RESEARCH ARTICLE

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Effects of Prescribed Surface Fires On Ground- and Shrub-Nesting Neotropical Migratory Birds in a Mature Indiana Oak Forest, USA

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ABSTRACT: Prescribed fires have been used as a forest vegetation management tool in the eastern United States during the past decade, but concerns have been raised about direct or indirect adverse effects on Neotropical migrant bird species that nest in forest interior habitats. Prescribed fires were set in 1993 and 1995 in a mature hardwood forest in southern Indiana, USA, to reduce shade-tolerant understory woody vegetation and thereby increase the abundance and diversity of ground layer vegetation and seedlings of tree species that require moderate light levels (e.g., *Quercus* L. spp.). The objective of this study was to determine if prescribed fires reduced the abundance or reproductive success of ground- and shrub-nesting Neotropical migrant bird species. The burned area and an adjacent unburned area were studied during the summers of 1996 and 1997. An unlimited-radius point count method was used to determine relative abundance. Nests were monitored to determine fledging success. Vegetation structure was quantified at nest sites and at random points to assess fire effects and bird nest-site selection. Abundance of birds in this nesting guild was greater in the unburned area during both years. The greatest difference in abundance was for ovenbird *(Seiurus aurocappilus* Linnaeus). The probability of nest success for all bird species in this nesting guild combined, determined by the Mayfield method, was significantly lower in the burned area (0.125) than in the unburned area (0.291). Abundance of the brood parasite brown-headed cowbird *(Molothrus ater* Boddaert) did not differ between burned and unburned areas. However, the probability of nest success for parasitized nests (0.140) was lower than that of unparasitized nests (0.735). The mean number of host young fledged from successful nests was significantly lower in parasitized nests (1.3) than from unparasitized nests (3.0). Pre-scribed fires significantly reduced vegetative cover in the burned area. Nest sites in the burned area had higher vegetative cover than random points, indicating that birds may have selected nest sites that were less affected by the fire. While prescribed fires that burn in a "natural" hit-or-miss pattern may retain nesting habitat for bird species in this nesting guild, lower nest success in the burned area indicates that management for desirable vegetation and for this nesting guild may not be compatible within the same forest stand at the same time. This argues for planning at a landscape level to attain objectives for both vegetation composition and maintenance of bird species diversity.

Index terms: abundance, Neotropical migrants nesting success, oak-hickory forest, pre-scribed burning

INTRODUCTION

A large body of scholarly work has documented that fire was an important influence on the structure and species composition of many forest types in the eastern United States in the past (see reviews by Abrams 1992, Lorimer 1993, Pyne 1982). However, state and federal fire suppression policies, initiated early in the twentieth century, have caused vegetation in many parts of this region to change substantially from that which prevailed before suppression (Abrams 1992, Lorimer 1993, Pyne 1982). Within forests that were historically dominated by oak *(Quercus L.* spp.) and pine *(Pinus* L. spp.), abundance of species that are fire-tolerant, but shade-intolerant, has decreased, while abundance of fire-sensitive species that are more shade-tolerant has increased.

In many cases, vegetation changes attributed to fire suppression are considered undesirable due to reduced levels of biodiversity (loss of fire-dependent species and community types) or the lower economic value of fire-sensitive tree species relative to fire-tolerant species (Lorimer 1993). One response to these concerns has been a re-turn to the use of fire as a vegetation management tool to maintain or expand populations and communities of fire-tolerant species (Van Lear and Watt 1993).

As land managers began to use fire to manage vegetation, questions were raised regarding adverse effects on various animal populations, especially obligate forest-nesting Neotropical migrant bird species. There is strong evidence that populations of migrant songbirds that breed in temperate North America and over-winter in subtropical regions have declined over the last 50 years (Robbins et al. 1989, Askins et al. 1990, Hagan and Johnston 1992, Askins 1995, Herkert 1995, Robin-son et al. 1995). Robinson et al. (1995) attributed these population declines to the fragmentation of formerly large, contiguous areas of forest in North America. Habitat fragmentation has resulted in higher rates of nest predation and brood parasitism by the brown-headed cowbird *(Molothrus ater* Boddaert), especially among a number of obligate forest-dwelling song-birds (Brittingham and Temple 1983, Askins 1995, Robinson et al. 1995).

Fire may adversely affect ground- and low-shrub-nesting bird species by reducing vegetative cover. Martin (1993) reported that predation rates were lower at nests concealed by vegetation and that birds may have selected nest sites with dense vegetation to reduce nest predation. Similarly, reduction in understory cover by fire may result in increased levels of brood parasitism. Cowbirds primarily locate host nests by following potential host species as they move to and from their nest (Thompson and Gottfried 1976, Lowther 1979).

The objectives of this study were to (1) determine the presence and relative abundance of ground- and shrub-nesting Neotropical migrant bird species in adjacent burned and unburned areas of a mature, oak-dominated forest; (2) compare the reproductive success and brood parasitism rates of these species in the burned and unburned areas; and (3) compare nest-site habitat characteristics of these species in burned and unburned areas. Species included in this nesting guild are ovenbird *(Seiurus aurocappilus* Linnaeus), Kentucky warbler *(Oporornis formosus* Wilson), hooded warbler *(Wilsonia citrina* Boddaert), black-and-white warbler *(Mniotilta varia* Linnaeus), and worm-eating warbler *(Helmitheros vermivorus* Gmelin).

STUDY AREA

Our study site was located on Fork Ridge, north of Kurtz, in the northwest corner of Jackson County, within the Hoosier National Forest, Indiana, USA. This area comprises small ridgetops, steep slopes (20-40%), and narrow hollows, with an elevation range from 195 to 290 m (Van Kley et al. 1995). The surrounding landscape is an approximately equal mixture of agricultural and forest lands. This site is near the southeast corner of the main body of the Pleasant Run unit of the Hoosier National Forest, one of the largest blocks of contiguous mature forest between the Appalachian Mountains and the Mississippi River.

The burned area on Fork Ridge was north of Buffalo Pike Road and a natural gas line, while the unburned area was south of the road. These two adjacent areas have similar topography and soils. Both study areas were approximately 140 ha, bordered by mature forest around most of their perimeter, but contiguous with agricultural fields along small segments of their perimeter.

Based on both vegetation descriptions in the fire prescription documentation and vegetation sampling for this study (Aquilani 1998), the overstory in burned and unburned areas was similar. Chestnut oak *(Quercus prinus* L.) woodlands occurred on high ridges and knobs, oak-dominated forests (including *Q. alba* L., *Q. coccinea* Muenchh., and *Q. velutina* Lam.) occurred on upper slopes, oak-hickory forest (including *Q. alba, Q. rubra* L., *Carya ovata* [Mill.] K. Koch, *C. glabra* [Mill.] Sweet var. *glabra,* and C. *tomentosa* [Poir.] Nutt.) occurred on lower slopes, and beech-maple forest *(Fagus grandifolia* Ehrh. and *Acer saccharum* Marsh.) occurred in and around hollow bottoms. Understory woody vegetation was dominated by greenbriar *(Smilax* L. spp.) and saplings of red maple *(Acer rubrum L.),* American beech, sassafras *(Sassafras albidum* [Nutt.] Nees), and flowering dogwood *(Cornus florida L.).*

In 1993 the U. S. Forest Service began a program of prescribed surface fires at the Fork Ridge site to reduce the density of shade-tolerant understory woody vegetation (mainly flowering dogwood and saplings of beech and maple species). The objectives of this fire program included enhancing understory herbaceous plant diversity and increasing regeneration of tree species with intermediate shade tolerance (e.g., oaks). The first fire, set in March 1993, was initiated at the downslope edge of the burn unit and was allowed to spread naturally, in a hit-or-miss pattern, to the upslope boundary at the ridgecrest. The postfire evaluation described that fire as hot and rapid, covering 30% to 80% of the project area; it top-killed 3% to 50% of the targeted species (red maple and American beech) with diameter at breast height up to 5 cm (unpubl., data, U.S. Forest Service, Bedford, Ind.). Approximately 50% to 70% of the leaf litter layer was consumed. A second fire was set in April 1995. However, the prescription for this fire called for spot fires to be set in areas missed by the natural spread of the fire to attain a more "even" burn. The postfire evaluation of this prescription estimated 80% top-kill of the targeted woody species. See Ring (1998) for more detailed documentation of the fire plans and outcomes.

METHODS

Relative Abundance of Birds

Birds were surveyed during the breeding season (18 May to 25 June 1996 and 15 May to 26 June 1997) using unlimited-radius point counts (Hutto et al. 1986, Thompson and Schwalbach 1995). Within each treatment area, 18 permanent points were established in 1996. In 1997, 5 additional points were established in each area. Points were spaced >150 m apart to en-sure independence among sample counts, and were not located within 50 m of an edge with surrounding nonforested areas.

Points were visited three times during each breeding season. During a 10-minute observation period, a tally of all birds seen or heard was recorded. Surveys were con-ducted between 0545 and 0900 hours. The order in which burned and unburned areas were visited was alternated daily, as were the times for the three observations at each point. All point counts were conducted on calm (wind speed < 20 km/hour) mornings without precipitation (Robbins 1981). Bird detections were recorded as either auditory or visual to determine if reduction of understory cover in the burned area resulted in birds being more easily detected visually. Detections that included both an auditory and a visual identification of one bird were recorded as visual. All bird surveys were done by a single individual. For each species, the number of birds detected per point count plot was averaged across the three days of observations.

Nesting Success

Nesting success data for ground- and shrub-nesting Neotropical migrants were obtained during the 1996 and 1997 breeding seasons. Nest searches were conducted using multiple observers (two or three) in 1996, and by one individual in 1997. The two treatment areas received equal search effort (person-hours) during each breeding season. At 3- to 4-day intervals, the number and species (host or parasite) of young in the nest were recorded until nesting effort succeeded or all young died or disappeared. Nests were considered successful if at least one offspring of the nesting species was fledged.

Nest Site Characteristics

Herbaceous ground cover, understory horizontal cover, understory woody stem density, and overstory basal area were measured at each nest site after nesting effort terminated. Herbaceous cover was measured in four 1-m' plots located 6 m from each nest along the four cardinal directions. In each plot the total cover of all herbaceous vegetation < 1.4 m tall was visually estimated using nine cover class-es (0=0%, 1=1-4%, 2=5-10%, 3=11-25%, 4=26-50%, 5=51-75%, 6=76-90%, 7=91-95%, and 8 for >95%) (Muir and McCune 1988). Cover class values for the four plots at each nest site were averaged. Understory horizontal cover was measured using a 2.5-m-tall x 0.15-m-wide cover board, with alternating 0.5-m bands of white and orange paint. The cover board was placed vertically at the nest and viewed from 15 m away in each of four directions: uphill, downhill, and to either side along the topographic contour. The percent of each 0.5- n band on the cover board obscured by vegetation was visually estimated using the cover classes described above. All cover estimations were made by one individual. The four cover class values for each 0.5-m band on the cover board were averaged for each nest site. Density of woody stems < 5 cm dbh was determined along four 25-m transects radiating uphill, downhill, and to either side from the nest. The number of live and dead stems en-countered while walking along transects with arms outstretched (1.7-m path) were counted. A Panama Pipe angle gauge (bas-al area factor of 10 ft^2 $acre^{-1}$) was used to determine overstory basal area at each nest.

To determine if bird nest-site selection was influenced by vegetation structure, we measured the same vegetation structure variables measured at nest sites at 12 randomly located points in each of the burned and unburned areas. Three sample points were randomly located in each of the following stratification categories: nort least aspect (315 to 135 degrees), southwest aspect (136 to 314 degrees), upper slope position (between ridgetop and midslope position), and lower slope position (between hollow bottom and midslope position). All vegetation sample points were located in mature forest areas that were free of any evidence of overstory blowdown dam age (debris, large canopy gaps). These data were also used to evaluate the effects of the pre-scribed fires on understory vegetation structure.

Statistical Analyses

Calculation of the probability of nesting success was based on Mayfield (1961, 1975), with standard errors calculated using the method of Johnson (1979). We tested for differences in the probability of nesting success using the computer program CONTRAST, which implements a Chi-square test for the comparison of rate estimates (Sauer and Williams 1989). Two-sample Z-tests for proportions were used to compare the proportion of visual versus auditory observations between burned and unburned areas. Fisher's exact test was used to compare the proportion of nests parasitized by brown-headed cow-birds between burned and unburned areas. Two-sample t-tests were used to compare the mean numbers of host and cowbird eggs per nest between burned and unburned areas, and the mean number of host young fledged per nest between cowbird parasitized and unparasitized nests. Comparisons

Table 1. Mean number of individual birds per unlimited-radius point count in burned and unburned areas at Fork Ridge, Hoosier National Forest, Indiana, for the time periods 18 May to 25 June 1996 (n = 18), and 15 May to 26 June 1997 (n = 23). Values are the average number of individuals detected from three visits to each point. P-values for the five species-specific comparisons that are followed by * are significant at the experiment-wise Type I error rate of p 0.05, as determined by the sequential Bonferroni procedure.

Year/ Species	Burned Area	Unburned Area	p-value
1996			
Ground/Low-Shrub Nesting Guild	0.122	0.248	0.013*
Ovenbird	0.019	0.278	0.006*
Kentucky warbler	0.000	0.167	0.071
Black-and-white warbler	0.000	0.074	0.075
Worm-eating warbler	0.167	0.130	0.736
Hooded warbler	0.130	0.204	0.779
Brown-headed cowbird	0.407	0.463	0.372
1997			
Ground/Low-Shrub Nesting Guild	0.053	0.196	0.001*
Ovenbird	0.043	0.391	0.005*
Black-and-white warbler	0.000	0.145	0.010*
Kentucky warbler	0.029	0.188	0.187
Hooded warbler	0.043	0.130	0.215
Worm-eating warbler	0.203	0.275	0.761
Brown-headed cowbird	0.362	0.507	0.185

of vegetation variables between burned and unburned areas, and between nest sites and random points, were done using two-sample t-tests or Mann-Whitney U-tests. Because two-sample tests for multiple bird species and multiple vegetation variables addressed the same overall null hypothesis (prescribed fire had no effect on birds or vegetation), a sequential Bonferroni procedure (Holm 1979) was used to control the experiment-wise Type I error rate for these analyses (Chandler 1995).

RESULTS

Bird Abundance

In both 1996 and 1997, the overall relative abundance of species in this nesting guild was significantly less in the burned area than in the unburned area (Table 1). Oven-birds were less abundant in the burned area in both years, and black-and-white warblers were less abundant in the burned area in 1997. The abundance of Kentucky warblers, worm-eating warblers, and hooded warblers did not differ significantly between burned and unburned areas in either year.

There was no significant difference in per-cent visual observations of Neotropical bird species between the burned area (2.4%) and the unburned area (2%) (p= 0.87, two-sample Z-test with n=41 and 98, respectively). This result indicated that reduction in vegetative cover in the burned area did not make detection of these birds easier. More brown-headed cowbird observations in the burned area were visual (47%) than in the unburned area (20%) (p=0.004, two-sample Z-test with n=47 and 59, respectively). However, the abundance of brown-headed cowbirds did not differ significantly between burned and unburned areas (Table 1).

Nest Success

Because of the relatively small number of nests found, nest success data for 1996 and 1997 were combined. Pooling was justified because there was no significant difference in vegetation variables between these two years (see below). Of 28 nests found during this study, 21 belonged to worm-eating warblers, 4 to hooded warblers, and 3 to Kentucky warblers. Eleven nests were found in the burned area and 17 nests were found in the unburned area. Only worm-eating warbler nests were found in both burned and unburned areas.

The probability of nest success from incubation to fledgling was higher in the unburned area (0.29 ± 0.02), 10 of 17 nests lost over 183 nest-days) than in the burned area (0.13, S.E. = 0.03, 10 of 11 nests lost over 111 nest-days) (X^2 = 26.8, df = 1, p < 0.001). There was no difference in the mean number of host eggs per nest at the time of initial observation between burned (3.7, S.E. = 0.24) and unburned (3.7, S.E. = 0.24) sites. The one successful nest in the burned area fledged four host young and was not parasitized by brown-headed cow-birds. The seven successful nests in the unburned area fledged an average of 2.3 (S.E. = 1.1) host young, and three of these nests fledged a single cowbird young each. There was no difference in the mean number of brown-headed cow-bird eggs per nest between burned (1.2, S.E. = 0.23) and unburned (1.0, S.E. = 0.19) areas (t = -0.61, df = 26,p = 0.55). In 5 of 10 failed nests in the burned area, the young completely disappeared between two successive observations, while the young in the remaining 5 nests disappeared progressively over multiple observations. In 7 of 10 failed nests in the unburned area, the young disappeared between two successive observations, while the young in 3 nests disappeared progressively over time.

While more nests in the burned area were parasitized by brown-headed cowbirds than in the unburned area (91% and 77%, re-

Table 2. Mean (±SE) for vegetation structure variables at worm-eating warbler nest sites and random points in burned and unburned areas at Fork Ridge, Hoosier National Forest, Indiana, 1996 and 1997. P-values followed by an * are significant with experiment-wise error rate limited to p < 0.05 using the sequential Bonferroni procedure across nine related tests.

Vegetation Variable	Nest Site	Random Point	p-value
Burned Area	**n = 11**	**n = 11**	
Herbaceous cover	2.7 (1.0)	3.3 (1.0)	0.184
Horizontal cover			
(0-0.5 m)	3.4 (0.7)	2.6 (1.1)	0.010
(0.5-1.0 m)	1.4 (0.5)	0.7 (0.6)	0.002*
(1.0-1.5 m)	1.1 (0.7)	0.4 (0.4)	0.004*
(1.5-2.0 m)	0.4 (0.3)	0.3 (0.3)	0.515
(2.0-2.5 m)	0.3 (0.3)	0.4 (0.2)	0.849
Woody stem (dbh 5 cm) density (per 100 m^2)			
Live stems	4.6 (1.2)	5.8 (2.4)	0.506
Dead stems	10.0 (3.7)	9.9 (4.0)	0.867
Overstory basal area (m^2/ha)	16.1 (5.4)	17.3 (8.1)	0.551
Unburned Area	**n = 10**	**n = 11**	
Herbaceous cover	2.6 (0.8)	2.8 (1.1)	0.396
Horizontal. cover			
(0-0.5 m)	3.6 (0.9)	4.3 (1.9)	0.643
(0.5-1.0 m)	2.6 (0.6)	2.8 (1.6)	0.778
(1.0-1.5 m)	2.3 (0.6)	2.7 (1.3)	0.643
(1.5-2.0 m)	2.1 (0.8)	2.4 (1.2)	0.304
(2.0-2.5 m)	1.8 (0.7)	2.3 (1.3)	0.307
Woody stem (dbh 5 cm) density (per 100 m^2)			
Live stems	25.1 (7.4)	15.5 (4.0)	0.033
Dead stems	4.6 (0.9)	3.1 (1.5)	0.134
Overstory basal area (m^2/ha)	20.3 (5.9)	18.2 (1.9)	0.393

spectively), this difference was not significant (Fisher's exact test, two-tailed p = 0.62). However, the probability of success for parasitized nests was significantly lower (0.14, S.E. = 0.02, 19 of 23 nests lost over 222 nest-days) than for unparasitized nests (0.74, S.E. = 0.01, 1 of 5 nests lost over 72 nest-days) (X^2 = 653.2, df = 1, p < 0.001). The average number of host young fledged from successful parasitized nests (1.3, S.E. = 0.33) was significantly less than the number of host young fledged from successful unparasitized nests (3.0, S.E. = 0.41) (t = 2.98, df = 5, two-tailed p < 0.04). In only one nest did all young of the host species disappear while a live cowbird chick remained in the nest. In the remaining parasitized nests, the cowbirds shared the nesting success or failure of the host species.

Nest Site Characteristics

Because species may differ in nest-site selection characteristics, this analysis was done using data only for worm-eating warblers. Nest-site vegetation data for 1996 and 1997 were combined to increase statistical power of this analysis. This pooling of data was justified because nest sites for each year were independent, and there were no significant differences in vegetation between these two years (see below). Worm-eating warbler nest sites in the burned area had significantly greater horizontal cover from 0.5 to 1.5 m above ground than randomly located points in that area (Table 2). There were no significant differences in herbaceous vegetation cover, small woody stem density, or over-story basal area between nest sites and random points in the burned area. In the unburned area, there were no differences between nest sites and randomly located sites for any vegetation structure variable (Table 2).

Worm-eating warbler nest sites in the burned area had significantly less horizontal cover (> 0.5 m high), and lower live small woody stem density than at nest sites for this species in the unburned area (Table 3). Nest sites in the burned area had significantly higher density of small dead woody stems than in the unburned area, indicating that the lower horizontal cover in the burned area was due to destruction of small woody stems by the prescribed fires.

Table 3. **Mean (±SE) for vegetation structure variables at worm-eating warbler nest sites in burned and unburned areas at Fork Ridge, Hoosier National Forest, Indiana, 1996 and '1997. P-values followed by an * are significant with experiment-wise error rate limited top < 0.05 using the sequential Bonferroni procedure across nine related tests.**

Vegetation Variable	Burned Area	Unburned Area	p-value
Herbaceous cover	2.7 (1.0)	2.6 (0.8)	0.887
Horizontal cover			
(0-0.5 m)	3.4 (0.7)	3.6 (0.9)	0.477
(0.5-1.0 m)	1.4 (0.5)	2.6 (0.6)	<0.001*
(1.0-1.5 m)	1.1 (0.7)	2.3 (0.6)	0.002*
(1.5-2.0 m)	0.4 (0.3)	2.1 (0.8)	<0.001*
(2.0-2.5 m)	0.3 (0.3)	1.8 (0.7)	<0.001*
Woody stem (dbh 5 cm) density (per 100 m-)			
Live stems	4.6 (1.2)	25.1 (7.4)	0.001*
Dead stems	10.0(3.7)	4.6 (0.9)	0.001*
Overstory basal area (m^{2}lha)	16.1(5.4)	20.3 (5.9)	0.914

Effects of Prescribed Fires on Vegetation Structure

Comparisons of means for vegetation structure variables measured at the same randomly located points in 1996 and 1997 indicated there was no significant change in vegetation between these two years. The measurements at these points in successive years are not independent observations, and only 1997 data are presented to document recovery of understory vegetation three growing sea-sons after the last fire.

Live small woody stem density and horizontal cover at levels > 50 cm above ground were significantly lower in the burned area than in the unburned area (Table 4), while the density of dead small woody stems was significantly higher in the burned area. Herbaceous ground cover, horizontal cover < 50 cm above ground, and overstory tree basal area did not differ between burned and unburned areas.

DISCUSSION

Relative Abundance of Ground- and Shrub-Nesting Neotropical Migrant Bird Species

When the data for all five study species were pooled, there was strong evidence that Neotropical migrant birds that nest on the ground or in low shrubs were less abundant in the burned area than in the adjacent unburned area. These results are consistent with those of other studies of the effect of reduced vegetative cover on the abundance of bird species. Rodewald and Smith (1998) documented decreased abundance of worm-eating warblers and ovenbirds after mechanical removal of the understory in an Arkansas oak-hickory forest. Annand and Thompson (1997) found that the relative abundance of both hooded warblers and ovenbirds in Missouri forests was greater in selection-cut and uncut mature forests than in clear-cut or shelterwood cut areas. Nonetheless, we cannot eliminate the possibility that the abundance of these bird species differed between the burned and unburned areas prior to the prescribed fire. This was a comparative study, rather than a before-after study, due to a lack of pre-fire data for the burned area. However, the burned and unburned areas were contiguous, and the overstory vegetation and site characteristics were similar. Hence, there is no compelling reason to believe that there was a difference in abundance of these bird species between the sites prior to the fire.

Table 4. Mean (E) for vegetation structure variables measured at randomly located points in the burned and unburned areas at Fork Ridge, Hoosier National Forest, Indiana, as measured in July and August 1997 (n = 11 sample points in each area). P-values followed by an * are significant with experiment-wise error rate limited to p < 0.05 using the sequential Bonferroni procedure across nine related tests.

Vegetation Variable	Burned Area	Unburned Area	p-value
Herb cover	3.5 (1.0)	2.9 (1.2)	0.156
Horizontal cover			
0-0.5 m	2.7 (0.9)	4.2 (1.9)	0.015
0.5-1.0 m	0.9 (0.5)	2.6 (1.7)	0.001
1.0-1.5 m	0.4 (0.4)	2.6 (1.5)	0.001
1.5-2.0 m	0.5 (0.3)	2.3 (1.6)	0.001
2.0-2.5 m	0.4 (0.2)	2.3 (1.5)	0.002
Woody stem (dbh 5 cm) density (per 100 m^2)			
Live stems	5.8 (2.4)	16.4 (7.3)	0.001
Dead stems	9.9 (4.0)	2.9 (2.4)	0.0001
Overstory basal area (m^2/ha)	17.3 (8.1)	18.2 (1.9)	0.934

Nesting Success

While our data provided strong evidence that nesting success of ground- and low-shrub-nesting Neotropical migrant bird species was lower in the burned area than in the unburned area, the causes of this difference are not clear. Our original pre-diction was that nesting success would be lower in the burned area because the fires would reduce vegetative cover around nest sites and increase the likelihood that nests would be found by visual-hunting predators and brood parasites. However, there was no significant difference between burned and unburned areas in the percent of nests parasitized by cowbirds. Parasitized nests fledged fewer host young, but we observed only one case of nest failure that was likely due to cowbird brood parasitism alone. No nest failed because of abandonment of eggs or young by the adult birds or because of physical damage (e.g., falling tree limbs). Hence, we believe that in all cases but the one nest described above, the likely cause of nest failure was predation or a mix of brood parasitism and predation. There is some evidence that nests parasitized by brown-headed cow-birds may have in-creased risk of predation, due to increased frequency and loudness of begging calls by nestlings (Dearborn 19991. The interaction of increased noise and activity at parasitized nests with reduced vegetative cover in the burned area may explain the lower nesting success rate in this area than in the unburned area. However, we have no way of determining if the predators responsible for nesting failure were visual/auditory hunters that may have benefitted from reduced vegetative cover, or were predators that found the nests by other means.

Nest Site Habitat Characteristics

Our results suggest that worm-eating warblers nesting in the burned area selected nest sites in patches of understory vegetation that escaped the full effect of the pre-scribed fires. If so, prescribed fires that are allowed to burn in a "natural," uneven pattern may retain more nesting habitat than uniform burns, thereby reducing the negative impact of fire on this nesting guild. However, nest sites in the burned area had less vegetative cover than nest sites in the unburned area, and this was associated with a lower nest success rate in the burned area. Thus, while hit-and-miss prescribed fires may retain nesting habitat, overall reproductive success of species in this nesting guild may still be reduced by pre-scribed surface fires.

Lack of appropriate nest-site habitat might explain the complete absence of Kentucky warblers in the burned area. The three Kentucky warbler nest sites found in the unburned area were all in dense tangles of greenbriar, where there was considerable horizontal cover. Virtually all aboveground greenbriar was eliminated in the burned area.

Vegetative Structure

The lack of a difference between burned and unburned areas in herbaceous ground cover and horizontal cover < 50 cm above ground likely reflects rapid regrowth of plants from perennial belowground structures that were little affected by the cool surface fire. Since the fires were set in the spring, and vegetation sampling was done in July and August of both years, the herbaceous cover data presented here reflect regrowth after three growing seasons.

Our data indicate that horizontal cover provided by woody understory vegetation was still lower in the burned area than in the unburned area three growing seasons after the most recent fire. The greater density of dead small woody stems in the burned area (most of which were charred) indicated that the lower amount of horizontal vegetative cover in the burned area probably was due to the prescribed fires.

Management Implications

The results of our study indicate that pre-scribed surface fires may adversely impact populations of bird species that nest on the ground or in low shrubs in mature forests for an as yet undetermined period of time. Adverse effects included reduced relative abundance and reduced reproductive success.

While the results of this study indicate that fires adversely impacted some forest bird species, a parallel study of understory vegetation (Ring 1998) provided evidence that the fires had the intended effects of in-creasing plant diversity and regeneration of tree species characteristic of the oak-hickory forest. In the absence of fire, shade-tolerant tree species such as maples and beech may come to dominate large areas that are currently oak-hickory forest (Abrams 1992). The loss of mast-producing oak and hickory species will reduce availability of food sources important for many species. Thus, it seems the land manager is left to choose between two undesirable outcomes. However, if managers take a landscape-scale perspective, prescribed fire could be implemented in patches, leaving larger areas unburned each year. If the objective of enhancing oak regeneration using prescribed fires is attained, oak saplings might ultimately pro-vide the vegetative cover that appears important for the ground- and low-shrub nesting guild. However, the amount of time and number of fires required to attain this outcome will vary from place to place, and must be determined by further research. Nonetheless, it should be possible to en-sure regeneration of the oak-hickory forest and maintain populations of these for-est-nesting bird species within a landscape, if not always within the same forest stand at the same time.

We believe this study is an object lesson for the opportunities and pitfalls of re-search in support of adaptive management. First, since this was a "case study" of fire effects on bird species at a single site, our results may or may not be representative of outcomes at other sites. However, given the complex nature of fire effects on ecological communities, we believe the best path toward understanding these effects will be a progressive accumulation of knowledge from case studies across a range of sites. Second, this was a comparative study, rather than a more powerful "before-and-after" study. With comparative studies, there is always the possibility that differences between study areas may have existed prior to the management action and so are not the result of the action. Managers should involve research scientists in the planning of management actions, so that the best possible assessment of outcomes can be developed. Only with scientifically rigorous assessment of management outcomes will the promise of adaptive management and ecosystem man-agement be fulfilled.

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LITERATURE CITED

Abrams, M.D. 1992. Fire and the development of oak forests. BioScience 42:346-353.

Annand, E.M. and F.R. Thompson. 1997. For-est bird response to regeneration practices in central hardwood forests. Journal of Wildlife Management 61:159-171.

Aquilani, S.M. 1998. The effects of prescribed surface fire on ground- and shrub-nesting nearctic migrants at Fork Ridge, Hoosier National Forest, 1996 and 1997. M.S. the-sis, Ball State University, Muncie, Ind. 53 pp.

Askins, R.A. 1995. Hostile landscapes and the decline of migratory songbirds. Science 267:1956-1957.

Askins, R.A., J.F. Lynch, and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. Pp. 1-57 in D.M. Power, ed., Current Ornithology, Vol. 7. Plenum Press, New York. 402 pp.

Brittingham, M.C. and S.A. Temple. 1983. Have cowbirds caused forest songbirds to decline? BioScience 33:31-35.

Chandler, R.C. 1995. Practical considerations in the use of simultaneous inference for multiple tests. Animal Behavior 49:524-527.

Dearborn, D.C. 1999. Brown-headed cowbird nestling vocalization and risk of nest preda-tion. The Auk 116:448-457.

Hagan, J.M. and D.W. Johnston. 1992. Ecolo-gy and Conservation of Neotropical Land-birds. Smithsonian Institution Press, Washington, D.C. 609 pp.

Herkert, J.R. 1995. An analysis of Midwestern breeding bird population trends: 1966-1993. American Midland Naturalist 131:41-50.

Holm, S. 1979. A simple sequentially rejective multiple test procedure. Scandinavian Jour-nal of Statistics 6:65-70.

Hutto, R.L., S.M. Pletshet, and P. Hendricks. 1986. A fixed radius count method for non-breeding and breeding season use. Auk 103:593-602.

Johnson, D.H. 1979. Estimating nest success: the Mayfield Method and an alternative. Auk 96:651-661.

Lorimer, C. 1993. Causes of the oak regenera-tion problem. Pp. 14-39 *in* D. Loftis and C.E. McGee, eds., Oak regeneration: seri-ous problems, practical recommendations. Symposium Proceedings, 8–10 September 1992, Knoxville, Tennessee. General Tech-nical Report SE-84, U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Asheville, N.C.

Lowther, P. E. 1979. Nest selection by brown-headed cowbirds. Wilson Bulletin 91:118-122.

Martin, T. E. 1993. Nest predation and nest sites. BioScience 43:523-533.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

. 1975. Suggestions for calculating nesting success. Wilson Bulletin 87:456-466.

Muir, P.S. and B. McCune. 1988. Lichens, tree growth, and foliar symptoms of air pollu-tion: are the stories consistent? Journal of Environmental Quality 17:361-370.

Pyne, S.J. 1982. Fire in America: A Cultural History of Wildland and Rural Fire. Prince-ton University Press, Princeton, N.J. 645 pp.

Ring, J.L. 1998. The effects of prescribed fire on herbaceous plant community composi-tion and tree seedling density in a mature oak forest: Fork Ridge, Hoosier National Forest, Pleasant Run Unit, Jackson County, Indiana. M.S. thesis, Ball State University, Muncie, Ind. 89 pp.

Robbins, C.S. 1981. Bird activity levels related to weather. Pp. 301-310 *in* C. J. Ralph and J.M. Scott, eds., Estimating Numbers of Terrestrial Birds. Studies in Avian Biology VI, Cooper Ornithological Society, Lawrence, Kan. 630 pp.

, J.R. Sauer, R.S. Greenberg, and S. Droege. 1989. Population declines in North American birds that migrate to the Neotropics. Proceedings, National Academy of Sciences 86:7658-7662.

Robinson, S.K., F.R. Thompson, T.M. Donovan, D.R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

Rodewald, P.G. and Smith, K.G. 1998. Short-term effects of understory and overstory management on breeding birds in Arkansas oak-hickory forests. Journal of Wildlife Management 62:1411-1417.

Sauer, J.R. and B.K. Williams. 1989. Generalized procedures for testing hypotheses about survival or recovery rates. .Journal of Wild-life Management 53:137-142.

Thompson, C.F. and B.M. Gottfried. 1976. How do cowbirds find nests to parasitize? Wilson Bulletin 88:673-675.

Thompson, F.R. and M.J. Schwalbach. 1995. Analysis of sample size, counting time, and plot size from an avian point count survey on Hoosier National Forest, Indiana. Pp. 45-48 *in* C.J. Ralph, J.R. Sauer, and S. Droege, tech. eds., Monitoring Bird Populations by Point Counts. General Technical Report PSW-GTR-149, U.S. Department of Agriculture, Forest Service, Pacific South-west Research Station, Albany, Calif. 181 pp.

Van Kley, J.E., G.R. Parker, D.P Franzmeir, and J.C. Randolf. 1995. Field guide to the ecological classification of Hoosier Nation-al Forest and surrounding areas of Indiana. U.S. Department of Agriculture, Forest Service, Hoosier National Forest, Bedford, Ind. 75 pp.

Van Lear, D.H. and J.M. Watt. 1993. The role of fire in oak regeneration. Pp. 66-78 *in* D. Loftis and C.E. McGee, eds., Oak regeneration: serious problems, practical recommendations. Symposium Proceedings, 8–10 September 1992, Knoxville, Tennessee. General Technical Report SE-84, U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Asheville, N.C. 319 pp.