Forest Ecology and Management 321 (2014) 81–93

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Riparian buffers and forest thinning: Effects on headwater vertebrates 10 years after thinning

Deanna H. Olson[a,*], Jeffery B. Leirness[a,1], Patrick G. Cunningham[a], E. Ashley Steel[b]

[a] *Pacific Northwest Research Station, USDA Forest Service, 3200 SW Jefferson Way, Corvallis, OR 97331, USA*
[b] *Pacific Northwest Research Station, USDA Forest Service, 400 N. 34th St., Suite 201, Seattle, WA 98103, USA*

ARTICLE INFO

Article history:
Available online 16 July 2013

Keywords:
Western Oregon
Amphibians
Salamanders
Small streams
Stream banks

ABSTRACT

We monitored instream vertebrate and stream-bank-dwelling amphibian counts during a stand-scale experiment of the effect of riparian buffer width with upland forest thinning in western Oregon, USA using a before/after/control methodology. We analyzed animal counts along 45 streams at 8 study sites, distributed from the foothills of Mount Hood to Coos Bay, Oregon using data collected pre-treatment and during the first decade post-treatment. We examined the role of four types of stream buffers in explaining the variability in post-treatment animal counts. We built separate linear regression models for stream-bank and instream animals, examining species and species-assemblages of specific interest. Stream-bank models addressed all amphibians, the subset of all terrestrial-breeding amphibians, *Plethodon dunni*, and *Plethodon vehiculum*, which were the two most abundant stream-bank species. Instream models were examined for all vertebrates, the subset of all stream-breeding amphibians, *Dicamptodon tenebrosus*, and *Rhyacotriton* species. All bank and instream models considered buffer treatment, survey area, stream width, pre-treatment count, and number of days post-treatment as possible explanatory variables. Instream models also considered survey method: hand sampling or electrofishing. Along banks there was support for a negative effect of the two narrowest buffers in the all-species model and the terrestrial-breeding amphibian assemblage model, and for an apparent negative effect of the narrowest buffer in the *P. dunni* model. Nevertheless, *P. dunni* were retained as one of the most common species along stream banks throughout the 10-years of our post-treatment monitoring. Instream, complex interactions among covariates in the model precluded determination of consistently positive or negative effects of buffers on animal counts. This is the first study to test the riparian reserve widths of the US federal Northwest Forest Plan, and it is encouraging that we documented no negative effects of those buffers with upland thinning in headwater drainages. Narrower buffers appeared to pose a risk to stream bank animals. Nevertheless, with our moderate thinning regime and in treatments with all buffer widths, species occurrences were retained through time. The joint buffers-with-thinning treatments appear to be relatively benign and may be reconciled by the designed long-term habitat restoration benefits of the thinning-and-buffer prescriptions. Mixed widths of buffers might be considered to hedge uncertainties, and balance the socioeconomic and ecological benefits of thinning in riparian areas with risks to some species.

1. Introduction

Legal mandates for biodiversity protection are drivers of riparian forest protection worldwide. In the United States, broad concerns for stream-and-riparian dependent species were raised in the 1960s (e.g., Everest and Reeves, 2007). Subsequently, three federal laws provided impetus for development of forest riparian protection guidelines: the Clean Water Act of 1972 (http://www.epa.gov/lawsregs/laws/cwa.html; accessed 27 February 2013); the Endangered Species Act of 1973 (ESA; http://www.fws.gov/laws/lawsdigest/esact.html; accessed 27 February 2013); and the National Forest Management Act of 1976 (NFMA; http://www.fs.fed.us/emc/nfma/index.htm; accessed 27 February 2013). In the European Union, the Water Framework Directive (WFD; 2000) protects running waters through river-basin management plans. Indicators of success include protection of species of interest, conservation of biodiversity through designation of protected areas, and species diversity (http://www.eea.europa.eu/data-and-maps/indicators/; accessed 10 June 2013). The Habitats Directive (1992), which established the Natura 2000 network, a

---

[*] Corresponding author. Tel.: +1 541 750 7373; fax: +1 541 750 7329.
E-mail address: dedeolson@fs.fed.us (D.H. Olson).

[1] Present addresses: USFWS Division of Migratory Bird Management, 11510 American Holly Dr., Laurel, MD 20708, USA. Department of Entomology and Wildlife Ecology, University of Delaware, Newark, DE 19716, USA.

0378-1127/$ - see front matter Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.foreco.2013.06.013

network of sites to protect Europe's most valuable and threatened species and habitats, provides additional legislative incentive for protection of biodiversity in forest-riparian areas across Europe. The Environment Protection & Biodiversity Conservation Act in Australia and The River Law in Japan provide similar legal frameworks supporting the protection of riparian forest biodiversity.

Riparian forest biodiversity protections in the US have been widely applied to the maintenance and restoration of habitat conditions for ESA-listed species, the rarest or most threatened species in dire need of protection. Secondarily, US regulations have been used to forestall perceived threats or disturbances that degrade habitat conditions that might lead a species with sensitive or concern status towards an ESA-listing proposal, especially on federally managed lands (e.g., Suzuki and Olson, 2007). The National Forest Management Act of 1976 specified the need to maintain viable populations of existing native and desired nonnative vertebrate species, hence extending protections to all species in this subphylum on National Forest lands.

Together, the content of these US laws was used to develop the federal Northwest Forest Plan (NFP) in the Pacific Northwest (USDA and USDI, 1993, 1994). The NFP was developed as a response to curtail the trends toward ESA-listing of late-successional and old-growth forest-dependent species in the region. Over 1000 forest-dependent species were considered during NFP development (Thomas et al., 1993, 2006; USDA and USDI, 1993, 1994). Expanded streamside riparian reserves were mitigation measures of the aquatic conservation strategy included in the NFP to provide for aquatic- and riparian-dependent species persistence (Reeves et al., 2006). In particular, both salmonids and amphibians were of high concern regionally (e.g., Stouder et al., 1996; Olson, 2009), and figured prominently in NFP riparian reserve design (Hohler et al., 2001; Olson and Burnett, 2013; Reeves, 2006; USDA and USDI, 1996a,b).

Salmonids and amphibians can be considered 'biodiversity indicators' (Holthausen and Sieg, 2007), representative of larger aquatic and riparian communities. Their population trends may reflect recent anthropogenic disturbances to forested aquatic–riparian habitats as well as patterns of disturbance over the last century (Harding et al., 1998; Walter and Merritts, 2008). In forested landscapes, these taxa often rely on physical habitat attributes such as down wood, microclimate conditions (e.g., cool temperatures) that may be limited in some areas, water availability in certain seasons, and clean water resources without excessive erosion or stream sedimentation. To maintain or restore these habitat elements for aquatic species, protective stream buffers of various widths have been designed (e.g., Gregory et al., 1991; Naiman and Décamps, 1997; Naiman et al., 2000; USDA and USDI, 1994). Prior to 1993, 30-m riparian zones were retained along fish-bearing streams on US federal lands west of the Cascade Range. After reassessment of scientific advances in 1993, the NFP expanded these areas for management consideration to the current 90–145 m interim riparian reserve zone along each side of fish-bearing streams, and added an interim riparian reserve zone of up to 45–70 m along non-fish bearing streams (these widths correspond to the distance of one or two site-potential tree heights – the tallest height a tree can grow at a site, a metric used for provision of down wood, shading and other attributes; e.g., Cissel et al., 2006; Everest and Reeves, 2007; USDA and USDI, 1994, 1996a). These are the widest riparian buffers in the region (Olson et al., 2007).

Most legal mandates for protection of freshwater biota have a scientific basis related to watershed ecology, and some of these considerations originate in small streams. Headwater streams can comprise up to ~80% of forested stream networks in the Pacific Northwest (Gomi et al., 2002), and affect the development of downstream aquatic habitat conditions such as down wood (Reeves, 2006; Reeves et al., 2003), sediment (Benda and Cundy, 1990; Benda and Dunne, 1997a,b; Rashin et al., 2006), and invertebrate prey (Wipfli and Gregovich, 2002). However, until relatively recently, stream buffers were not mandated on small headwater streams, and most managed forests in their first forest-harvest rotations were clearcut without headwater stream protection. For example, on federal forest lands west of the Cascade Range, buffers in small fishless streams have been implemented only as of 1994 (USDA and USDI, 1994). Although protections are provided to many forested headwaters now, small-stream management approaches vary considerably with land ownership, and some headwaters lack protection (Olson et al., 2007). How much headwater protection is warranted is still a point of controversy because few studies have reported on the natural resource values and effects of protection on species and habitats in this uppermost portion of the stream network. Although several recent advances have increased our understanding of small stream characterizations (Kroll et al., 2008; Janisch et al., 2011) and stream–riparian species and habitat responses to forest management effects (De Groot et al., 2007; Hawkes and Gregory, 2012; Jackson et al., 2007; Janisch et al., 2012; Kreutzweiser and Capell, 2001; Leuthold et al., 2012; Raphael et al., 2002; Rykken et al., 2007a,b; Stoddard and Hayes, 2005; Vesely and McComb, 2002; Wilk et al., 2010; Wilkins and Peterson, 2000), there continues to be a need for baseline information on the effects of alternative stream–riparian protective measures, particularly given the variety of site conditions, forest practices, species, and habitats across the landscape. Our study contributes to narrowing these knowledge gaps by being the first relatively long-term and spatially extensive experimental study examining the effects on aquatic and semi-aquatic amphibians of alternative headwater stream buffer widths in managed forests after upland thinning.

In 1994, we initiated our riparian buffer study as part of the larger Density Management Study of Western Oregon (Cissel et al., 2006). The aim of this overarching framework was to examine upland forest density management approaches to accelerate development of late-successional forest characteristics in managed federal forests. We monitored instream vertebrates and stream-bank amphibians as part of the riparian component, using a before/after/control methodology. The riparian buffers were specifically designed in response to the interim riparian reserve widths identified in the NFP, extending one and two site-potential tree-height widths on each side of streams (Hohler et al., 2001; USDA and USDI, 1994). We examined those widths in addition to two narrower buffers within the upland density management "moderate retention" prescription (Cissel et al., 2006). Previously, we reported on pre-treatment vertebrate assemblages found in and along streams at 12 sites (Olson and Weaver, 2007), headwater assemblages occurring in unmanaged old-forest 'reference' sites near one of our treatments (Sheridan and Olson, 2003; also plant assemblages, Sheridan and Spies, 2005), post-treatment responses of instream and bank assemblages 1–2 years after thinning at 11 sites (Olson and Rugger, 2007), and responses of upland salamanders at selected sites 1–2 years post-treatment at 2 sites (Rundio and Olson, 2007) and 5–6 years post-treatment at 3 sites (Kluber et al., 2008). Animal responses to buffers have been variable among our different studies, with no dominant or consistent pattern emerging in the first years after thinning. We propose that a longer-term response might be easier to detect and of greater ecological importance for these relatively long-lived animals.

Herein, we examine instream vertebrates (fish and amphibians) and streambank amphibians throughout a 15-year time period, 1995–2010, including a 10-year post-treatment time span at our western Oregon study sites. Our objective was to assess whether there was an effect of buffer width on instream and streambank communities during the first decade after upland forest thinning. We built the simplest possible statistical model to explain the