Effect of Prescribed Burning of Clearcuts on Ruffed Grouse Brood Habitat

Darroch M. Whitaker, *Department of Fisheries and Wildlife Sciences, Virginia Tech, Blacksburg, VA 24061-0321*

Dean F. Stauffer, *Department of Fisheries and Wildlife Sciences, Virginia Tech, Blacksburg, VA 24061-0321*

Gary W. Norman, *Virginia Department of Game and Inland Fisheries, Rt. 1, Box 243 A., Mt. Sidney, VA 24467*

Woodrow B. Chandler, *Deerfield District, U.S. Forest Service, Route 6, Box 419, Staunton, VA 24401*

Abstract: We evaluated short-term effects of prescribed burning of clearcuts on potential ruffed grouse *(Bonasa umbellus)* brood habitat in oak-hickory forests in western Virginia. We divided six <1-year-old clearcuts into two portions and designated one portion for prescribed burning during late fall or winter. Because of dry conditions, only four treatment areas were burned. We monitored habitat conditions on burned and unburned portions of clearcuts during the growing season preceding treatment and during the two subsequent growing seasons. Excessive coarse woody debris (CWD) can hinder movements of grouse chicks and inhibit growth of plant foods; prescribed burning reduced density of small-diameter CWD approximately 50%. Numbers of some early successional plants were greater on burned than control sites by the second growing season post-treatment, whereas some species associated with shaded sites, including red maple *(Acer rubrum)*, declined after burning. Numbers of soft mast producing shrubs, which were initially reduced by burning, increased rapidly on burned sites by the second growing season post-treatment. Insect availability was ≈38% greater on burned areas during the second growing season after treatment. These findings suggest prescribed burning can improve the value of clearcuts as grouse brood habitat.

Key Words: brood habitat, prescribed burning, ruffed grouse

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In much of the 20th century, fire was viewed as a destructive and dangerous phenomenon in forest ecosystems and was thought to cause economic losses and degradation of forest wildlife habitat. However, attitudes towards fire in forest ecosystems have changed, and most natural resource professionals now view fire as a natural phenomenon to which plants and animals in many forest ecosystems are well adapted. In fact, many species prosper in or even depend on pyrogenic habitats (Yahner 2000). In central Appalachian broadleaf forests, wildfires are most often low-intensity ground fires, burning dead wood, shrubs, and leaf litter on the forest floor and killing only thin-barked fire-intolerant trees such as red maple *(Acer rubrum)* and beech *(Fagus grandifolia)* (Yahner 2000). Consequently, in this region prescribed fire is often used to rejuvenate understory vegetation. Following forest harvesting, prescribed burning can reduce accumulations of slash, stimulate growth of groundcover vegetation, and favor oak regeneration (Thompson and Dessecker 1997, Yahner 2000).

Wildfire was a natural and regular occurrence in forest ecosystems throughout much of the geographic range of ruffed grouse *(Bonasa umbellus;* Gullion 1972). Though prescribed burning has been recommended as a technique to improve ruffed grouse habitat (e.g., Miller 1963, Sharp 1970, Gullion 1972, Kubisiak 1985), few studies have documented suitability of burned habitats for this species. Euler and Thompson (1978) reported that adult grouse showed a marked preference for burned areas during the first 30 days following early spring burns, primarily because of increased availability of insect prey. Rogers and Samuel (1984) reported that the rate at which imprinted grouse captured invertebrates increased in recently thinned and burned forests, and the rate of feeding on plants was higher on two-year-old burned sites than on control areas. Escape cover was enhanced on two-year-old burns (Rogers and Samuel 1984). Fire may improve grouse habitat by reducing ground litter and woody debris, improving foraging for soft mast and herbaceous plants, and by controlling diseases of food plants (Sharp 1970). Burning improves the nutritional value and palatability of plants eaten by grouse (Thackston et al. 1982), and this increase in palatability of plants could also lead indirectly to increased availability of arthropods (e.g., Taylor 2003), an important food for grouse chicks (Rusch et al. 2000). Haulton et al. (2003) reported that ruffed grouse females with broods preferred sites with relatively dense and tall herbaceous cover that had greater arthropod densities than randomly located sites.

Our objective was to measure effects of prescribed burning of newly-created clearcuts on habitat features considered important to ruffed grouse. We specifically evaluated response of habitat features known to be important to ruffed grouse broods.

Methods

We conducted research on the Camp Ridge timber sale within the Deerfield Ruffed Grouse Management Area (RGMA), a 2,000-ha unit of the Deerfield Ranger District of George Washington-Jefferson National Forest, Augusta County, Virginia. Forest cover on treated sites represented the oak-hickory association (Braun 1950). Dominant tree species included white, chestnut, red, scarlet, and black oak (*Quercus alba, Q. prinus, Q. rubra, Q. coccinea,* and *Q. velutina*, respectively); shagbark, pignut, bitternut, and mockernut hickory (*Carya ovata, C. glabra, C. cordiformis*, and *C. tomentosa*, respectively); white, Virginia, pitch, and Table Mountain pine (*Pinus strobus, P. virginiana, P. rigida,* and *P. pungens*, respectively); black gum *(Nyssa sylvatica)*, black locust *(Robinia pseudoacacia)*, and red maple. In the understory, mountain laurel *(Kalmia latifolia)* often formed dense evergreen thickets and blueberries (*Vaccinium* spp.) and huckleberries (*Gaylussacia* spp.) were locally abundant.

We selected six clearcuts harvested during the fall–winter of 1996–97 for this study and designated them Blocks A–F. We divided clearcuts approximately in half based on existing firebreaks (e.g., skid roads), and designated one-half of each clearcut for prescribed burning. Units designated for burning averaged approximately 1.7 ha, and, where fire control was not an issue (i.e., either portion could be safely burned), were randomly selected. USDA Forest Service specialists conducted prescribed burning. Prior to burning, any remaining stems >2.5 cm were felled, and slash from logging operations was scattered on the site. Burns were conducted with air temperatures < 27 C, wind speed < 28 kph, and relative humidity $> 25\%$. Treatment units in clearcuts A, B, and D were prescribe-burned during March 1998. An extended drought made conditions unsafe for burning during much of the designated treatment window. Thus, clearcut F was not burned until January 1999, and we were unable to prescribe-burn clearcuts C and E. Consequently, we dropped clearcuts C and E from all analyses.

We established a series of 0.04-ha plots (6–14, depending on clearcut size) in each treatment and control unit. We sampled these during the summer preceding prescribed burning and the two subsequent growing seasons (July–August). We randomly located plots; however, plots were large enough that we effectively sampled the maximum number of plots possible on most units. We marked each plot with a steel stake, and 11.3 m transects were established in each cardinal direction. All vegetation >0.5 m tall occurring within 1 m of the north-south transects was tallied by species, height (0.5–1.0, 1.1–2.0, >2 m) and number of stems (total area sampled = 45.2 m^2). We tallied all coarse woody debris (CWD) intersecting the east/west transect by size classes selected to reflect standards (the time it takes a fuel particle to reach ⅔ of its way to equilibrium with its local environment) for fire behavior fuel models (Anderson 1982; <0.6 cm, 1 h fuels; 0.7–2.5 cm, 10 h fuels; 2.6–7.6 cm, 100 h fuels; 7.7–20.3 cm, 1000 h fuels; and >20.3 cm, 10,000 h fuels). We established groundcover quadrats (1 m^2) at the apex of each transect. Within each quadrat we tallied all herbaceous and low shrub plants <0.5 m tall by species. We estimated percentage ground cover for cinquefoil (*Potentilla* spp.), mosses (Bryophyta), grasses (Poaceae), and sedges (Cyperaceae) and for five cover classes: organic soil and litter, wood, vegetation, rock, and mineral soil. We quantified groundcover mast production by counting the number of seedheads or fruit within each 1-m^2 quadrat.

During summer 1999, we measured insect availability on prescribe-burned and control units on clearcuts that had been treated with prescribed fire two winters previously. We sampled insects at five stations in each burned and control unit using a yellow double-sided tanglefoot (sticky) trap suspended at a height of 0.25–0.5 m (Aerokure International, Inc.; $2 \times 25 \times 10$ cm = 500 cm^2 surface area). We first set traps on 2 June, and recorded captures and installed a fresh tanglefoot trap at one-week intervals for the subsequent three weeks. This time period corresponded approximately with the period during which newly-hatched grouse chicks on the site would have been foraging heavily on insects (Rusch et al. 2000; Haulton et al. 2003). We tallied the number of insects captured on a trap by length (<2, 2.1–4.0, 4.1–6.0, 6.1–10.1, and >10 mm) and order (Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, or other). Insects <2 mm in length were not classified to order. We used total number of captures of each class of insects over the three-week period for statistical analyses.

Because site preparation resulted in an increase in CWD on both treatment and control plots between our pre- and post-burning sampling events and because insects were only sampled during one year, statistical analyses of these data were restricted to within-year comparisons. We analyzed data using a mixed model where treatment (burn or control) and block (clearcut) were entered as fixed effects and a block × treatment interaction was included as a random effect (Bennington and Thayne 1994, SAS 2000). To avoid pseudoreplication, we entered individual monitoring plots or insect trapping stations as subsamples within blocks, and blocks were considered the sampling unit.

For all other datasets, we analyzed observations from all three years in a single repeated measures mixed model (SAS 2000). In these analyses, block, treatment, and year were fixed effects. A significant treatment × year interaction would indicate a divergence in conditions on treatment and control plots resulting from prescribed burning. We used the average value from all plots within a treatment or control portion of a clearcut for each year as our observations and specified that data from different years were repeated measures. For all analyses we report the least squares means and standard errors from our statistical models as parameter estimates. We considered relationships statistically significant at $\alpha = 0.10$.

Results

On clearcuts A, B, and D approximately 50% of the length of each 22.6-m sampling transect showed evidence of burning and 42%–57% of 1-m^2 quadrats were heavily (>75% of area burned) burned. Conditions were dry when clearcut F was treated, leading to more extensive and intensive burning than on the other sites. Greater than 90% of each 22.6-m transect showed evidence of burning and >80% of groundcover quadrats were heavily (>75%) burned

There was a net reduction in dead wood (CWD) on burned units, which was greatest for the smallest diameter classes (Table 1). The apparent increase in amount of CWD between pre- and post-burning samples (Table 1) resulted from the silvicultural preparation of clearcuts for burning where all residual stems, primarily subdominant trees, were felled.

Prescribed burning appeared to alter physical ground cover in sampling quadrats. After burning, mean percentage cover of organic soil (81.7% ± 8.0% [SE] vs. 59.7% ± 7.0%, pre- and post-burn, respectively) and wood (7.8% ± 0.7% vs. 6.0% ± 0.6, pre- and post-burn, respectively) were lower, whereas exposure of mineral soil (5.1% ± 8.5% vs. 21.0% ± 7.4%, pre- and post-burn, respectively) and rock (0.8% ± 1.6% vs. 4.7% ± 1.5%, pre- and post-burn, respectively) increased. However, none of these relationships was statistically significant.

Cover of mosses was lower on burned portions of clearcuts (Table 2). Percentage cover of grasses and sedges increased during our monitoring, but did not differ between control and burned portions of clearcuts (Table 2). Forbs increased dramatically in the first year post-treatment on both treatment and control units, and then dropped to near pre-treatment levels during the last year of sampling (Table 2). This

Table 1. Abundance (number encountered; least squares mean ± SE) of coarse woody debris (CWD) along 22.6-m transects in prescribe-burned and control portions of clearcuts in George Washington National Forest, Virginia.

Size class	Phase	Control	Burn	F (Type III)	*P*
<0.6 cm[a]	Pre-burn	52.0 ± 6.9	47.6 ± 16.7	$F_{1,2} = 0.21$	0.6927
	Post-burn	79.9 ± 8.3	30.7 ± 8.5	$F_{1,3} = 17.45$	0.0250
0.7–2.5 cm	Pre-burn	52.4 ± 4.2	44.5 ± 4.1	$F_{1,2} = 1.79$	0.3131
	Post-burn	85.4 ± 3.3	47.8 ± 3.5	$F_{1,3} = 63.91$	0.0041
2.6–7.6 cm	Pre-burn	16.4 ± 2.1	18.9 ± 2.1	$F_{1,2} = 0.69$	0.4927
	Post-burn	22.6 ± 1.9	17.9 ± 1.9	$F_{1,3} = 3.11$	0.1763
7.7–20.3 cm	Pre-burn	6.7 ± 1.3	6.6 ± 1.2	$F_{1,2} = 0.01$	0.9340
	Post-burn	6.7 ± 0.6	4.4 ± 0.6	$F_{1,3} = 8.87$	0.0587
> 20.3 cm	Pre-burn	0.5 ± 0.2	0.5 ± 0.2	$F_{1,2} < 0.01$	0.9718
	Post-burn	0.9 ± 0.2	0.7 ± 0.2	$F_{1,3} = 0.54$	0.5153

a. <0.6 cm size class does not include wood on the ground, which was considered organic litter.

pattern resulted primarily from an irruption in numbers of fireweed *(Erechtites hieracifolia)* during the second year of the study ($\bar{x}$ = 116 individuals/m^2). Mean numbers of forb species on plots increased during the study, but did not differ between burned and control areas (Table 2). As with forbs, we observed a temporary increase in numbers of shrubs and trees on both treatment and control units during the growing season following treatment of our burned plots, but again detected no effect of prescribed burning (Table 2).

Of 91 plant species observed on groundcover quadrats, few showed statistically significant responses to prescribed burning (Table 3). Common mullein *(Verbascum thapsus)* and black locust became more abundant on burned portions of clearcuts, whereas burning appeared to have a negative effect on numbers of twisted stalk *(Streptopus roseus)* and red maple (Table 3). Production of soft mast increased on both treatment (1.0 ± 14.6 soft mast plants/m^2 vs. 81.2 ± 12.4/m^2 pre- and post-burn, respectively) and control (0.1 ± 14.6/m^2 vs. 27.7 ± 12.4/m^2, pre- and post-burn, respectively) units during the study, but we detected no effect of treatment on fruiting.

On transects, numbers of trees and shrubs >0.5 m tall increased during our study (Table 4). Numbers of blueberries and huckleberries >0.5 m tall declined following prescribed burning (19.6 ± 6.9 stems vs. 33.5 ± 6.4 stems, pre- and post-burn, respectively on control sites; 13.5 ± 6.9 stems vs. 11.1 ± 6.4 stems, pre- and post-burn, respectively on treatment sites), but the greater numbers of stems <0.5 m tall on groundcover quadrats suggested an increase in new growth (Table 3). Numbers of flowering dogwood *(Cornus florida)* were reduced on burned areas during the first year following treatment, but by the second growing season were more abundant on these areas than on controls (1.0 ± 1.2 stems vs. 2.3 ± 1.0 stems, pre- and post-burn, respectively, on control sites; 1.7 ± 1.2 stems vs. 3.5 ± 1.0 stems, pre- and post-burn, respectively, on treatment sites).

During the second growing season following prescribed burning, total number

Table 2. Mean abundance of herbaceous and woody plants on vegetation monitoring plots (4 × 1-m^2 quadrats per plot) on prescribe-burned and control portions of four clearcuts in George Washington National Forest, Virginia (least squares mean ± SE). Because vegetative growth makes identification of individuals difficult, moss, grasses, and sedges were recorded as percent cover rather than counts of individuals.

	Vegetation class		Linear model results			
Phase	Control	Burn	Block	Year	Treatment	Trmt × Year
Moss (% cover)						
Pre-burn	1.4±0.8	1.6±0.8	$F_{3,4.2} = 0.28$	$F_{2,10.1} = 0.93$	$F_{1,4.5} = 4.28$	$F_{2,10.5} = 1.48$
Year 1	2.4±0.7	1.1±0.7	$P = 0.8372$	$P = 0.4252$	$P = 0.0999$	$P = 0.2723$
Year 2	3.6±0.7	1.3±0.7				
Grass and sedge (% cover)						
Pre-burn	2.2±1.8	4.2±1.8	$F_{3,2.7} = 3.34$	$F_{2,9.0} = 5.55$	$F_{1,2.7} = 1.61$	$F_{2,9.3} = 0.73$
Year 1	3.9±1.6	5.2±1.6	$P = 0.1894$	$P = 0.0269$	$P = 0.3034$	$P = 0.5079$
Year 2	5.7±1.6	9.5±1.6				
Number forbs (count)						
Pre-burn	60.7±48.2	34.1±48.2	$F_{3,5.3} = 7.53$	$F_{2,8.3} = 1.80$	$F_{1,12.9} = 0.04$	$F_{2,8.1} = 0.18$
Year 1	159.0±43.4	158.7±43.4	$P = 0.0238$	$P = 0.2253$	$P = 0.8368$	$P = 0.8415$
Year 2	56.4±43.4	68.5±43.4				
Forb species richness						
Pre-burn	2.9±0.7	3.7±0.7	$F_{3,4.0} = 4.33$	$F_{2,9.8} = 7.83$	$F_{1,3.9} = 2.89$	$F_{2,10.1} = 0.13$
Year 1	4.9±0.6	5.6±0.6	$P = 0.0962$	$P = 0.0092$	$P = 0.1668$	$P = 0.8828$
Year 2	4.9±0.6	6.1±0.6				
N trees						
Pre-burn	9.1±3.2	8.9±3.2	$F_{3,5.5} = 9.98$	$F_{2,12.2} = 5.96$	$F_{1,9.1} = 0.57$	$F_{2,12.1} = 0.39$
Year 1	18.3±2.7	23.2±2.7	$P = 0.0118$	$P = 0.0156$	$P = 0.4710$	$P = 0.6841$
Year 2	11.4±2.7	10.6±2.7				
N oaks (*Quercus* spp.)						
Pre-burn	3.1±0.7	3.2±0.7	$F_{3,3.7} = 4.62$	$F_{2,9.5} = 2.74$	$F_{1,3.7} = 3.26$	$F_{2,9.9} = 1.17$
Year 1	2.3±0.6	4.2±0.6	$P = 0.0959$	$P = 0.1152$	$P = 0.1504$	$P = 0.3489$
Year 2	1.6±0.6	2.5±0.6				
N shrubs						
Pre-burn	54.5±13.9	38.5±13.9	$F_{3,3.4} = 13.2$	$F_{2,9.2} = 4.2$	$F_{1,3.5} = 0.12$	$F_{2,9.7} = 0.87$
Year 1	73.8±11.7	88.7±11.7	$P = 0.0229$	$P = 0.0499$	$P = 0.7537$	$P = 0.4502$
Year 2	50.2±11.7	61.6±11.7				

of insects captured was 38% greater on treated than control areas (Table 5). When subdivided by size class this difference was significant only for insects <2 mm in length, although mean captures for all but the largest size class (>10 mm) were greater on the burned units than the controls (Table 5). When analyzed by order, counts of beetles (Coleoptera) were greater on burned than control areas.

Discussion

Excess logging slash can reduce the quality of a site as brood habitat for ruffed grouse by acting as a barrier to chick movement (Gullion 1972). Further, reductions

Table 3. Abundance of individual plant species (*N* per m^2) on groundcover plots (4 ± 1-m^2 quadrats per plot) on prescribe-burned and control portions of clearcuts in western Virginia. Only those species showing significant Treatment or Treatment ± Year differences are reported.

Plant species			Linear model results			
Phase	Control	Burn	Block	Year	Treatment	Trmt ± Year
Common mullein *(Verbascum thapsus)*						
Pre-burn	0.3±1.1	0.9±1.1	$F_{3,5.0} = 1.45$	$F_{2,10.9} = 0.20$	$F_{1,5.5} = 4.07$	$F_{2,11.2} = 0.37$
Year 1	<0.1±0.9	1.7±0.9	$P = 0.3333$	$P = 0.8230$	$P = 0.0946$	$P = 0.7021$
Year 2	0.1±0.9	2.3±0.9				
Twisted stalk *(Streptopus roseus)*						
Pre-burn	0.5±0.3	<0.1±0.3	$F_{3,4.8} = 2.15$	$F_{2,10.4} = 0.60$	$F_{1,4.8} = 9.76$	$F_{2,10.7} = 0.60$
Year 1	1.0±0.3	<0.1±0.3	$P = 0.2166$	$P = 0.5654$	$P = 0.0273$	$P = 0.5642$
Year 2	0.9±0.3	0.2±0.3				
Black locust *(Robinia pseudoacacia)*						
Pre-burn	0.2±0.3	0.2±0.3	$F_{3,5.6} = 2.00$	$F_{2,10.9} = 18.1$	$F_{1,5.7} = 27.99$	$F_{2,11.2} = 12.9$
Year 1	0.5±0.3	3.3±0.3	$P = 0.2212$	$P = 0.0003$	$P = 0.0022$	$P = 0.0012$
Year 2	0.2±0.3	1.3±0.3				
Red maple *(Acer rubrum)*						
Pre-burn	4.4±0.9	4.7±0.9	$F_{3,4.5} = 17.04$	$F_{2,10.6} = 3.94$	$F_{1,5.1} = 5.99$	$F_{2,11.1} = 1.70$
Year 1	7.4±0.7	5.2±0.7	$P = 0.0065$	$P = 0.0523$	$P = 0.0570$	$P = 0.2268$
Year 2	5.4±0.7	3.0±0.7				
Blueberries and huckleberries (*Vaccinium* spp. and *Gaylussacia* spp.)						
Pre-burn	40.0±8.9	30.9±8.9	$F_{3,3.2} = 17.62$	$F_{2,9.0} = 2.52$	$F_{1,3.1} = 0.44$	$F_{2,9.3} = 1.60$
Year 1	41.4±7.7	57.9±7.7	$P = 0.0181$	$P = 0.1352$	$P = 0.5543$	$P = 0.2524$
Year 2	34.5±7.7	42.4±7.7				

in woody debris on burned sites can improve the ability of grouse chicks to conceal themselves from predators (Rogers and Samuel 1984). Prescribed burning on our sites reduced abundance of woody debris by about 50%, suggesting an improvement in this aspect of brood habitat.

We identified few significant changes in vegetation between prescribe-burned and control portions of clearcuts which, we suspect, resulted primarily from low statistical power. This low power resulted from two unplanned events. First, we were unable to burn two of the six experimental units because conditions exceeded parameters for safe burning reducing our sample size by one-third. Second, clearcut F was not treated until the second year of the study, and dry conditions resulted in a more extensive fire than was prescribed for the desired vegetation response. Thus, vegetation changes were extreme and regeneration was delayed, adding considerable variance to data from the treated sites and further reducing statistical power. While these events were undesirable with regards to our research and management goals, they point to some realities with the use of fire in forest management. Conditions may be too wet to achieve the desired intensity or coverage of burning or so dry that fire can be difficult to control and sites become scorched (i.e., burned to mineral soil, killing all vegetation and seeds), retarding vegetation recovery for years. Consequently, pre-

Table 4. Mean count of stems >0.5 m tall occurring on 45.2-m^2 strip transects on prescribe-burned and control portions of four clearcuts in George Washington National Forest, Virginia (least squares mean±SE %).

Vegetation class			Linear model results			
Phase	Control	Burn	Block	Year	Treatment	Trmt × Year
Herbaceous stems						
Pre-burn	26.5±61.4	129.0±61.4	$F_{3,5.2} = 12.49$	$F_{2,9.3} = 1.59$	$F_{1,12.8} = 1.32$	$F_{2,9.1} = 0.94$
Year 1	167.0±54.5	188.9±54.5	$P = 0.0082$	$P = 0.2555$	$P = 0.2710$	$P = 0.4257$
Year 2	62.2±54.5	43.5±54.5				
Shrubs						
Pre-burn	41.1±12.5	40.2±12.5	$F_{3,3.2} = 2.79$	$F_{2,9.3} = 8.62$	$F_{1,3.2} = 3.73$	$F_{2,9.6} = 2.08$
Year 1	64.1±10.9	24.8±10.9	$P = 0.2006$	$P = 0.0077$	$P = 0.1442$	$P = 0.1778$
Year 2	91.1±10.9	63.8±10.9				
Trees						
Pre-burn	33.5±15.7	31.1±15.7	$F_{3,3.1} = 0.17$	$F_{2,8.9} = 7.09$	$F_{1,3.0} = 0.05$	$F_{2,9.2} = 0.37$
Year 1	45.2±13.4	41.1±13.4	$P = 0.9105$	$P = 0.0145$	$P = 0.8361$	$P = 0.7032$
Year 2	73.0±13.4	88.4±13.4				
Soft mast producers						
Pre-burn	22.3±14.8	18.8±14.8	$F_{3,3.1} = 0.32$	$F_{2,9.4} = 7.86$	$F_{1,3.0} = 1.61$	$F_{2,9.6} = 1.12$
Year 1	39.8±13.2	7.0±13.2	$P = 0.8105$	$P = 0.0099$	$P = 0.2928$	$P = 0.3640$
Year 2	68.3±13.2	46.9±13.2				
N oaks ÷ total *N* trees						
Pre-burn	0.39±0.05	0.39±0.05	$F_{3,3.6} = 13.72$	$F_{2,9.4} = 3.65$	$F_{1,3.6} = 0.24$	$F_{2,9.7} = 2.89$
Year 1	0.32±0.04	0.45±0.04	$P = 0.0191$	$P = 0.0673$	$P = 0.6521$	$P = 0.1033$
Year 2	0.32±0.04	0.26±0.04				

scribed fire may not always be a dependable silvicultural option (Smith et al. 1997).

The gradual decline in the extent of organic soil and surface litter in clearcuts following timber harvesting likely resulted from the removal of the forest canopy, which would have been an important source of organic detritus. However, this loss of organic soil appeared to be accelerated by burning, leading to an approximately three-fold increase in exposure of mineral soils on treated sites (see also Stribling and Barron 1995, Yahner 2000). Exposed mineral soils may be an important seedbed for many pioneer plant species on disturbed sites including mullein, grasses and sedges, dogwood, and black locust, all of which were more abundant on burned areas. Leaves and seeds of black locust and grasses and sedges are important grouse forage in the southern Appalachians as are dogwood berries (Nelson et al. 1938, Rogers and Samuel 1984).

Numbers of some plants declined on sites treated with prescribed fire. Many were species associated with organic soils and shaded moist sites typical of the forest understory including twisted stalk, red maple, and mosses. Red maple, a shade tolerant species, contributes to a loss of dominance by oaks in many stands in the southern Appalachians (Elliott et al. 1999, Yahner 2000). Red maples are fire intolerant, and prescribed fire has been suggested as one approach to preventing succession to forests dominated by this and other shade-tolerant species (Yahner 2000, Johnson et

Table 5. Abundance (least squares mean ± SE) of insects on prescribe-burned and control plots two years after prescribed burning of three clearcuts in George Washington National Forest, Virginia.

Insect class	Control	Burn	F (Type III)	*P*
All insects <2 mm	518.1 ± 29.5	770.7 ± 29.5	$F_{1,2} = 36.57$	0.0263
All insects 2–4.1 mm	260.0 ± 33.5	315.3 ± 33.5	$F_{1,2} = 1.37$	0.3627
All insects 4.1–6 mm	64.8 ± 15.4	86.7 ± 15.4	$F_{1,2} = 1.02$	0.4194
All insects 6.1–10 mm	12.2 ± 1.8	17.1 ± 1.8	$F_{1,2} = 3.48$	0.2031
All insects >10 mm	7.0 ± 1.1	6.3 ± 1.1	$F_{1,2} = 0.19$	0.7069
All Coleoptera	61.1 ± 8.9	100.0 ± 8.9	$F_{1,2} = 9.55$	0.0907
All Diptera	55.5 ± 10.9	78.7 ± 10.9	$F_{1,2} = 2.29$	0.2694
All Hemiptera	177.1 ± 32.0	195.5 ± 32.0	$F_{1,2} = 0.16$	0.7244
All Hymenoptera	46.1 ± 5.0	43.5 ± 5.0	$F_{1,2} = 0.13$	0.7531
All Lepidoptera	1.6 ± 0.5	2.2 ± 0.5	$F_{1,2} = 0.87$	0.4492
All Others	3.1 ± 0.8	2 .9 ± 0.8	$F_{1,2} = 0.03$	0.8740
Total Captures	862.6 ± 68.6	1193.5 ± 68.6	$F_{1,2} = 11.62$	0.0763

al. 2002). This recommendation is supported by our observations and elsewhere (Elliott et al. 1999) and may be important for the long-term maintenance of grouse in oak-hickory forests as these birds are heavily dependent on acorn crops (Whitaker 2003).

Many plant species were less abundant on treatment sites than control sites during the first growing season after burning, but this reduction appeared to be temporary. Regeneration on burned sites was rapid, and by the second growing season post-burn these species were becoming abundant. This was particularly true for blueberries and huckleberries >0.5 m tall, which declined by 80% following burning but began to recover during the following growing season. Blueberries and huckleberries on groundcover quadrats (i.e. <0.5 m tall) were most abundant during the first growing season following burning indicating that fire had stimulated growth of new stems. Production of soft mast also was reduced following burning but had increased again by the second growing season post-burning. Replacement of decadent, nonfruiting stems of these species is cited as a key benefit of prescribed burning (Sharp 1970) and our observations suggest this may require more than two growing seasons for full benefits to develop under the unusually dry conditions we experienced.

During the second growing season, post-burn overall availability of insects was greater on prescribed burned than control portions of clearcuts (see also Taylor 2003). Though not statistically significant in all cases, this relationship was present for four of six orders of insects and all but the largest size class. This difference could result either from increased production or increased activity of insects on burned areas. While it is not certain that absolute numbers of insects had increased, from the perspective of grouse, availability of insects would have been greater on burned sites. Insects are an important food for female grouse during the laying period and for chicks during the first few weeks after hatching, and grouse show little discrimination in the species of insects consumed (Bump et al. 1947). Consequently, this increase in insect abundance can be viewed as an improvement in the quality of these sites as grouse habitat. Elevated rates of insect capture have been reported for grouse hens and chicks foraging in burned areas (Euler and Thompson 1978, Rogers and Samuel 1984; see also Rogers 1985).

Our results suggest that prescribed burning on clearcuts has the potential to enhance habitat conditions for ruffed grouse broods. Sites that were burned had less CWD, greater herbaceous cover, and more soft mast producing plants and arthropods. Additional consideration should be given to location of burns within clearcuts. Whitaker (2003) showed a preference of grouse for mesic sites, and burning of clearcuts in moister sites may be expected to have greater beneficial effects than burns on more xeric sites. Our results are applicable only to the first two years after burning; additional research should address longer-term response of vegetation to burning.

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