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Long-term partial cutting impacts on *Desmognathus* salamander abundance in West Virginia headwater streams

Kurtis R. Moseley [a], W. Mark Ford [b,*], John W. Edwards [a], Thomas M. Schuler [b]

[a] *Division of Forestry and Natural Resources, West Virginia University, Morgantown, WV 26506, USA*
[b] *USDA Forest Service, Northern Research Station, Parsons, WV 26287, USA*

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Abstract

To understand long-term impacts of partial cutting practices on stream-dwelling salamanders in the central Appalachians, we examined pooled abundance of *Desmognathus fuscus* and *D. monticola* salamanders (hereafter *Desmognathus*) in headwater streams located within long-term silvicultural research compartments on the Fernow Experimental Forest, Tucker County, West Virginia. We sampled *Desmognathus* salamanders in 12 headwater streams within silvicultural research compartments that have been subjected to partial cutting for approximately 50 years. We used an information-theoretic approach to test five *a priori* models explaining partial cutting effects at the compartment-level on *Desmognathus* abundance and eight *a priori* models explaining stream reach-scale habitat effects on *Desmognathus* abundance. Our modeling efforts resulted in the selection of two competing models explaining partial cutting effects on *Desmognathus* abundance at the compartment-level. The VOLUME model, which incorporated cumulative timber volume harvested within compartments, received the greatest support and indicated that *Desmognathus* abundance was impacted negatively by increased timber volume removal. The second model, LASTDISTURB, incorporating the single variable of time since last harvest activity, indicated that *Desmognathus* abundance increased with time since last harvest at the compartment-level. For stream reach-scale habitat variables, the EMBEDDED model incorporating the percent of embedded substrate within streams, received the strongest support for explaining *Desmognathus* abundance. Our results suggest that long-term partial cutting suppresses *Desmognathus* abundance, possibly by increasing stream sedimentation and thereby reducing available cover for juvenile and adult salamanders. However, these practices do not appear to have threatened long-term persistence of *Desmognathus* in central Appalachian headwater streams.
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Keywords: Best management practices; Central appalachians; *Desmognathus*; Forest management; Headwater streams; Partial cutting; Sedimentation

1. Introduction

In the eastern United States, stream salamanders are the most numerically abundant vertebrates in most headwater streams, often replacing fish as top predators (Petranka, 1983; Hairston, 1987; Lowe and Bolger, 2002). Because of their abundance and high trophic level position, these salamanders serve as keystone predators, thereby exerting disproportionate influence on biotic community structure in headwater stream habitats (Davic and Welsh, 2004). Although many species frequently forage in surrounding non-aquatic riparian areas (Petranka and Smith, 2005), aquatic habitats for breeding, larval growth, and refugia are necessary for survival (Petranka, 1998). Accordingly, aquatic salamanders often are sensitive to stream habitat alterations resulting from upland watershed disturbances, such as timber harvesting. Despite the importance of aquatic habitats for cover and reproduction, investigations of partial cutting impacts in the Central and Southern Appalachian Mountains have primarily focused on terrestrial environments (Harpole and Haas, 1999; Ford et al., 2000, 2002; Duguay and Wood, 2002; Knapp et al., 2003). These studies suggest that partial cutting practices somewhat adversely affect salamander capture rates and population demography, at least in the short-term. In New England, Lowe and Bolger (2002) observed that *Gyrinophilus porphyriticus* density in headwater streams increased with increasing time since last harvest disturbance (e.g., clearcutting, commercial thinning, single-tree selection, and group selection). Also, Perkins and Hunter (2006) found *Eurycea bislineata* exhibited a trend of decreasing abundance with increasing harvest intensity within streams adjacent to

* Corresponding author. Tel.: +1 304 478 2000x111; fax: +1 304 478 8692.
E-mail address: mford@fs.fed.us (W. Mark Ford).

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riparian areas subject to partial cutting 4–10 years prior to sampling, clearcut with 35 m forested buffers along streams, and unmanipulated mature forest (>50 years since last harvest). Upland harvesting activities can negatively alter stream habitat components important to aquatic salamander species (de Maynadier and Hunter, 1995; Corn et al., 2003). Soil disturbance, skid road creation, and removal of streamside vegetation can increase stream siltation and stream temperature in the short-term (Reinhart et al., 1963; Patric, 1980; Kochenderfer et al., 1987), possibly reducing cover sites important to stream salamanders by filling interstitial spaces (Bury and Corn, 1988; Corn and Bury, 1989; Lowe and Bolger, 2002; Lowe et al., 2004). The degree to which streams are impacted, and subsequently recover, depends on a variety of factors including harvesting intensity and frequency, and road density within watersheds (Aubertin and Patric, 1974; Stuart and Edwards, 2006). Water quality measures outlined in many state best management practice (BMP) guidelines, such as retention of forested buffer zones and proper skid and logging road placement, can help mitigate many adverse timber harvesting effects on stream habitats (Kochenderfer et al., 1997; Kochenderfer and Edwards, 1990). However, because partial cutting practices often involve periodic timber removal operations every 10–20 years (Smith et al., 1997), repeated harvesting may produce chronic sedimentation effects that reduce stream habitat quality for aquatic salamanders. In the central Appalachians, Knapp et al. (2003) suggested that if salamander populations do not recover following partial cutting to precutting levels before successive cuts then populations may never reach precutting levels and could remain suppressed in the long-term.

A better understanding of how stream salamander populations are affected by partial cutting is needed as many regions in the eastern United States are experiencing increased timber harvesting following maturation of second- and third-growth forests. Public concern over clearcut harvesting effects on wildlife habitat and aesthetics has, in part, prompted increased use of partial cutting practices, such as single-tree selection, patch cutting, and diameter-limit cutting, regardless of ownership. For both public and privately owned forests, partial cutting practices provide a continuous canopy cover, thereby enhancing aesthetic value, and satisfies economic objectives by generating periodic financial returns throughout the rotation (Miller, 1993). Currently, partial cutting is the most commonly practiced harvesting method on non-industrial private forests (NIPF) in the central Appalachians (Fajvan et al., 1998; Fajvan, 2006). Because NIPF account for the majority of commercially utilized forestlands in the East, the effects of timber harvest practices implemented on these forests have important consequences for wildlife conservation in the region (Fredericksen et al., 2000).

To determine cumulative effects of partial cutting practices on stream salamanders in the Allegheny Mountain region of the central Appalachians in West Virginia, we examined the pooled abundance of *Desmognathus fuscus* and *D. monticola* salamanders (hereafter *Desmognathus*) in headwater streams within long-term silvicultural research compartments that have been subjected to repeated partial cutting over the past 50 years. The long life span, small home ranges, and limited dispersal ability of *Desmognathus* (Barbour et al., 1969; Barthalamus and Bellis, 1972) makes them well-suited as indicators of disturbance in forested landscapes (Welsh and Ollivier, 1998; Welsh and Droege, 2001). Accordingly, our objective was to determine how repeated partial cutting over an approximate 50-year period affected *Desmognathus* abundance. Specifically, we examined (1) the influence of variables associated with partial cutting on *Desmognathus* abundance within adjacent headwater streams and (2) the importance of reach-scale stream variables in determining *Desmognathus* abundance. We hypothesized that *Desmognathus* abundance within sampled streams would decrease with increased amount of cumulative timber volume removed. In addition, we hypothesized that stream reaches with greater sedimentation impacts, such as greater percentages of fine sediments and embedded substrate, would exhibit reduced *Desmognathus* abundance.

2. Study site and methods

2.1. Site description

We conducted our study on the Fernow Experimental Forest (FEF) in Tucker County, West Virginia. The FEF is a 1902-ha experimental forest located wholly within the Unglaciated Allegheny Mountains subsection of the Appalachian Plateau Physiographic region. Broad ridge tops, narrow valleys, steep side-slopes ranging from 10 to 60%, and high-gradient streams characterize the topography of the FEF. Soils are predominantly of the Calvin and Dekalb series originating from sandstone parent material or the Belmont series originating from limestone parent material. All types are well-drained, medium-textured loams and silty loams, with an average depth of 1 m. The climate is cool and moist with mean annual precipitation approximating 145 cm and being evenly distributed throughout the year. Elevations range from 533 to 1112 m. Forest cover is primarily second-growth mixed mesophytic hardwood type consisting of sugar maple (*Acer saccharum*), red maple (*A. rubrum*), northern red oak (*Quercus rubra*), chestnut oak (*Q. prinus*), yellow-poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), sweet birch (*Betula lenta*), black cherry (*Prunus serotina*), and basswood (*Tilia americana*; Madarish et al., 2002). The majority of the FEF initially was logged between 1903 and 1911. In the 1930s approximately 25% of the standing tree volume was reduced as a result of chestnut blight (*Cryphonectria parasitica*) (Trimble, 1977). The FEF is managed by the USDA Forest Service's Northern Research Station for long-term silvicultural watershed and ecological research (Schuler and Gillespie, 2000). Research stands on the FEF are managed using a variety of silvicultural practices including even-aged, patch cutting, diameter-limit, and uneven-aged single-tree selection.

2.2. Methods

We identified 12 silvicultural research compartments, ranging in size from 13 to 73 ha, that had been subjected to