

Woodland Salamander and Small Mammal Responses to Alternative Silvicultural Practices in the Southern Appalachians of North Carolina

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Abstract: The effects of 2 years post-treatment of group selection and 2-aged timber harvests on woodland salamanders and mammals were assessed on stands in high elevation, southern Appalachian northern red oak (*Quercus rubra*)-flame azalea (*Rhododendron calendulaceum*) communities, in the Nantahala National Forest. We collected 4 salamander species and 10 small mammal species. We detected no difference in woodland salamander relative abundance between timber harvests and uncut (control) stands. Similarly, relative abundance of all small mammal species, except masked shrews (*Sorex cinereus*), was unaffected by timber harvest. Masked shrew relative abundance was greater post-harvest in 2-aged harvest stands than in group selection harvest stands or uncut stands. For masked shrews, these high elevation, 2-aged harvests may have provided an optimal mix of residual overstory shading, dense shrub-layer shading from new regeneration, and abundant downed coarse woody debris. Alternative silvicultural practices such as group selection harvest and 2-aged harvests are compatible with goals of providing timber production without altering small mammal and woodland salamander assemblages on the Wine Spring Creek Ecosystem Management Project area.

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The ecosystem management paradigm has been adopted as the guiding theme for national forest management in the southern Appalachian region and elsewhere

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(Sharitz et al. 1992, Ford et al. 1994, Wear et al. 1996, Ford et al. 1999). Successful decision support for ecosystem management depends largely on a complete understanding of ecosystem processes and the impact of adaptive management activities on a wide array of biological attributes (Rauscher 1999), including nongame wildlife species (Ford et al. 1999, Menzel et al. 1999). One result of nearly a decade of ecosystem management-guided activities on southern Appalachian national forests has been the cessation of clearcutting and increased interest in use of alternative silvicultural practices such as group selection harvests, shelterwood harvests, and 2-aged harvests (Guldin 1996). Although both short-term and long-term effects of clearcutting on woodland salamanders and small mammals are well documented in the southern Appalachians (Ash 1988, Kirkland 1990, Petranka et al. 1994, Ford et al. 1997, Harper and Guynn 1999, Ford et al. 2002), responses to most other forest management practices are poorly known (Ford and Rodrigue 2001). Accordingly, we studied short-term response of woodland salamanders and small mammals following group selection harvests and 2-aged harvests in the southern Appalachian Mountains of North Carolina on the Wine Spring Creek Ecosystem Management Project (WSCEMP).

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Methods

We surveyed woodland salamander and small mammal communities in September 1995 prior to 1997 timber harvests and again 2 years post-harvest in June 1999 at 3 group selection harvests, 3 2-aged harvests, and 2 uncut control stands on the WSCEMP. The 1,820-ha WSCEMP area is located within the Blue Ridge Physiographic province in Macon County, North Carolina (Fenneman 1938) on the Nantahala National Forest, approximately 25 km south of the Great Smoky Mountains National Park. Topography was mountainous with steep slopes and narrow, deeply incised watercourses. Elevations ranged from 1,380 to 1,500 m on our study sites. Mean annual precipitation and temperature was 180 cm and 11.5 C, respectively.

Pre-harvest, the 6 timber harvest stands and 2 uncut control stands we studied were dominated by oak (*Quercus* spp) -deciduous heath and dry northern hardwood communities characterized by a northern red oak (*Q. rubra*) overstory and a flame azalea (*Rhododendron calendulaceum*) shrub layer (Wharton 1978). These stands originated following widespread clearcut logging in the early 1900s (Yarnell 1998), and were further modified by chestnut blight fungus (*Cryphonectria parasitica*) in

the 1930s and selection logging in the early 1970s (Elliot and Hewitt 1997). A complete study area description is provided by Elliot and Hewitt (1997).

Pre-harvest overstory basal area on group selection harvest stands, 2-aged stands, and uncut control stands was approximately 27 m²/ha. Harvest sites and uncut control stands averaged 6.2 ha in size. All trees within 2–3 marked “groups” of 0.5 to 1 ha were felled in the group selection harvests. Within 2-aged stands, 4–8 m²/ha of residual overstory basal area was retained with emphasis given to oak species to maintain hard mast production. The purpose of 2-aged harvests is to perform stand regeneration in combination with provisions for late successional wildlife habitat benefits such as hard mast production and complex stand structure (Miller et al. 1995).

We surveyed woodland salamanders and small mammals using pitfall and live-trapping on 7×7 grids with 10 m spacing (Jones et al. 1996) placed in each group selection harvest stand, each 2-aged harvest stand, and both uncut control stands pre-harvest in September 1995 and post-harvest in June 1999. One pitfall and live-trap was placed at each of 49 trapping stations on each grid. Trapping station location was constant between pre- and post-harvest survey efforts. Trapping grids in group selection harvests were placed so that approximately half of the traps were in the cut areas and uncut areas, respectively. Pitfalls consisted of 943 cm³ plastic cups buried flush to the ground and filled 1/3 of volume with 10% formalin to preserve specimens (Barker 1997, McCay et al. 1998). Pitfalls were opened for 2 weeks during both sampling periods. Woodland salamanders and soricids collected by pitfall-trapping were identified to species based on external morphology and repositied in the teaching and research collections of the University of Georgia Museum of Natural History, Athens, and Ferrum College, Ferrum, Virginia.

To live-trap small mammals, we used 5 cm×6.45 cm×16.5 cm folding Sherman® traps baited with rolled oats (Jones et al. 1996). Live-trapping was conducted for 4 days concurrent to the last 4 days during the pitfall trapping session for both sampling periods. We identified live-trapped small mammals to species and sexed and aged them based on external morphology and pelage, ear-tagged with Size 1 Monel Tags (Natl. Band and Tag Co., Newport, Ky.), and released. Because recapture rates were too low in most grids for all species (≤2 recaptures per trapping session) to calculate reliable density estimates (Otis et al. 1978, White et al. 1982) for deer mice (*Peromyscus maniculatus*), white-footed mice (*P. leucopus*), and southern red-backed voles (*Clethrionomys gapperi*), relative abundances based on numbers of uniquely marked animals within trapping periods (Cameron 1977, Buckner and Shure 1985) were recorded during pre- and post-harvest sampling periods. Research was conducted under the authority and guidelines of North Carolina Scientific Collecting Permit 95-ES-10 and the University of Georgia Museum of Natural History collection guidelines.

Relative abundance of woodland salamanders and small mammals were compared among group selection harvests, 2-aged harvests, and uncut control stands post-harvest using Analysis of Covariance (Steel and Torrie 1980, Montgomery 1991). Pre-harvest relative abundance values were used as covariates for each species to minimize individual site-to-site variation inherent in these types of data;

moreover, pre-treatment species assemblage and relative abundance for each stand surveyed directly influenced post-harvest treatment effects. We tested for normality of abundance data using a Shapiro-Wilk procedure (Shapiro and Wilk 1965). Non-normal data were square-root transformed. Mean values of relative abundance were reported/100 trapnights using treatment means adjusted for the covariate (SAS 1991). When significant treatment effects were detected among species ($\alpha=0.05$), separation of means adjusted for the covariate was performed using Scheffe's test (Ott 1988).

Results

We accumulated 5,998 pitfall trapnights and 1,176 live-trapping trapnights pre-harvest in 1995, and 5,488 pitfall trapnights and 1,176 live-trapping trapnights post-harvest on the WSEMP. Post-harvest, there was no significant difference in relative abundance of Jordon's salamanders (*Plethodon jordoni*), Ocoee salamanders (*Desmognathus ocoee*), and two-lined salamanders (*Eurycea bislineata*) between group selection harvest areas, 2-aged harvest areas, and uncut control stands (Table 1). Pre-harvest, 1 eastern newt (*Notophtalmus viridescens*) was collected in group selection harvest area pitfalls and 1 was collected in 2-aged harvest area pitfalls. No eastern newts were collected post-harvest.

Post-harvest, there was no significant difference in the relative abundance of smoky shrews (*Sorex fumeus*), pygmy shrews (*S. hoyi*), northern short-tailed shrews (*Blarina brevicauda*), deer mice, white-footed mice, and southern red-backed voles among group selection harvest areas, 2-aged harvest areas, and uncut control stands (Table 2). Masked shrews (*S. cinereus*) were more abundant in 2-aged harvest areas than in group selection harvests and uncut control stands (Table 2). One golden mouse (*Ochrotomys nuttalli*) was collected pre-harvest in a 2-aged stand. Pre-harvest, 5 pine voles (*Microtus pinetorum*) were collected in group selection harvest areas pitfalls, 6 were collected in 2-aged harvest areas pitfalls, and 3 were collected in uncut stand pitfalls. Similarly, pre-harvest, 2 woodland jumping mice (*Napaeozapus insignis*) were collected in group selection harvest area live-traps, 3 were collected in 2-aged harvest

Table 1. Mean post-harvest collection of woodland salamanders in group selection harvests ($N=3$), two-aged harvests ($N=3$), and uncut control stands ($N=2$) in northern red oak-flame azalea communities on the Wine Spring Creek Ecosystem Management, Nantahala National Forest, North Carolina, 1999. Data are reported as adjusted means/100 pitfall trapnights using 1995 pre-harvest collection values as covariates.

Species	Group selection		Two-aged		Uncut		F	P
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE		
Jordan's salamander	2.06	0.51	1.00	0.51	2.38	0.63	1.75	0.247
Ocoee salamander	1.45	0.80	1.86	1.13	0.46	2.25	0.26	0.781
Two-lined salamander	0.11	0.18	0.01	0.20	0.58	0.25	1.57	0.314

Table 2. Mean post-harvest collection of small mammals in group selection harvests ($N=3$), two-aged harvests ($N=3$), and uncut control stands ($N=2$) in northern red oak-flame azalea communities on the Wine Spring Creek Ecosystem Management, Nantahala National Forest, North Carolina, 1999. Data are reported as adjusted means/100 pitfall trapnights for soricids and per 100 live-trap trapnights for rodents using 1995 pre-harvest collection values as covariates. Adjusted means within a row not followed by same letter differ in the transformed data ($P < 0.05$).

Species	Group selection		Two-aged		Uncut		F	P
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE		
Masked shrew	1.23a	0.48	4.49b	0.52	1.14a	0.66	11.47	0.022
Smoky shrew	1.55	0.79	3.34	0.90	0.87	1.14	1.63	0.303
Pygmy shrew	0.20	0.16	0.39	0.12	0.23	0.20	0.65	0.569
Northern short-tailed shrew	0.42	0.47	0.67	0.41	0.23	0.55	0.24	0.793
Deer mouse	5.36	2.05	4.32	1.72	5.96	2.57	0.19	0.834
White-footed mouse	1.27	0.83	0.32	0.67	0.11	1.96	0.44	0.672
Southern red-backed vole	0.09	0.18	0.13	0.14	0.16	0.18	0.14	0.870

area live-traps, and 2 in uncut control stand live-traps. No golden mice, pine voles, or woodland jumping mice were collected post-harvest despite being collected in similar habitats in 1996 and 1997 on a concurrent WSCOMP study (Ford et al. 1999).

Discussion

Our finding of no significant short-term impact from group selection and 2-aged timber harvests to woodland salamanders on the WSCOMP contrasts with salamander response to clearcutting in the southern Appalachians (Petranka et al. 1993, Petranka et al. 1994, Ford et al. 2001). This is particularly true for the genus *Desmognathus* that generally require relatively undisturbed and mesic conditions (Petranka 1998). For the wholly terrestrial genus *Plethodon*, Ash (1988) found that Jordon's salamander declined 40% immediately following clearcutting when compared to an adjacent uncut stand because of altered site conditions from increased solar radiation, decreased leaf litter, and increased bare soil. Bartman (1998) reported a decline from pre-harvest in 1996 to post-harvest in 1997 for Jordon's salamanders at one WSCOMP group selection harvest following a mark-recapture effort. However, a similar decline was noted in the uncut control area indicating that summer drought conditions that occurred on the WSCOMP in 1997 influenced salamander populations more than timber harvest. Interestingly, no marked salamander was documented moving from the group selection cut into adjacent uncut forests (Bartman 1998), confirming assertions of Petranka (1994) that salamanders do not emigrate following disturbance.

Retained overstory cover may be the most important habitat factor in determining timber harvest impacts to salamanders in the southern Appalachians (Harpole

and Haas 1999). For example, salamander declines were noted in clearcut and shelterwood harvest systems removing substantial overstory in xeric, Ridge and Valley forests in Virginia (Harpole and Haas 1999); whereas selection logging did not impact salamander abundance in northern hardwood stands in New York (Messere and Ducey 1998). Although group selection harvests are small clearcuts, shading from adjacent uncut forests shield much of the harvested area. Similarly, 2-aged stands, after 2 growing seasons, retained beneficial overstory shading from residual trees and contained abundant post-harvest, 1.5 to 2-m high, woody regeneration that might have retained microsite moisture and provided sufficient annual leaf litter inputs.

Harper and Guynn (1999) noted that the high elevations and cool climate on the WSCEMP probably ameliorate many of the negative microhabitat and microclimatic conditions thought to impact salamanders following timber harvest. At lower elevations, proximity to watercourses such as seeps, springs, and perennial streams can confound salamander response to forest management studies in the southern Appalachians (Ford et al. 2002). Although each of our trapping grids was ≥ 200 m from a perennial stream, Jordon's salamander, Ocoee salamanders, and Blue Ridge two-line salamanders are widely distributed at high elevation far from running water in the southern Appalachians (Petranka 1998).

We recognize that low treatment replication and high between-site variation in this study severely limits our ability to detect changes in salamander response. Additionally, because salamander response to timber harvest often is delayed for several years following timber harvest (Harpole and Haas 1999), expanded post-harvest research will be required to fully understand long-term impact of group selection and 2-aged timber harvests on woodland salamanders at the WSCEMP.

Small mammal assemblage changes from forest to early successional habitats analogous to shifts from cotton mouse (*P. gossypinus*)-southern short-tailed shrew (*B. carolinensis*) dominance to old field mouse (*P. polionotus*)-least shrew (*Cryptotis parva*) dominance in the Piedmont or Coastal Plain (Atkenson and Johnson 1979, Yates et al. 1997, Menzel et al. 2002) are unapparent in the southern Appalachians. Within southern Appalachian cove hardwood forests, smoky and northern short-tailed shrew abundance is greater in stands ≥ 85 years old than those 15 to 25 years old (Ford et al. 1997), but species assemblages are identical. Pygmy shrews occur throughout the southern Appalachians across all habitats in low densities (Laerm et al. 1999); however, they appear to be most abundant in disturbed habitats on xeric sites (Ford et al. 1994). Ford and Rodrigue (2001) found no difference in sorcid community structure and relative abundance between cut and uncut Allegheny/northern hardwood forests in West Virginia following 2-aged harvests and diameter-limit thinning. Of habitat variables important to shrews in West Virginia, uncut stands contained more leaf litter and greater overstory canopy cover; whereas coarse woody debris loadings and understory woody cover were greater in cut stands. Masked shrews on the WSCEMP did respond favorably to 2-aged harvests. Kirkland (1990) noted that masked shrews appeared to increase in abundance following disturbance in northern forests so long as cool, moist conditions prevailed. The masked shrew, a Pleistocene relict in the southern Appalachians (Pagels et al. 1994), is uncommon at

mid- to low elevations south of the Smokies (Laerm et al. 1999). The large extent of high elevation area (>1,200 m) on the WSCEMP provides post-disturbance conditions more similar to those reported by Kirkland (1990) than studies from lower elevations in the southern Appalachians or Piedmont and Coastal Plain.

Unlike the rodent population response patterns we observed, southern red-backed voles and white-footed mice generally increase following clearcutting (Kirkland 1990). Group selection harvests and 2-aged harvests we surveyed apparently did not surpass habitat quality or structure thresholds (Buckner and Shure 1985) to significantly alter relative abundances. Residual overstory trees in the 2-aged harvests probably allowed the more arboreal deer mouse to maintain its numerical and competitive dominance over white-footed mice. Moreover, it is possible that newly created early successional areas in the group selection harvests were too small to elicit a white-footed mouse population response. Annual hard mast production can have profound impacts on wildlife, including rodents (Goodrum et al. 1971, Beck 1977, Wentworth et al. 1992). In years following high acorn abundance, both undisturbed and disturbed or modified woodlands may support high densities of deer mice and white-footed mice. Similarly, in years following poor mast crops, rodent densities in the southern Appalachians may be extremely low across all habitat types (McShea and Schwede 1993). Our 1995 and 1999 surveys were preceded by "fair" area fall acorn mast index ratings (Whitehead 1969) of 2.06 in 1994 and 3.34 in 1998 (S. Osborne, N.C. Wildl. Resour. Comm., unpubl. data) indicating that our results probably were not confounded greatly by annual hard mast variation.

Woodland salamanders and small mammals are important ecosystem components that can be impacted by forest management activities (deMaynadier and Hunter 1995, Tappe et al. 1994). Based on short-term faunal response, it appears that use of alternative silvicultural practices such as group selection harvests and 2-aged harvests succeeds in meeting commodity production and stand regeneration objectives without significantly altering woodland salamander and small mammal communities on the WSCEMP. In addition to continued long-term monitoring, efforts should be directed towards more detailed and manipulative analyses of woodland salamander and small mammal microhabitat relationships in the southern Appalachians. Without a complete understanding of ecological mechanisms that influence these groups following timber harvest, documentation of cause and effect relationships will remain speculative.

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