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Effects of timber harvest within streamside management zones on salamander populations in ephemeral streams of southeastern Kentucky

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ABSTRACT

Timber harvest is an important extractive, economic activity to many human economies, but it can be detrimental to ecosystem function and species viability therein by degrading and fragmenting forest habitat. Salamanders comprise a significant amount of forest community biomass, and given their sensitivity to environmental stressors, including those caused by timber harvest, they often serve as important indicators of declines in forest ecosystem function. Several studies have focused on the impacts of timber harvest on salamanders inhabiting perennial and intermittent streams, the findings of which have helped inform best management practices for timber harvest in the U.S. Ephemeral headwater streams and associated riparia account for a small fraction of the total landscape, yet these features are critical to the functioning of forested ecosystems; however, few studies have examined how timber harvest impacts salamanders in or near these areas. Our objective was to investigate the effects of three different silvicultural treatments, each involving different streamside management zone (SMZ) characteristics, on salamander communities in southeastern Kentucky hardwood forest ephemeral streams. Data were collected by regular checks of pitfall traps, coverboards, and transect searches. Using both pre- and post-harvest data, abundance estimates were acquired using binomial mixture models. Declines in some species of terrestrial and stream-breeding salamanders were detected, and were shown to be likely related to characteristics of the corresponding silvicultural treatment. We suggest that application of modest SMZ regulations to ephemeral streams would likely reduce or alleviate salamander declines in these important headwater areas.

1. Introduction

Headwater streams and associated riparia account for a small fraction of the total landscape, yet these habitats are critical to the functioning of forested ecosystems. These areas are involved in regulation of soil moisture, preserving nutrients and soil from runoff and erosion, and influencing air, water, and soil temperatures (Lowe and Likens, 2005). However, headwater streams and riparia are sensitive to damage from anthropogenic changes to forested landscapes, particularly changes associated with timber harvest (Brown et al., 1997).

Numerous federal, state, and local regulations have been implemented to protect streams from timber harvest, including Streamside Management Zones (SMZs), otherwise referred to as stream buffers. SMZs typically have requirements for improved crossings, road construction, and the preservation of standing timber, dictated by stream characteristics including classification into perennial, intermittent, or ephemeral types. Perennial streams are often afforded the most liberal protections; in Kentucky, this includes leaving an unharvested stream buffer free of trails, roads, and landings that range in width from 7.6 m to 50.3 m depending on bank slope (Stringer and Perkins, 2001). Additionally, 50% of canopy trees must be preserved within 16.8 m on either side of the perennial streams with bank slopes >15%; no canopy retention

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requirements exist for intermittent streams; however, a 7.6 m buffer is required on flat ground, and the buffer increases in width by 1.5 m for every 5% increase in bank slope (Stringer and Perkins, 2001). Conversely, no buffer or canopy retention requirements exist for ephemeral streams in Kentucky, and few exist anywhere in the eastern United States (Witt et al., 2013).

Salamanders (Plethodontidae) are the dominant vertebrate in low order streams and riparia within eastern North America, and can substantially contribute to the biomass of these environments (Peterman et al., 2008). Numerous studies have demonstrated that salamander populations are particularly vulnerable to large scale anthropogenic landscape disturbances (Semlitsch et al., 2009; Price et al., 2011). Specifically, timber harvests can be particularly detrimental to many terrestrial breeding salamander species, populations of which may require long periods of time for full recovery (Petranka et al., 1993; Connette and Semlitsch, 2013). Many terrestrial species are dependent on key microhabitat variables such as surface moisture and canopy cover (Peterman and Semlitsch, 2013), which can be affected by timber harvest (Petranka et al., 1993). In addition, changes to the in-stream habitat of low-order streams after timber harvests can cause decreased abundances of stream salamanders; these declines have been shown to likely result from logging-associated sediment inputs (Lowe and Bolger, 2002; Lowe et al., 2004; Moseley et al., 2008; Peterman and Semlitsch, 2009). For example, Peterman and Semlitsch (2009) found that sediment associated with even-aged timber harvest was the only habitat variable they measured that was negatively associated with larval two-lined salamander (*Eurycea wilderae*) abundance.

Numerous studies have looked at plethodontid salamander populations at sites with different histories of timber harvest (Petranka et al., 1993; Ford et al., 2002; Lowe and Bolger, 2002; Knapp et al., 2003; Crawford and Semlitsch, 2008; Moseley et al., 2008; Peterman and Semlitsch, 2009). However, the use of before-after control-impacted (BACI) studies to evaluate the response of salamander populations to timber harvest are uncommon (but see Perkins and Hunter, 2006). BACI studies are often preferred to control versus impacted designs because they incorporate both time and control sites and they can alleviate the chance that variation in unmeasured covariates among sites are influencing observed effects (McDonald et al., 2000). Because salamander populations can be distributed unevenly spatially and temporally (Wyman, 1988; Connette and Semlitsch, 2013; Peterman and Semlitsch, 2013), assuming pre-treatment site homogeneity can potentially weaken experimental conclusions (deMaynadier and Hunter, 1995).

We conducted a BACI study to examine salamander populations in a managed, mixed-mesophytic forest of southeastern Kentucky. Specifically, we examined how timber harvest using the current Kentucky Best Management Practices (BMPs) affected salamander abundances in ephemeral streams and the adjacent riparian habitat if SMZ regulations similar to those for intermittent streams were applied to ephemeral streams.

2. Methods

2.1. Study site

Our study was conducted in the main block of the University of Kentucky's Robinson Forest (RF), located in Breathitt and Knott counties, in southeastern Kentucky. The main block of RF contains 4450 ha of relatively intact second growth deciduous forest. Elevations range from approximately 243–487 m (Overstreet, 1984). All roads are dirt or gravel, and most stream crossings are unimproved. The predominant forest assemblage is characterized as mixed mesophytic, including roughly 30 co-dominant tree species (Braun, 1950). Common tree species include American beech (*Fagus grandifolia*), yellow-poplar (*Liriodendron tulipifera*), basswood (*Tilia spp.*), sugar maple (*Acer saccharum*), northern red oak (*Quercus rubra*), white oak (*Quercus alba*), eastern hemlock (*Tsuga canadensis*), and yellow buckeye (*Aesculus octandra*) (Braun, 1950). Understory species included eastern redbud (*Cercis canadensis*), flowering dogwood (*Cornus florida*), spicebush (*Lindera benzoin*), pawpaw (*Asimina triloba*), umbrella magnolia (*Magnolia tripetala*), and bigleaf magnolia (*Magnolia macrophylla*). Ridge tops, south facing slopes and areas with rocky shallow soils are characterized by oak-hickory (*Quercus-Carya*) and oak-pine (*Quercus-Pinus*) communities (Overstreet, 1984).

Both pre- and post-harvest salamander sampling was conducted in 11 randomly selected ephemeral streams in 6 watersheds, all within the 1545 ha Clemons Fork drainage. Our study sites were selected at random from a pool containing all the ephemeral channels in both watersheds of each treatment. We defined ephemeral streams as those which flow only during short periods of surface runoff events, such as after snowmelt or heavy rainfall (Fritz et al., 2008). The watersheds ranged from 25–60 ha, were located in the same elevation range (305–378 m), and all had bank slopes exceeding 15% (Schneider, 2010).

2.2. Timber harvest methods

Between June 2008 and March 2009, four first-order watersheds were harvested. A two-age deferment harvest (shelterwood with reserves system) was applied, resulting in a two-age stand with a residual target basal area of 3.4 m^2 per ha of reserve trees (4 dominant or co-dominant trees per ha) (Witt, 2012). This method was used over the entirety of the watersheds, with the exception of landings, trails, and the areas subject to SMZ treatments. Blocking of ephemeral channels with logging debris was not permitted, in accordance with Kentucky's BMP regulations (Stringer and Perkins, 2001).

The ephemeral streams included in this study were subjected to one of three treatments. Treatment 1 ($n = 3$) was designed to reflect the current SMZ requirements for ephemeral streams (no buffers or basal area retention). Additionally, no improved crossings were used for ephemeral streams assigned to treatment 1. Machinery crossed the streams at right angles, and material moved during skid trail construction was placed in areas not susceptible to erosion into ephemeral channels (Witt, 2012). Treatment 2 ($n = 4$) consisted of guidelines similar to those currently applied to intermittent streams including a 7.6 m buffer and the retention of a tree stringer (defined as retaining the canopy tree nearest to the stream bank along the length of the channel). Additionally, improved crossings were used for streams assigned to treatment 2. Crossings were composed of wooden skidder bridges, steel culverts, or PVC pipe bundles (Mason and Moll, 1995). Typically, skid trail stream crossings were in use for a two to six week period, and were removed after the area was harvested. The third treatment ($n = 4$) consisted of a no-harvest control.

All skid trails were constructed with a bulldozer, typically along the contour intervals. The most common vehicles using stream crossings included rubber tired cable or grapple skidders, although occasional crossings were made by tracked machines such as feller bunchers and bulldozers (Witt, 2012). After the harvests were completed, skid trails were retired in accordance with Kentucky's BMP law (Stringer and Perkins, 2001). This entailed the removal of all improved crossing structures, building of permanent water control structures ("water bars"), and seeding of the skid trail surfaces adjacent to ephemeral stream channels.