Riparian Buffers and Thinning in Headwater Drainages in Western Oregon: Aquatic Vertebrates and Habitats

Deanna H. Olson

Abstract

The Density Management and Riparian Buffer Study (DMS) of western Oregon is a template for numerous research projects on managed federal forestlands. Herein, I review the origins of Riparian Buffer Study component and summarize key findings of a suite of associated aquatic vertebrate projects. Aquatic vertebrate study objectives include characterization of headwater fauna and habitats, and examination of the effects on headwater-dwelling species of combined buffer-and-thinning treatments in years 1, 2, 5, and 10 post-treatment. Some treatment effects have emerged, with negative effects on bank amphibian counts occurring in treatments with the narrowest buffers 10 years post-thinning. Nevertheless, all taxa appear to be persisting at sites. Instream amphibians, in particular, appear to be highly resilient to the types of disturbances resulting from the thinning and buffer treatments of the DMS.

Keywords: riparian reserves, density management, small streams, NWFP, Aquatic Conservation Strategy Objectives.

Introduction

The Density Management and Riparian Buffer Study (DMS) of western Oregon is an over-arching template for numerous research projects on managed federal forestlands, conducted collaboratively by scientists and natural resource managers with several agency and institution affiliations (Cissel et al. 2006). Herein, I provide background on the development of the Riparian Buffer Study component, and I summarize key findings of a suite of DMS projects on aquatic vertebrates and their habitats in managed forest headwaters. This review of the study context and compendium of the various aquatic-related elements may inform research and management decisions regarding riparian management options in west-side forests of the Pacific Northwest.

Background

In the early 1990s, ecological knowledge was synthesized (fig. 1) to develop the one and two site-potential tree height interim riparian reserves of the U.S. federal Northwest Forest Plan (NWFP; USDA and USDI 1993, 1994). Although these reserves were derived from the science and expert opinion of the time, many concepts had not been field-tested or were drawn from upland empirical studies (e.g., microclimate edge effects: Chen et al. 1995) because riparian studies had not yet been conducted.

Riparian reserves were conceived to contribute to the desired future conditions of aquatic-riparian portions of forest landscapes as characterized by the list of Aquatic Conservation Objectives (ACS) in the NWFP (USDA and USDI 1994; p B-11). These included maintenance and restoration of

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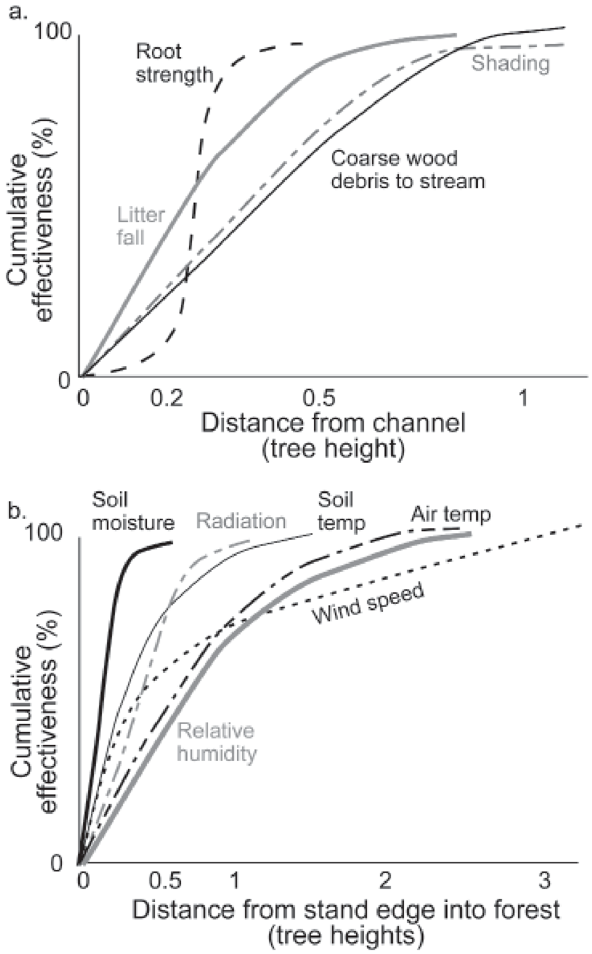

Figure 1—Concepts synthesized from a blend of expert opinion, theoretical knowledge, and empirical studies conducted in a variety of forest contexts that were integral to the development of the interim riparian reserve widths of the federal NWFP (redrawn from USDA and USDI 1993). (a) Contributing factors to stream habitat conditions were expected to be associated with distance from a stream channel. (b) Microclimate edge effects—predicted changes from a clearcut edge into the interior of an old forest stand (from Chen et al. 1995).

the physical integrity of aquatic systems, species composition, and habitats to support well-distributed populations of riparian-dependent species, and within- and between-watershed connectivity. In addition to riparian reserves, ACS objectives were to be attained through additional NWFP components including late-successional reserves, key watersheds, watershed analysis, and watershed restoration (Hohler et al. 2001). ACS objectives were written with landscape-scale language, and their application to project scales and portions of watersheds such as headwater drainages was vague. However, preliminary analyses of perennial and intermittent stream densities in watersheds across the region were conducted, which provided some baseline information about the scope of the intended riparian reserve network: intermittent streams comprised the majority of stream lengths throughout west-side forests (Appendix V–G: USDA and USDI 1993).

The riparian reserve "module" (USDA and USDI 1997) of the federal guide for watershed analysis (USDA and USDI 1995) provided a toolbox of considerations and analyses of physical and biological conditions to help forest natural resource specialists and land managers implement refinements to the interim riparian reserve measures of the NWFP as smaller spatial-scale forest planning ensued. Relative to species, benefits of riparian reserves were recognized not only for aquatic- and riparian-dependent species, but also for a host of terrestrial organisms occurring within west-side forests. Riparian reserves conceptually provided habitats for reproduction, foraging, overwintering, and dispersal of a diverse array of taxa. Before alteration of interim riparian reserve boundaries, or before decisions about management scenarios within boundaries, analysis of additional species information was suggested, so that management decisions would consider the various uses of the newly reserved habitats by an array of target species and communities of organisms. Species with certain ecological attributes were of specific interest, including species: 1) with critical habitats coinciding with riparian areas; 2) with inherently low mobility; 3) occurring over a relatively small portion of the NWFP, being "localized"; and 4) considered to be rare, found in relatively low numbers, including federally listed Survey and Manage species (USDA and USDI 1994). The module aimed to develop a systematic approach for the integration of physical and biological factors so that the interim riparian reserve widths could be potentially altered and managed. However, knowledge of the general ecology of headwater portions of forested watersheds was largely unavailable, hindering full use of the module.

The Bureau of Land Management's (BLM) Density Management Study of western Oregon (Cissel et al. 2006) was originally intended to explore thinning approaches to accelerate the development of upland late-successional forest conditions. The frequency of streams in the study areas complicated BLM site selection and potential layout of treatment blocks within sites, but also created an opportunity to test the efficacy of riparian buffers. The study was adapted to test the effects of the NWFP's riparian reserve widths, within upland thinning, on aquatic-riparian resources.

Two new no-entry riparian buffer widths (variable-width buffer, streamside-retention buffer) were added to the DMS design to address thinning within interim riparian reserve boundaries. These buffers were developed with a two-fold rationale, to: 1) stretch the concepts of the federal riparian reserves, testing narrower buffers with upland forest thinning, which was expected to be a relatively more benign disturbance compared to historical clearcutting; and 2) examine approaches to restore near-stream riparian habitats, accelerating tree growth and the development of late-successional old-growth (LSOG) conditions near streams, and growing future large down wood for instream and streamside habitats. The variable-width buffer (with a 50-ft [~15-m] minimum width on each streamside) was designed to follow ecological gradients along streams, potentially expanding with a significant change in slope gradient (becoming a steeper, more incised stream channel), seeps and slumps, or unique microhabitats or plant species, as detected at local scales during pre-project planning. The variable-width buffer was anticipated to provide advantages to natural-resource specialists and managers at the layout stage of site-level project implementation because stringent fixed distances from streams were not expected; rather, riparian edges could be uneven with varying widths. The streamside retention buffer (~20-ft [6-m] width on each streamside) was conceived as a minimum width to retain bank stability and direct overhead shading of streams.

Overall, these four buffer widths (fig. 2) were conceptually derived, with their implementation on-site reliant on the stream geometry and other site conditions and constraints (Olson et al. 2002). The study design included metrics of lateral and longitudinal distances of treatment units: laterally, perpendicular to streams, ~200 ft (~60 m) of thinning treatment was desired between the buffer edge and the ridgeline; longitudinally along streams, a stream buffer

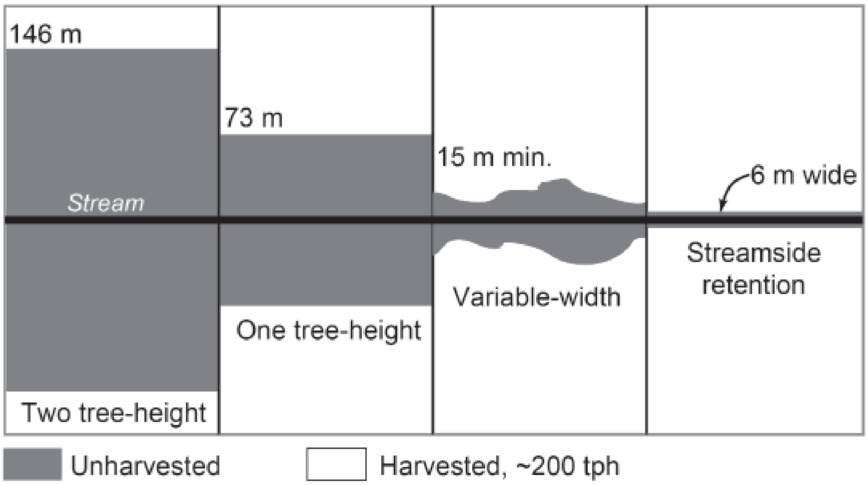

Figure 2—Riparian buffer widths examined in the Density Management and Riparian Buffer Study of western Oregon.

treatment length of about 2.5 site-potential tree heights was desired (e.g., Green Peak study site: 550 ft, ~170 m) (Cissel et al. 2006). Not all stream replicates met these exact criteria, and some stream geometries resulted in treatment units or sites being entirely unsuitable for Riparian Buffer Study implementation. Consequently, an attempt was made to prioritize replication of riparian buffer treatments within the moderate upslope thinning treatment unit, which initially reduced the overstory tree density to ~200 trees per hectare, tph (80 trees per acre, tpa) at most sites. This DMS upland thinning treatment was more intensive than standard commercial thinning densities of the early 1990s, and was established as the treatment that would be optimal to test relative to combined upland and buffer objectives for site restoration. In addition, the study design included reference streams in unthinned control units. Hence, stream geometry was considered during assignment of the moderate and control treatments within a study site. Even so, when few streams occurred at potential study sites, some sites could not be implemented, and not all buffer treatments could be planned within other sites. When stream density was high at a site, the one and two site-potential tree height buffers often extended over sub-drainage ridgelines into the adjacent stream channel drainage. This compromised the study layout criterion calling for a minimum thinned distance between the buffer and ridgeline, and hence, fewer wider buffers could be implemented. For example the two site-potential tree height buffer treatment could not be implemented at the Green Peak study site (fig. 3). The final riparian buffer study design was implemented without full replication across 12 study sites, on lands managed by BLM and the Forest Service (fig. 4).

Upon examination of sites and stream networks proposed for use by DMS, it reinforced the fact that DMS was being implemented in headwater sub-drainages with relatively abundant intermittent streams. Because comparatively little was known about the ecology of forested headwaters at the time, research needs emerged to "down-scale" and add specificity to the ACS objectives. Characterizing site-level conditions within headwaters became a second major goal of the Riparian Buffer Study component.

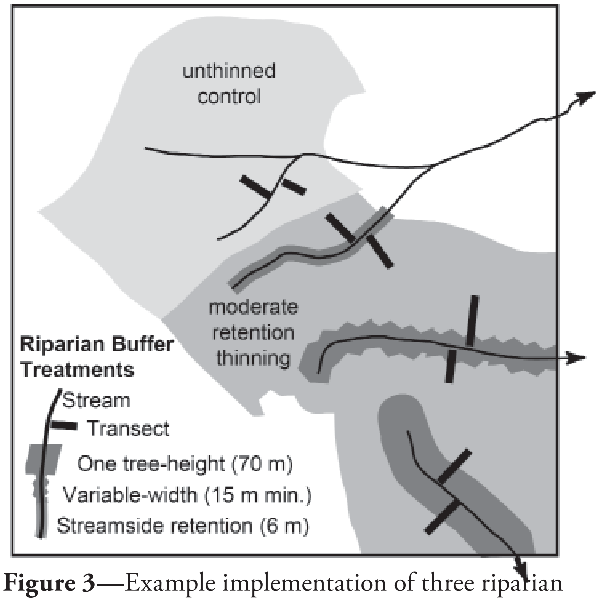

Figure 3—Example implementation of three riparian buffer widths in the moderate upslope thinning treatment at the Green Peak study site of the Density Management and Riparian Buffer Study of western Oregon. Reference streams in the unthinned control unit are shown. Transects perpendicular to streams were used for upland terrestrial salamander assessments (Olson et al. 2006; Rundio and Olson 2007) and pre-treatment down wood assessment (Olson et al. 2006). From Olson and Rugger 2007.

At the time of the development of the DMS study, aquatic-riparian vertebrates and their habitats had become a focus of management attention in the Pacific Northwest due to three factors. First, the US Forest Service's Forest Planning Rule (Sec. 219.19 Fish and wildlife resource: *http://www.fs.fed.us/emc/nfma/includes/nfmareg.html#Fish and wildlife resource*) specified that "Fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area." Second, there was an historical taxonomic emphasis on vertebrates for listing under the Endangered Species Act. Third, many aquatic-dependent vertebrates had a status of

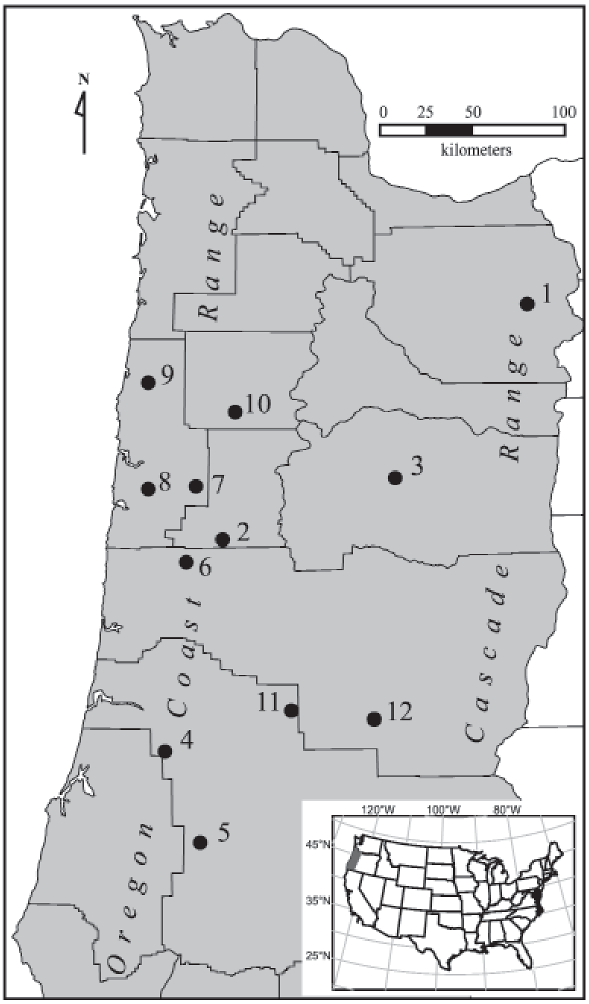

Figure 4—Riparian buffer treatments were implemented at 12 study sites in western Oregon on lands administered by the Bureau of Land Management (sites 1-6, 10-12)) and the Forest Service (sites 7-9). 1: Delph Cr.; 2: Green Peak; 3: Keel Mountain; 4: North Soup Cr.; 5: O.M. Hubbard; 6: Ten High; 7: Cougar; 8: Grant; 9: Schooner Cr.; 10; Callahan Cr.; 11: North Ward; 12: Perkins. From Olson and Weaver 2007.

general concern in the region (see Cissel et al. 2006), and many of these were amphibians. Hence, DMS aquatic ecology research has focused on amphibians and habitat attributes relevant to these animals (Hohler et al. 2001; Cissel et al. 2006).

In summary, the aquatic vertebrate component of the Riparian Buffer Study aimed to characterize the ecological values of headwaters relative to amphibians and their habitats, and assess the effects of the thinning and buffer treatments on these aquatic-dependent biota and their habitats. Key findings of analyses of headwater pre-treatment conditions and post-treatment conditions in years 1, 2, 5, and ~10 after thinning are summarized below (table 1).

Research Findings

Ecological Characterization of Headwater Streams

Animals

At DMS sites, 13 species of amphibians and 5 different fish taxa have been detected (table 1). At a single site, up to 11 amphibian species have been detected, and three sites had this species richness (OM Hubbard, Keel Mountain, North Soup Creek). Up to four fish taxa have been detected at a single site, with two sites having this diversity (Callahan Creek, North Ward).

Amphibian species found in and along streams of the DMS study reaches are organized into assemblages based on habitat associations (fig. 5; Sheridan and Olson 2003; Olson and Weaver 2007). Occurring at all DMS sites are the stream-breeding Coastal Giant Salamander (*Dicamptodon tenebrosus*) and torrent salamanders (*Rhyacotriton* species; fig. 6), the semi-aquatic stream-bank associated Dunn's Salamander (*Plethodon dunni*), the pond-breeding Rough-skinned Newt (*Taricha granulosa*), and the terrestrial-breeding Ensatina (*Ensatina eschscholtzii*).

Of this diverse aquatic-dependent forest fauna, torrent salamanders were highly associated with the uppermost headwater reaches of streams with discontinuous flow (Sheridan and Olson 2003; Olson and Weaver 2007). Furthermore, streams with spatially discontinuous flow, or "intermittent" streams, were the most frequent hydrological flow type in our study (fig. 7). Because torrent salamanders are northwest-endemic species and are species of concern, they and their stream habitats with discontinuous flow are ecological values warranting consideration relative to forest management in headwaters. These salamanders

Table 1—Amphibian and fish species occurrences at Density Management and Riparian Buffer Study sites in western Oregon.

	Study site											
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Amphibians												
Ambystoma gracile	x	x			x	x	x	x		x		
Aneides ferreus						x	x	x	x	x	x	
Ascaphus truei	x	x		x	x	x	x		x	x	x	
Batrachoseps wrighti			x				x					
Dicamptodon tenebrosus	x	x	x	x	x	x	x	x	x	x	x	x
Ensatina eschscholtzii	x	x	x	x	x	x	x	x	x	x	x	x
Plethodon dunni	x	x	x	x	x	x	x	x	x	x	x	x
Plethodon vehiculum	x	x		x	x	x	x	x	x	x	x	x
Pseudacris regilla	x	x	x	x	x	x			x	x	x	
Rana aurora	x	x	x	x	x	x	x		x	x	x	x
Rhyacotriton cascadae			x				x	x				
Rhyacotriton variegatus	x	x		x	x	x			x	x	x	x
Tarich granulosa	x	x	x	x	x	x	x	x	x	x	x	x
Fishes												
Oncorhynchus clarkii	x		x				x	x	x	x		x
Oncorhynchus mykiss	x											
Salmonid sp. age 0+	x		x				x	x	x	x		x
Cottus sp.	x		x					x				x
Lamprey sp. (ammocete)						x						x

Study sites: 1= Callahan Creek; 2 = Cougar Creek; 3 = Delph Creek; 4 = Grant Creek; 5: Green Peak; 6: OM Hubbard; 7: Keel Mountain; 8: Perkins Creek; 9: Schooner Creek; 10 = North Soup Creek; 11: Ten High; 12 = North Ward Creek.

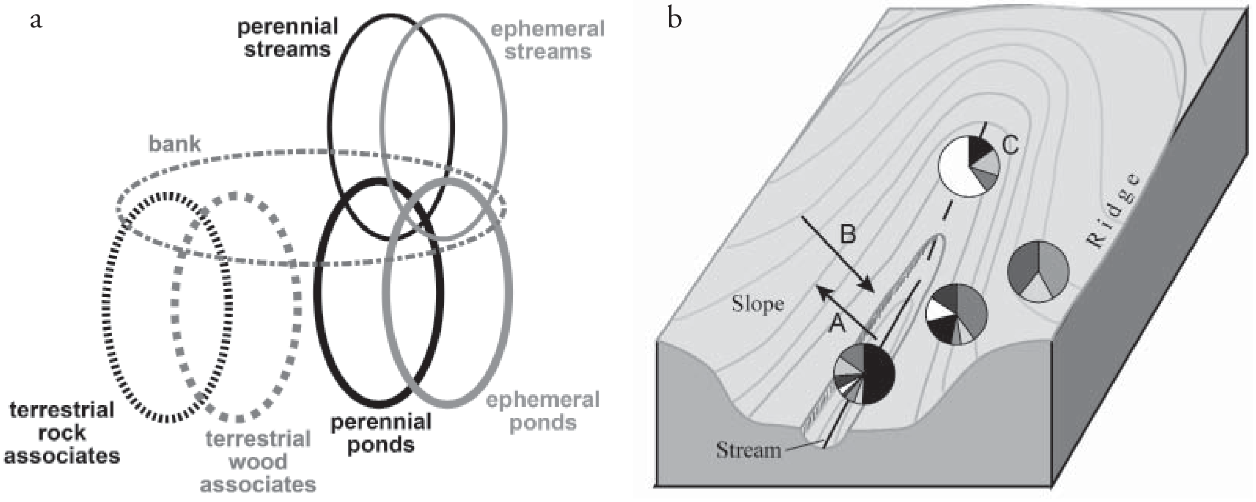

Figure 5—Amphibian assemblages occurring in headwater drainages of western Oregon. Amphibians can be categorized by (a) habitat associations, such as two stream-breeding assemblages (in perennial and ephemeral streams), two pond-breeding assemblages (in perennial and ephemeral ponds), two terrestrial-breeding assemblages (wood and rock associates), and bank-dwelling species which may include members of other assemblages; or (b) species composition by pie-charts within different portions of drainages, showing four dominant assemblages in headwaters (Sheridan and Olson 2003; Olson and Weaver 2007). Arrow A depicts direction of cool, moist microclimates from the "stream effect". Arrow B depicts direction of opposing warmer, dryer microclimates from upslope.

Figure 6—The Southern Torrent Salamander (*Rhyacotriton variegatus*) is reliant on the uppermost headwater stream reaches. (Photo by William P. Leonard.)

do not appear to be associated with larger streams (Olson and Weaver 2007). It is likely that dispersal over ridgelines rather than through the downstream aquatic network is needed to maintain connectivity among sub-populations. A torrent salamander has been documented in a pitfall trap 200 m (656 ft) from a stream (Gomez and Anthony 1996), supporting their ability to venture upslope. Although additional research is needed on this topic of overland dispersal, ongoing genetic studies of headwater amphibians in the Oregon Coast Range are confirming over-ridge connectivity among watersheds (L. Knowles and M.R. Marchán-Rivadeneira, Univ. Michigan, unpubl. data), and genetic studies in other landscapes have similarly documented both riparian movements (Spear and Storfer 2010) and upland dispersal tendencies of amphibians (Spear and Storfer 2008).

Forested uplands at our headwater study sites are habitat for a variety of amphibians requiring moist microhabitats, but not necessarily requiring standing or flowing water for any part of their life history. The upslope amphibian assemblage is distinct from instream and bank assemblages, and is largely composed of down-wood-associated species and species associated with rocky microhabitats (fig. 5a; Sheridan and Olson 2003; Wessell 2005; Rundio and Olson 2007; Kluber et al. 2008). These animals may be found within near-stream riparian areas, and the Western Red-backed Salamander (*Plethodon vehiculum*) was highly associated with near-stream areas (Kluber et al. 2008). Using mark-recapture methods to study movement patterns of terrestrial-breeding amphibians at the Green Peak DMS study site are under investigation. Short-distance movements of animals have been detected, with more movements occurring in near-stream areas. This supports the "funnel" concept, in which near-stream areas funnel animal movements along streams (Olson and Burnett 2013), possibly because either the stream acts as a barrier to dispersal or due to the cool, moist conditions near streams (Anderson et al. 2007; Olson et al. 2007; Rykken et al. 2007)

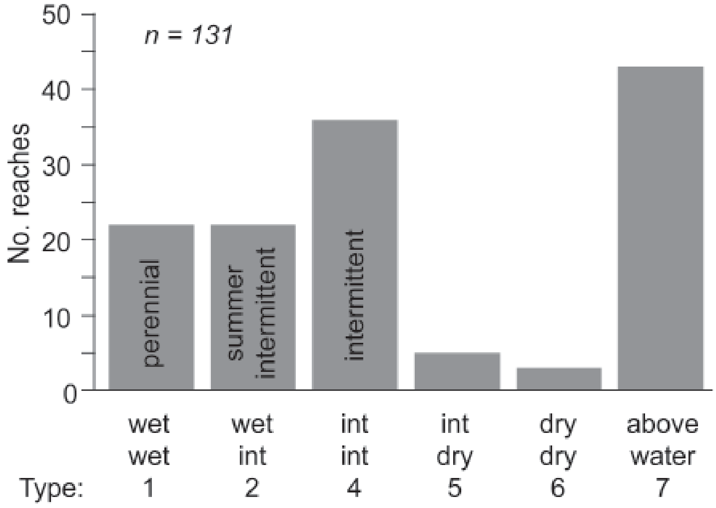

Figure 7—Spatially discontinuous streams that flowed intermittently in spring and summer were the most common stream-channel type at the Density Management and Riparian Buffer Study sites in western Oregon. Int = spatially intermittent flow. Wet = continuous flow. Dry = no water flow, but evidence of scour.

which are ideal microhabitats for many northwest amphibians.

The life history of many of these amphibian species remains largely unknown, however knowledge gained from DMS studies is incrementally adding to our understanding of the basic biology of these species. For example, the nests of two amphibian species that have been observed at the DMS sites: Dunn's Salamanders (Nauman et al. 1999) and Ensatina (Olson et al. 2006). Although most amphibian species are from instream, bank-dwelling, or upland forest assemblages, four pond-breeding amphibians (*Ambystoma gracile*, Northwestern Salamander; *Rana aurora*, Northern Red-legged Frog; *Pseudacris regilla*, Pacific Chorus Frog; Rough-skinned Newt) were found routinely in and along streams at our sites. These four species may move relatively long distances in forests, and streams and near-stream habitats likely "funnel" animals from lower in aquatic networks into headwaters (Olson and Burnett 2009, 2013). Incidental sightings of single egg masses of Northwestern Salamanders have been found in shallow pools or roadside ditches at DMS sites, confirming pond-breeder reproduction at some sites.

Various aspects of the population and community ecology of headwater forest amphibians have been addressed by companion studies at locations outside of our study sites, in order not to disturb our experimental treatments. Sagar et al. (2005) reported on the survival and growth of juvenile Coastal Giant Salamanders in small streams of the Oregon Coast Range near our North Soup Creek study site. Predator-prey interactions have been investigated among three species. Antipredator behaviors were described for Coastal Giant Salamanders in response to Cutthroat Trout (*Oncorhynchus clarkii*) presence (Rundio and Olson 2003). Southern Torrent Salamanders (*Rhyacotriton variegatus*) were unpalatable to Coastal Giant Salamanders: the giant salamanders consistently rejected torrent salamanders during predation attempts (Rundio and Olson 2001). The conceptual model of "trophic cascades" may apply to headwater stream systems. In this model, a few dominant predators (Coastal Giant Salamanders, Cutthroat Trout) control the occurrences of other trophic levels (Terborgh and Estes 2010). Further research is needed to more fully document the hypothesis that repeated predation attempts by the larger Coastal Giant Salamanders on torrent salamanders restrict the downstream distribution of torrent salamanders. Also, an abundance of sculpins (*Cottus* species) at some sites indicates that they are a potentially dominant predator in those systems, and warrants further investigation.

Biodiversity characterization at DMS sites has been conducted in companion studies. At four DMS sites, Wessell (2005) examined four taxonomic groups in upslope areas: vascular plants, mollusks, soil arthropods, and amphibians. In her comprehensive study, she found 120 vascular plant species, 3,608 mollusks of 12 taxa, 30,447 arthropods of 289 taxa, and 7 amphibian species. Her multivariate statistical analyses showed interesting associations between species assemblages and habitat attributes, microclimate metrics, sites, and mountain ranges (Coast, Cascade). Because there were no matched old-growth forest sites available in the study landscape to compare to the DMS sites, a study characterizing amphibian and plant biodiversity of unmanaged forested headwaters was conducted near one DMS site, Soup Creek, near Coos Bay (Sheridan and Olson 2003; Sheridan and Spies 2005).

Lastly, a case study of detection probabilities and occupancies of instream and bank amphibians has been conducted at Green Peak. Both giant and torrent salamanders had consistently high occupancy and detection rates, indicating that their distributions were not patchy within our treatment reaches and that our light-touch hand-sampling ("rubble rousing") methods were effective at detecting them. Greater variability in occupancy and lower detection probabilities were found for bank *Plethodon* species.

Habitat

Characterization of DMS headwater habitat conditions has focused on instream habitat typing. Along each study reach, the dimensions (width, length, depth) of fast and slow water units (e.g., pools and riffles/cascades) are recorded, in addition to the substrate type and down wood per unit. From these data, reach hydrotypes (fig. 7) were developed (Hohler et al. 2001; Olson and Weaver 2007). Published analyses have focused on assessing species-habitat associations (Olson and Weaver 2007).

Using the long-term data set (1994 to present) of multiple stream flow metrics, the hypothesis of "shrinking heads" relative to retrospective annual weather patterns is being addressed: do headwater streams shrink in size during dry years? (Burton et al. 2013a). This analysis is relevant to exploring effects of climate change scenarios on stream flow conditions, with treatment interactions also considered. Additionally, an ongoing companion study is examining how water availability in headwaters among years may contribute to forest vegetation development, again with climate change and treatment as interacting factors.

Analyses of DMS down wood metrics are ongoing (e.g., Anderson and Meleason 2009; Burton et al. 2013b). Instream down wood data have been collected during pre-treatment surveys and in years 1, 2, 5, and 10 post-treatment. Analyses include down wood patterns over time, relative to treatments, and distance-from-stream of the source tree for each instream down wood piece. From preliminary analyses, the number of wood pieces for which sources could be determined ranged from 425 to 841 per site. The average slope distance-from-stream of a source of down wood ranged from 2.6 to 9 m (8.5–29.5 ft) for 25 stream reaches, the maximum distance at four sites examined ranged from 29.4 to 40.9 m (96.5–134 ft), and the most frequent decay classes (Maser et al. 1979) of instream wood were classes 3 and 4. As these data are more fully compiled, new information will become available about down wood recruitment patterns to small streams from sites with riparian buffers and thinning.

Upslope habitat conditions relative to amphibian microhabitat requirements have been assessed during various DMS studies. At two DMS sites (Green Peak, Keel Mountain), Olson et al. (2006) reported pre-treatment percent cover of down wood which occurred in plots along transects spanning stream to upslope areas, perpendicular to streams (fig. 3). At four DMS sites (Green Peak, Keel Mountain, Delph Creek, Bottom Line) 1–5 years post-treatment, Wessell (2005) reported on upslope substrate, down wood, and forest structural components in leave islands, the moderate-density thinning treatment, and the unthinned control. At three DMS sites (Green Peak, Ten High, Schooner Creek), 5–6 years post-thinning, Kluber et al. (2008) analyzed associations of percent cover of upslope canopy, down wood, litter, forbs, and moss with distance-from-stream and treatment effects. Habitat within the near-stream survey bands differed from upslope survey bands relative to several attributes, including more down wood near streams. Thermal profiles of large- and small-diameter logs and soils in near-stream and upslope positions, in treatments and unthinned reference stands, were examined by Kluber et al. (2009). Lastly, riparian-to-upland microclimate gradients at the DMS sites were characterized by Anderson et al. (2007) and a similar study of streamside microclimates along small west-side Oregon streams was conducted by Rykken et al. (2007). Both studies documented a "stream effect" where distinctly cooler temperatures occurred within ~10–15 m (33–49 ft) of headwater streams (review: Olson et al. 2007).

Treatment effects of buffers and thinning on amphibians, other taxa, and habitat attributes

Instream and bank species

Among amphibian species occurring instream, along banks, and in upland forests, there have been a variety of effects of the DMS thinning and buffer treatments. Several caveats are needed, however. Statistical analyses have been a challenge because most species do not occur at all sites, or all reaches within sites, and many species (table 1) occur in low numbers within reaches. The most robust analyses have been possible with the more commonly occurring species, including Coastal Giant Salamanders, torrent salamanders, Dunn's Salamanders, Western Red-backed Salamanders, and Ensatina.

Instream and bank amphibians

In years 1–2 post-thinning, we found no reduction in species abundances in and along streams (Olson and Rugger 2007). This suggests that the mechanical disturbance of the thinning and the immediate effects on animals or their habitats was not substantial. Because amphibians live several years, we felt that a lag time in treatment effects on survival and reproduction warranted monitoring.

Year-5 and year-10 post-treatment results of instream and streambank animal abundances have not yet been published, hence I provide only general preliminary findings here. In year-5 post-treatment, analyses of instream and bank species were conducted with data from 68 stream reaches at 11 sites and the entire time series of data to date. Intriguing findings include reduced abundances of two streambank-occurring amphibians in year 5 compared to pre-treatment. In year-10 post-treatment, different analyses have been conducted using the entire time series of data among years (Olson et al. in press). Results included some effects on both instream and stream-bank animals, with riparian buffers and interacting factors jointly accounting for the differences in animal abundances over time. In particular, bank-dwelling salamander counts decreased over the 10-year post-thinning timeframe in treatments with the narrowest buffers. Pre-treatment abundances were consistently a factor explaining post-treatment species abundances, suggesting that animal abundances after thinning and buffer treatments are contingent on the site-specific contexts of pre-treatment abundances. The strongest take-home message emerging from our long-term instream faunal dataset is the overall resiliency of these assemblages to the treatments.

Analyses of fish species have been problematic due to their uneven distribution among sites (table 1), in addition to their uneven occupancy among both stream reaches and riparian buffer treatments within sites. Fish species have been included in exploratory analyses of year-5 and year-10 data, and no significant insights relative to treatment effects on fishes resulted.

Upland amphibians

Case studies on upland salamanders at the DMS sites tell the same story of variable responses yet apparently resilient assemblages. Although some effects on abundances have been observed, the assemblages have remained intact.

At two DMS sites, 1–2 years post-treatment, Rundio and Olson (2007) examined terrestrial salamanders occurring in transects arrayed perpendicular to streams in the moderate upslope thinning treatment (fig. 3). They reported that captures of two salamander species declined by 40 percent post-thinning at one site (Green Peak), and no treatment effect was detected at the other site (Keel Mountain). Site differences in down wood cover were hypothesized to be related to these results, with down wood potentially ameliorating effects of thinning on salamanders.

At four DMS sites (Green Peak, Bottom Line, Delph Creek, Keel Mountain), 1–5 years post-treatment, Wessell (2005) found various treatment effects of the moderate thinning treatment and leave island sizes on species and diversity metrics. For example, for amphibians, she found that species richness of amphibians was greater in unthinned than thinned forest. Effects of leave island sizes on amphibian species richness and Oregon Slender Salamander (*Batrachoseps wrighti*) abundances also were detected, with more animals in the 0.1- and 0.2-ha leave islands than in the 0.4-ha leave island (0.25, 0.5, and 1 ac, respectively).

At three DMS sites (Green Peak, Ten High, Schooner Creek), 4–5 years post-treatment, Kluber et al. (2008) found no treatment effects of the moderate thinning treatment on upslope salamanders. However, they found that distance-from-stream was associated with amphibian abundance, hence riparian buffers could play a role in upland salamander persistence at sites if adverse effects of upland disturbance did occur. Their results also suggested that rocky substrates may aid amphibian persistence in thinned forests.

Case studies ongoing at two DMS sites investigate the efficacy of artificial cover boards for long-term monitoring of the terrestrial amphibian assemblage. Using mark-recapture methods, we are documenting movements of individual salamanders between boards. At the Green Peak study site, cover boards are arrayed at different distances from the stream, and we have been examining movement patterns related to stream proximity since year 2000. At the Keel Mountain study site, cover board arrays are assessing overland movement patterns of the Oregon Slender Salamander, a species of concern in western Oregon (Clayton and Olson 2007).

In summary, although the value of the different buffer widths with thinning for amphibians is still under investigation, there is evidence that thinning near streams may be conducted at a relatively minor cost to these animals. Variable effects on species abundances are being detected, and although some species abundances have decreased, populations appear to be persisting. Given that the treatments are intended to restore riparian forests, a short-term cost for a longer-term gain of accelerated development of LSOG-forest conditions may be acceptable to land and natural-resource managers, and interested public groups. If upland areas are to be managed over the long term, continued monitoring of both instream and upslope aquatic fauna is warranted to assess population stability.

Habitat

Analyses of combined riparian buffer and upland thinning treatment effects relative to stream flow metrics and instream down wood are ongoing. Integrated multivariate analyses of additional instream habitat attributes and analyses of species-habitat relationships comparing pre-treatment to post-treatment years 1, 2, 5, and 10 data are planned.

Treatment effects on water-quality metrics have been of interest for monitoring at the DMS sites, yet despite multiple proposals over the years, we have been unable to gain sufficient funding to deploy sensors to assess sedimentation or temperature in stream reaches among sites. Nevertheless, at two case-study sites, Keel Mountain and Callahan Creek, with DMS collaborator Paul D. Anderson, instream temperature dataloggers were deployed for year-round temperature monitoring. Unfortunately, in the first winter of deployment, high flows resulted in the loss of many sensors at Callahan Creek. Since then, we have maintained a network of instream temperature dataloggers only at Keel Mountain. They are positioned at stream junctions and at the boundaries of treatment units along stream reaches. We plan to begin analyses following DMS Phase 2 data collection.

Phase 2 – Second-entry DMS Thinning Treatments

A second thinning treatment (Cissel et al. 2006) has now occurred at eight DMS study sites that include Riparian Buffer treatments: Callahan Creek, Delph Creek, Green Peak, OM Hubbard, Keel Mountain, Perkins Creek, North Soup Creek, and Ten High. This second entry was designed to reduce the overstory to near-LSOG-forest densities in order to maintain accelerated overstory tree-growth rates and further enhance understory development. The retained overstory will become the largest trees in the future forest stand. In the initial thinning thinning phase, the moderate-density treatment unit had been thinned to 200 tph; in phase 2, this unit was reduced to ~90 tph (37 tpa; with two trees destined to be future down wood and five destined for snag recruitment). Post-treatment surveys for instream vertebrates and habitats and streambank amphibians in year-1 post-phase-2 thinning will be completed in 2012 at these eight sites. At this time, there is no funding to pursue phase 2 treatment effects on upslope amphibians, with the exception that the upslope cover boards deployed at Green Peak and Keel Mountain will be monitored as time permits.

Three of the four original riparian buffer widths are continued as treatments relative to this second-entry thinning: one site-potential tree height, variable width, and streamside retention (fig. 8). The two BLM study sites at which the two site-potential tree height buffer had been implemented (Callahan Creek, Keel Mountain) are now case studies of a "thin-through" two-tree buffer, where the buffer has been thinned to ~150 tph (60 tpa), and the upland thinned to ~90 tph. There is no stream buffer in this thin-through treatment, meaning that thinning occurred up to streambanks. These case studies will assess the effects on instream resources of thinning without buffers. At one study site, Keel Mountain, the number of stream reaches with a variable-width buffer in the high-density thinning unit, initially thinned to ~300 tph (120 tpa), allowed a similar examination of thin-through buffers with unthinned reaches for comparison. These variable-width buffer reaches were thinned-through (no stream buffer) with 150 tph in both the buffer and the upland treatment unit. Although the inference drawn from case studies is limited to the sites at which the studies occur, the thin-through treatment effects will be monitored to provide insights about the utility of thin-through buffers for riparian forest restoration elsewhere.

Conclusions

The aggregate studies outlined above add to our knowledge of aquatic vertebrates and their habitats in forested headwater basins in western Oregon. Relative to ACS objectives from the NWFP, additional specificity of species and habitat conditions in headwaters has been achieved. Although analyses are still ongoing, early findings have reported relatively mixed effects of these treatments on amphibians or their habitats. The use of these riparian buffer widths in operational thinning projects in west-side forests with similar characteristics will likely have some short-term effects on specific resources, but are also likely to have long-term gains for site restoration. Continued monitoring of species-at-risk in these headwater stream locations, such as

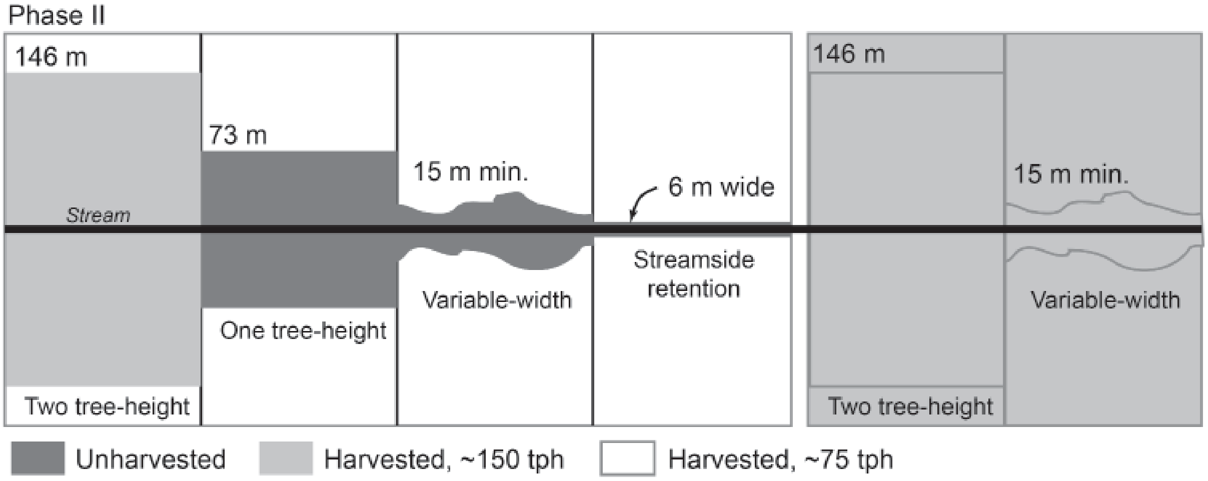

Figure 8—Riparian buffer design for Phase 2 of the Density Management and Riparian Buffer Study of western Oregon. Thin-through buffers were implemented at selected case-study reaches.

torrent salamanders, would be needed to address uncertainty about potential long-term or site-specific detrimental effects. Similarly, where neighboring private-land parcels continue to be managed using regeneration-harvest approaches, the utility of adjoining federal land parcels such as those included in this study is likely to become increasingly important for aquatic resource protection. Monitoring of selected resources into the future will help to gain knowledge about cumulative effects over time and this potential emerging role of federal lands for aquatic-resource conservation emphasis when such lands are nested within a patchwork (e.g., checkerboard pattern) of mixed land ownerships.

Ongoing research efforts are using these study sites and the overall experimental design as a template to explore emerging topics. For example: 1) knowledge gained by these studies has contributed to development of landscape-level designs for managing joint aquatic-terrestrial habitat connectivity (Olson and Burnett 2009, 2013); and 2) climate change scenarios are under study relative to headwater stream-flow and the interaction of water availability, thinning treatments, and vegetation growth. These study sites are valuable for the continued monitoring of phase 2 treatment effects, and for potential future research opportunities.

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