Effectiveness of Experimental Riparian Buffers on Perennial Non-fish-bearing Streams on Competent Lithologies in Western Washington

EXECUTIVE SUMMARY

Headwater streams, which comprise approximately 65% of the total stream length on forestlands in western Washington, are largely understudied relative to their frequency in the landscape. We evaluated the effectiveness of riparian forest management prescriptions for small non-fish-bearing (Type N) headwater stream basins in western Washington by comparing current prescriptions to alternatives with longer riparian leave-tree buffers and no buffers. We looked at the magnitude, direction (positive or negative), and duration of change for riparian-related inputs and response of instream and downstream components (see Chapter 1 – *Introduction and Background*). The focus of the study was on Forests and Fish-designated species of stream-associated amphibians. We also evaluated riparian processes affecting in-channel wood recruitment and loading, stream temperature and shade, discharge, nutrient export, suspended sediment export (SSE), channel characteristics, litterfall input and detritus export, biofilm and periphyton, macroinvertebrate export, and downstream fish density and population structure (see **Supplement 1** for a complete list of response variables). The results of this study will inform the efficacy of current Forest Practices rules, including how landowners can continue harvesting wood resources while protecting important headwater habitats and associated species.

We used a Before-After Control-Impact (BACI) study design with blocking to examine how harvest treatments influenced resource response. We collected pre-harvest data from 2006 through 2008 and post-harvest data from 2009 into 2011 (see Chapter 2 – *Study Design*). Study sites included 17 Type N stream basins located in managed second-growth conifer forests across western Washington. Sites were restricted to Type N basins less than 54 ha (133 ac) in size with relatively competent lithologies. We evaluated four experimental treatments, including an unharvested **Reference** (i.e., in the harvest rotation but withheld from harvest; n = 6) and three alternative riparian buffer treatments involving clearcut harvest of the entire basin. Riparian buffer treatments included the following: **100% treatment** (a two-sided 50-ft [15.2-m] riparian leave-tree buffer along the entire riparian management zone [RMZ; n = 4]); **FP treatment** (a two-sided 50-ft [15.2-m] riparian buffer along at least 50% of the RMZ, consistent with the current Forest Practices buffer prescription for Type N streams [n = 3]); and **0% treatment** (clearcut harvest throughout the entire RMZ [n = 4]). The buffer treatments were implemented between October 2008 and August 2009 (see Chapter 3 – *Management Prescriptions*). Results presented in this summary include those that had statistically significant pre- to post-harvest changes that differed between treatments (alpha of 0.05 or 0.1, depending on the response and clarified in each chapter).

We found that harvest of timber in and adjacent to streamside riparian forests directly affected tree mortality, tree fall rates, and large wood recruitment to streams. The highest mortality rates and greatest reductions in density and basal area occurred in the FP treatment RMZ buffers and the buffers surrounding the uppermost points of perennial flow (PIPs; see Chapter 5 – *Stand Structure and Tree Mortality Rates in Riparian Buffers).* Mortality and tree fall rates in FP treatment RMZs were significantly greater than in either the 100% treatment or reference RMZs. Tree mortality and tree fall were significantly greater in both the 100% and FP treatment PIPs relative to reference rates. Windthrow-associated tree fall in riparian buffers increased large

wood (≥10 cm [4 in] diameter) recruitment to channels in the 100% and FP treatments (see Chapter 6 – *Wood Recruitment and Loading*). However, the vast majority of recruited trees were completely suspended above the active stream channel. We observed a significant post-harvest increase in small wood (<10 cm [4 in] diameter) in the channel in the 0% treatment relative to the FP and 100% treatments, and an increase in in-channel large wood in all three buffer treatments relative to the reference. Increases in in-channel wood loading in treated sites may have been responsible for the changes we saw in stream channel characteristics. We observed a significant post-harvest increase in stream pool length in all three riparian buffer treatments (see Chapter 11 – *Stream Channel Characteristics*). The pre- to post-harvest change in stream bankfull and wetted widths, and the proportion of the stream channel rise attributed to steps, was significantly less in the 0% treatment than in any other treatment including the reference.

Shade decreased and water temperature increased in all buffer treatments, with the greatest change in temperature occurring during the July–August period (see Chapter 7 – *Stream Temperature and Cover*). Both maximum and minimum daily temperatures increased significantly in all buffer treatments over some part of the year. The maximum daily temperature showed signs of recovery toward pre-harvest conditions downstream from the harvest unit (i.e., within 100 m downstream of the harvest boundary); however, stream temperature remained above pre-harvest levels at five of the six sites where downstream recovery could be assessed. While we observed post-harvest reductions in canopy across all riparian buffer treatments, that reduction did not result in differences in biofilm ash-free dry mass (AFDM) or chlorophyll *a* by treatment following harvest (see Chapter 13 - *Biofilm and Periphyton*).

We measured discharge, SSE and nutrient export in eight study sites, four each in the Olympic and Willapa Hill ecoregions. Annual runoff increased in all buffer treatment sites as a result of harvest, but the magnitude of change varied by season and return interval (see Chapter 8 – *Discharge*). As expected, total water yield increased as a function of the proportion of the total area of each basin harvested, which was 88% and 94% in the two FP treatments and 45% and 89% in the two 100% treatments. We saw very little change in the 100% treatment site, where only 45% of the basin was harvested. All sites exhibited changes in discharge, and mean discharge increased in the FP and 0% treatment, but not in the 100% treatment. Baseflows decreased in the 100%, were largely unchanged in the FP, and increased in the 0% treatment.

The sites monitored for SSE appeared to be supply limited (i.e., sediment transport was limited by the sediment delivered to the stream from the adjacent uplands) both before and after harvest (see Chapter 10 – *Sediment Processes*). Most of the sediment export occurred during late fall or early winter storm events, and the relative magnitude of export was stochastic across sites and treatments. In four of the six buffer treatment sites, SSE was greater during clearcut harvest implementation or in the two year post-harvest period, but spikes in sediment export were of similar magnitude to those observed in one of the two reference sites during the same periods.

Mean total nitrogen (N) and nitrate-N concentrations increased in all buffer treatments. The estimated change was greatest in the 0%, intermediate in the FP, and lowest in the 100% treatment, consistent with an increase in the proportion of the watershed harvested, but only the 0% differed statistically from the other buffer treatments (see Chapter 9 – *Nutrient Export*).

Overall, total litterfall input was slightly higher after harvest in the 100% treatment, lower in the FP treatment and lowest in the 0% treatment; however, we observed statistical differences only for deciduous inputs between the 0% treatment and the other treatments (see Chapter 12 – *Litterfall Input and Detritus Export*). Total detritus export decreased in the 0% treatment relative to the reference, and in the FP and 0% treatments relative to the 100% treatment.

We observed some changes in macroinvertebrate export after harvest, but did not detect any major reductions in macroinvertebrate export or major shifts in functional feeding groups (see Chapter 14 – *Macroinvertebrate Export*). Collector-gatherer export in biomass per day decreased in the 0% treatment relative to the FP treatment, but increased in the FP treatment relative to the reference and the 100% treatment.

Treatment effects for stream-associated amphibians (Coastal Tailed Frog [*Ascaphus truei*], and torrent [*Rhyacotriton*] and giant [*Dicamptodon*] salamanders) were variable among genera and, for tailed frogs, life stage (see Chapter 15 – *Stream-associated Amphibians*). We found statistical support for a negative effect of buffer treatment on the density of giant salamanders in the FP treatment. We found that larval Coastal Tailed Frog density increased significantly in the 100% and FP treatments relative to the reference and 0% treatment. Post-metamorphic Coastal Tailed Frog density also increased, but only in the 0% treatment. We lacked evidence of a treatment response for torrent salamanders, except when stream reaches that were visibly obstructed by dense matrices of logging slash in the form of downed wood, litter and fines were included in the analysis; here, torrent salamander density increased significantly in the 0% treatment.

Based on results from six study sites, we found that cutthroat trout (*Oncorhynchus clarkii*) density and population structure downstream of study sites were highly variable across sites, months and years (see Chapter 16 – *Downstream Fish*). Variability in total fish abundance was not correlated with physical stream habitat metrics such as gradient and percent pool area. Consistently low recapture rates for passive integrated transponder (PIT)-tagged fish over the course of the study provided evidence of a high level of fish emigration from, and/or mortality within, study reaches.

During the two years post-harvest, the 100% buffer treatment was the most effective in maintaining pre-harvest conditions, the FP was intermediate, and the 0% treatment was least effective compared to reference sites (see Chapter 17 – *Summary and Discussion*). The collective effects of timber harvest, both in terms of statistical significance and magnitude, were most apparent in the 0% treatment. The direction and magnitude of changes for the 100% and FP treatments did not differ statistically for some metrics, including large wood recruitment, wood cover and loading, water temperature, discharge and channel unit metrics, and Coastal Tailed Frog density. However, some differences existed between the 100% and FP treatments, including for tree mortality and stand structure, riparian cover, detritus and macroinvertebrate export and giant salamander density. While post-harvest differences in the response of treatments were readily apparent across a suite of variables, we noted no consistent negative impacts for stream-associated amphibians.