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Amphibian distributions in riparian and upslope areas and their habitat associations on managed forest landscapes in the Oregon Coast Range

Matthew R. Kluber[a,*], Deanna H. Olson[a], Klaus J. Puettmann[b]

[a] USDA Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331, United States
[b] Department of Forest Science, Oregon State University, 321 Richardson Hall, Corvallis, OR 97331, United States

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ABSTRACT

Over the past 50 years, forested landscapes of the Pacific Northwest have become increasingly patchy, dominated by early successional forests. Several amphibian species associated with forested headwater systems have emerged as management concerns, especially after clearcutting. Given that headwater streams comprise a large portion of the length of flowing waterways in western Oregon forests, there is a need to better understand how forest management affects headwater forest taxa and their habitats. Mitigation strategies include alternatives to clearcutting, such as harvests that remove only part of the canopy and maintenance of riparian buffer strips. Our study investigates effects of upland forest thinning coupled with riparian buffer treatments on riparian and upland headwater forest amphibians, habitat attributes, and species-habitat associations. Amphibian captures and habitat variables were examined 5–6 years post-thinning within forest stands subject to streamside-retention buffers and variable-width buffers, as well as unthinned reference stands. We found no treatments effects, however, our results suggest that ground surface conditions (e.g., amount of rocky or fine substrate) play a role in determining the response of riparian and upland amphibians to forest thinning along headwater streams. Distance from stream was associated with amphibian abundance, hence retention of riparian buffers is likely important in maintaining microclimates and microhabitats needed for amphibians and other taxa. Moderate thinning and preservation of conditions in riparian and nearby upland areas by way of variable-width and streamside-retention buffers may be sufficient to maintain suitable habitat and microclimatic conditions vital to amphibian assemblages in managed headwater forests.

1. Introduction

Between 1950 and 1995 approximately 80–90% of old-growth forest stands in Oregon and Washington were harvested (Spies and Franklin, 1988; Smith et al., 1998) resulting in a patchy landscape dominated by early successional forest (Biek et al., 2002; Franklin et al., 2002). In the Coast Range of western Oregon, headwater drainages comprise a large proportion of the forested landscape (Bury, 1988). Hill-slopes and streams in these forested headwater systems are tightly coupled (Gomi et al., 2002), resulting in steep, spatially compressed habitats (Sheridan and Olson, 2003). Because of this, a need exists to better understand how forest management activities affect headwater forest taxa and their habitats in these compacted riparian systems (Bury, 1988; Meyer and Wallace, 2001; Sheridan and Olson, 2003). A variety of approaches to managing forests along headwater streams have been applied ranging from no protection to a one or two site-potential tree height buffer (USDA and USDI, 1994; Sheridan and Olson, 2003; Olson et al., 2007). Although effects of thinning and buffer retention on species and habitats found in headwater forests are likely less than clearcut timber harvest, the efficacy of buffers for protecting headwater riparian and upland species against disturbances experienced during thinning has yet to be quantified (Olson and Rugger, 2007).

In the Pacific Northwest, several amphibian species are associated with forested headwater systems (Sheridan and Olson, 2003; Olson and Weaver, 2007) including stream-associated species, such as tailed frogs (*Ascaphus truei*; Olson et al., 2000, 2007; Bisson et al., 2002; Raphael et al., 2002; Stoddard and Hayes, 2005) and torrent salamanders (*Rhyacotriton* spp.; Olson et al., 2000, 2007; Bisson et al., 2002; Raphael et al., 2002; Russell et al., 2004a; Stoddard and Hayes, 2005), and terrestrial species, such as western red-backed salamanders (*Plethodon vehiculum*; Wilkins and Peterson, 2000; Sheridan and Olson, 2003) and Dunn's

* Corresponding author. Tel.: +1 541 757 4800; fax: +1 541 750 7329.
E-mail address: matt.kluber@gmail.com (M.R. Kluber).

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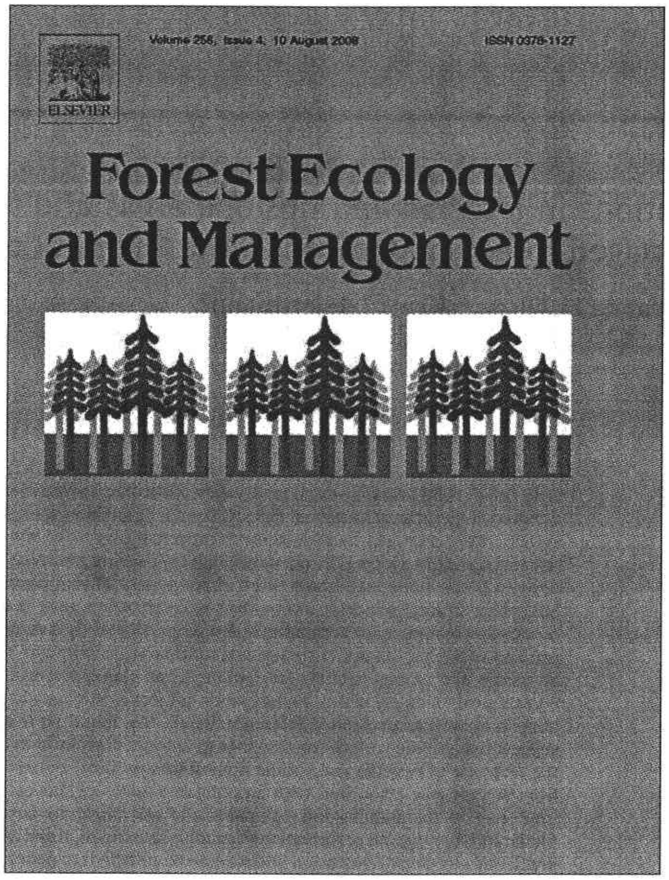
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salamanders (*Plethodon dunni*; Bury et al., 1991; Wilkins and Peterson, 2000; Sheridan and Olson, 2003). Amphibians may play important roles in functions of headwater ecosystems by providing a central link in food webs as both predators and prey (Davic and Welsh, 2004). In particular, amphibians with life history functions potentially requiring both terrestrial and aquatic habitats, such as *A. truei*, *Rhyacotriton* spp., and *Dicamptodon tenebrosus* (Olson et al., 2007), may be pivotal in the exchange of nutrients between streams and uplands in headwater forests (Davic and Welsh, 2004). Disruption of these processes by forest management activities, such as reduction of forest canopy, disturbance of substrates, and altered microclimates, could affect biological processes involving aquatic and terrestrial headwater fauna, in turn resulting in negative impacts on downstream systems (Gomi et al., 2002).

Many plethodontid salamanders are long-lived (e.g., *P. vehiculum* may live up to 10 years) and do not reproduce annually (Ovaska and Davis, 2005). Therefore, effects of silvicultural treatments on some amphibian populations may not be fully realized for many years after timber harvest (Ash, 1988; Petranka et al., 1993). Although there is a lack of long-term data on thinning effects on terrestrial amphibians (Heyer et al., 1994; Perkins and Hunter, 2006), short-term effects of thinning are beginning to emerge. In Virginia, Harpole and Haas (1999) found that salamander relative abundance was significantly lower after partial cutting. Knapp et al. (2003) had similar findings in Virginia (same sites used by Harpole and Haas, 1999) and West Virginia. In western Maine, Perkins and Hunter (2006) found that, although partial harvests along headwater streams had the least affect on amphibians, harvest effects were seen and recommended that riparian buffers may help maintain populations. In southwestern Washington, Grialou et al. (2000) found that although species presence was not affected by thinning, capture rates were reduced. Two years post-thinning, Rundio and Olson (2007) found a negative effect on terrestrial amphibian abundance in response to thinning with riparian buffers at one of two case study sites in western Oregon. In moderately and heavily thinned stands in western Oregon, Suzuki (2000) found short-term (2 years post-thinning) declines in total amphibian captures. During the following year amphibian captures continued to decrease in the heavily thinned stands, but recovered to pre-treatment levels in moderately thinned stands. As an alternative to clearcutting, thinning treatments that remove only part of the canopy and maintain riparian buffer strips may help sustain microclimate (Anderson et al., 2007) and habitat conditions suitable for amphibians (Olson and Rugger, 2007), potentially allowing for a quicker recovery from disturbances experienced during timber harvest (Harpole and Haas, 1999; Ford et al., 2002; Russell et al., 2002, 2004b; Vesely and McComb, 2002; Perkins and Hunter, 2006).

Our study is one of the first to investigate effects of upland forest thinning coupled with riparian buffer treatments on headwater forest amphibians. Our primary objectives for this study were to: (1) examine effects of upland thinning and riparian buffers on terrestrial amphibian abundance and distribution of habitat attributes, accounting for distance from stream; and (2) explore amphibian-habitat associations on managed landscapes. The first objective is particularly relevant as alternative riparian buffer widths are considered for forested headwaters.

We predicted that areas retaining greater canopy cover and experiencing fewer disturbances from thinning operations would result in more favorable microhabitat conditions for terrestrial amphibians (e.g., moss and litter cover, rocky substrates with interstitial spacing, undisturbed downed wood). Therefore, we expected amphibian captures to be greater in the undisturbed areas of our study sites where canopy cover was retained (e.g., wider stream buffers and unthinned areas) compared to narrower buffers and thinned uplands.

2. Methods

Our study area was located in the central Oregon Coast Range within the western hemlock (*Tsuga heterophylla*) vegetation zone, characterized by wet, mild maritime conditions (Franklin and Dyrness, 1988). Three sites were selected from U.S. Bureau of Land Management and U.S. Forest Service lands (Fig. 1). Criteria for site selection included location in the Oregon Coast Range; implementation of thinning and riparian buffer treatments, generally as per the U.S. Bureau of Land Management Density Management Study protocol (Cissel et al., 2006); a minimum of 50 m of upland perpendicular to streams before reaching a ridgeline or entering into the next sub-drainage; and a minimum of 100 m of riparian and upslope area parallel to streams. Two study sites were managed by the Bureau of Land Management (Green Peak, BLM, Salem District; Benton Co., OR; 44°22′00″N, 123°27′30″W, and Ten High, BLM, Eugene District; Lane Co., Benton Co., OR; 44°16′50″N, 123°31′06″W) and one study site was managed by the U.S. Forest Service (Schooner Creek, USFS, Siuslaw National Forest; Lincoln

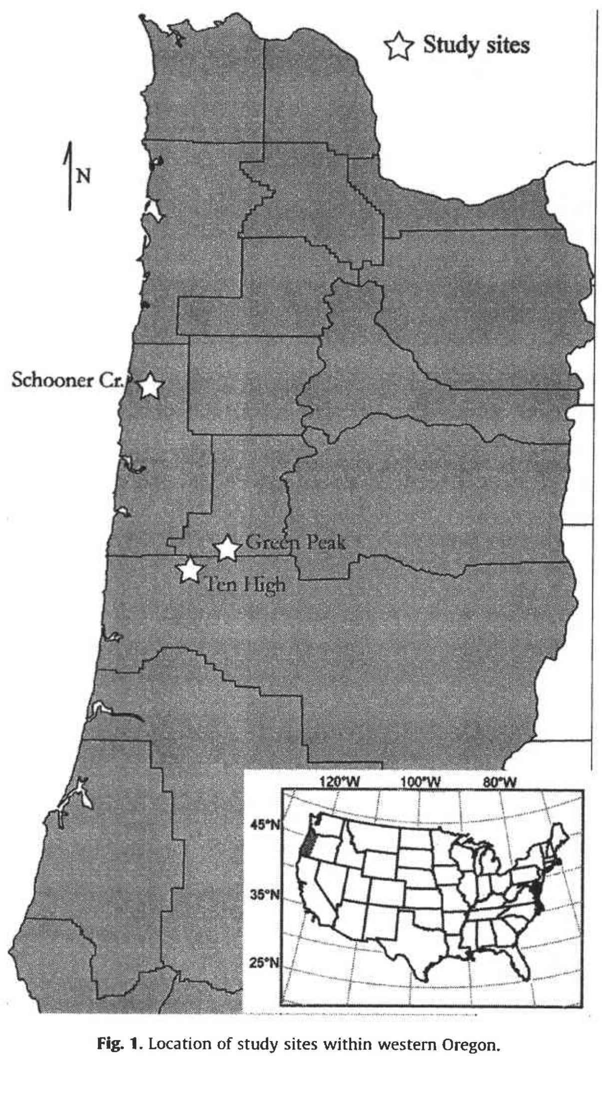

Fig. 1. Location of study sites within western Oregon.

Co., OR; 44°55′45″N, 123°59′18″W). Elevation of the sites ranged from 384 to 870 m.

Each site consisted of two streams with riparian buffer treatments and thinning in the uplands on both sides of the streams, as well as one reference stream with no upslope thinning. The stream reaches were perennial (with the exception of the streamside-retention buffer stream at Ten High, which was intermittent), ranging in width from 0.5 to 1.5 m, and non-fishbearing. Sites ranged from 12–24 ha in size and consisted of previously unthinned 40–60 year old second-growth stands dominated by Douglas-fir (*Pseudotsuga menziesii*), naturally regenerated after clearcut harvests. In 1999 and 2000, thinning occurred at sites as part of a study examining approaches to develop late-successional habitat, such as accelerating development of understory and midstory canopies and increasing spatial heterogeneity of trees and understory vegetation (Cissel et al., 2006). All sites received density management prescriptions, which reduced tree density from 600 trees per hectare (tph) to 200 tph. An unthinned reference stand was retained at each site.

Our study was conducted along streamside-retention and variable-width buffers within thinned treatments (Cissel et al., 2006). The streamside-retention buffers were 6 m wide, and were designed to retain trees along stream banks that likely contributed to bank stability and allowed for overhead shading of streams by their crowns extending over the channel. To ensure a higher degree of stream and riparian shading, as well as litter and wood inputs, the variable-width buffers had a minimum slope distance of 15 m from stream edges on both sides of the stream. Widths were increased for unique riparian vegetation, as well as breaks in slope character such as steep slopes, slumps, and surface seeps. In unthinned reference stands, no harvesting was conducted upslope or adjacent to streams.

During the spring of 2005, amphibian and habitat sampling transects (hereafter bands) were established at all sites, at four distances from each stream, each band extending parallel to streams (Fig. 2). Bands ranged from 100 to 360 m in length, depending on the amount of suitable upland available. Within bands, amphibians and habitat conditions were sampled by randomly placing five, 5 × 10 m sub-sample units for each of the 4 distance categories (resulting in 20 sub-sample units per treatment, 60 per site, 180 total sub-sample units; Fig. 2). Sub-sample units within a band were a minimum of 10 m apart.

Amphibian sampling was limited to one site visit during one sampling season between 4 April and 7 June 2005. Sampling was area-constrained (Olson, 1999) and followed a 1-m-wide zigzag path within sub-sample units (approximately 24 m^2 per sub-sample unit). All moveable cover objects (e.g., rocks, small pieces of wood, moss) were lifted and replaced, any moveable downed wood was turned, decaying logs were dismantled, but not totally destroyed (Olson, 1999), litter was searched, and substrates were

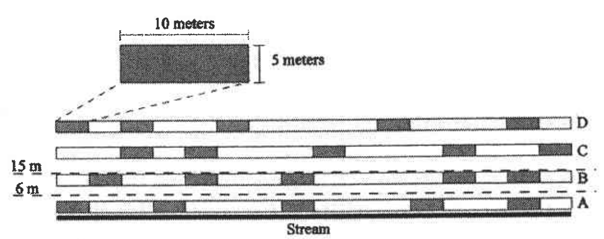

Fig. 2. Schematic diagram of sub-sample units (shaded areas) within four bands (A, B, C, D) aligned along headwater streams in western Oregon. A-band is 0–5 m from stream, B-band is 10–15 m from stream, C-band is 20–25 m from stream, D-band is 30–35 m from stream. Dotted line at 6 m from stream indicates streamside-retention buffer width. Dotted line at 15 m from stream indicates minimum width of variable-width buffer.

Table 1
Habitat variables for which percent cover was collected at our western Oregon study sites

Variable	Description
Fine substrate	Substrate <3 cm diameter
Rocky substrate (coarse substrate)	Substrate >3 cm diameter
Litter and duff	Twigs, dead foliage, branches <10 cm diameter, organic detritus
Shrub cover	Woody plants <3 m in height
Forbs cover	Herbaceous plants (including graminoids)
Moss	Bryophytes
Miscellaneous wood	Chips, chunks, slabs, stumps, loose bark on ground
Downed wood	Downed wood >10 cm diameter and >1 m in length
Midstory cover	Foliage of trees <10 m in height
Canopy cover	Foliage of trees >10 m in height

Visual estimation of percent cover within sub-sample unit was used for all habitat variables except canopy cover, which was measured using a spherical densiometer.

searched to maximum depth of 20 cm using a hand tool. No more than 5 min were spent searching any cover object. Bark and dismantled logs were replaced as best as possible. When amphibians were captured, species was recorded, as well as cover object and substrate association (Bury and Corn, 1988). To estimate amphibian occurrence per distance from stream, amphibian captures in the five sub-sample units within each band were averaged within treatments.

Ten habitat variables were measured or estimated within each sub-sample unit (Table 1). Visual estimates were used to determine percent cover for 9 habitat variables. Percent canopy cover for overstory species was measured at the center of each sub-sample unit using a spherical densiometer (Lemmon, 1956). Percent cover of habitat variables within bands was aggregated by averaging values collected across sub-sample units. All estimates of cover were rounded to the nearest 5%.

We tested for differences in amphibian captures relative to distance from stream and treatment using ANOVA with repeated measures of distance (PROC MIXED) in SAS v. 9.1 statistical software (SAS Institute, 2004). Captures of all amphibian species and captures of the most abundant amphibian species (species with captures >50) were modeled as a randomized complete block (by site) with three treatments (streamside-retention and variable-width buffers, and unthinned reference). Distance from stream was treated as a repeated measure factor with four levels (i.e., bands). The Tukey–Kramer adjustment was applied to accommodate multiple comparisons. A treatment × distance interaction was used to determine if effects of distance from stream was similar among treatments. After viewing residual plots, logarithmic transformations were performed on amphibian captures to meet model assumptions of normality and constant variance. We analyzed whether distance and treatment affected distributions of habitat variables using the same approach. Logarithmic transformations were also performed on habitat variables. Because the number of replications for this study was relatively small ($n = 3$), we considered $P < 0.10$ as statistically significant in all analyses to reduce the chance of committing a type II error (deMaynadier and Hunter, 1995, p. 247; Steidel et al., 1997).

Electivity indices (D) were used to gain insight into how amphibians were using habitat variables at our sites (Afonso and Eterovick, 2007). We used the method of Jacobs (1974):

$$D = \frac{R_i - P_i}{[(R_i + P_i) - (2R_iP_i)]}$$

where R_i = proportion of habitat type 'i' available and where P_i = proportion of habitat 'i' amphibians were associated with at the time of capture. The range of D varies from +1 (indicating