanical understory felling (M), mechanical understory feeling followed by burning (MB), and controls (C) (n=3 each), Green River Game Land, Polk County, NC. Treatments were not yet implemented in 2001 (pretreatment); in 2002 only (C) (including C and B) and M (including M and MB) were implemented; in 2003 and 2004 all 4 treatments were implemented. P-values represent block effects (P_{Block}) and treatment effects ($P_{Treatment}$). Significant differences among treatments within years were determined by least square means tests and are denoted by different letters.

(in 2003) reduction in numbers in response to all fuel reduction treatments, but differences were not detected by 2004. During 2003 (after treatments had been implemented), the ground-nesting Worm-eating Warbler (*Helmitheros vermivorous*) was less abundant in MB than in C or M, and, in 2004, it was less abundant in both B and MB compared to C or M *(table 2)*. However, in 2001 (before any treatments were implemented), they were less abundant in B than in C or M *(table 2)*. Hooded Warblers (*Wilsonia citrina*) also declined in numbers in all fuel reduction treatments, compared to C, following fuel reduction treatments during 2003 and 2004 *(table 2)*. Indigo Buntings (*Passerina cyanea*), which are associated with young, open habitat, were more abundant in MB than other treatments during 2004 *(table 2)*. Block effects were detected for some species and community-level measures during some years, indicating that there was variability among replicate blocks, at least during some years.

Discussion

The fuel reduction treatments resulted in dramatic changes in habitat structure. Tall shrub cover averaged ≥ 4.3 times lower in all fuel reduction treatments compared to C. Leaf litter depth in both burned treatments (B and MB) averaged ≥ 4.6 times less compared to unburned treatments (M or C). However, snag densities and canopy openness were much higher in MB compared to other treatments, likely contributing to our observed changes in the abundance of some breeding bird species. In MB, snag density doubled, with a corresponding eightfold increase in canopy openness compared to C. High overstory mortality in

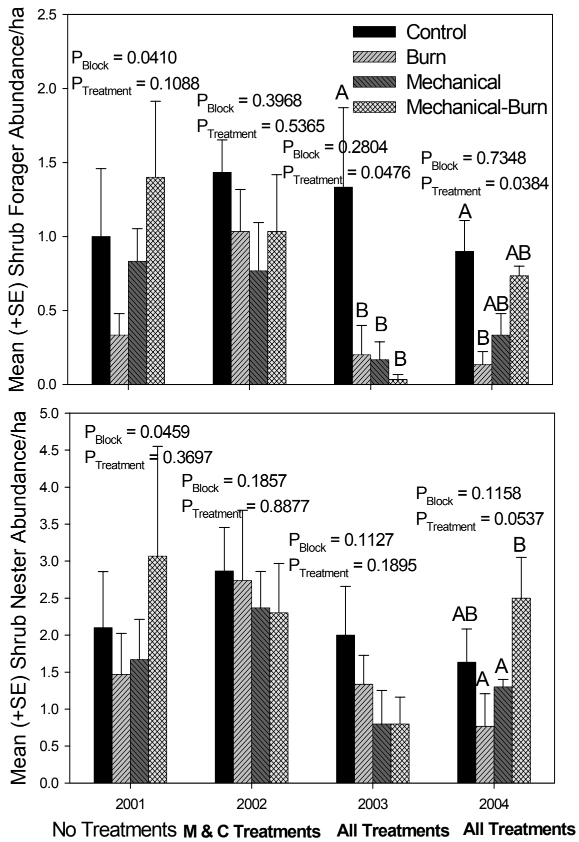

Figure 3—Mean (+SE) abundance of a) shrub foragers, and b) shrub nesters in 3 treatments: burned (B), mechanical understory felling (M), mechanical understory feeling followed by burning (MB), and controls (C) (n=3 each), Green River Game Land, Polk County, NC. Treatments were not yet implemented in 2001 (pretreatment); in 2002 only (C) (including C and B) and M (including M and MB) were implemented; in 2003 and 2004 all 4 treatments were implemented. P-values represent block effects (P_{Block}) and treatment effects ($P_{Treatment}$). Significant differences among treatments within years were determined by least square means tests and are denoted by different letters.

MB sites was likely due to the stress of hotter fires resulting from higher fuel loadings. Xeric site conditions, prolonged drought, and root-borne pathogens may also have contributed to tree mortality in response to burning.

In our community-level analyses, we detected little response by breeding birds to the fuel reduction treatments. We found no difference in total bird abundance among the four treatments, except during 2003 when it was lower in M than in C. Artman et al. (2001) also found no difference in total bird abundance in burned and unburned mixed-oak forest in Ohio. This finding is likely because many common species do not show a detectable response; other species may decline or increase, with little net change in total bird abundance.

During 2004, species richness was higher in MB than in the other treatments. This was due to the addition of a few species that are typically associated with open habitat, created in this case by high tree mortality, such as Chipping Sparrows (*Spizella passerina*), Eastern Bluebirds (*Sialia sialis*), and Indigo Buntings. Higher snag densities may also have contributed to more Eastern Bluebirds (which are cavity nesters) in MB, but we did not document nesting. Weakland et al. (2002) also reported that the mosaic of shrub cover and tree mortality created by patchy burns likely promoted higher bird species richness.

Table 2—*Mean (±SE) abundance (per ha) of select breeding bird species in three treatments: burned (B), mechanical understory felling (M), mechanical understory felling followed by burning (MB), and controls (C) (n = 3 each), Green River Game Land, Polk County, NC. P-values represent block effects (P_{Block}) and treatment effects ($P_{Treatment}$). Differences among treatments within years were determined by least square means tests and are denoted by different letters within rows. Treatments were not yet implemented in 2001 (pretreatment); in 2002 mechanical understory felling had been implemented (in M and MB); in 2003 and 2004 all fuel reduction treatments had been implemented.*

Species Common Name *(Scientific Name)*	Year	Treatment B	 C	 M	 MB	P_{bloc}	$P_{treatment}$
Blue-headed Vireo	2001	0.8±0.5	0.6±0.4	0.4±0.2	0.6±0.4	0.0023	0.4471
(Vireo solitarius)	2002	0.9±0.6	0.8±0.3	1.2±0.5	0.7±0.3	0.0857	0.7818
	2003	0.3±0.2	0.3±0.1	0.4±0.2	0.2±0.1	0.3440	0.7620
	2004	0.3±0.3	0.4±0.2	0.6±0.2	0.3±0.2	0.0644	0.6312
Tufted Titmouse	2001	0.3±0.1	0.4±0.2	0.4±0.3	0.2±0.1	0.5914	0.9273
(Baeolophus bicolor)	2002	0.6±0.2	0.5±0.1	0.7±0.3	0.8±0.3	0.4736	0.8487
	2003	0.4±0.2	0.4±0.2	0.1±0.1	0.4±0.1	0.3500	0.5979
	2004	0.4±0.2	0.4±0.2	0.5±0.2	0.7±0.1	0.1203	0.5178
Hooded Warbler	2001	0.3±0.1	1.0±0.5	0.8±0.2	1.0±0.3	0.0408	0.1715
(Wilsonia citrine)	2002	1.0±0.2	1.2±0.2	0.5±0.1	0.7±0.3	0.4011	0.1822
	2003	0.2±0.2^{A}	1.2±0.5^{B}	0.2±0.1^{A}	0.0±0.0^{A}	0.2850	0.0497
	2004	0.1±0.1^{A}	0.8±0.3^{B}	0.3±0.1^{A}	<0.1±0.1^{A}	0.6631	0.0680
Indigo Bunting	2001	0.0±0.0	0.0±0.0	0.0±0.0	0.3±0.2	0.4219	0.1386
(Passerina cyanea)	2002	<0.1±0.1	0.1±0.1	0.2±0.2	0.2±0.2	0.6016	0.7288
	2003	0.0±0.0	0.0±0.0	0.0±0.0	<0.1±01	0.4219	0.4547
	2004	0.1±0.1^{A}	0.0±0.0^{A}	0.0±0.0^{A}	0.7±0.1^{B}	0.6141	<0.0001
Red-eyed Bunting	2001	1.0±0.5	1.0±0.4	0.9±0.3	1.1±0.2	0.8960	0.9896
(Vireo Olivaceus)	2002	0.8±0.1	0.7±0.2	0.7±0.3	1.1±0.4	0.0556	0.4958
	2003	0.4±0.2^{A}	0.8±0.1^{B}	0.3±0.1^{A}	0.4±0.1^{A}	0.1447	0.0847
	2004	0.3±0.2	0.7±0.2	0.4±0.2	0.4±0.1	0.0339	0.4645
Worm-eating Warbler	2001	0.0±0.0^{A}	0.5±0.2^{B}	0.3±0.2^{B}	0.2±0.2^{AB}	0.0307	0.0741
(Helmitheros vermivorus)	2002	0.4±0.2	0.4±0.1	0.3±0.1	0.3±0.1	0.2553	0.8011
	2003	0.2±0.1^{AB}	0.3±0.1^{A}	0.3±0.1^{A}	0.0±0.0^{B}	0.1053	0.0967
	2004	0.1±0.1^{A}	0.3±0.1^{B}	0.3±0.0^{B}	0.0±0.0^{A}	0.3302	0.0366

At a guild-level, only shrub-associated breeding birds showed a detectable response to the fuel reduction treatments. Interestingly, no response was evident after mechanical understory reductions had been implemented (2002) but before the prescribed burns (which were conducted in 2003). In 2003, shrub foragers showed reduced densities in all fuel reduction treatments; some recovery was evident by 2004 when their numbers were lower only in B compared to C. Artman et al. (2002) also reported declines in ground and shrub nesting and foraging guilds in response to burning in Ohio, but not for other guilds.

Rodewald and Smith (1998) found fewer shrub nesters after an understory removal in an Arkansas oak-hickory forest. In contrast, we found similar numbers of shrub nesters among all treatments during all years except 2004, when they were more abundant in MB than in B or M. Aquilani (2000) reported lower nest success of ground and shrub nesters in an Indiana forest after burning. In our study, canopy foraging and nesting guilds were not affected by the fuel reduction treatments, despite substantially lower canopy cover between MB and the other treatments. Similarly, cavity nesters did not differ in abundance among treatments, despite much higher snag densities in MB. We hypothesize that cavity nesters will increase in MB as snags decay and become suitable for excavation by woodpeckers.

Community-level parameters, such as species richness, total density, or bird abundance within guilds, are useful as indices to gauge the effects of forest management practices. However, they are often too crude to detect changes that may be occurring at the species level. For example, the species richness may be similar among treatments, but the species that are present, or the relative abundance of each, might differ. Similarly, overall bird density does not address what species are more or less abundant in the various treatments. Assignment of birds to guilds may impose rigid categories on species that in fact use many habitats, or components of habitats, for various activities. In our study, however, understory reductions clearly affected birds that use shrubs for foraging and/or nesting at the guild level.

Most bird species showed no significant difference in relative abundance among the fuel reduction treatments, even two years post-burn. For example, Tufted Titmice and Blue-headed Vireos did not differ in abundance among treatments in any year. However, presence, or habitat use by a species, is not necessarily indicative of habitat quality (Van Horne 1983), and must be viewed with caution.

A few species showed a significant response to some or all of the fuel reduction treatments. Red-eyed Vireos nest and forage primarily in tree canopies, and were more abundant in C than in other treatments in 2003, but not during other years. Possibly understory felling in the fuel reduction treatments influenced their abundance in the short-term. Duguay et al. (2001) also found that Red-eyed Vireos were abundant in stands with different levels of basal area, ranging from clearcuts to unharvested stands. Hooded Warblers, which nest and forage primarily in shrubs, occurred in much lower numbers in all fuel reduction treatments compared to C, after all treatments had been implemented (2003 and 2004). This was likely due to reductions in shrub cover in the fuel reduction treatments. However, we did not detect differences in Hooded Warbler abundance among treatments in 2002, after the mechanical understory felling treatments (only) had been done in the M and MB treatments. Worm-eating Warblers are ground nesters, and forage on the ground and in shrubs. They also showed reduced numbers in both burned treatments (B and MB) after the burns had been implemented (but also showed lower numbers in B during 2001 before the burns had been conducted). This is likely due to reductions in shrub cover, and lower leaf litter depth (and probably litter cover) in the burned treatments. In an Ohio oak forest, Artman et al. (2001) also found that some species, including Ovenbirds, Worm-eating Warblers, Hooded Warblers, and Northern Cardinals (*Cardinalis cardinalis*), were negatively affected by 1-4 years of annual burning. Rodewald and Smith (1998) also found fewer Worm-eating Warblers where the understory and (or) tree basal area was reduced.

In contrast, Indigo Buntings showed a significant increase in numbers in the MB treatment during 2004 (15 months after burning). This species is associated with open habitat, but they also nest and forage in shrubs. However, Indigo Buntings did not increase in abundance in B where light and snag numbers were similar to C and M. Their positive response to the MB treatment was likely due to the more open conditions that resulted from tree death after the hotter prescribed fire. Rodewald and Smith (1998) reported a higher density of Indigo Buntings in oak-hickory forest stands that had received understory removal and basal area reduction treatments. Hejl (1994) suggested that bird response to fire varies according to fire severity, and the corresponding post-burn conditions.

After initial changes in vegetation structure from mechanical understory felling or prescribed fire, post-disturbance vegetation structure continues to change rapidly for several years. Snag densities will likely decrease in MB as they decay and fall, and canopy openness will correspondingly increase. The shrub layer will likely recover, and leaf litter depth may increase as dead leaves fall from trees and shrubs. The abundance of food resources for birds, such as insects (Whitehead 2003) and fruit (Greenberg and Levey 2004), also can change over time after disturbance (Blake and Hoppes 1986). Bird species respond differently to habitat structure, so changes in the relative abundance of species might be expected for several years after the initial disturbance. Specifically, we hypothesize that (1) differences in the relative abundance of shrub-associated species will disappear as the shrub layer recovers in fuel reduction treatments, (2) cavity nesters will increase in MB as snags decay, and (3) bird species associated with open habitat will increase in MB as snags fall, at least in the short-term. To fully understand how fire affects breeding birds at the community- and species-level, post-fire surveys of birds and vegetation structure must continue for several years (Raphael et al. 1987).

Summary

Our results indicate that the habitat alterations resulting from mechanical understory felling and (or) burning affect breeding bird communities and species differently. At the guild level, shrub foragers showed the greatest response, with lower abundance in all fuel reduction treatments. In our study, bird response was better detected at the species-level than at the community-level. Most species showed no change in density after the fuel reduction treatments. Some species, such as Hooded Warblers and Worm-eating Warblers, decreased in density after some or all treatments, whereas others, such as Indigo Buntings, increased in abundance. Responses likely differed among bird species depending upon habitat suitability for nesting, foraging, and cover. Heterogeneous habitat conditions, especially within the B and MB treatments, likely reduced our ability to detect some breeding bird response to the fuel reduction treatments. To fully understand how fire and fire surrogates for fuel reduction affect breeding bird communities, post-fire surveys of birds and vegetation structure must continue for several years.

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