



ELSEVIER

Forest Ecology and Management 114 (1999) 233–243

Forest Ecology
and
Management

Effects of a community restoration fire on small mammals and herpetofauna in the southern Appalachians

William M. Ford^{a,*}, M. Alex Menzel^b, David W. McGill^c,
Joshua Laerm^{1,d}, Timothy S. McCay^e

^a Westvaco Corporation, Box 577, Rupert WV 25984, USA

^b Warnell School of Forest Resources, University of Georgia, Athens, GA 30602, USA

^c Westvaco Corporation, Box 608, Rupert, WV 25984, USA

^d Museum of Natural History, University of Georgia, Athens, GA 30602, USA

^e Institute of Ecology, University of Georgia, Athens, GA 30602, USA

Abstract

As part of the Wine Spring Creek ecosystem management project on the Nantahala National forest, North Carolina, we assessed effects of a community restoration fire on small mammals and herpetofauna in the upper slope pitch pine (*Pinus rigida*) stands, neighboring midslope oak (*Quercus* spp.) stands and rhododendron (*Rhododendron maximum*) dominated riparian areas during 1995 and 1996. Using drift-fence arrays with pitfalls and snap-trapping, we collected these small mammals: masked shrew (*Sorex cinereus*), smoky shrew (*S. fumeus*), water shrew (*S. palustris*), pygmy shrew (*S. hoyi*), northern short-tailed shrew (*Blarina brevicauda*), deer mouse (*Peromyscus maniculatus*), white-footed mouse (*P. leucopus*), golden mouse (*Ochrotomys nuttalli*), southern red-backed vole (*Clethrionomys gapperi*), pine vole (*Microtus pinetorum*) and woodland jumping mouse (*Napaeozapus insignis*). Herpetofauna collected from drift-fence arrays and time-constrained searches included: eastern newt (*Notophtalmus viridescens*), seepage salamander (*Desmognathus aeneus*), mountain dusky salamander (*D. ochrophaeus*), Blue Ridge two-lined salamander (*Eurycea wilderae*), spring salamander (*Gyrinophilus porphyriticus*), Jordan's salamander (*Plethodon jordani*), wood frog (*Rana sylvatica*), five-lined skink (*Eumeces fasciatus*), eastern garter snake (*Thamnophis sirtalis*), and northern ringneck snake (*Diadophis punctatus*). Prior to the prescribed community restoration fire in the spring of 1995, there were no significant differences in small mammal or herpetofauna collections between burned and control areas. Post-treatment in 1995 and 1996, showed no significant differences among collections of most species between burned and control areas. Slope position accounted for more variation among the species of greatest abundance than did burning. Concern for the effects of prescribed fire as a management tool on small mammals and herpetofauna in the southern Appalachians seems unwarranted. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Community restoration; Herpetofauna; Pitch pine; Prescribed fire; Small mammals

1. Introduction

Fire-dominated pine communities have undergone drastic declines as a result of fire suppression on national forest lands in the southern Appalachians

*Corresponding author. Tel.: +1-304-392-6373; fax: +1-304-392-6058; e-mail: wmford@westvaco.com

¹Deceased.

over the last century (Sharitz et al., 1992). Inadequate pine regeneration has been attributed to the absence of fire (Williams and Johnson, 1992; Waterman et al., 1995). Pine community regeneration has been further aggravated by the widespread outbreak of southern pine beetle (*Dendroctonus frontalis*) and by drought in the 1980s; both caused extensive mortality and consequently a reduction in potential pine seed sources in the region (Swift et al., 1989; Smith, 1991). Although these pine and mixed pine-hardwood types account for less than 10% of the landscape in the southern Appalachians, they are important components of regional floral and faunal biodiversity (Vose et al., 1994). As the USDA forest service adopts ecosystem management to achieve desirable management objectives and outcomes, restoration of these declining communities may become a high priority (USDA Forest Service, 1996).

Use of high intensity, prescribed fire can control fire-intolerant plant species such as rhododendron and mountain laurel (*Kalmia latifolia*) (Hooper, 1969; Vose et al., 1994) and improve conditions for the maintenance or re-establishment of pine-dominated types in the southern Appalachians (Clinton et al., 1993). Forest management practices that mimic disturbance, such as timber harvesting or prescribed fire, inadvertently alter a wide variety of ecosystem processes and biotic groups along with those targeted by management activities (Elliot and Hewitt, 1997). Vose et al. (1994) noted that while effects of fire on target overstory communities in the southern Appalachians were well-understood, effects on other ecosystem attributes, particularly wildlife, are poorly known. Information concerning impacts of forest management activities on most non-game wildlife species in the southern Appalachians is lacking. Scientific attention has focused primarily on the relationships of timber harvesting to non-game species such as small mammals (McComb and Rumsey, 1982; Ford et al., 1997) and woodland salamanders (Petranka et al., 1993; Ash and Bruce, 1994; Petranka et al., 1994). With increasing applications for the use of prescribed fire in forest ecosystem management, information concerning fire effects on all elements of biotic communities becomes increasingly important. As part of the Wine Spring Creek ecosystem management project (WSCEMP), we undertook a study of the response of small mammal and herpetofauna communities following high

intensity prescribed fires intended to restore relictual, upper slope pitch pine communities in the Nantahala national forest (NNF) of North Carolina.

2. Methods

In April 1995, we began a survey of small mammal and herpetofauna communities prior to and for two occasions following the Wine Spring Creek and Indian Camp Branch community-restoration burns within the WSCEMP area of the NNF. The 1820 ha WSCEMP area is located within the Blue Ridge Physiographic province in southwestern North Carolina (Fenneman, 1938), approximately 30 km south of the Great Smoky Mountains National Park. Elevations range from a low of 915 m at Nantahala Lake to over 1500 m at Wine Spring Bald. Average annual precipitation ranges from 1697 mm at Nantahala Lake to 1839 mm at Wayah Bald (1625 m), 1.5 km northeast from Wine Spring Bald. Soils, primarily Inceptisols and Ultisols, are moderately to strongly acidic. Forest cover types, which vary by elevation and aspect, consist primarily of upland hardwoods (61%), northern hardwoods (24%), cove hardwoods (7%), and rhododendron-hemlock (*Tsuga canadensis*) dominated riparian areas (7%). Small areas of pitch pine with dense understories of mountain laurel and greenbrier (*Smilax* spp.) occur on south-facing, xeric upper slopes on the WSCEMP. The extent and integrity of these pitch pine stands has been greatly reduced due to overstory mortality from stand senescence, drought and insect attack. Moreover, fire suppression has allowed a dense ericaceous understory to develop, preventing successful pine seedling establishment and development.

In April 1995, the USDA forest service conducted high intensity, prescribed fires along south-facing slopes above Wine Spring Creek and Indian Camp Branch totaling approximately 200 ha in area. The purpose of the burn was to restore degraded pitch pine communities on the upper slopes, as well as stimulate oak regeneration and wildlife forage development along the rhododendron-dominated riparian areas through the midslope communities.

Three weeks prior to the burn in March, we installed pitfall drift-fence arrays and snap-trap stations at three sites each in upper slope, midslope, and riparian areas scheduled to be burned in both the Indian Camp

Branch burn and the Wine Spring Creek burn. Pitfall trapping is an effective sampling technique to collect small mammals, many amphibians, and reptiles (Handley and Varn, 1994; Kirkland and Sheppard, 1994; Ford et al., 1994, 1997). To serve as study control sites, we also installed pitfall drift-fence arrays and snap-trap stations at three sites each in similar south-facing upper slope, midslope and riparian areas within portions of the WSEMP area not scheduled to be burned. Drift-fence arrays consisted of three, 3 m long, 61 cm high aluminum flashing arms arranged in a triad design (Kirkland and Sheppard, 1994). The bottom of the flashing was buried approximately 20 cm. One pitfall was placed on either side of the flashing near each end, and one each at the intersections of the three fences at the center of the array. Pitfalls (plastic 946 cm³ drink cups) were placed against the side of the fence arms and buried flush with the ground and one-third filled with 10% formalin to quickly drown and then preserve specimens. Five snap-trapping stations consisting of two Museum SpecialTM snap-traps to target rodents were established at 5 m spacings, away from the center of each drift-fence triad in each cardinal direction (20 stations total per array) at upper slope, midslope and riparian burn and control sites. Snap-traps were baited with a mixture of rolled oats and peanut butter. Pitfalls were opened for 14 days prior to the prescribed burn to assess pre-treatment relative abundance and species richness. Snap-trapping was conducted for 3 days concurrent to the last 3 days of pitfall trapping. Following the burn in April, post-treatment sampling occurred in June of 1995 and August of 1996 following the same 14 day pitfall schedule and 3 day snap-trap schedule when soricid numbers in the southern Appalachians are highest (Ford et al., 1997). The fire intensity was sufficient at three of the upper slope sites to necessitate extensive repair of drift-fence arrays and replacement of pitfalls. Fire effects on the remainder of the arrays were negligible.

Small mammal and herpetofauna specimens collected by pitfall-trapping and snap-trapping were identified to species based on external morphology and repositied in the University of Georgia Museum of Natural History. To further assess the post-treatment effects of high intensity burn on woodland salamanders, we established 100 m² time-constrained search areas (Campbell and Christman, 1982; Bury and Corn,

1988) within each of the upper slope, midslope, and riparian areas burned within the Wine Spring Creek burn and the Indian Camp Branch burn (six search areas total) and in the upper slope, midslope and riparian control areas (three search areas total). Time-constrained searches were conducted at each individual search area for approximately 4 h using three searchers from 21:00 h until 01:00 h in August 1995 and September 1995 and then again in September 1996 and October 1996. Overall mean captures of plethodontid salamanders are lowest in mid-summer and highest in mid-fall in the southern Appalachians (Barker, 1997). Our time-constrained search efforts were timed to take advantage of both the low ebb and high peak of salamander activity for the year.

Pre- and post-burn pitfall and snap-trap data were combined by pre- or post-burn categories for all small mammals by species and were reported on a combined trapnight basis. Data for herpetofauna based on pitfall-trapping and data based on time-constrained searches were analyzed separately. Pre-burn data for both small mammals and herpetofauna were analyzed by individual species using a two-way ANOVA with treatment factors being burn type (burn vs. no-burn control) and slope position (upper slope, midslope, and riparian). Post-burn data for both small mammals and herpetofauna were analyzed by individual species using a three-way ANOVA with treatment factors being burn type, slope position, and date (1995 and 1996 sampling periods). Pre- and post-burn pitfall data were analyzed separately due to the disparate collection times between pre-burn collections (April) and post-burn collections (summer). Time-constrained search data were compared by species between years using a paired *t*-test. Because no differences were detected between searches in 1995 and 1996 for seepage salamanders, mountain dusky salamanders, Blue Ridge two-lined salamanders and Jordan's salamander, these data were pooled to increase replication by burn type and slope position. These data then were analyzed as a two-way ANOVA with treatment factors being burn type and slope position. Because the pitfall, snap-trapping and time-constrained search data were not normally distributed, each were square-root transformed as recommended for count data before analysis (Steele and Torrie, 1980). When significant main effects were detected among species by treatment factor, mean separation was performed using Tukey's

Table 1

Pre-burn mean total pitfall drift-fence and snap-trap captures of small mammals among community restoration fire and no-burn control sites in the Wine Spring ecosystem management area, Nantahala National forest, North Carolina, April 1995

		Burn			Control		
		Mean	<i>n</i>	SE	Mean	<i>n</i>	SE
<i>Masked shrew (Sorex cinereus)</i> ^a							
Upper slope ^b	A	0.50	6	0.34	0.66	3	0.66
Midslope	A	1.33	6	0.71	1.00	3	0.58
Riparian	A	1.83	6	0.87	1.00	3	0.58
<i>Deer mouse (Peromyscus maniculatus)</i> ^a							
Upper slope ^b	A	4.83	6	0.98	7.33	3	1.67
Midslope	B	1.83	6	0.65	4.67	3	0.57
Riparian	A	8.83	6	1.11	4.00	3	1.00
<i>Golden mouse (Ochrotomys nuttalli)</i> ^a							
Upper slope ^b	A	0.50	6	0.50	1.00	3	0.57
Midslope	A	0.17	6	0.17	0.33	3	0.33
Riparian	A	0.00	6	0.00	0.00	3	0.00
<i>Southern red-backed vole (Clethrionomys gapperi)</i> ^a							
Upper slope ^b	A	1.50	6	0.76	0.67	3	0.33
Midslope	A	0.67	6	0.49	0.67	3	0.67
Riparian	A	1.17	6	0.60	2.67	3	1.21

^aTreatment effects (burn vs. no-burn) not significantly different ($P>0.05$) in the transformed data.

^bSite positions not followed by same letter within columns by species significantly different ($P<0.05$) in the transformed data. Mean totals are expressed as mean numbers per 246 combined trapnights for upper slope, midslope, and riparian sites.

multiple-comparison procedure (Ott, 1988). Statistical significance was accepted at $\alpha=0.05$.

3. Results

Pre-fire in April 1995, we recorded 3404 pitfall trapnights and 3240 snap-trap trapnights on the WSCEMP area. Post-fire collections in the summers of 1995 and 1996 accounted for 10212 pitfall trapnights, 6480 snap-trap trapnights, and approximately 432 man-hours of search effort in time-constrained searches. Pre-fire combined pitfall and snap-trap collections of small mammals included: masked shrews, smoky shrews, deer mice, golden mice and southern red-backed voles (Table 1). In the pre-fire collections, only two smoky shrews were collected at the riparian control areas. In the analysis of pre- and post-fire collections, species uncommon in our surveys were excluded from statistical analysis, but are reported in our results to document their occurrence on the WSCEMP area. There were no significant differences in mean numbers collected of masked shrews, deer mice, or golden mice between pre-fire burn sites or

control sites (Table 1). Significantly higher mean numbers of deer mice were collected in the riparian sites and upper slope sites than in the midslope sites (Table 1). There was a significant interaction between the burn type and slope position factors in pre-fire deer mice collections ($F=7.79$, d.f.=2, 21, $P=0.003$).

Post-fire collections of small mammals included: masked shrews, smoky shrews, water shrews, pygmy shrews, northern short-tailed shrews, deer mice, white-footed mice, golden mice, southern red-backed voles, pine voles, and woodland jumping mice (Table 2). In the post-fire collections, only two water shrews were collected, both in 1995 with one taken in a riparian burn site and one in a midslope burn site. There were no significant differences in mean numbers collected of masked shrews, smoky shrews, pygmy shrews, northern short-tailed shrews, deer mice, white-footed mice, golden mice, southern red-backed voles, or woodland jumping mice between post-fire burn or control sites (Table 2). Significantly higher mean numbers of pine voles were collected in control sites than in post-fire burn sites in 1996 (Table 2). Significantly higher mean numbers of smoky shrews were collected in riparian and midslope

Table 2

Mean total pitfall drift-fence and snap-trap captures of small mammals among community restoration fire and no-burn control sites in the Wine Springs ecosystem management area, Nantahala National forest, North Carolina, June 1995 and August 1996

		1995						1996					
		Burn			Control			Burn			Control		
		Mean	<i>n</i>	SE	Mean	<i>n</i>	SE	Mean	<i>n</i>	SE	Mean	<i>n</i>	SE
<i>Masked shrew (Sorex cinereus)</i> ^a													
Upper slope ^c	A	8.66	6	2.23	13.00	3	3.61	5.33	6	1.52	5.00	3	2.08
Midslope	A	6.00	6	1.12	9.33	3	1.20	8.67	6	1.36	14.67	3	2.60
Riparian	A	13.33	6	1.74	10.33	3	3.71	9.67	6	3.22	9.33	3	1.85
<i>Smoky shrew (Sorex fumeus)</i> ^a													
Upper slope ^c	A	2.33	6	0.91	1.00	3	0.58	3.00	6	1.18	0.33	3	0.33
Midslope	B	2.67	6	0.71	6.00	3	2.08	4.33	6	1.62	9.33	3	1.76
Riparian	B	6.50	6	1.74	8.00	3	1.73	2.67	6	1.17	5.00	3	1.54
<i>Water shrew (Sorex palustris)</i> ^a													
Upper slope ^c	A	0.17	6	0.17	0.00	3	0.00	0.00	6	0.00	0.00	3	0.00
Midslope	A	0.17	6	0.17	0.00	3	0.00	0.00	6	0.00	0.00	3	0.00
Riparian	A	0.00	6	0.00	0.00	3	0.00	0.00	6	0.00	0.00	3	0.00
<i>Pygmy shrew (Sorex hoyi)</i> ^a													
Upper slope ^c	A	0.00	6	0.00	0.00	3	0.00	0.33	6	0.22	0.33	3	0.33
Midslope	A	0.33	6	0.33	0.00	3	0.00	0.83	6	0.54	0.00	3	0.00
Riparian	A	0.67	6	0.49	0.00	3	0.00	0.33	6	0.33	0.00	3	0.00
<i>Northern short-tailed shrew (Blarina brevicauda)</i> ^a													
Upper slope ^c	A	0.17	6	0.17	0.00	3	0.00	0.67	6	0.33	0.00	3	0.00
Midslope	AB	0.00	6	0.00	0.33	3	0.33	0.33	6	0.33	1.33	3	0.33
Riparian	B	1.50	6	0.22	0.33	3	0.33	0.33	6	0.21	0.33	3	0.33
<i>Deer mouse (Peromyscus maniculatus)</i> ^{a,d}													
Upper slope ^c	A	5.50	6	0.92	7.00	3	0.58	2.50	6	1.06	2.33	3	0.67
Midslope	A	7.83	6	1.10	6.00	3	1.73	5.00	6	1.24	6.67	3	3.18
Riparian	A	12.83	6	1.38	6.00	3	0.58	5.17	6	1.53	2.00	3	1.00
<i>White-footed mouse (Peromyscus leucopus)</i> ^{a,d}													
Upper slope ^c	A	1.17	6	0.60	0.00	3	0.00	4.67	6	1.45	4.67	3	1.86
Midslope	A	0.33	6	0.33	0.33	3	0.33	2.83	6	1.27	3.67	3	1.20
Riparian	B	0.00	6	0.00	0.00	3	0.00	0.50	6	0.21	0.00	3	0.00
<i>Golden mouse (Ochrotomys nuttalli)</i> ^{a,d}													
Upper slope ^c	A	1.00	6	0.36	0.00	3	0.00	0.00	6	0.00	0.33	3	0.33
Midslope	A	0.33	6	0.22	0.00	3	0.00	0.33	6	0.22	0.00	3	0.00
Riparian	B	0.00	6	0.00	0.00	3	0.00	0.00	6	0.00	0.00	3	0.00
<i>Southern red-backed vole (Clethrionomys gapperi)</i> ^{a,d}													
Upper slope ^c	A	1.83	6	0.90	0.67	3	0.33	0.17	6	0.17	4.00	3	4.00
Midslope	A	1.83	6	0.70	2.33	3	1.33	1.00	6	0.36	0.67	3	0.33
Riparian	A	3.00	6	0.63	5.33	3	1.45	0.83	6	0.54	1.67	3	0.88
<i>Pine vole (Microtus pinetorum)</i> ^{b,d}													
Upper slope ^c	A	0.00	6	0.00	0.00	3	0.00	0.17	6	0.17	0.67	3	0.33
Midslope	A	0.00	6	0.00	0.00	3	0.00	0.50	6	0.50	1.33	3	0.33
Riparian	A	0.00	6	0.00	0.00	3	0.00	0.00	6	0.00	0.33	3	0.33
<i>Woodland jumping mouse (Napaeozapus insignis)</i> ^a													
Upper slope ^c	A	0.00	6	0.00	0.00	3	0.00	0.50	6	0.34	0.33	3	0.33
Midslope	AB	1.00	6	0.82	0.00	3	0.00	0.33	6	0.21	0.00	3	0.00
Riparian	B	1.50	6	0.67	1.67	3	0.33	0.33	6	0.21	0.33	3	0.33

^aTreatment effects (burn vs. no-burn) not significantly different ($P>0.05$) in the transformed data.

^bTreatment effects (burn vs. no-burn) significantly different ($P<0.05$) in the transformed data.

^cSite positions not followed by same letter within columns by species significantly different ($P<0.05$) in the transformed data.

^dDate effects (1995 vs. 1996) significantly different ($P<0.05$) in the transformed data.

Mean totals are expressed as mean numbers per 246 combined trapnights for upper slope, midslope, and riparian sites.

sites than in upper slope sites (Table 2). Significantly higher mean numbers of northern short-tailed shrews and woodland jumping mice were collected in riparian than in upper slope sites across both burn types (Table 2). Significantly higher mean numbers of white-footed mice and golden mice were collected in upper slope and midslope sites than in riparian sites across both burn types (Table 2). There were significant interactions between the burn type and year of collection in post-fire pine vole collections ($F=4.98$, d.f.=1, 42, $P=0.03$) and between slope position and year of collection in post-fire masked shrew collections ($F=3.43$, d.f.=2, 42, $P=0.04$), northern short-tailed shrew collections ($F=7.08$, d.f.=2, 42, $P=0.01$), white-footed mice collections ($F=4.45$, d.f.=2, 42, $P=0.02$), and woodland jumping mice collections ($F=4.06$, d.f.=2, 42, $P=0.02$).

Pre-fire pitfall collections of herpetofauna included: mountain dusky salamanders, spring salamanders, Jordan's salamanders, and a single specimen of northern ringneck snake from a riparian control site (Table 3). In the pre-fire collections, only two spring salamanders were collected, both from riparian controls areas. There were no significant differences among burn type or slope position for pre-fire collections of mountain dusky salamanders and Jordan's salamanders (Table 3).

Post-fire pitfall collections of herpetofauna included: eastern newts, seepage salamanders, mountain dusky salamanders, Blue Ridge two-line salamanders, Jordan's salamanders, as well as a single

specimen of wood frog, five-lined skink, and eastern garter snake (Table 4). In the post-fire collections, four eastern newts were collected, two from upper slope burn sites in 1995 and two from upper slope line control sites in 1995. The one wood frog was collected in an upper slope burn site in 1996, the one five-lined skink was collected in an upper slope burn site in 1995, and the one eastern garter snake was collected in an upper slope burn site in 1995. There were no significant differences among burn type, slope position, and year of collection for mean numbers collected of seepage salamanders, Blue Ridge two-line salamanders, or Jordan's salamanders (Table 4). No mountain dusky salamanders were collected in upper slope sites, regardless of burn type (Table 4). There was a significant interaction between the burn type and slope position in post-fire seepage salamander pitfall collections ($F=3.28$, d.f.=2, 42, $P=0.05$).

Post-fire time-constrained search collections included: seepage salamanders, mountain dusky salamanders, Blue Ridge two-lined salamanders, and Jordan's salamanders (Table 5). There was no significant differences between burn type among mean number collected of seepage salamanders, mountain dusky salamanders, Blue Ridge two-lined salamanders, or Jordan's salamander. Significantly higher mean numbers of mountain dusky salamanders and Jordan's salamanders were collected at riparian and midslope sites than in upper slope sites across burn types and significantly higher mean numbers of Blue Ridge two-line salamanders were collected in riparian

Table 3

Pre-burn mean total pitfall drift-fence captures of woodland salamanders among community restoration fire and no-burn control sites in the Wine Spring ecosystem management area, Nantahala National Forest, North Carolina, April 1995

		Burn			Control		
		Mean	<i>n</i>	SE	Mean	<i>n</i>	SE
<i>Mountain dusky salamander (Desmognathus ochrophaeus)</i> ^a							
Upper slope ^b	A	0.00	6	0.00	0.00	3	0.00
Midslope	A	0.17	6	0.17	0.00	3	0.00
Riparian	A	0.33	6	0.21	0.00	3	0.00
<i>Jordan's salamander (Plethodon jordani)</i> ^a							
Upper slope ^b	A	0.67	6	0.22	2.00	3	1.15
Midslope	A	1.50	6	0.72	1.67	3	0.67
Riparian	A	1.00	6	0.63	0.67	3	0.33

^aTreatment effects (burn vs. no-burn) not significantly different ($P>0.05$) in the transformed data.

^bSite positions not followed by same letter within columns by species significantly different ($P<0.05$) in the transformed data. Mean totals are expressed as mean numbers per 126 trapnights for upper slope, midslope, and riparian sites.

Table 4

Mean total pitfall drift-fence captures of woodland salamanders among community restoration fire and no-burn control sites in the Wine Springs ecosystem management area, Nantahala National Forest, North Carolina, June 1995 and August 1996

		1995						1996					
		Burn			Control			Burn			Control		
		Mean	<i>n</i>	SE	Mean	<i>n</i>	SE	Mean	<i>n</i>	SE	Mean	<i>n</i>	SE
<i>Seepage salamander (Desmognathus aeneus)</i> ^a													
Upper slope ^b	A	0.00	6	0.00	0.00	3	0.00	0.17	6	0.17	0.00	3	0.00
Midslope	A	0.50	6	0.34	0.00	3	0.00	0.17	6	0.17	0.00	3	0.00
Riparian	A	0.00	6	0.00	0.00	3	0.00	0.17	6	0.17	1.33	3	0.89
<i>Mountain dusky salamander (Desmognathus ochrophaeus)</i> ^a													
Upper slope ^b	A	0.00	6	0.00	0.00	3	0.00	0.00	6	0.00	0.00	3	0.00
Midslope	A	0.00	6	0.00	0.00	3	0.00	0.00	6	0.00	0.00	3	0.00
Riparian	B	0.83	6	0.54	1.67	3	1.67	0.83	6	0.66	2.33	3	1.85
<i>Blue Ridge two-lined salamander (Eurycea wilderae)</i> ^a													
Upper slope ^b	A	0.33	6	0.22	0.00	3	0.00	0.00	6	0.00	0.00	3	0.00
Midslope	A	0.33	6	0.22	0.00	3	0.00	0.33	6	0.22	0.00	3	0.00
Riparian	A	0.00	6	0.00	0.00	3	0.00	0.17	6	0.17	0.00	3	0.00
<i>Jordan's salamander (Plethodon jordani)</i> ^a													
Upper slope ^b	A	6.83	6	1.99	5.33	3	0.88	2.00	6	0.73	7.67	3	1.76
Midslope	A	6.83	6	1.66	2.33	3	0.33	3.66	6	1.25	2.33	3	0.33
Riparian	A	4.50	6	1.14	3.00	3	0.57	3.83	6	0.94	4.00	3	0.57

^aTreatment effects (burn vs. no-burn) not significantly different ($P>0.05$) in the transformed data.

^bSite positions not followed by same letter within columns by species significantly different ($P<0.05$) in the transformed data.

Mean totals are expressed as mean numbers per 126 trap-nights for upper slope, midslope, and riparian sites.

Table 5

Time-constrained search captures of woodland salamanders among community restoration fire and no-burn control sites in the Wine Spring ecosystem management area, Nantahala National Forest, North Carolina, 1995–1996

		Burn			Control		
		Mean	<i>n</i>	SE	Mean	<i>n</i>	SE
<i>Seepage salamander (Desmognathus aeneus)</i> ^a							
Upper slope	A	0.00	8	0.00	0.00	4	0.00
Midslope	A	0.13	8	0.12	0.00	4	0.00
Riparian	A	0.00	8	0.00	0.00	4	0.00
<i>Mountain dusky salamander (Desmognathus ochrophaeus)</i> ^a							
Upper slope ^b	A	0.00	8	0.00	0.25	4	0.25
Midslope	B	1.75	8	0.79	3.25	4	1.44
Riparian	B	2.12	8	0.77	2.75	4	1.44
<i>Blue Ridge two-lined salamander (Eurycea wilderae)</i> ^a							
Upper slope ^b	A	0.00	8	0.00	0.00	4	0.00
Midslope	A	0.75	8	0.25	0.25	4	0.18
Riparian	B	2.00	8	0.50	3.75	4	2.09
<i>Jordan's salamander (Plethodon jordani)</i> ^a							
Upper slope ^b	A	3.85	8	0.81	5.75	4	1.43
Midslope	B	13.87	8	1.55	23.25	4	3.94
Riparian	B	20.25	8	3.98	17.25	4	3.25

^aTreatment effects (burn vs. no-burn) not significantly different ($P>0.05$) in the transformed data.

^bSite positions not followed by same letter within columns by species significantly different ($P<0.05$) in the transformed data.

Mean totals are expressed as mean numbers collected per 100 m² transects (12 man-hour periods) for upper slope, midslope, and riparian sites.

sites than in either midslope or upper slope sites across burn types (Table 5).

4. Discussion

For most species of small mammals and herpetofauna there were few discernable differences between burned and control areas, supporting the contention that these high intensity, prescribed fires in the WSCEMP area had little overall impact on the terrestrial vertebrate fauna we studied. We support this based on the few differences detected among species collected between burn and non-burned control areas. Overall increase in species richness of both small mammals and herpetofauna between pre- and post-fire sampling periods were an artifact of our early (April) pre-treatment collections when overwintering numbers of shrews and southern red-backed voles may have been at their lowest (Terman, 1966; Merritt, 1981; Owen, 1984), woodland jumping mice may still have been in hibernation (Choate et al., 1994) and woodland salamander activity may still have been limited at these high elevations (Martof et al., 1980).

Shrews and woodland salamanders have high habitat moisture requirements (Getz, 1961; Spotila, 1972) so the higher relative abundance of smoky shrews, northern short-tailed shrews, and mountain dusky salamanders in the post-fire pitfall collections and of Blue Ridge two-line salamanders, Jordan's salamanders, and mountain dusky salamanders from the time-constrained searches from the riparian sites were not unusual. Other researchers in the southern Appalachians have documented this phenomenon for both groups (Howard, 1987; Petranka et al., 1993; Ford et al., 1994).

Our results are tempered by interactions that occurred between main effects. Most of the interactions we recorded between slope position and year of collection may have been a result of the high amount of intersite variation documented within small mammal and herpetofauna populations in the WSCEMP area (Gassett et al., 1997). The interaction between burn type and slope position among seepage salamander collections could be due to the variable proximity of small seeps and feeder streams which provide habitat suitable for these salamanders (Wilson, 1995). Seeps and streams were located near several

drift-fence arrays in the midslope areas as well as near one array in the Wine Spring Creek Burn upper slope area. We did see significant variation among deer mice, white-footed mice, golden mice, and southern red-backed voles between the 1995 and 1996 collections. Cyclic population fluctuations in arvicoline rodents such as southern red-backed voles have been well-documented (Terman, 1966; Merritt, 1981; Henttonen et al., 1985), and cyclic fluctuations with significant year to year variations in Cricetine rodents such as white-footed mice also have been recently noted (Kesner and Linzey, 1997).

We observed that the burns on the WSCEMP areas created a mosaic-vegetative pattern with a great deal of micro- and macro-site variability across relatively short distances. Owing to the extreme amounts of habitat heterogeneity, even on upper slope sites where burning impacts were most apparent, there were ample unburned or lightly affected areas. Still, changes in vegetation were statistically significant, particularly from pre- to post-fire sampling periods on the upper slope sites. Elliot et al. (1997) tracked the response of vegetation following the high intensity, prescribed fire on the Indian Camp Branch burn. On this burn, overstory mortality was high (42%) and understory shrub reductions in basal area were significant ($11.6 \text{ m}^2 \text{ ha}^{-1}$ pre-burn to $0.8 \text{ m}^2 \text{ ha}^{-1}$ post-burn) at the upper slope sites, though overstory mortality and changes in understory density were considered negligible at the midslope and riparian sites. Regrowth from sprouts was common on upper slope sites within 1 year post-burn following the prescribed fire.

Immediate impacts of the burn on small mammals in the WSCEMP area were slight, as most of the mammal species we collected, particularly the shrews, exhibit varying degrees of fossorial habits. Most of these species readily utilize runways under the forest litter, mole tunnels, stump and root holes, spaces under rock and talus beds, as well as spaces under and within downed coarse woody debris, all of which may have served as refugia during and immediately after the burn (Long, 1974; Linzey and Packard, 1977; Merritt, 1981; Smollen, 1981; Owen, 1984; Lackey et al., 1985). Goatcher (1990) and Blanchard (1991) found that cotton mice (*Peromyscus gossypinus*) on stream-terrace hardwood stands in Louisiana were relatively unaffected by the immediate impacts of prescribed fire. Kirkland et al. (1996) reported the impact of fire

on small mammal communities in the central Appalachians of Pennsylvania was transitory, with differences in small mammal abundance between burned and unburned habitats disappearing within 8 months following a wildfire. Rapid recovery of small mammal populations was linked to the rapid regrowth of ground cover within the study area, particularly of blueberry (*Vaccinium* spp.). This linkage between small mammals, particularly the rodents, and vegetation undoubtedly occurred on the WSCEMP burn areas as well. Within the period that declines were noted, Kirkland et al. (1996) hypothesized that combustion of available coarse woody debris could possibly explain declines in white-footed mice which tend to avoid areas with minimal coarse woody debris. Though not confirmed by actual sampling, anecdotal evidence would suggest that the amount of coarse woody debris consumed by the fire throughout most of the burn sites was small, with new inputs of large coarse woody debris added in some upper slope areas due to overstory mortality. Ahlgren (1966) in Minnesota and Sullivan and Boateng (1996) in British Columbia saw dramatic increases in deer mice on burn sites following fires, presumably because the rodents' ability to forage for seeds and insects was greatly increased. Southern red-backed vole numbers were depressed for 2–3 years in both studies following burning until recovery in the groundstory vegetation had occurred. Based on comparisons with our non-burned control area, we did not see a significant positive response by deer mice to the fire, or a significant negative response by southern red-backed voles. Unlike our study, the sites examined by Ahlgren (1966) were large, relatively homogeneous jack pine (*P. banksiana*) habitats in which burned areas may have provided a more dramatic change in habitat conditions relative to unburned controls for small mammals.

Fire effects on herpetofauna, particularly woodland salamanders in the southern Appalachians is virtually unknown. In the Coastal Plain of the southeastern United States where fire-adapted pine communities are widespread, fire may have little direct effect on herpetofauna, particularly reptiles (Means and Campbell, 1980). In the central Appalachians, Kirkland et al. (1996) was unable to draw inferences regarding the effects of fire on salamanders due to the low numbers collected in their study of burned and unburned forest

sites, although more red-backed salamanders (*Plethodon cinereus*) and slimy salamanders (*P. glutinosus*) were collected in the burned sites than in the unburned sites.

Management suggestions for many species of woodland salamanders in the southern Appalachians include riparian zone protection and the avoidance of excessive site desiccation following timber harvest (Petranka et al., 1993, 1994; Wilson, 1995). Ash (1995) reported that declines in Plethodontid salamanders following clearcutting in the southern Appalachians could be a result of reductions in leaf litter mass and depth, both of which are important in maintaining a mesic micro-habitat for woodland salamanders. From that standpoint, in the southern Appalachians, fire could have a negative impact on important components of salamander habitat, such as leaf litter. Because effects of burning on the overstory and understory vegetation in the riparian and midslope areas most important to woodland salamanders were slight, we think impacts to herpetofauna in this study were minimal.

Acknowledgements

Funding for this study was provided by the USDA Forest Service Southern Research Station's Wine Spring Creek Ecosystem Management Project, NSF Grant BSR90116611, and the University of Georgia Museum of Natural History. L. Swift and W. Swank contributed greatly to the initial design of this study. Field assistance was provided by K. Barker, T. Carter, S. Castleberry, N. Hicks, D. Krishon, L. Lepardo, L. Lewis, and L. Lindsley. Special thanks goes to the personnel of the Nantahala National Forest's Wayah Ranger District for implementing and successfully carrying out the Wine Spring Creek and Indian Camp Branch burns. An earlier draft of this manuscript was reviewed by S. Clapham and J. Rodrigue.

References

- Ahlgren, C.E., 1966. Small mammals and reforestation following prescribed burning. *J. For.* 64, 614–618.
- Ash, A.N., 1995. Effects of clear-cutting on litter parameters in the southern Blue Ridge Mountains. *Castanea* 60, 89–97.
- Ash, A.N., Bruce, R.C., 1994. Impacts of timber harvesting on salamanders. *Conserv. Biol.* 8, 300–301.

- Barker, K., 1997. Relationships between salamander communities and cove hardwood stand age in the southern Appalachians. M.S. Thesis, University of Georgia, Athens, GA, p. 69.
- Blanchard, V.J., 1991. Stream-terrace hardwood forest as refuge for small mammals when adjacent pine forest is burned. M.S. Thesis, Louisiana State University, Baton Rouge, LA, p. 89.
- Bury, R.B., Corn, P.S., 1988. Douglas-fir forests in the Oregon and Washington Cascades: Relation of the herpetofauna to stand age and moisture. In: Szaro, R.C., Severson, K.E., Patton, D.R. (Eds.), Management of Amphibians, Reptiles, and Small Mammals in North America. USDA Forest Service General Technical Report RM-166, pp. 11–22.
- Campbell, H.W., Christman, S.P., 1982. Field techniques for herpetofaunal community analysis. In: Scott, Jr., N.J. (Ed.), Herpetological Communities. US Fish and Wildl. Ser., Wildl. Res. Report No. 13, pp. 193–200.
- Choate, J.R., Jones, J.K., Jones, C., 1994. Handbook of Mammals of the South-Central United States. Louisiana State University Press, Baton Rouge, LA, p. 304.
- Clinton, B.D., Vose, J.M., Swank, W.T., 1993. Site preparation burning to improve southern Appalachian pine-hardwood stands: Vegetation composition and diversity of 13-year-old stands. Can. J. For. Res. 23, 2271–2277.
- Elliot, K.J., Henrick, R.L., Major, A.E., Vose, J.M., Swank, W.T., 1997. Vegetation dynamics following stand-replacement prescribed fire in the southern Appalachians. For. Ecol. Manage., in review.
- Elliot, K.J., Hewitt, D., 1997. Forest species diversity in upper elevation hardwood forests in the southern Appalachian Mountains. Castanea 62, 32–42.
- Fenneman, N.M., 1938. Physiography of the Eastern United States. McGraw-Hill, New York, p. 714.
- Ford, W.M., Laerm, J., Weinand, D.C., Barker, K.G., 1994. Abundance and distribution of shrews and other small mammals in the Chattahoochee National Forest of Georgia. Proc. Annu. Conf. Southeast. Fish Wildl. Agencies 48, 310–320.
- Ford, W.M., Laerm, J., Barker, K.G., 1997. Soricid response to forest stand age in southern Appalachian cove hardwood communities. For. Ecol. Manage. 91, 175–181.
- Gassett, J., Laerm, J., Menzel, M.A., McCay, T.S., Elliot, K.J., Knoepp, J., Ford, W.M., 1997. Variation in species richness and abundance of small mammals and amphibians in relation to microhabitat parameters in an upper elevation Appalachian hardwood forest. Abstracts First Biennial North Amer. For. Ecol. Workshop 1, 20.
- Getz, L.L., 1961. Factors influencing the local distribution of shrews. Amer. Midl. Nat. 65, 67–88.
- Goatcher, B.L., 1990. A preliminary investigation of the importance of stream-terrace hardwood forests as refuge for small mammals to escape fires. M.S. Thesis, Louisiana State University, Baton Rouge, LA, p. 53.
- Handley, C.O., Varn, M., 1994. The trapline concept applied to pitfall arrays. In: Merritt, J.F., Kirkland, Jr., G.L., Rose, R.K. (Eds.), Advances in the Biology of Shrews. Carnegie Museum of Natural History Special Publication 18, pp. 285–287.
- Henttonen, H., McGuire, A.D., Hansson, L., 1985. Comparisons of amplitudes and frequencies (spectral analysis) of density variations in long-term data sets of *Clethrionomys* species. Annals. Zoologica Fennici. 22, 221–227.
- Howard, T.A., 1987. Population and biomass estimates in four species of terrestrial Plethodontid salamanders. M.S. Thesis, Appalachian State University, Boone, NC, p. 76.
- Hooper, R.M., 1969. Prescribed burning for laurel and rhododendron control in the southern Appalachians. USDA Forest Service Res. Note SE-116, p. 6.
- Kesner, M.H., Linzey, A.V., 1997. Modeling population variation in *Peromyscus leucopus*: An exploratory analysis. J. Mammal. 78, 643–654.
- Kirkland, G.L., Sheppard, P.K., 1994. Proposed standard protocol for sampling small mammal communities. In: Merritt, J.F., Kirkland, Jr., G.L., Rose, R.K. (Eds.), Advances in the Biology of Shrews. Carnegie Museum of Natural History Special Publication 18, pp. 277–284.
- Kirkland, G.L., Snoddy, H.W., Amsler, T.L., 1996. Impact of fire on small mammals and amphibians in a central Appalachian deciduous forest. Amer. Midl. Nat. 135, 253–260.
- Lackey, J.A., Huckaby, D.G., Ormiston, B.G., 1985. *Peromyscus leucopus*. Mammal. Species No. 247, p. 10.
- Linzey, D.W., Packard, R.L., 1977. *Ochrotomys nuttalli*. Mammal. Species No. 75, p. 6.
- Long, C.A., 1974. *Microsorex hoyi* and *Microsorex thompsoni*. Mammal. Species No. 33, p. 4.
- Martof, B.S., Palmer, W.M., Bailey, J.R., Harrison, J.R., 1980. Amphibians and Reptiles of the Carolinas and Virginia. University of North Carolina Press, Chapel Hill, NC, p. 264.
- McComb, W.C., Rumsey, R.L., 1982. Response of small mammals to forest clearings created by herbicides in the central Appalachians. Brimleyana 8, 121–134.
- Means, D.B., Campbell, H.W., 1980. Effects of prescribed burning on amphibians and reptiles. In: Wood, G.W. (Ed.), Prescribed Fire and Wildlife in Southern Forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, SC, pp. 89–97.
- Merritt, J.F., 1981. *Clethrionomys gapperi*. Mammal. Species No. 146, p. 9.
- Owen, J.G., 1984. *Sorex fumeus*. Mammal. Species No. 215, p. 8.
- Ott, L., 1988. An Introduction to Statistical Methods and Data Analysis. PWS-Kent Publishing, Boston, MA, p. 835.
- Petranka, J.W., Eldridge, M.E., Haley, K.E., 1993. Effects of timber harvesting on southern Appalachian salamanders. Conserv. Biol. 7, 363–370.
- Petranka, J.W., Brannon, M.P., Hopey, M.E., Smith, C.K., 1994. Effects of timber harvesting on low elevation populations of southern Appalachian salamanders. For. Ecol. Manage. 67, 135–147.
- Sharitz, R.R., Boring, L.R., Van Lear, D.H., Pinder, J.E., 1992. Integrating ecological concepts with natural resource management of southern forests. Ecol. Appl. 2, 226–237.
- Smith, R.N., 1991. Species composition, stand structure, and woody detrital dynamics associated with pine mortality in the southern Appalachians. M.S. Thesis, University of Georgia, Athens, GA, p. 163.

- Smollen, M.J., 1981. *Microtus pinetorum*. Mammal. Species no. 147, p. 7.
- Spotila, J.R., 1972. Role of temperature and water in the ecology of lungless salamanders. Ecol. Monogr. 42, 95–125.
- Steele, R.G.D., Torrie, J.H., 1980. Principles and Procedures of Statistics: A Biometrical Approach. McGraw-Hill, New York, p. 633.
- Sullivan, T.P., Boateng, J.O., 1996. Comparison of small-mammal community responses to broadcast burning and herbicide application in cutover forest habitats. Can. J. For. Res. 26, 462–473.
- Swift Jr., L.W., Waide, J.B., White, D.L., 1989. Refinements in the Z–T method of extreme value analysis for small watersheds. Proc. Amer. Meteorological Soc. Conf. Appl. Climatology 6, 60–65.
- Terman, C.R., 1966. Population fluctuations of *Peromyscus maniculatus* and other small mammals as revealed by the North American Census of small mammals. Amer. Midl. Nat. 76, 240–243.
- USDA Forest Service, 1996. The Southern Appalachian Assessment: Terrestrial Technical Report. USDA Forest Service, Southern Region, Atlanta, GA, p. 288.
- Vose, J.M., Clinton, B.D., Swank, W.T., 1994. Fire, drought, and forest management influences on pine/hardwood ecosystems in the southern Appalachians. Proc. International Conf. Fire and Forest Meteorology 12, 232–238.
- Waterman, J.R., Gillespie, A.R., Vose, J.M., Swank, W.T., 1995. The influence of mountain laurel on regeneration in pitch pine canopy gaps of the Coweeta Basin, North Carolina, USA. Can. J. For. Res. 25, 1756–1762.
- Williams, C.E., Johnson, W.C., 1992. Factors affecting recruitment of *Pinus pungens* in the southern Appalachian Mountains. Can. J. For. Res. 22, 878–887.
- Wilson, L.A., 1995. The land manager's guide to the amphibians and reptiles of the South. The Nature Conservancy and USDA Forest Service, Atlanta, GA, p. 324.