***Type N Experimental Buffer Treatment Project in Hard Rock Lithologies – Report to Policy on Stand Structure and Tree Mortality Rates in Riparian Buffers (Chapter 5)***

***11 December 2017 – For CMER Review***

**Study Report**

The results from this study are found in the following Study Report:

McIntyre, A.P., M.P. Hayes, W.J. Ehinger, D. Schuett-Hames, S.M. Estrella, G. Stewart, R.E. Bilby, E.M. Lund, J. Walter, J.E. Jones, R. Ojala-Barbour, F.T. Waterstrat, C.R. Milling, A.J. Kroll, B.R. Fransen, J. Giovanini, S.D. Duke, G. Mackenzie, R. Tarosky, J.G. MacCracken, J. Thronton and T. Quinn. 2017. Effectiveness of Experimental Riparian Buffers on Perennial Non-fish-bearing Streams on Competent Lithologies in Western Washington. Cooperative Monitoring Evaluation and Research Report CMER XX-XXX, Washington State Forest Practices Adaptive Management Program, Washington Department of Natural Resources, Olympia, WA.

**CMER/Policy Interaction Framework Six Questions**

1. **Does the study inform a rule, numeric target, Performance Target, or Resource Objective?** Yes.

2. **Does the study inform the Forest Practices Rules, the Forest Practices Board Manual guidelines, or Schedules L-1 or L-2?** Yes.

The objective of the Type N Experimental Buffer Treatment Project in Hard Rock Lithologies (Hard Rock Study) was to evaluate the effectiveness of the current westside riparian management zone (RMZ) prescriptions for Type N (non-fish-bearing) Waters in maintaining key aquatic conditions and processes affected by Forest Practices. Specifically, we evaluated whether the riparian buffer prescription for Type N streams met the following Overall Performance Goals, namely: (1) to support the long-term viability of stream-associated amphibians, and (2) to meet or exceed water quality standards. As part of this evaluation, we assessed the Forest Practices Resource Objectives (defined as a series of Functional Objectives and corresponding Performance Targets in Schedule L-1) for heat/water temperature, large wood/organic inputs, and hydrology.

The overall study design addressed the following CMER Work Plan Critical Questions:

- Are riparian processes and functions provided by Type N buffers maintained at levels that meet Forest Practices (FP) Habitat Conservation Plan (HCP) Resource Objectives and Performance Targets for shade, stream temperature, large wood recruitment, litterfall, and amphibians?
- How do other buffers compare with the FP Type N prescriptions in meeting Resource Objectives?
- How do Type N riparian prescriptions affect water quality delivered to downstream Type F/S waters?

3. **Was the study carried out pursuant to CMER scientific protocols?**

Yes. The study design was carried out according to the CMER and Independent Scientific Peer Review (ISPR) approved study design (including sampling methodologies, statistical

methods, and study limitations). SAGs (RSAG and LWAG), CMER, and ISPR reviewed all of the study chapters and their associated findings, and CMER approved the entire final report in September 2017.

4. **A. What does the study tell us?**

In the two years immediately post-harvest we saw the greatest changes in stand structure in the clearcut portions of the RMZ where all trees were removed during treatment implementation. In stream reaches that maintained a riparian buffer in the RMZ, windthrow was the primary cause of mortality and tree fall. In stream reaches that maintained a two-sided 50-ft riparian buffer, tree mortality rates were significantly higher in the FP treatment than the 100% treatment and reference sites; however, tree mortality in the 56-ft radius buffer surrounding the uppermost points of perennial flow (PIPs) increased significantly above reference levels in both the 100% and FP treatments, likely due to their exposed locations and vulnerability to windthrow.

***Stand Structure and Tree Mortality Rates***

The LWD/Organic Inputs Resource Objective addresses riparian stands. The Hard Rock Study reduces uncertainty for riparian stand condition with an evaluation of tree mortality and tree fall during the two years after harvest.

**Functional Objective**: Develop riparian conditions that provide complex habitats for recruiting large woody debris and litter.

**Performance Targets**: There are no Performance Targets specific to riparian condition for Type N Waters.

We can also indirectly inform the critical question regarding the frequency and distribution of windthrow in forest practices buffers on Type N Waters.

**Critical Question**: How do survival and growth rates of riparian leave trees change following Type Np buffer treatments?

*Results:*

- The greatest change in stand structure occurred in the treatments where riparian trees were completely removed to the stream edge (clearcut) and replanted with conifers (the 0% treatment and unbuffered portions of the FP treatment RMZs).
- Two year post-harvest tree mortality rates were higher in the FP buffered RMZs compared to unharvested reference sites and 100% treatment RMZs. Post-harvest tree mortality (% basal area/yr) in FP buffered RMZs was over four times greater than in unharvested reference RMZs ($P = 0.01$) and over two times greater than in 100% RMZs ($P = 0.09$). The mortality rate in the 100% RMZs was double the reference rate, but the difference was not statistically significant. The mortality (% basal area) in both the FP and 100% PIPs were significantly higher than the rate for the reference PIPs, eight ($P < 0.01$) and four ($P = 0.05$) times higher, respectively.
- Stand structure as measured by trees per acre in the FP buffered RMZs was highly variable two years post-harvest. Most (~75%) stands had densities greater than 120 trees/acre, while a subset (~25%) had densities below 120 trees/acre.

- Windthrow was the primary cause of mortality and tree fall in both RMZ and PIP buffers. There was substantial variability in windthrow mortality among and within sites. We observed higher rates of windthrow in the RMZs of the coastal blocks (Willapa 1 and Willapa 2) than in sites located further inland in both the pre- and post-harvest periods.
- Higher tree mortality in PIP buffers was likely due to their exposed locations and vulnerability to windthrow.

*Conclusions:*

- Removal of streamside trees in the 0% treatment and unbuffered portions of the FP treatment returned these areas to the stand-initiation stage of development and is likely to have the greatest effect on the quantity, characteristics and timing of wood input.
- Unless the rates of tree mortality change significantly over time, FP and 100% RMZ buffers, which experienced low mortality, are likely to continue developing as single cohort, conifer dominated stands. The future trajectory for the sub-set of buffer stands with higher mortality remains unclear. Since replanting is not required in these areas under Forest Practice rules, success of natural conifer regeneration will likely determine if these stands develop as multi-cohort conifer stands, or become dominated by broadleaf trees or shrubs.
- Results from the Hard Rock Study are consistent with the findings from the Westside Type N Buffer Characteristics, Integrity, and Function Project (BCIF) Study (Schuett-Hames *et al.* 2011). Post-harvest mortality rates in the FPB RMZs were similar, and both studies documented statistically significant increases in mortality in FPB RMZs compared to reference sites.

**B. What does the study not tell us?**

One should consider a number of study limitations when interpreting and generalizing the results.

**Spatial Scope of Inference:** The spatial scope of inference is limited to Type N basins dominated by competent lithologies, which comprise approximately 29% of western Washington Forests and Fish-regulated lands (P. Pringle, personal communication, September 2005). One should not assume that the results apply equally to other lithologies. Additional considerations include the fact that sites were located in second-growth forests and ranged from approximately 12 to 53 ha (30 to 130 ac). See McIntyre and colleagues (2009) for a summary of the site selection process.

**Temporal Scope of Inference:** The temporal scope of inference can only be made to the two year post-harvest interval. Do not assume that the results are applicable over a longer period. One can only understand the scope of potential long-term response with longer-term monitoring. Stand development is a long-term process, there will be height and diameter growth in existing buffer trees, mortality from suppression, windthrow and other factors, and regeneration and ingrowth of new trees in response to disturbance. For metrics that changed from pre-harvest levels, we do not know how much time will be needed for recovery to pre-harvest conditions.

**Riparian Buffering/BMPs:** Application of clearcut timber harvest included buffers for sensitive sites and unstable slopes, and followed other best management practices (BMPs), ultimately, influencing the level of buffering (width and length) in the FP treatment sites. CMER did not design this study to examine directly the influence of specific rules or BMPs, but rather to evaluate the overall influence of the FP buffer strategy as it is applied under real world circumstances. We do not know if the results for the FP buffers would have been different if only the minimum riparian buffers had been applied. We also do not know how frequently more than the minimum buffer length is applied across the managed landscape. Since the proportion of the stream length buffered in FP treatment sites was more than the minimum required under Forest Practice's rules, some consistency in responses between the 100% and FP treatments may reflect the fact that the stream length buffered was more similar between these treatments than between the FP and 0% treatments. Furthermore, protection of unstable slopes resulted in wider riparian buffers along some portions of two of four 100% buffer treatment sites, although it should be noted that this study was designed to evaluate buffer length, not buffer width. Nonetheless, wider buffers in some 100% treatment sites may have resulted in a consistency of response between reference and 100% sites. Buffers along the FP treatments sites were 50 ft, as specified in the FPHCP. As stated above, and based on the results from sites with buffers 50 ft wide, it is very likely that sites containing buffered sections wider than 50 ft would still have experienced increases in stream temperature associated with shade reductions.

**Pre-harvest Windthrow Event:** Interpretation of results, especially for riparian vegetation and wood, required consideration of the timing and severity of a windthrow event that occurred 1-4 December 2007. During this time, a series of storms caused extensive windthrow throughout western Washington. The storms resulted in extensive damage to forestlands along the Washington coast, leading us to add an additional, third year, of pre-treatment sampling for some response variables. We found that study sites assigned to all treatments were impacted, including references and riparian buffer treatments. Since we had the opportunity to collect additional pre-harvest data, our data reflect the broad range of disturbances that occur throughout the managed forestlands of western Washington.

**5. What is the relationship between this study and any others that may be planned, underway, or recently completed?**

The results from the Hard Rock Study, BCIF Study, Soft Rock Study, Shade Study, and Amphibian Recovery Project in combination are expected to provide a thorough assessment of riparian prescription effectiveness for westside Type N Waters. They will generate data that can be used to determine if the resource objectives for heat/water temperature, LWD/organic inputs, sediment, hydrology and stream-associated amphibians (with the exception of terrestrial Dunn's and Van Dyke's Salamanders) are being met.

- Westside Type N Buffer Characteristics, Integrity, and Function Project [BCIF Study, completed]: The BCIF Study evaluated the magnitude of change in riparian stand conditions, tree mortality, shade and LWD recruitment when prescriptions were applied on a reach-scale at sites selected from a random sample of forest practice applications. The Hard Rock Study expanded on the knowledge gained in the BCIF Study, supplementing the results from the latter by increasing the sample of clearcut,

50-ft buffer and PIP buffer RMZ reaches. These results are particularly helpful in reducing the level of uncertainty in PIP buffer response, increasing the sample size and providing PIP reference data. Additionally, the Hard Rock Study included responses that were not incorporated in the BCIF study, including riparian-related inputs (light, litterfall, sediment, and wood) and the response of instream (amphibians, water temperature, and habitat) and downstream components (export of nutrients, organic matter, macroinvertebrates, and sediment; water temperature; and fish in the downstream fish-bearing reach). Findings through five years post-harvest are reported on in Schuett-Hames and colleagues (2011). A report on findings through 10 years post-harvest is in development.

- Type N Experimental Buffer Treatment Project in Soft Rock Lithologies [Soft Rock Study, underway]: The Soft Rock Study will expand on the knowledge gained from the Hard Rock Study by evaluating the post-harvest changes in riparian stand conditions, buffer tree mortality, LWD recruitment, shade and stream temperature, and nutrient and sediment export from westside Type N basins with sedimentary lithologies. This study differs from the Hard Rock study in that it includes only study basins underlain with sedimentary lithologies, and includes only one riparian buffer treatment (equivalent to the Hard Rock Study FP treatment; no alternative buffers are tested). Both the Hard and Soft Rock studies use a manipulative experimental design to compare effectiveness of riparian buffers with unharvested controls. Like the Hard Rock Study, the Soft Rock Study is limited to western Washington. It also does not evaluate the response of stream-associated amphibians, which are largely restricted to competent lithology types, fish, or litterfall. The Soft Rock Study will provide important confirmation of the effect of forest practices prescriptions on more erodible substrates that were not included in the Hard Rock Study.

These studies will not address the effectiveness of the riparian prescriptions for eastside Type N Waters, for which CMER needs to complete the ENREP Study (underway), Eastside Np Effectiveness Project (planned).

- Eastside Type N Riparian Effectiveness Project [ENREP Study, underway]: The ENREP study will determine if, and to what extent, the eastside riparian prescriptions are effective in achieving Performance Targets and water quality standards, particularly as they apply to sediment and stream temperature. Study objectives include: (1) quantify the magnitude of change in stream flow, canopy closure, water temperature, suspended sediment transport and wood loading within eastern Washington RMZs following harvesting, and (2) evaluate the effects of these changes on downstream waters where possible. This study complements the Hard Rock Study by evaluating Type N prescription effectiveness in eastern Washington.
- Eastside Np Effectiveness Project [planned]: The Eastside Np Effectiveness Project will determine if and to what extent the riparian prescriptions for eastside Ns streams (non-fish-bearing seasonally dry) maintain Performance Targets and water quality with a particular focus on effects in downstream typed waters. A literature review will inform a field study to examine the effect of riparian prescriptions on Ns streams on downstream Type Np and F Waters. Responses will include in-channel wood loading, channel stability, and downstream water quality (temperature, turbidity, and sediment) and quantity, stream channel stability and magnitude and frequency of scour. This

study complements the Hard Rock Study by evaluating Type N prescription effectiveness in eastern Washington.

Additional studies related to the Hard Rock Study include:

- Windthrow Frequency, Distribution, and Effects Project [planned]: Preliminary results of the BCIF Study indicated that windthrow mortality in westside Type N buffers was widespread. In response to this finding and supported by direction from TFW Policy, the intent of the Windthrow Frequency, Distribution, and Effects Project is to include a windthrow assessment in existing Type N riparian projects. While assessments of windthrow mortality were included in both the Hard and Soft Rock Studies, it was not in response to this Project *per se* but findings from these studies may inform this Project as it is scoped.

- ***Feasibility of obtaining more information to better inform Policy about resource effects.***

Opportunities exist to better inform Policy with data that have already been collected for the Hard Rock Study through eight years post-harvest (through 2016). The CMER budget for the current biennium includes funding for analyses of these data and report writing. Future and continued data collection is possible if interest exists. However, some reference sites have been or will be harvested for timber in the near future, making them unsuitable for use as references in the study. Opportunity may exist to establish new reference sites or to use nearby references from the Soft Rock study in lieu of harvested references for selected response variables, including stream temperature. This is a unique long-term data set evaluating applicable riparian buffer treatments in a BACI-designed study. Value exists in continued monitoring of treated sites for interpretation of the longer-term trajectory of change. To date, only one reference site has been harvested, one is currently being harvested, and two are expected to be harvested during calendar year 2019. Due to regulatory constraints, it is unlikely that the remaining two reference sites would ever be harvested.

- ***What are the costs associated with additional studies?***

Analysis and report development through eight years post-harvest are a part of the current CMER 2017-2019 biennium budget. Costs estimates associated with additional monitoring beyond eight years post-harvest are variable and dependent on which responses interest Policy. Budget placeholders exist in the CMER Master Schedule. We estimate that another round of sampling for riparian vegetation, wood recruitment and loading, and stream-associated amphibian demographics would be an additional $897,000. Modifying the specific responses included, as well as the number and timing of future sampling events, affects the budget estimate.

- ***What will additional studies help us learn?***

Results from the extended study period through eight years post-harvest will provide additional information for understanding the effectiveness of the current Forest Practices rules and buffer alternatives. Additional long-term monitoring will provide a unique opportunity to evaluate the longer-term response of variables of interest to forest practices. Originally, the Hard Rock Study was proposed to cover an entire harvest rotation (i.e., 30 to 40 years in western Washington). Future monitoring would allow us to evaluate stand structure, tree mortality and associated responses in riparian buffers.

***When will these additional studies be completed (i.e., when will we learn the information)?***

CMER anticipates development and approval of reports from the extended period (through eight years post-harvest) during the current biennium (2017-2019) and beginning of the following biennium (2019-2021), with transmission to Policy estimated for the 2019-2021 biennium. Timing of dissemination of findings to Policy for any future sampling would depend on the number of responses for which Policy is interested in continuing to monitor and the timing of that effort. We highly encourage Policy to consider the benefits of continued or future monitoring throughout an entire harvest rotation.

- ***Will additional information from these other studies reduce uncertainty?***

Future monitoring beyond eight years post-harvest will reduce uncertainty associated with trajectories of potential changes in riparian stand conditions. Only longer-term study can provide guidance on the effectiveness of the current Forest Practices rules to meet Functional Objectives over the long-term.

6. **What is the scientific basis that underlies the rule, numeric target, Performance Target, or Resource Objective that the study informs? How much of an incremental gain in understanding do the study results represent?**

The management approach for westside Type N riparian prescriptions employs a patch-cut strategy, where a portion of the riparian stand in a Type N basin RMZ may be clearcut, providing that sensitive sites and at least 50% of the perennial stream length is buffered. CMER intended this study, along with BCIF and Soft Rock Studies, to evaluate the effectiveness of this strategy.

This study provides a substantial gain for riparian vegetation. While previous studies may have evaluated many of the metrics we included in this study as they relate to forestry practices, the Hard Rock Study provides results in context of the specific forest practices rules for riparian prescriptions required on Type N streams in western Washington.

The BACI study design provides a more precise estimate of the response to forest harvest. The inclusion of variable buffer treatments, both more restrictive and less restrictive than the current rules, was established to provide a response curve along a gradient of buffer length.

We expanded on the knowledge gained from other CMER studies, for example by supplementing the findings from the BCIF study by increasing the sample of riparian vegetation and wood recruitment clearcut, 50-ft buffer and PIP buffer RMZ reaches.

We are more confident in many of our findings because we were able to utilize new technology and sampling techniques that were not previously available, because of the duration and/or intensity of sampling, and because we were able to take advantage of more recent statistical methods.

**Technical Implications and Recommendations:**

**Research/monitoring suggestions.**

To better understand the scope of stand response to the various treatments, we highly encourage Policy to consider the benefits of extended monitoring of riparian stand conditions over time. This study covered only the first two years after harvest, which is not enough time to evaluate fully the duration of harvest effects and the long-term trajectory of response. To

understand completely the impacts of the treatments on the managed landscape one would have to monitor the response for a longer period. Substantial amounts of time and money have been invested in this study to date. Currently we have collected data through eight years post-harvest, and a report outlining those findings is in development. Data collection at existing study sites over a longer time will reduce scientific uncertainty about the duration of disturbance and the progress of recovery in Type N riparian buffers and clearcuts. Considering the amount of time and money that would be required to re-initiate a similar study from the beginning, the best opportunity for evaluating long-term recovery is with continued monitoring in the existing study. Additional data collection may be especially important for evaluating long-term mortality rates due to the continued effects of windthrow and other tree mortality processes in riparian buffers, and the effects of natural regeneration and stand development in stands impacted by disturbance. Continued study for this and other related studies (see **What is the relationship between this study and any others that may be planned, underway, or recently completed**?) would result in a more confident assessment of prescription effectiveness as we monitor response to treatments over time.

### Suggested changes to rules/board manual.

A review and evaluation of the Performance Targets for westside and eastside Type N streams, both in context of the results of these studies and other current scientific research, by CMER and the Timber, Fish and Wildlife (TFW) Policy Committee would be appropriate once the studies outlined under #5 are completed. They could propose changes to Performance Targets and/or new measures if appropriate. Currently, there are no Performance Targets specific to riparian condition for Type N Waters. Related Performance Targets for some metrics are tied to the objective of providing 50% of the riparian function available within 50 feet of the stream, which is more closely related to a compliance target than a Performance Target *per se*.

### References

McIntyre, A.P., M.P. Hayes and T. Quinn. 2009. *Type N Feasibility Study*. A report submitted to the Landscape and Wildlife Advisory Group, Amphibian Research Consortium, and the Cooperative Monitoring, Evaluation, and Research Committee. Washington Department of Natural Resources, Olympia. 48 pp.

Schuett-Hames, D., A. Roorbach and R. Conrad. 2011. *Results of the Westside Type N Buffer Characteristics, Integrity and Function Study Final Report. Cooperative Monitoring Evaluation and Research Report, CMER 12-1201. Washington Department of Natural Resources, Olympia, WA*. 93 pp.

***Type N Experimental Buffer Treatment Project in Hard Rock Lithologies – Report to Policy on Wood Recruitment and Loading (Chapter 6)***

***11 December 2017 – For CMER Review***

**Study Report**

The results from this study are found in the following Study Report:

McIntyre, A.P., M.P. Hayes, W.J. Ehinger, D. Schuett-Hames, S.M. Estrella, G. Stewart, R.E. Bilby, E.M. Lund, J. Walter, J.E. Jones, R. Ojala-Barbour, F.T. Waterstrat, C.R. Milling, A.J. Kroll, B.R. Fransen, J. Giovanini, S.D. Duke, G. Mackenzie, R. Tarosky, J.G. MacCracken, J. Thronton and T. Quinn. 2017. Effectiveness of Experimental Riparian Buffers on Perennial Non-fish-bearing Streams on Competent Lithologies in Western Washington. Cooperative Monitoring Evaluation and Research Report CMER XX-XXX, Washington State Forest Practices Adaptive Management Program, Washington Department of Natural Resources, Olympia, WA.

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The overall study design addressed the following CMER Work Plan Critical Questions:

- Are riparian processes and functions provided by Type N buffers maintained at levels that meet Forest Practices (FP) Habitat Conservation Plan (HCP) Resource Objectives and Performance Targets for shade, stream temperature, large wood recruitment, litterfall, and amphibians?
- How do other buffers compare with the FP Type N prescriptions in meeting Resource Objectives?
- How do Type N riparian prescriptions affect water quality delivered to downstream Type F/S waters?

3. **Was the study carried out pursuant to CMER scientific protocols?**

Yes. The study design was carried out according to the CMER and Independent Scientific Peer Review (ISPR) approved study design (including sampling methodologies, statistical methods, and study limitations). SAGs (RSAG and LWAG), CMER, and ISPR reviewed all of the study chapters and their associated findings, and CMER approved the entire final report in September 2017.

4. **A. What does the study tell us?**

In the two years following harvest, we observed a significant post-harvest increase in in-channel wood loading in all buffer treatments. We observed the greatest increase, especially of small wood, in the clearcut RMZs of the FP and 0% treatments, where slash related to harvest of the streamside riparian stand accumulated. Tree fall rates in FP buffered RMZ were significantly greater than rates in the 100% treatment and unharvested reference RMZs, while rates in both FP and 100% treatment PIPs were greater than in reference PIPs, primarily due to windthrow. LW recruitment rates were greater in both the FP and 100% treatment than in the reference RMZs and PIPs, but most comparisons were not significant. As a result, we observed increased large wood recruitment and loading in streams with buffers. Future large wood recruitment will depend on several factors, including existing recruitment potential (the density and size of the current stand), ingrowth of new trees, future silvicultural activities, and the magnitude and frequency of disturbances, such as wind, that cause tree mortality and wood input. Future wood loading will depend on rates of wood recruitment as well as decay and transport of in-channel wood downstream.

***Wood Recruitment and Loading***

The LWD/Organic Inputs Resource Objective addresses wood recruitment and loading. The study reduces uncertainty for instream wood through an evaluation of wood recruitment and loading in the two years following harvest.

**Functional Objective**: Develop riparian conditions that provide complex habitats for recruiting large woody debris and litter.

**Performance Targets**: There are no Performance Targets specific to wood recruitment and loading for Type N Waters.

*Wood Recruitment Results:*

- Two year post-harvest tree fall rates, as a percentage of standing stems, in the FP buffer RMZs and PIPs were >5 ($P = 0.02$) and 12 ($P = 0.01$) times greater than the comparable unharvested reference rates. Tree fall rates in the 100% treatment PIPs were 7 times ($P = 0.03$) greater than in reference PIPs; however, no significant difference existed between tree fall rates in the 100% treatment and reference RMZs.
- In the two years following harvest, in-channel wood recruitment experienced the greatest change in the clearcut RMZs and PIPs, with little additional wood recruitment to the stream because trees were removed as part of the harvest treatments.
- Two year post-harvest large wood recruitment rates (volume) from RMZs in the FP buffer and 100% treatment were somewhat greater than for reference RMZs (1.1 and 1.6 times, respectively), but the differences were not statistically significant.

- Large wood recruitment volume in the FP and 100% treatment PIP buffers was substantially greater than in the reference PIPs (12 and 19 times, respectively) and the differences were statistically significant (P = 0.08 and 0.04, respectively).
- Riparian buffers prevented input of logging slash into the stream from upland clearcut harvest. In these buffers, wood input was mostly due to windthrow.
- Ninety percent of trees recruited during the two year post-harvest period were suspended over the stream channel.

*Wood Loading Results:*

- The post-treatment change in the number of in-channel large wood pieces (>10 cm [4 in] diameter) differed between the reference and riparian buffer treatments (P <0.01). We estimated a between-treatment average increase of 60% (P <0.001), 40% (P = 0.03) and 50% (P = 0.01) in the number of large wood pieces per stream meter in the 100%, FP and 0% treatments, respectively. The pattern for functional large wood (i.e., contributing to step formation, bank stability, or hydraulic roughness) was similar to that for total large wood (P <0.01).
- The post-treatment change in the number of in-channel small wood pieces differed between the reference and riparian buffer treatments (P <0.01). We estimated a between-treatment average increase of 60% (P = 0.05), 70% (P = 0.07) and 170% (P <0.0001) in the number of small wood pieces per stream meter in the 100%, FP and 0% treatments, respectively. The pattern for functional small wood was similar to that for total small wood (P <0.01).
- The only significant difference in numbers of wood pieces among the three buffer treatments was for total small wood, which had a greater post-harvest increase in the 0% than in the 100% (P = 0.01) and FP (P = 0.08) treatments. The increase in total small wood in the 0% treatment was 70% greater than in the 100% treatment and 60% greater than in the FP treatment.
- Greater than 75% of all wood pieces were classified as small. Small wood played a functional instream role in all sites, with approximately 50% of small wood pieces contributing to instream function, regardless of treatment.
- When in-channel windthrow and slash were considered in combination, the channel length covered (hereafter “wood-obstructed reaches”) differed significantly among treatments (P = 0.001). In the first post-harvest year, wood-obstructed reach length in the 100%, FP and 0% treatments was estimated to be 3, 8, and 9 times greater than in the reference, and the FP and 0% treatments were significantly greater than in the reference (P <0.01).
- The proportion of wood-obstructed reaches in the post-harvest period increased with a decrease in the length of buffered RMZ, ranging from 8 to 25% in the FP treatment and 0 to 61% in the 0% treatment.
- We observed up to 5 times more large wood and up to 15 times more small wood in wood-obstructed reaches than in reaches that were not obstructed by wood. Ninety-

one percent (91%) of all wood pieces in wood-obstructed reaches were classified as small wood (≤10 cm [4 in] diameter).

- Large wood pieces most frequently contributed to bank stability in both the pre- and post-harvest periods, except in wood-obstructed reaches in the post-harvest period where the predominant function was hydraulic roughness. Large wood in wood-obstructed reaches also spanned the channel more frequently than in reaches that were not obstructed by wood.
- Small wood was generally loose in the stream (e.g., not anchored in the stream and easily moved downstream during periods of higher flow) in both the pre- and post-harvest periods. In the post-harvest period, the proportion of small wood pieces that were loose declined, while the proportion of pieces that contributed to hydraulic roughness increased. The proportion of pieces contributing to hydraulic roughness or spanning the channel was greater in wood-obstructed reaches.

*Conclusions:*

- Streams with buffers (FP buffered and 100% treatments) had increases in wood recruitment and loading over the two year post-harvest period.
- For streams with buffers, differences in wood recruitment were associated with levels of disturbance (mostly windthrow), including frequency and severity, regardless of treatment. Variability in stand structure associated with differences in post-harvest mortality has implications for future wood input and loading in the buffered streams, creating uncertainty about the ability of disturbed buffers to supply wood over the long-term.
- Future large wood recruitment from buffered RMZs and PIPs will depend on several factors, including existing recruitment potential (the density and size of the current stand), ingrowth of new trees, future silvicultural activities, and the magnitude and frequency of disturbances, such as wind, that cause tree mortality and wood input. In buffered RMZs without extensive mortality, future recruitment potential is good. For the sub-set of buffers with substantial wind mortality, wood recruitment rates were higher during the first two years after harvest, but the number of trees remaining in the stand were depleted. Uncertainty remains about the ability of these stands to regenerate and supply instream wood over the long-term.
- Future large wood recruitment from unbuffered (clearcut) RMZs in the FP and 0% treatments will require the establishment and development of a new forest stand. Over time, wood loading is likely to decrease as logging slash decays; however, these channels are likely to receive another pulse of logging slash during the next harvest. This process will result in an episodic wood input regime and changes in wood loading through time.
- We observed the greatest post-harvest increase in wood loading, especially small wood related to harvest of the streamside riparian stand (i.e., slash), as a result of harvest activity in the clearcut RMZs. In these reaches, equipment limitation zones (ELZs), in combination with additional rules intended to minimize wood input during harvest, did not prevent recruitment of logging slash to streams. However, our study

streams had substantially less slash input than streams in some similar studies (e.g., Jackson *et al.* 2001).

- In clearcut stream reaches, there was very little additional large wood recruitment during the two years after harvest. Harvest of streamside trees eliminates potential future wood recruitment for an extended period, which will likely result in smaller and lower wood loading levels over longer periods (e.g., a harvest rotation). Uncertainty remains about the fate and persistence of logging slash, especially small wood, which decays at a much faster rate than, and does not provide the same opportunity for instream sediment storage as, large wood. In Type N basins with clearcut RMZs, replacement of large wood with smaller pieces will likely reduce long-term sediment storage capacity.
- We cannot evaluate whether this wood input regime meets the Functional Objective of providing complex habitats and developing riparian conditions for recruiting large wood through time with only two years of post-harvest study.
- Wood pieces suspended above the stream channel provides shade and cover and are expected to provide in-channel functions eventually as they decay and are recruited to the stream. Uncertainty remains about the timeframe for suspended pieces to fall into the channel.

**B. What does the study not tell us?**

One should consider a number of study limitations when interpreting and generalizing the results.

**Spatial Scope of Inference:** The spatial scope of inference is limited to Type N basins dominated by competent lithologies, which comprise approximately 29% of western Washington Forests and Fish-regulated lands (P. Pringle, personal communication, September 2005). One should not assume that the results apply equally to other lithologies. Additional considerations include the fact that sites were located in second-growth forests and ranged from approximately 12 to 53 ha (30 to 130 ac). See McIntyre and colleagues (2009) for a summary of the site selection process.

**Temporal Scope of Inference:** The temporal scope of inference can only be made to the two year post-harvest interval. Do not assume that the results are applicable over a longer period. One can only understand the scope of potential long-term response with longer-term monitoring. For example, there will be opportunities for continued windthrow from riparian buffers, recruitment of spanning large wood, as well as the decay and downstream transport of wood currently in the channel, especially the small wood that contributed most to the increased wood load we observed in the clearcut RMZs of the FP and 0% treatments.

**Riparian Buffering/BMPs:** Application of clearcut timber harvest included buffers for sensitive sites and unstable slopes, and followed other best management practices (BMPs), ultimately, influencing the level of buffering in the FP treatment sites. CMER did not design this study to examine directly the influence of specific rules or BMPs, but rather to evaluate the overall influence of the FP buffer strategy as it is applied under real world circumstances. We do not know if the results for the FP buffers would have been different if only the minimum riparian buffers had been applied. We also do not know how frequently more than

the minimum buffer length is applied across the managed landscape. Since the proportion of the stream length buffered in FP treatment sites was more than the minimum required under Forest Practice's rules, some consistent results between the 100% and FP treatments may reflect the fact that the stream length buffered was more similar between these treatments than between the FP and 0% treatments.

**Pre-harvest Windthrow Event**: Interpretation of results, especially for riparian vegetation and wood, required consideration of the timing and severity of a windthrow event that occurred 1-4 December 2007. During this time, a series of storms caused extensive windthrow throughout western Washington. The storms resulted in extensive damage to forestlands along the Washington coast, leading us to add an additional, third year, of pre-treatment sampling for some response variables. We found that study sites assigned to all treatments were impacted, including references and riparian buffer treatments. Since we had the opportunity to collect additional pre-harvest data, our data reflect the broad range of disturbances that occur throughout the managed forestlands of western Washington.

**5. What is the relationship between this study and any others that may be planned, underway, or recently completed?**

The results from the Hard Rock Study, BCIF Study, Soft Rock Study, Shade Study, and Amphibian Recovery Project in combination are expected to provide a thorough assessment of riparian prescription effectiveness for westside Type N Waters. They will generate data that can be used to determine if the resource objectives for heat/water temperature, LWD/organic inputs, sediment, hydrology and stream-associated amphibians (with the exception of terrestrial Dunn's and Van Dyke's Salamanders) are being met.

- Westside Type N Buffer Characteristics, Integrity, and Function Project [BCIF Study, completed]: The BCIF Study evaluated the magnitude of change in riparian stand conditions, tree mortality, shade and LWD recruitment when prescriptions were applied on a reach-scale at sites selected from a random sample of forest practice applications. The Hard Rock Study expanded on the knowledge gained in the BCIF Study, supplementing the results from the latter by increasing the sample of clearcut, 50-ft buffer and PIP buffer RMZ reaches. These results are particularly helpful in reducing the level of uncertainty in PIP buffer response, increasing the sample size and providing PIP reference data. Additionally, the Hard Rock Study included responses that were not incorporated in the BCIF study, including riparian-related wood inputs. Findings through five years post-harvest are reported on in Schuett-Hames and colleagues (2011). A report on findings through 10 years post-harvest is in development.
- Type N Experimental Buffer Treatment Project in Soft Rock Lithologies [Soft Rock Study, underway]: The Soft Rock Study will expand on the knowledge gained from the Hard Rock Study by evaluating the post-harvest changes in riparian stand conditions, buffer tree mortality, large wood recruitment, shade and stream temperature, and nutrient and sediment export from westside Type N basins with sedimentary lithologies. This study differs from the Hard Rock study in that it includes only study basins underlain with sedimentary lithologies, and includes only one riparian buffer treatment (equivalent to the Hard Rock Study FP treatment; no

alternative buffers are tested). Both the Hard and Soft Rock studies use a manipulative experimental design to compare effectiveness of riparian buffers with unharvested controls. Like the Hard Rock Study, the Soft Rock Study is limited to western Washington. The Soft Rock Study will provide important confirmation of the effect of forest practices prescriptions on more erodible substrates that were not included in the Hard Rock Study.

- Amphibian Recovery Project [completed]: This project evaluated the effects of three buffer treatments on headwater streams throughout coastal western Washington. Riparian buffer treatments in this study differed from those included in the Hard Rock Study and included: (1) unthinned riparian buffers, (2) partial buffer, (3) buffer of non-merchantable trees, and (4) clearcut to the channel edge. The study included an evaluation of stream channel characteristics, wood loading, stream temperature, sediment, macroinvertebrates and stream-associated amphibians. One year of pre-harvest and three years (immediately post-harvest and two additional years beyond that) of post-harvest data were collected; not all metrics were evaluated in every post-harvest year. The study included 15 study sites. Since the treatments in the Amphibian Recovery Project were not designed to evaluate the current Forest Practices prescriptions for Type N streams, direct comparisons of results between this and the Hard Rock Study are only available for what we call the 0% treatment (their clearcut RMZ treatment). See Jackson and colleagues (2001; 2007) and Haggerty and colleagues (2004).

These studies will not address the effectiveness of the riparian prescriptions for eastside Type N Waters, for which CMER needs to complete the ENREP Study (underway), Eastside Np Effectiveness Project (planned).

- Eastside Type N Riparian Effectiveness Project [ENREP Study, underway]: The ENREP study will determine if, and to what extent, the eastside riparian prescriptions are effective in achieving Performance Targets and water quality standards, particularly as they apply to sediment and stream temperature. Study objectives include: (1) quantify the magnitude of change in stream flow, canopy closure, water temperature, suspended sediment transport and wood loading within eastern Washington RMZs following harvesting, and (2) evaluate the effects of these changes on downstream waters where possible. This study complements the Hard Rock Study by evaluating Type N prescription effectiveness in eastern Washington.
- Eastside Np Effectiveness Project [planned]: The Eastside Np Effectiveness Project will determine if and to what extent the riparian prescriptions for eastside Ns streams (non-fish-bearing seasonally dry) maintain Performance Targets and water quality with a particular focus on effects in downstream typed waters. A literature review will inform a field study to examine the effect of riparian prescriptions on Ns streams on downstream Type Np and F Waters. Responses will include in-channel wood loading, channel stability, and downstream water quality (temperature, turbidity, and sediment) and quantity, stream channel stability and magnitude and frequency of scour. This study complements the Hard Rock Study by evaluating Type N prescription effectiveness in eastern Washington.

- ***Feasibility of obtaining more information to better inform Policy about resource effects.***

Opportunities exist to inform Policy with data that have already been collected for the Hard Rock Study through eight years post-harvest (through 2016). The CMER budget for the current biennium includes funding for analyses of these data and report writing. Future and continued data collection is possible if interest exists. However, some reference sites have been or will be harvested for timber in the near future, making them unsuitable for use as references in the study. Opportunity may exist to establish new reference sites or to use nearby references from the Soft Rock study in lieu of harvested references for selected response variables. This is a unique long-term data set evaluating applicable riparian buffer treatments in a BACI-designed study. Value exists in continued monitoring of treated sites for interpretation of the longer-term trajectory of change. To date, two reference sites have been harvested and two are expected to be harvested during calendar year 2019. Due to regulatory constraints, it is unlikely that the remaining two reference sites would ever be harvested.

- ***What are the costs associated with additional studies?***

Analysis and report development through eight years post-harvest are a part of the current CMER 2017-2019 biennium budget. Costs estimates associated with additional study beyond eight years post-harvest are variable and dependent on which responses interest Policy. Budget placeholders exist in the CMER Master Schedule. We estimate that another round of sampling for riparian vegetation, wood recruitment and loading, and stream-associated amphibian demographics would be an additional $897,000. Modifying the specific responses included, as well as the number and timing of future sampling, affects budget estimates.

- ***What will additional studies help us learn?***

Results from the extended study period through eight years post-harvest will provide additional information for understanding the effectiveness of the current Forest Practices rules and buffer alternatives. Additional long-term monitoring will provide a unique opportunity to evaluate the longer-term response of variables of interest to forest practices. Originally, the Hard Rock Study was proposed to cover an entire harvest rotation (i.e., 30 to 40 years in western Washington). Future monitoring would allow us to evaluate wood recruitment and loading over an extended period. We also see enormous value in continuing to monitor more than one or two variables, as continued data collection for multiple covariates may be useful in better understanding the mechanisms of potential change. For example, the Functional Objective for large wood and organic inputs is to develop riparian conditions that provide complex habitats for recruiting large wood and litter. Therefore, to address rule effectiveness it would be best to continue monitoring of stand conditions, large wood recruitment, in-channel wood loading and litter inputs simultaneously.

- ***When will these additional studies be completed (i.e., when will we learn the information)?***

CMER anticipates development and approval of reports from the extended period (through eight years post-harvest) during the current biennium (2017-2019) and beginning of the following biennium (2019-2021), with transmission to Policy estimated for the 2019-2021 biennium. Timing of dissemination of findings to Policy for any future sampling would depend on the number of responses for which Policy is interested in continuing to monitor and

the timing of that effort. We highly encourage Policy to consider the benefits of continued or future monitoring throughout an entire harvest rotation.

- ***Will additional information from these other studies reduce uncertainty?***

Future monitoring beyond eight years post-harvest will reduce uncertainty associated with trajectories of potential changes in wood recruitment and loading. Only longer-term study can provide guidance on the effectiveness of the current Forest Practices rules and their ability to meet Functional Objectives over the long-term.

6. **What is the scientific basis that underlies the rule, numeric target, Performance Target, or Resource Objective that the study informs? How much of an incremental gain in understanding do the study results represent?**

The management approach for westside Type N riparian prescriptions employs a patch-cut strategy, where a portion of the riparian stand in a Type N basin RMZ may be clearcut, providing that sensitive sites and at least 50% of the perennial stream length is buffered. CMER intended this study, along with BCIF and Soft Rock Studies, to evaluate the effectiveness of this strategy.

This study provides a substantial gain for wood recruitment and loading. While previous studies may have evaluated many of the metrics we included in this study as they relate to forestry practices, the Hard Rock Study provides results in context of the specific forest practices rules for riparian prescriptions required on Type N streams in western Washington.

The BACI study design provides a more precise estimate of the response to forest harvest. The inclusion of variable buffer treatments, both more restrictive and less restrictive than the current rules, was established to provide a response curve along a gradient of buffer length.

We expanded on the knowledge gained from other CMER studies, for example by supplementing the findings from the BCIF study by increasing the sample of riparian vegetation and wood recruitment clearcut, 50-ft buffer and PIP buffer RMZ reaches.

While most previous studies have focused on large wood (≥10 cm [4 in] diameter), small wood (<10 cm [4 in] diameter) is frequently abundant in smaller channels, where stream power is typically too low to transport wood downstream. Small wood in headwater provides functional roles (e.g., sediment storage) and influences channel morphology. Our study is among a few that addresses the prevalence, characteristics and function of small wood in headwater streams.

We are more confident in many of our findings because we were able to utilize new technology and sampling techniques that were not previously available, because of the duration and/or intensity of sampling, and because we were able to take advantage of more recent statistical methods.

**Technical Implications and Recommendations:**

**Research/monitoring suggestions.**

To better understand whether the current FP rules for Type N Waters meet the Functional Objective for large wood and organic inputs (i.e., to develop riparian conditions that provide complex habitats for recruiting large wood and litter), we highly encourage Policy to consider

the benefits of extended monitoring of wood recruitment and loading response to treatments over time. This study covered only the first two years after harvest, which is not enough time to evaluate fully the duration of harvest effects and the long-term trajectory of response. To understand completely the impacts of the treatments on the managed landscape one would have to monitor the response for a longer period. Substantial amounts of time and money have been invested in this study to date. Currently we have collected data through eight years post-harvest, and a report outlining those findings is in development. Data collection at existing study sites over a longer time will reduce scientific uncertainty about the duration of disturbance and the progress of recovery in Type N riparian buffers and clearcuts. Considering the amount of time and money that would be required to re-initiate a similar study from the beginning, the best opportunity for evaluating long-term recovery is with continued monitoring in the existing study. Additional data collection may be especially important for evaluating the continued effects of windthrow and tree mortality in riparian buffers, in-channel wood recruitment and loading, and decay and transport of wood pieces downstream. Continued study for this and other related studies (see **What is the relationship between this study and any others that may be planned, underway, or recently completed**?) would result in a more confident assessment of prescription effectiveness as we monitor response to treatments over time.

Specifically, we propose two areas for potential future studies:

*Analysis of Existing Data*

- Buffered versus unbuffered Np reach-scale effectiveness: An evaluation of within-stream variability and characteristics between buffered and unbuffered reaches and between wood-obstructed and unobstructed reaches may prove informative for understanding the effects of alternative riparian buffer prescriptions. For example, based largely on retrospective studies, stream-associated amphibians were thought to be mostly absent from areas lacking overstory canopy and covered with dense matrices of wood and stored sediment; however, we found all focal amphibians, and even evidence of reproduction in the form of egg masses, in wood-obstructed reaches filled with fines and organic debris. CMER could address reach-scale effectiveness, at least in part, with existing data from the Hard Rock Study. We recommend an evaluation of reach-scale variability with existing data from this study, which could inform the utility of continued monitoring and/or future projects.

*New Field Study*

- Investigation of wood loading and amphibian use through time: Even with Forest Practices rules intended to minimize slash input into streams, we observed heavy slash loading in some stream reaches. In the two years immediately following harvest, we observed amphibian use of, and evidence of reproduction (i.e., egg masses) in, these reaches. Future evaluations could assess persistence of these wood-obstructed reaches, including overall stream coverage as a function of time since harvest. We could also address trends in amphibian density in wood-obstructed reaches through time.

**Suggested changes to rules/board manual.**

- A review and evaluation of the Performance Targets for westside and eastside Type N streams, both in context of the results of these studies and other current scientific research,

by CMER and the Timber, Fish and Wildlife (TFW) Policy Committee would be appropriate once the studies outlined under #5 are completed. The Functional Objective for large wood and organic inputs is to provide complex habitats for recruiting large woody debris and litter. However, there are no Performance Targets specified for riparian conditions and in-stream large wood for Type N Waters. If Policy is interested in an evaluation of the effectiveness of FP rules for Type N Waters in maintaining Functional Objectives for large wood and organic inputs, they should consider the development of measurable Performance Targets.

## References

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McIntyre, A.P., M.P. Hayes and T. Quinn. 2009. *Type N Feasibility Study*. A report submitted to the Landscape and Wildlife Advisory Group, Amphibian Research Consortium, and the Cooperative Monitoring, Evaluation, and Research Committee. Washington Department of Natural Resources, Olympia. 48 pp.

Schuett-Hames, D., A. Roorbach and R. Conrad. 2011. *Results of the Westside Type N Buffer Characteristics, Integrity and Function Study Final Report. Cooperative Monitoring Evaluation and Research Report, CMER 12-1201. Washington Department of Natural Resources, Olympia, WA*. 93 pp.

# *Findings Report*

## *Chapter 7. Stream Temperature and Shade*

## *Type N Experimental Buffer Treatment Project in Hard Rock Lithologies*

## *11 May 2018*

The results from this study are found in the following Study Report:

McIntyre, A.P., M.P. Hayes, W.J. Ehinger, S. Estrella, D. Schuett-Hames and T. Quinn (technical coordinators). 2017. Effectiveness of Experimental Riparian Buffers on Perennial Non-fish-bearing Streams on Competent Lithologies in Western Washington. Cooperative Monitoring Evaluation and Research Report CMER XX-XXX, Washington State Forest Practices Adaptive Management Program, Washington Department of Natural Resources, Olympia, WA.

**CMER/Policy Interaction Framework Six Questions**

1. **Does the study inform a rule, numeric target, Performance Target, or Resource Objective?** Yes.

2. **Does the study inform the Forest Practices Rules, the Forest Practices Board Manual guidelines, or Schedules L-1 or L-2?** Yes.

The objective of the Type N Experimental Buffer Treatment Project in Hard Rock Lithologies (Hard Rock Study) was to evaluate the effectiveness of the current westside riparian management zone (RMZ) prescriptions for Type N (non-fish-bearing) Waters in maintaining key aquatic conditions and processes affected by Forest Practices. Specifically, we evaluated whether the riparian buffer prescription for Type N Waters met the following overall Performance Goals, namely: (1) to support the long-term viability of stream-associated amphibians and (2) to meet or exceed water quality standards (WQS).

CMER ranked the Hard Rock study as the highest priority based on the potential high risk to aquatic resources (CMER work plan 2005 - 2017) and because the Type Np rules for western Washington were based on the results from only a few studies with limited scope and inference. We assessed the Forest Practices Resource Objectives defined for key aquatic conditions and processes described in the Forest Practice's Habitat Conservation Plan (WADNR 2005; hereafter, FPHCP), Appendix N, Schedule L-1. Resource Objectives are consist of Functional Objectives, or broad statements of objectives for the major watershed functions, and Performance Targets, or measurable criteria defining specific, attainable targets. This findings report addresses Resource Objectives for heat/water temperature only as requested by the TFW Policy Committee.

The Hard Rock study addresses one of the key questions that drives adaptive management:

> *"Will the rules produce forest conditions and processes that achieve resource objectives as measured by the performance targets, while taking into account the natural spatial and temporal variability inherent in forest ecosystems?*" (FPHCP, Appendix N, Schedule L-1)

The overall study addressed CMER Work Plan Critical Questions derived from Schedule L-1, including:

- Are riparian processes and functions provided by Type N buffers maintained at levels that meet Forest Practices (FP) Habitat Conservation Plan (HCP) Resource Objectives and Performance Targets for shade, stream temperature, large wood recruitment, litterfall, and amphibians?
- How do other buffers compare with the FP Type N prescriptions in meeting Resource Objectives?
- How do Type N riparian prescriptions affect water quality delivered to downstream Type F/S waters?

3. **Was the study carried out pursuant to CMER scientific protocols?**

Yes. The study was implemented according to the CMER and Independent Scientific Peer Review (ISPR) approved study design (including sampling methodologies, statistical methods, and study limitations). SAGs (RSAG and LWAG), CMER, and ISPR reviewed all of the study chapters and their associated findings. CMER approved the final report in September 2017.

4. **A. What does the study tell us?**

We evaluated the performance a clearcut harvest with one of three riparian buffer strategies relative to unharvested reference sites. The experimental treatments are described below in Table 1 and Figure 1. Riparian buffers were two-sided 50-ft (15-m) minimum leave-tree buffers. In addition, 56-ft (17-m) radius buffers were required around some sensitive sites, (PIPs, which includes both the headwater spring and headwall seep sensitive site categories) and Type Np intersections. All sites had a two-sided 30-ft (9-m) equipment limitation zone (ELZ) along the entire Np channel.

The riparian buffer along some 100% treatment streams was wider than the 50 feet width intended. due to regulatory and/or logistical constraints (e.g., unstable slopes or intersection with another riparian buffer). The FP streams were buffered along 55-73% of the perennial length.

We utilized an experimental Before-After Control-Impact (BACI) design. We maximized the treatment impact by harvesting the entire Type N basin (i.e., study site), when possible. Since the response of stream-associated amphibians was a primary variable of interest, we only included study sites where the species was known to occur, which restricted sites to those underlain by competent (i.e., hard rock) lithologies.

We collected pre-harvest temperature data continuously since mid-2006 (Table 2). Timber harvest occurred July 2008 through August 2009. We continued to monitor stream temperature and shade because of widespread increases in stream temperature noted immediately after harvest. These data will be reported in a separate document due in draft form September 2018.

***Shade and Stream Temperature***

The Heat/Water Temperature Resource Objective addresses shade and stream temperature.

**Functional Objective**: Provide cool water by maintaining shade, groundwater temperature, flow, and other watershed processes controlling stream temperature.

**Performance Targets**:

- Shade – Westside, Type N Waters: shade available within 50 feet for and least 50% of stream length.
- Stream temperature – Water quality standards (WQS) – current and anticipated in next triennial review[1].

*Shade and Stream Temperature Results-First two years post-harvest:*

- Type Np stream lengths (and percent of Np stream buffered) in the FP sites were 1050 m (62%), 325 m (73%), and 822 m (55%).
- We observed a significant post-harvest reduction in all shade metrics in all buffer treatments. Effective shade and canopy closure measured 1 m above the water surface were reduced 10% and 5%, respectively, in the 100% treatment, 36 and 27%, respectively, in the FP treatment, and 72% and 78%, respectively, in the 0% treatment.
- Slash and understory vegetation can provide shade, especially in unbuffered stream reaches, compared to measurements taken 1 m above the water surface. However, in spite of there being no significant ($P > 0.05$) change in shade at the water surface in the 100% and FP treatments, water temperature increased post-harvest in both treatments.
- Pre-harvest streams in this study were cool compared to the random sample of western Washington Type Np streams on industrial forestland sampled in the Westside Extensive Study (Figure 2) (Ecology in review). Streams in the Extensive Study were not stratified by area, substrate, lithology or amphibian presences as the Hard Rock streams were. The pre-harvest maximum 7-day average daily maximum (7DADM) water temperature ranged from 10.0-16.1°C, with a median value of 13.0°C in the eleven harvested streams in this study. Only one stream exceeded 16.0°C pre-harvest. In comparison, the 7DADM in the random sample ranged from 8.6 – 23.7°C, with a median water temperature of 15.2ºC.
- The 7DADM at four sites exceeded the 16°C threshold criteria (see description of water quality standards [WQS] below) in at least one of the two post-harvest years (Figure 3). These were the four warmest sites pre-harvest and included one 100% treatment site and three 0% treatment sites.
- The average post-harvest increase in the 7DADM temperature, measured at the Buffer Treatment locations (the lowermost monitoring location on each stream that represented the buffer treatment), was 1.2ºC in the 100% and FP treatments and 3.2ºC

[1] The Forests and Fish Report was established in 1999 while revisions were being proposed to the state's water quality standards. This performance objective provides direct support for Forests and Fish Report's Overall Performance Goal: "c) Meet or exceed water quality standards (protection of designated uses, narrative and numeric criteria, and antidegradation)."

in the 0% treatment. The post-harvest increase in 7DADM in the three FP treatment streams ranged from 0.4 to 2.3°C.

- Further downstream at the F/N break, the magnitude of the 7DADM increase was 0.7°C, 1.2°C, and 2.9°C in the 100%, FP, and 0% treatments, respectively.
- Post-harvest increases in 7DADM were significant ($P < 0.05$) in all buffer treatments at the Buffer Treatment location and at the F/N break. There was no significant difference between the 100% and FP treatments, while the increase in both the 100% and FP treatments was significantly less than in the 0% treatment.
- Significant ($P < 0.05$) increases in the maximum daily stream temperature, averaged by month, were detected over a broad seasonal range at most sites and in all buffer treatments, typically occurring from early spring through the fall in both post-harvest years.
- Small (<1.0°C), but significant ($P < 0.05$), increases in the 7-day average minimum daily water temperature were noted in all buffer treatments, most frequently for the July-August period.

*Shade and Stream Temperature Results-Years three through eight post-harvest (data not included in the report):*

- In all three buffer treatments shade, measured at 1 m above the stream, declined through the first four years post-harvest then began an increasing in fifth year post-harvest 5.
- Mean monthly summer water temperatures, seven years after harvest, were significantly ($P < 0.05$) greater than pre-harvest levels at two of the four 100% treatment sites (one site >1.0°C), two of three FP sites (one site >1.0°C), and all four 0% sites. In addition, spring and fall temperatures were significantly higher at all 11 treatment sites.
- At seven years post-harvest mean monthly summertime water temperatures measured at downstream locations where the stream had flowed through approximately 100 m of unharvested forest (i.e. a reach within a Type F fish-bearing stream buffer or an unharvested forest) were significantly ($P < 0.05$) warmer at five of the six treatment sites (1-FP site, 4-0% sites). Summer temperature was significantly cooler only at the 100% treatment site. Spring and fall temperatures were higher at five of the six sites.

*Conclusions:*

- None of the three riparian buffer treatments were effective at preventing statistically significant changes; e.g., reductions in shade and increases in stream temperature.
- The immediate post-harvest reductions in effective shade and canopy closure were consistent with the intensity of buffer treatments and were of similar magnitude to the BCIF study (Schuett-Hames et al. 2011) and the Type 5 study (Janisch et al. 2012).
- Shade reductions in the FP treatment roughly met the expectations in the Forest Practices HCP. (The HCP expectations are in terms of angular canopy density. We used a densiometer and canopy photos.)

- Consistent with reductions in shade, we observed increases in the maximum and minimum daily stream temperatures and diel ranges across all buffer treatments.
- Both the 100% and FP treatments resulted in significantly ($P < 0.05$) smaller increases in water temperature than the 0% treatment, but temperature increases in the 100% and FP treatments did not differ significantly ($P > 0.05$) from each other.
- Even small reductions in shade (e.g., <10% in effective shade) lead to measureable increases in stream temperature (e.g., in the 100% treatment).
- The estimated increase for each buffer treatment is greater than the 0.3ºC increase allowable in the WQS for waters which are at or above the assigned temperature criteria (WAC 173-201A-200(1)(c)(i)). This magnitude of increase would trigger a Tier II antidegradation review to determine if the warming is necessary and in the overriding public interest (see and WAC 173-201A-320).

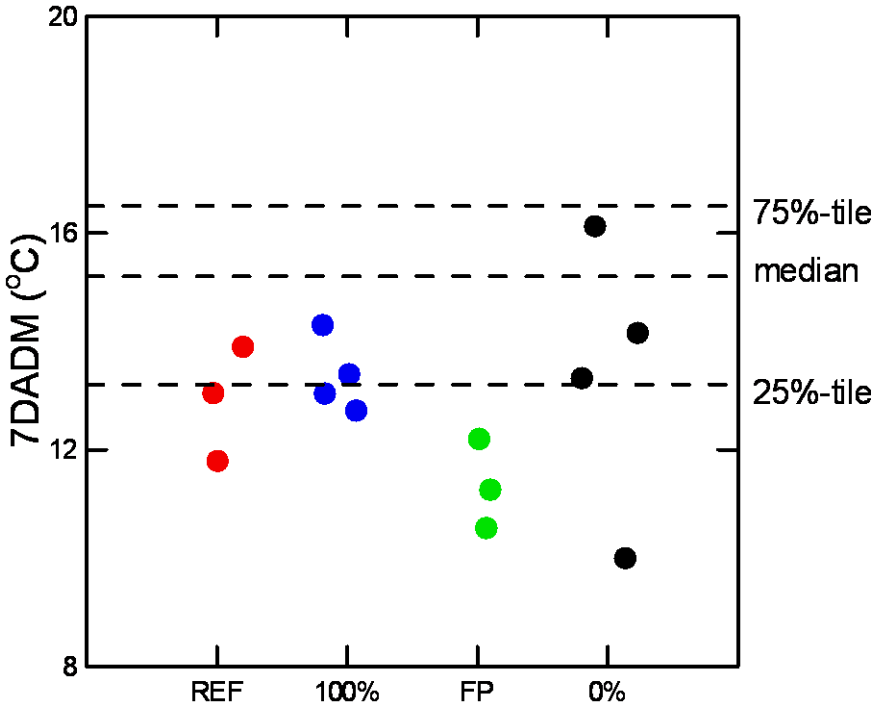


**Figure 2.** Pre-harvest seven day average daily maximum water (7DADM) temperature plotted by buffer treatment. Quartiles (dashed horizontal lines) from the westside Type Np Extensive Riparian Monitoring Study are shown for comparison. The random sample of Type N Waters was not stratified by basin area, lithology, or amphibian presence.

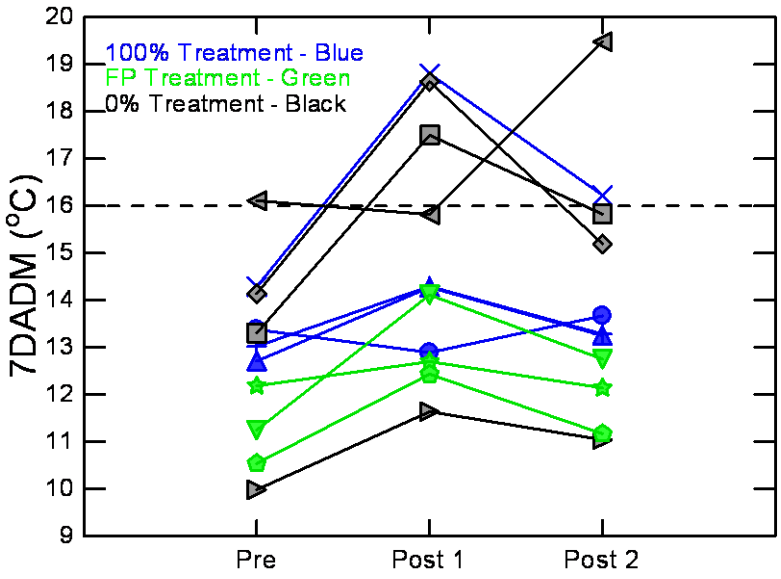


**Figure 3.** Seven-day average daily maximum temperature for each site by year. Sites that were warmer than 13°C pre-harvest tended to warm to 16°C or more after harvest. Nine of the eleven harvested buffer treatment sites were cooler in Post 2 than Post 1.

***Summary of Treatment Performance***

None of the buffer treatments prevented shade loss or increased stream temperatures after harvest. The 100% and FP performed similarly with respect to temperature and the 0% warmed significantly more than either the 100% or FP.

### B. What does the study not tell us?

The study sites and buffer treatments did not include all possible combinations of physical conditions, stand conditions, and harvest. One should consider these when generalizing the results.

**Spatial Scope of Inference:** The spatial scope of inference is limited to Type N basins dominated by competent lithologies, which comprise approximately 29% of western Washington Forests and Fish-regulated lands (P. Pringle, personal communication, September 2005, formerly Washington Department of Natural Resources). Additional considerations include the fact that all sites, including references, were located in second-growth forests and ranged from approximately 12 to 53 ha (30 to 130 ac). See McIntyre and colleagues (2009) for a summary of the site selection process.

**Temporal Scope of Inference:** The temporal scope of inference is limited. The results from the extended monitoring through fall 2017 will be in a report due in fall 2018.

**Riparian Buffering/BMPs:** First, buffering of unstable slopes resulted in some 100% treatment sites having buffers much wider than 50 feet along at least a portion of the perennial length. This has no effect on the analysis of treatment effects at the Buffer Treatment locations because the stream above these locations always matched the intended treatment (i.e., 50-ft buffers).

Second, the presence of sensitive sites resulted in buffering of 55, 62, and 73% of the Type N length in the three FP sites, i.e., more than the 50% minimum required. Shorter (e.g., 50%) buffers would likely result in greater shade loss and higher water temperature.

Third, harvest in this study was done on both side of the stream. Anecdotal information from landowners suggests that harvest is not typically done on both sides of Type N streams simultaneously but that harvest could be separated by months to years. If so, this could lessen the impact to shade and stream temperature to an unknown degree.

**Table 1.** Description of four experimental treatments included in the Type N Study and the sample size for each treatment. All study sites are located on lands managed for timber production.

| **Treatment** | **Description** | **Sample size (n)** |
|---|---|---|
| Reference | No harvest during study period | 6 |
| 100% | Two-sided 50-ft (15-m) no-harvest riparian buffer along entire Type Np RMZ, with 56-ft (17-m) radius buffers around Type Np intersections and uppermost points of perennial flow (i.e., PIPs). | 4 |
| FP | Two-sided 50-ft (15-m) no-harvest riparian buffer along at least 50% of the Type Np RMZ, with 56-ft (17-m) radius buffers around Type Np intersections and headwater springs, consistent with current FP rules.[2] | 3 |
| 0% | No buffer | 4 |

[2] The length of the buffer in the three FP treatments was greater than the minimum 50% required under Forest Practices rules, equaling 55%, 62%, and 73% of the perennial Type N channel.

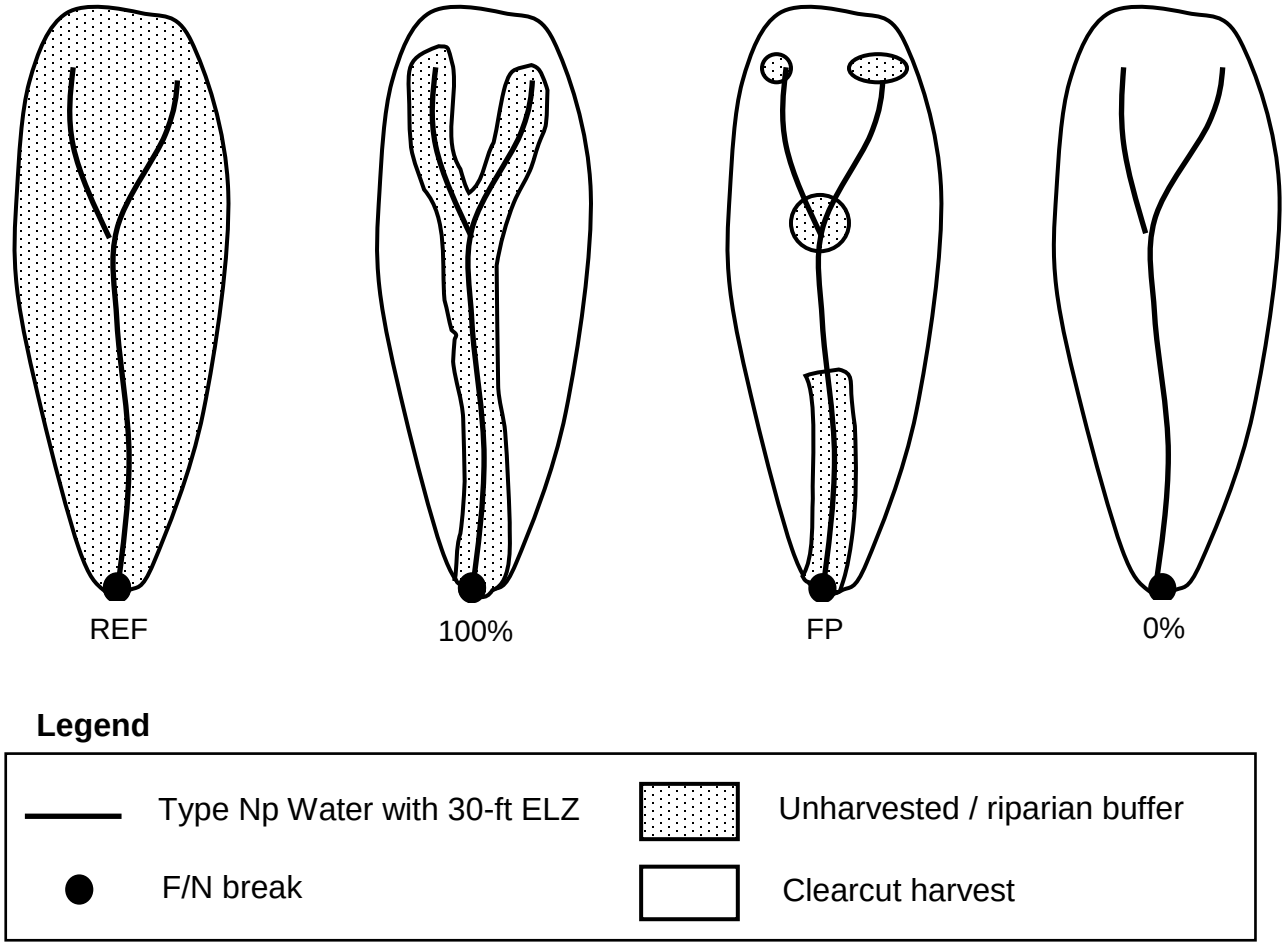


**Figure 1.** Schematic of the four experimental treatments included in the Type N Study. Treatments included unharvested reference sites (REF) and sites receiving a clearcut harvest with one of three riparian buffer treatments along the Type Np Water RMZ: two-sided 50-ft (15-m) riparian buffers of 100%, Forest Practice (FP), and 0%. All streams had a two-sided 30-ft (9-m) equipment limitation zone (ELZ).

**Table 2.** Timeline of data collection and report development for past, current and potential future work related to the Type N Hard Rock Study.

| | Sampling Period and Year | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-harvest | | | Harvest | Post-harvest | | Extended | | | | | | | | Future Potential Extended Work | | | | | |
| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
| Stand Structure/Tree Mortality | | x | x | x | x | | | x | | | x | | | | | x | | | | |
| Wood Recruitment/Loading | x | x | x | x | x | | | x | | | x | | | | | x | | | | |
| Stream Temperature/Cover | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | | | | | |
| Discharge/Turbidity | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | | | | | |
| Nutrient Export | x | x | x | x | x | x | | | | | x | x | | | | | | | | |
| Sediment Processes | x | x | x | x | x | | | | | | | | | | | | | | | |
| Stream Channel Characteristics | x | x | x | x | x | | | x | | | x | | | | | x | x | | | |
| Litterfall Input/Detritus Export | x | x | x | x | x | x | | | | | | | | | | | | | | |
| Biofilm/Periphyton | x | x | x | x | x | | | | | | | | | | | | | | | |
| Macroinvertebrate Export | x | x | x | x | x | x | | | | | | | | | | | | | | |
| Amphibian Demographics | x | x | x | x | x | | | | | x | x | | | | | | x | x | | |
| Amphibian Genetics | x | x | x | | | | | | | x | x* | | | | | | | | | |
| Downstream Fish | x | x | x | x | x | | | | | | | | | | | | | | | |
| Trophic Pathways | x | x | x | x | x | | | | | | x | | | | | | | | | |
| Two year post-harvest report | | | | | | | x | x | x | x | x | x | | | | | | | | |
| "Extended" post-harvest report | | | | | | | | | | | | x | x | x | | | x | x | x | x |
| Amphibian Genetics reports | | | | x | x | x | | | | | | x* | | | | | | | | |

* Stream-associated Amphibian Genetics sampling in 2015 and 2016 was the first post-harvest sampling, with the report developed in 2017

**5. What is the relationship between this study and any others that may be planned, underway, or recently completed?**

The results from the Hard Rock Study, BCIF Study, Soft Rock Study, Shade Study, and Amphibian Recovery Project are expected to provide a thorough assessment of riparian prescription effectiveness for westside Type N Waters. These data can be used to determine if the resource objectives for heat/water temperature are being met.

- Westside Type N Buffer Characteristics, Integrity, and Function Project [BCIF Study, completed]: The BCIF Study evaluated the magnitude of change in riparian stand conditions, tree mortality, shade and LWD recruitment when prescriptions were applied on a reach-scale at sites selected from a random sample of forest practice applications. The shade results are most pertinent to Chapter 7.
- Type N Experimental Buffer Treatment Project in Soft Rock Lithologies Project [Soft Rock Study, underway]: The Soft Rock Study will evaluate the post-harvest changes in riparian stand conditions, buffer tree mortality, LWD recruitment, shade and stream temperature, and nutrient and sediment export from westside Type N basins with sedimentary lithologies. This study differs from the Hard Rock study in that it includes only study basins underlain with sedimentary lithologies and includes only one riparian buffer treatment equivalent to the Hard Rock Study FP treatment. Both the Hard and Soft Rock studies use a BACI experimental design to compare effectiveness of riparian buffers with unharvested controls.
- Eastside Type N Riparian Effectiveness Project [ENREP Study, underway]: The ENREP study will determine if, and to what extent, the eastside riparian prescriptions are effective in achieving Performance Targets and WQS, particularly as they apply to sediment and stream temperature. Study objectives are to quantify the magnitude of change in stream flow, canopy closure, water temperature, suspended sediment transport and wood loading in eastern Washington Type Np streams.
- Eastside Ns Effectiveness Project [planned]: A literature review will inform a field study to examine the effect of riparian prescriptions on Ns streams on downstream Type Np and F Waters. Responses may include in-channel wood loading, channel stability, and downstream water quality (temperature, turbidity, and sediment) and quantity, stream channel stability and magnitude and frequency of scour.

- ***Feasibility of obtaining more information to better inform Policy about resource effects.***

The CMER budget for the current biennium includes funding for analyses of these data and report writing. Future and continued data collection is possible if interest exists at Policy and the Board. To date, only one reference site has been harvested, one is currently being harvested, and two are expected to be harvested during calendar year 2019. Due to regulatory constraints, it is unlikely that the remaining two reference sites would ever be harvested. This is a unique long-term data set evaluating applicable riparian buffer treatments in a BACI-designed study. Value exists in continued monitoring of treated sites for interpretation of the longer-term trajectory of change.

***What are the costs associated with additional studies?***

Analysis and reporting of results through eight years post-harvest are included in the CMER 2017-2019 budget. Budget placeholders are in the CMER Master Schedule for continued stream temperature monitoring at a cost of $150,000 in the 19-21 biennium.

***What will additional studies help us learn?***

Additional monitoring in this study allowed us to estimate the rate of change of riparian shade and stream temperature over time. This is of interest because neither shade nor temperature has returned to pre-harvest levels in any of the treatments.

- ***When will these additional studies be completed (i.e., when will we learn the information)?***

A draft analysis of the extended data is due September 2018.

- ***Will additional information from these other studies reduce uncertainty?***

Yes. Future monitoring beyond eight years post-harvest will reduce uncertainty associated with long-term trajectories of shade and stream temperature.

6. **What is the scientific basis that underlies the rule, numeric target, Performance Target, or Resource Objective that the study informs? How much of an incremental gain in understanding do the study results represent?**

*What is the scientific basis that underlies the rule, numeric target, Performance target or Resource Objective that the study informs?*

RMZ requirements for Type N Waters were developed to maintain important ecological processes and provide levels of large wood, shade and other riparian functions adequate to meet conservations objectives (FPHCP, Chapter 4d – Rationale for the Plan). The management approach for westside Type N riparian prescriptions employs a patch-cut strategy, where a portion of the riparian stand in a Type N basin RMZ may be clearcut, providing that sensitive sites and at least 50% of the perennial stream length is buffered with a two-sided 50-ft buffer. The underlying assumptions of the current rule prescriptions for Type N Waters were based on limited experimental research studies related to riparian ecological processes, habitat needs of covered species and forest management effects on larger streams (FPHCP). The following information is based on that found in Chapter 4d of the FPHCP. For discussions that include relevant literature published since the FPHCP was finalized in 2005 see the chapters for the individual response metrics in the study report.

Shade: Riparian forests and the shade they provide are key factors affecting the thermal regime of aquatic ecosystems (Brown 1985), reducing incoming solar radiation and moderating water temperatures. Reductions in streamside shade alter the thermal regime of a stream (Beschta *et al.* 1987). Based on these findings from two studies (Brazier and Brown 1973; Steinblums *et al.* 1984), it was anticipated that riparian buffers retained on Type N Waters under Forest Practices rules would maintain between 50% and 75% of the pre-harvest Angular Canopy Density (ACD). Shade reduction along small streams in western Washington were expected to recover within five years, due to the rapid growth of understory vegetation (Summers 1982; Caldwell *et al.* 1991).

Stream Temperature: The FPHCP concluded that there was a reduced risk of temperature impacts to Type N Waters compared with Type S and Type F waters and that temperature increases within buffered reaches of the RMZ would be small. Temperature effects downstream of the harvest unit were expected to be minimal, based on the findings from three studies (Caldwell *et al.* 1991; Dent and Walsh 1997; Robison *et al.* 1999). Based on the findings of one study (Summers 1982), if temperature increases associated with timber harvest did occur in Type N Waters, recovery to pre-harvest levels was expected to be rapid.

*How much of an incremental gain in understanding do the study results represent?*

This study provides a substantial gain in understanding of the degree to which Type Np Forest Practices rules meet the Resource Objectives and Performance Targets. While previous studies may have evaluated stream temperature and shade, the Hard Rock Study provides results in context of the specific Forest Practices rules for riparian prescriptions required on Type N Waters in western Washington.

## Technical Implications and Recommendations:

**New rule tools or field method development.**

- Year round monitoring, a solid study design (BACI), and multiple reference sites enabled us to detect even small changes in temperature using modern statistical techniques.

**Research/monitoring suggestions.**

- Forestry works over long time periods. Monitoring and evaluation recognize this.

**Suggested rules/board manual sections to review/revise.**

- We agree with the suggestion in the BCIF Study Findings Report (Schuett-Hames *et al.* 2011) that CMER and Policy should review and potentially revise some of the Type Np Performance Targets for westside and eastside Type N Waters.
    - Performance Targets for some metrics were tied to the objective of providing 50% of the riparian function available within 50 feet of the stream, and are more closely related to compliance targets than Performance Targets *per se*. For example, shade and litterfall Performance Targets merely restate the prescriptions, so if the harvest is done in compliance with the rules, the Performance Target will be met, at least immediately following harvest.
    - Schedule L-1 specifies that there will be idenfication of timelines for Performance Targets that can be met within short, mid- and long-term time periods, a process that has not yet occurred, but that is likely very important for evaluating the effectiveness of rules through time.

**Evaluation of whether key aquatic Resource Objectives (Schedule L-1) are being met.**

The rules for stream temperature are complex, especially as they are related to the state surface water quality standards (WQS). We provide additional information and discussion here regarding the degree to which state WQS were or were not met.

*Heat/Water Temperature*. The Schedule L-1 Performance Target for stream temperature is to meet the state surface WQS (Chapter 173-201A WAC). The WQS for stream temperature include:

(1) A threshold 7-day average daily maximum (7-DADM) temperature determined by the designated uses for that water body.
(2) Limits for warming that apply when waters are both cooler and warmer than the threshold criteria.
(3) Anti-degradation criteria designed to protect waters which are colder than the threshold criteria and that is triggered by a human-caused increase of 0.3°C or greater.

The state surface WQS direct that:

- Human actions alone or in combination are not allowed to cause or contribute to the exceedance of the threshold criteria. These include an annual 7-DADM of 12°C for Char spawning and rearing and 16°C for core summer salmonid habitat, which are the most common threshold criteria applied within lands subject to the forest practices HCP. Non-fish bearing tributaries are protected with the same annual threshold criteria as the fish-bearing waters into which they flow.
- When a waterbody is naturally at or above the threshold criteria, human activities, considered alone or in combination, cannot raise the temperature by more than 0.3°C.
- When a waterbody is cooler than the threshold criteria, an increase of 0.3°C or greater would trigger the need to determine if the action (warming due to implementing the Type Np rules in this case) is necessary and in the overriding public interest (required by the Antidegradation rules). If it is so determined to be necessary and in the overriding public interest, nonpoint sources could cumulatively raise temperatures by a maximum of 2.8°C or up to the threshold criteria, whichever is more stringent.

Interpretation of the WQS is the responsibility of the Washington State Department of Ecology, but the first step is a scientifically credible estimate of the post-harvest temperature change. Chapter 7 provides these estimates and includes the following relevant observations.

Did the application of the Type Np rules cause temperatures to exceed the standard that would trigger a Tier II water quality antidegradation review?

- The average increase post-harvest at the Buffer Treatment locations was 1.2, 1.2, and 3.2°C in the 100%, FP, and 0% treatments, respectively. This is greater than 0.3°C in all buffer treatments.
- Warming in excess of 0.3°C, calculated on a monthly basis, occurred throughout the spring to fall period at most of the monitoring locations.
- Statistically significant ($P < 0.05$) warming occurred at our downstream monitoring stations (placed 100 m or more downstream of the harvested portion of the site.
- Results indicate neither the Type N rules, nor the other two buffer treatments, were effective in preventing warmer stream temperatures. Water temperature remains significantly elevated at most sites seven years after harvest.

Assuming a greater than 0.3°C warming due to the Type Np rules were to be found to be both necessary and in the overriding public interest by the Department of Ecology under the Antidegradation rules, would the warming be greater than the 2.8°C allowed cumulatively for nonpoint sources?

- This criterion applies to all sources of warming by non-point sources (e.g. forestry, agriculture, commercial and residential development) throughout a waterbody, and so cannot be directly informed by this study alone.
- The average (across both post-harvest years) increase at the lower end of the buffer treatment was 1.2°C in the 100% and FP treatments and 3.2°C in the 0% treatment.
- This indicates that a single Type Np basin harvested in conformance with the 100% or FP treatment would not cause warming in excess of the allowed 2.8°C for at least the first two years post-harvest but the 0% treatment would.
- Results also indicate that warming was observed approximately 100 m downstream. Four of the six sites showing treatment effects of 0.4°C or less while the other two remained elevated 0.9°C and 1.6°C as an average response over the two year post-harvest period. This suggests some potential for cumulative increases in downstream temperature in watersheds where adjacent Type Np streams are harvested over a short period. The results also suggest that for many streams the risk of exceeding 2.8°C will be quite low.

Did the application of the Type Np rules cause temperatures to exceed the threshold criteria (e.g. 12°C or 16°C), or to exceed the increment for warming (0.3°C) allowed for waters naturally warmer than the assigned threshold criteria?

- The threshold standard was an annual 7-DADM of 16°C at all but one of the Hard Rock study sites.
- Pre-harvest the 7-DADM temperature exceeded 16°C only at the CASC-0% site.
- Post-harvest three streams which were less than 16°C pre-harvest exceeded 16°C post-harvest (one-100%, two-0% sites; Figure 3). The CASC-0% site was greater than 16°C pre-harvest and warmed after harvest.
- The 7-DADM at the remaining seven buffer treatments sites (3-100% sites, 3-FP sites, 1-0% site) was less than 14.3°C.
- The average (across both post-harvest years) post-harvest increase in 7DADM at the lower end of the buffer treatment was 1.2°C in the 100% and FP treatments and 3.2°C in the 0% treatment.
- Our study streams were relatively cool but these results suggest that streams in the warmer range of those tested in this study may be at risk of exceeding the threshold criterion after harvest.
- In addition, the greater than 0.3°C warming observed in each of the Hard Rock study buffer treatments strongly suggests the incremental warming allowance for waters that are naturally warmer than the assigned threshold may also occur.

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To: Howard Haemmerle
From: Bill Ehinger
RE: Hard Rock Study Chapter 7 Findings Report
Cc: Mark Hicks, Hans Berge, Aimee McIntyre, Dave Schuett-Hames, Reed Ojala-Barbour, Tim Quinn
Date: 16 May 2018

Below is a more detailed response the comments received than was possible in the spreadsheet matrix. I encourage Policy to consider a conversation with the PIs about the Hard Rock Study results. Often, seemingly simple, questions can require very long, detailed answers to present the entire picture.

1. Many comments (ID# 8, 9, and 10) referred to the approved Hard Rock final report or did not pertain to Chapter 7 (ID# 4 and 14). I ignored these per instructions.
2. ID# 5 ("*How similar is study physical setting (geology, topography, elevation, weather, basin size) to the range of physiographic conditions where BMP is typically applied (spatial context)?*") This was addressed to the extent possible in the 2005 site selection report. A more precise answer will require substantial additional effort that is outside the scope of the Findings Report.
3. ID# 7 ("*How similar is study treatment (size, density, structure, age composition) to real-world application of rule or BMP (BMP context)?")* This will require substantial additional effort that is outside the scope of the Findings Report.
4. ID# 3 (*"For each REF, 100% and FP treatment site, how often does the temperature (7day max; 7day min; diurnal) exceed pre-harvest levels and by how much?"*) This level of detail isn't appropriate for the Findings Report. Plus processing daily temperature data over 11 sites for 9 years post-harvest will require substantial effort (365 days x 9 years x 11 sites x 3 variables).
5. ID# 13 (*"…I am now requesting such, not just for stream temperature and cover (Chapter 7) but also for stand structure (Chapter 5) and wood recruitment (Chapter 6) "*) This level of detail is not appropriate for the Findings Report. FYI, these data are shown in graphical form in the Chapter 7 Appendices.
6. ID# 11 ("*Just my opinion, but having only 3 or 4 sites per treatment (beyond the references) places the Hard Rock study into the category of multiple "case studies", and I think that the implication of these small numbers of sites needs to be clearly conveyed to TFW Policy and the Forest Practices Board."*)
    a. The Hard Rock Study Plan was reviewed by ISPR as was every chapter of the final report. In addition, we worked closely with several industry and state agency scientists and statisticians when writing the study plan and analyzing the data. The total number of independent experts probably exceeded 30 individuals from a wide range of scientific fields, including statisticians, and employers. None of them expressed this opinion.
    b. The commenter assumes that three to four replicates of each experimental buffer treatment (as well as six reference sites) is small, when in fact it is more than most field studies. Jeremy Groom's work in western Oregon and the Bull Trout Study in eastern Washington had more replication, but these were reach-scale studies with all the associated limitations.

c. The most serious implication of low replication is low power to detect changes. That we did detect treatment effects (changes in stream temperature) in the buffer treatment sites that were overwhelmingly positive in direction while the reference sites showed no change, demonstrates that the study had sufficient statistical power.

7. ID# 12 (*"My biggest concerns associated with the overall Type N findings report and what's already shown in these three chapters is a bit of inconsistency and also lack of strong emphasis in discussing the limitations or level of inference of the Hard Rock study….* ") This seems to be related to #11. As discussed above, this is a BACI study with sufficient statistical power to detect changes in shade and stream temperature. The limitations of this study are discussed in section 4.B of the Findings Report. FWIW, the results are remarkably similar to other studies in the direction and magnitude of the change in stream temperature and shade (see Discussion section Chapter 7).

***Type N Experimental Buffer Treatment Project in Hard Rock Lithologies – Report to Policy on Stream-associated Amphibians (Chapter 15)***

***11 December 201 7– For CMER Review***

**Study Report**

The results from this study are found in the following Study Report:

McIntyre, A.P., M.P. Hayes, W.J. Ehinger, D. Schuett-Hames, S.M. Estrella, G. Stewart, R.E. Bilby, E.M. Lund, J. Walter, J.E. Jones, R. Ojala-Barbour, F.T. Waterstrat, C.R. Milling, A.J. Kroll, B.R. Fransen, J. Giovanini, S.D. Duke, G. Mackenzie, R. Tarosky, J.G. MacCracken, J. Thronton and T. Quinn. 2017. Effectiveness of Experimental Riparian Buffers on Perennial Non-fish-bearing Streams on Competent Lithologies in Western Washington. Cooperative Monitoring Evaluation and Research Report CMER XX-XXX, Washington State Forest Practices Adaptive Management Program, Washington Department of Natural Resources, Olympia, WA.

**CMER/Policy Interaction Framework Six Questions**

1. **Does the study inform a rule, numeric target, Performance Target, or Resource Objective?** Yes.

2. **Does the study inform the Forest Practices Rules, the Forest Practices Board Manual guidelines, or Schedules L-1 or L-2?** Yes.

The objective of the Type N Experimental Buffer Treatment Project in Hard Rock Lithologies (Hard Rock Study) was to evaluate the effectiveness of the current westside riparian management zone (RMZ) prescriptions for Type N (non-fish-bearing) Waters in maintaining key aquatic conditions and processes affected by Forest Practices. Specifically, we evaluated whether the riparian buffer prescription for Type N streams met the following overall Performance Goals, namely: (1) to support the long-term viability of stream-associated amphibians, and (2) to meet or exceed water quality standards. As part of this evaluation, we assessed the Forest Practices Resource Objectives (defined as a series of Functional Objectives and corresponding Performance Targets in Schedule L-1) for heat/water temperature, large wood/organic inputs, and hydrology.

The overall study design addressed the following CMER Work Plan Critical Questions:

- Are riparian processes and functions provided by Type N buffers maintained at levels that meet Forest Practices (FP) Habitat Conservation Plan (HCP) Resource Objectives and Performance Targets for shade, stream temperature, large wood recruitment, litterfall, and amphibians?
- How do other buffers compare with the FP Type N prescriptions in meeting Resource Objectives?
- How do Type N riparian prescriptions affect water quality delivered to downstream Type F/S waters?

3. **Was the study carried out pursuant to CMER scientific protocols?**

Yes. The study design was carried out according to the CMER and Independent Scientific Peer Review (ISPR) approved study design (including sampling methodologies, statistical

methods, and study limitations). SAGs (RSAG and LWAG), CMER, and ISPR reviewed all of the study chapters and their associated findings, and CMER approved the entire final report in September 2017.

4. **A. What does the study tell us?**

When considering stream network-wide amphibian density in the two years immediately following harvest, we observed an increase in larval Coastal Tailed Frog density in the 100% and FP treatments that differed significantly from the estimated pre- to post-harvest change in the reference and 0% treatment. We also observed an increase in post-metamorphic Coastal Tailed Frog density in the 0% treatment that differed significantly from the estimated change in the reference, 100% and FP treatments. We did not detect a difference in the change of torrent salamander density between any of the treatments. Finally, though not an FP-designated amphibian, we observed a decrease in giant salamander density in the FP treatment that differed significantly from the estimated change in reference, 100% and 0% treatments.

There are no Resource Objectives specific to stream-associated amphibians outlined in Schedule L-1. However, we used the response of stream-associated amphibians to alternative riparian buffer prescriptions on Type N Waters to evaluate the Schedule L-1 Overall Performance Goal of supporting the long-term viability of "other covered species," which includes stream-associated amphibians. There is also a Resource Objective and several Critical Questions for stream-associated amphibians outlined in the CMER Work Plan.

**Resource Objective** (CMER Work Plan): Provide conditions that sustain stream-associated amphibian population viability within occupied sub-basins.

**Critical Questions** (CMER Work Plan):

- Is stream-associated amphibian population viability maintained by the Type N prescriptions?
- What are the effects of three buffer treatments on stream-associated amphibians two years post-harvest?
- How do stream-associated amphibian populations respond to the Type N prescriptions over time?

The definition of population viability is the ability of a population to persist and avoid extinction. The rules do not designate a metric for evaluating amphibian population viability. We used population density as an indicator of viability; however, to address amphibian population viability adequately, longer-term study is required.

Though we did not design the study to address occupancy or reproduction on the reach scale, we do have data that can inform the following additional Critical Questions:

- Do stream-associated amphibians continue to occupy and reproduce in the patch buffers?
- Do stream-associated amphibians continue to occupy and reproduce in ELZ-only reaches?

The forest practices-designated amphibians included in this study were Coastal Tailed Frog and three species of Torrent Salamanders (Olympic, Columbia, and Cascade). We also evaluated the response of two species of Giant Salamanders (Coastal and Cope's).

*Results:*

- The post-harvest change in stream network-wide larval Coastal Tailed Frog (*Ascaphus truei*) density differed among treatments ($P < 0.0001$). Density increased in intermediate treatments (i.e., 100% and FP) relative to both the reference and 0% treatment. We detected significant post-harvest increases in the 100% and FP treatments that were 4 ($P = 0.02$) and 8 ($P < 0.0001$) times greater, respectively, than the post-harvest change in the reference. The change in the 0% treatment did not differ statistically from the change in the reference, but did differ from the change in both the 100% ($P = 0.01$) and FP ($P < 0.001$) treatments.
- The post-harvest change in stream network-wide post-metamorphic Coastal Tailed Frog density differed among treatments ($P = 0.10$). We detected a post-harvest increase in the 0% treatment that was 6 times greater than the change in the reference ($P = 0.07$), an increase that was significantly greater than the change in the 100% and FP treatments ($P = 0.02$ and 0.03, respectively).
- We saw no difference in torrent salamander (*Rhyacotriton*) density among treatments using one method of determining density. However, when we applied another method where we included animals that were encountered in wood-obstructed reaches, we detected a post-harvest increase in torrent salamander density in the 0% treatment that was 3 times greater than the change in the reference ($P < 0.01$).
- The post-harvest change in stream network-wide giant salamander (*Dicamptodon*) density differed among treatments ($P < 0.01$). Giant salamander density decreased by 82% in the FP treatment relative to the reference ($P < 0.001$), a decrease that was significantly greater than the change in the 100% and 0% treatments ($P < 0.01$ and $P = 0.02$, respectively). We did not note a significant change in density for any other treatment, including the reference.
- We found all genera in clearcut RMZs with wood-obstructed reaches covered by dense matrices of wood, organic debris (e.g., leaves and needles) and fine sediment. Densities in these reaches were sometimes quite high with values as high as 3, 20, and 6 animals per stream meter for tailed frog, torrent and giant salamanders, respectively.
- We observed egg masses for all three genera in harvested streams, including in the 0% treatment and in the wood-obstructed reaches of clearcut RMZs.
- We had no evidence of a treatment effect on body condition for any species, though we were unable to include tailed frog post-metamorphs in our analysis due to a small sample size.
- The density of focal FP-designated amphibians did not decline in any buffer treatment, including in the 0% treatment, where the July-August 7-DADMax increased by 3.2°C in the two years post-harvest.

*Conclusions:*

- The Type N prescriptions maintained tailed frog and torrent salamander density within occupied basins two years after harvest in all riparian buffer treatments.

- The very high densities of torrent salamanders observed in some wood-obstructed reaches explains the differing results that we obtained when we did and did not include density estimates from these reaches in our overall stream-network wide density analysis.
- Though it is not an FP-designated species, post-harvest conditions did not sustain giant salamander density within the FP treatment in the two years after harvest. The negative response of giant salamanders in the FP treatment is inconsistent with study findings for the other stream-associated amphibian species. Further, the lack of a statistically significant difference in the pre- to post-harvest change between the reference and the 0% treatment leads us to suspect that the response to the FP treatment may not be driven by treatment *per se*, but may reflect complex ecological interactions, including site-specific factors.
- In theory, body condition reflects an animal's energy reserves and can be associated with environmental characteristics such as habitat quality and prey availability. We did not observe an effect of treatment on body condition for any species.
- We used the presence of egg masses as a sign of reproduction. Although sample sizes were limited, we concluded that all genera continued to occupy and reproduce in stream reaches with buffered (i.e., patch buffer) and clearcut (i.e., ELZ-only) RMZs in the two years following harvest.
- Evaluation of a genetic response requires generational turnover of amphibian populations that will require a minimum of seven to eight years after treatment implementation. Consequently, we report the results from this component of the study separately. A report evaluating the response of measures of amphibian genetic diversity has been through CMER review and is currently in ISPR review. The genetics response can be used to inform further the degree to which meeting the overall Performance Goal of long-term viability is being met.
- An evaluation of a response of amphibian population viability to the Type N prescriptions will require study over a longer temporal scale that reflects reproductive success through time. Analysis of amphibian demographic data collected seven and eight years post-harvest (after one generational turnover) will provide our first opportunity for understanding the true impacts to long-term amphibian viability, though continued monitoring even beyond one generational turnover would be more informative.

**B. What does the study not tell us?**

One should consider a number of study limitations when interpreting and generalizing the results.

**Spatial Scope of Inference:** The spatial scope of inference is limited to Type N basins dominated by competent lithologies, which comprise approximately 29% of western Washington Forests and Fish-regulated lands (P. Pringle, personal communication, September 2005). One should not assume that the results apply equally to other lithologies. Additional considerations include the fact that sites were located in second-growth forests and ranged from approximately 12 to 53 ha (30 to 130 ac). See McIntyre and colleagues (2009) for a summary of the site selection process.

**Temporal Scope of Inference:** The temporal scope of inference can only be made to the two year post-harvest interval. Do not assume that the results are applicable over a longer period. One can only understand the scope of potential long-term response with longer-term monitoring. For example, there will be opportunities for a delayed response to the reproductive success of stream-associated amphibians, among other things. In fact, preliminary findings for Coastal Tailed Frog response through eight years post-harvest indicate a significant decline in tailed frog density in all three riparian buffer treatments that we did not observe in the two years following harvest.

**Riparian Buffering/BMPs:** Application of clearcut timber harvest included buffers for sensitive sites and unstable slopes, and followed other best management practices (BMPs), ultimately, influencing the level of buffering in the FP treatment sites. CMER did not design this study to examine directly the influence of specific rules or BMPs, but rather to evaluate the overall influence of the FP buffer strategy as it is applied under real world circumstances. We do not know if the results for the FP buffers would have been different if only the minimum riparian buffers had been applied. We also do not know how frequently more than the minimum buffer length is applied across the managed landscape. Since the proportion of the stream length buffered in FP treatment sites was more than the minimum required under Forest Practice's rules, some consistent results between the 100% and FP treatments may reflect the fact that the stream length buffered was more similar between these treatments than between the FP and 0% treatments.

**Stream-associated amphibians:** We selected study sites based on specific criteria, including the presence of stream-associated amphibians. Sites chosen tended to have cooler pre-treatment stream temperatures than are typical of Type N streams in western Washington. We do not know whether amphibian presence is a reflection of cooler than average temperatures; however, this creates some uncertainty around the application of results broadly across the westside-managed landscape. The study cannot tell us if specific taxa would respond differently in Type N streams with warmer pre-harvest temperatures. Additionally, the precision of our scales may have limited our ability to detect a statistically significant change in amphibian body condition if changes to individual body weight were small, i.e., less than 0.1 g. Also, since our methodology focused on instream sampling, impacts to terrestrial post-metamorphic Coastal Tailed Frog and Coastal Giant Salamanders were not adequately addressed in this study.

5. **What is the relationship between this study and any others that may be planned, underway, or recently completed?**

The results from the Hard Rock Study, BCIF Study, Soft Rock Study, Shade Study, and Amphibian Recovery Project in combination are expected to provide a thorough assessment of riparian prescription effectiveness for westside Type N Waters. They will generate data that can be used to determine if the resource objectives for heat/water temperature, LWD/organic inputs, sediment, hydrology and stream-associated amphibians (with the exception of terrestrial Dunn's and Van Dyke's Salamanders) are being met.

- Buffer Integrity – Shade Effectiveness (Amphibians) Project [Shade Study, underway]: The Shade Study was intended to isolate the impacts of shade reduction from the impacts of potential increased sedimentation related to timber removal in the RMZ. This project examined the effects of shade reductions on stream-associated

amphibians, water temperature, primary productivity, litterfall and macroinvertebrates. This study can be used to supplement the findings for the Hard Rock Study, especially for results related to amphibian response to treatment.

- Amphibian Recovery Project [completed]: This project evaluated the effects of three buffer treatments on headwater streams throughout coastal western Washington. Riparian buffer treatments in this study differed from those included in the Hard Rock Study and included (1) unthinned riparian buffers, (2) partial buffer, (3) buffer of non-merchantable trees, and (4) clearcut to the channel edge. The study included an evaluation of stream channel characteristics, wood loading, stream temperature, sediment, macroinvertebrates and stream-associated amphibians. One year of pre-harvest and three years (immediately post-harvest and two additional years beyond that) of post-harvest data were collected; not all metrics were evaluated in every post-harvest year. Fifteen study sites were included, but amphibians were not detected in all study sites so amphibian response was limited to a small sample size (e.g., prior to harvest Coastal Tailed Frogs were detected in only five of 15 sites). Since the treatments in the Amphibian Recovery Project were not designed to evaluate the current Forest Practices prescriptions for Type N streams, direct comparisons of results between this and the Hard Rock Study are only available for what we call the 0% treatment (their clearcut RMZ treatment). Differences in sampling methodologies, especially as they relate to amphibians, must be noted. In particular, the Recovery project did not evaluate amphibian presence/abundance in stream reaches that were inaccessible due to post-harvest wood loading in the form of slash whereas the Hard Rock Study did. See Jackson and colleagues (2001; 2007) and Haggerty and colleagues (2004).

To address the effectiveness of westside riparian prescriptions in maintaining terrestrial salamander populations, CMER would need to complete the Van Dyke's Salamander Project:

- Van Dyke's Salamander Project [underway]: The Van Dyke's Salamander was the only FP-designated amphibian that was not addressed by another CMER study. This study will result in the development of sampling protocols for adequately evaluating Van Dyke's presence and abundance, and if warranted, include a BACI-type manipulative study to compare Van Dyke's populations between harvested and unharvested units. This study will address a gap in information from the Hard Rock Study, which did not include effectiveness of riparian prescriptions in maintaining FP-designated terrestrial amphibians (Dunn's and Van Dyke's Salamanders).

One additional amphibian-focused study that has the potential to inform riparian prescription effectiveness for westside Type N Waters is the Amphibians in Intermittent Streams Project.

- Amphibians in Intermittent Streams Project [planned]: This study will examine amphibian use of the non-fish-bearing stream segments having discontinuous perennial flow, conditions that often occur at or near the origins of headwater streams. It is intended to inform the efficacy of the westside riparian prescription in maintaining amphibian occupancy in intermittent reaches. Data from the Hard Rock Study may be able to inform the importance of completing this project.

These studies will not address the effectiveness of the riparian prescriptions for eastside Type N Waters, for which CMER needs to complete the ENREP Study (underway), Eastside Np

Effectiveness Project (planned), and the Eastside Amphibian Evaluation Project (currently scheduled for FY22).

- Eastside Amphibian Evaluation Project [planned]: The Hard Rock Study focused entirely on managed landscapes in western Washington, because most FP-designated amphibians have westside distributions, and those with eastside distributions are believed to have little overlap with eastside-managed landscapes. The Eastside Amphibian Evaluation Project is an occupancy study intended to address the distribution of FP-designated amphibians throughout eastern Washington, to determine if their distribution on eastside managed landscapes deserves larger study attention. This study will supplement the findings of the Hard Rock study by evaluating amphibians in eastern Washington.

Additional studies related to the Hard Rock Study include:

- SAA Detection/Relative Abundance Methodology Project [completed]: This project was designed to evaluate and develop a standard sampling methodology for stream-associated amphibians (SAA) in headwater forest streams. Results from this study informed the sampling methodology for the amphibian component of the Hard Rock Study. See Quinn and colleagues (2007).

- ***Feasibility of obtaining more information to better inform Policy about resource effects.***

Opportunities exist to better inform Policy with data that have already been collected for the Hard Rock Study through eight years post-harvest (through 2016). The CMER budget for the current biennium includes funding for analyses of these data and report writing. Future and continued data collection is possible if interest exists. However, some reference sites have been or will be harvested for timber in the near future, making them unsuitable for use as references in the study. Statistical options for addressing this loss need to be thoroughly explored. Additionally, opportunity may exist to establish new reference sites. This is a unique long-term data set evaluating applicable riparian buffer treatments in a BACI-designed study. Value exists in continued monitoring of treated sites for interpretation of the longer-term trajectory of change. To date, two reference sites have been harvested, and two are expected to be harvested during calendar year 2019. Due to regulatory constraints, it is unlikely that the remaining two reference sites will ever be harvested.

- ***What are the costs associated with additional studies?***

Analysis and report development through eight years post-harvest are a part of the current CMER 2017-2019 biennium budget. A budget placeholder exists in the CMER Master Schedule for future stream-associated amphibian demographic data collection and report writing, currently projected to begin in the 21-23 biennium. We estimate that future resample of amphibian demographics would be approximately $980,000 for two years for all three taxa or $567,000 for one year. We strongly encourage Policy to consider the relative costs and benefits of one versus two years of additional resample. Based on the minimal sample size we obtained for Coastal Tailed Frog seven and eight years after harvest, it is likely that restricting a future resample to a single year would negatively affect our ability to compare density for this species over time. If density remains low (e.g., further decline and/or small increase compared to the current period) it is highly likely that we would not be able to detect trends through time with only one year of resample. However, if tailed frog density rebounds

substantially between now and then, then a single year of resample may be sufficient to detect trends; and, a single year of resample would still allow us to determine if species density remained very low, and/or had declined so much locally that we were not able to detect them in study sites. Finally, while we strongly discourage conducting future amphibian demographic sampling starting any sooner than FY22 due to the timing of generational turnover, future sampling could be postponed for a year or two without substantial consequence.

- ***What will additional studies help us learn?***

Results from the extended study period through eight years post-harvest will provide additional information for understanding the effectiveness of the current Forest Practices rules and buffer alternatives. Additional long-term monitoring will provide a unique opportunity to evaluate the longer-term response of variables of interest to forest practices in a research backdrop where such studies are extremely rare for most variables (e.g., temperature, amphibians). Originally, it was proposed that this cover an entire harvest rotation (i.e., 30 to 40 years in western Washington). Future monitoring would allow us to monitor recovery of response variables that were significantly different from pre-harvest conditions in the years immediately post-harvest (e.g., stream temperature). It would also allow us to detect potential lag effects in response in those variables that did not reveal an immediate impact in the years immediately post-harvest (e.g., FP-designated stream-associated amphibians).

- ***When will these additional studies be completed (i.e., when will we learn the information)?***

CMER anticipates development and approval of reports from the extended period (through eight years post-harvest) during the current biennium (2017-2019) and beginning of the following biennium (2019-2021), with transmission to Policy estimated for the 2019-2021 biennium. Timing of dissemination of findings to Policy for future sampling would depend on the number of responses for which Policy is interested and the timing of field sampling. We highly encourage Policy to consider the benefits of continued or future monitoring throughout an entire harvest rotation.

- ***Will additional information from these other studies reduce uncertainty?***

Future monitoring beyond eight years post-harvest will reduce uncertainty associated with trajectories of potential change. For example, in the case of stream-associated amphibians, no FP-designated species was negatively impacted in the two years immediately post-harvest. However, only longer-term study of the impacts of clearcut timber harvest can provide guidance on the effectiveness of the current Forest Practices rules and their ability to maintain viable populations of the stream-associated amphibians of interest through time. Preliminary results for Coastal Tailed Frog density through eight years post-harvest indicate a significant decline in all three riparian buffer treatments that was not detected through two years post-harvest. Additional study will inform the long-term trajectory of this decline, including the possibility of identifying the time to recovery.

6. **What is the scientific basis that underlies the rule, numeric target, Performance Target, or Resource Objective that the study informs? How much of an incremental gain in understanding do the study results represent?**

The management approach for westside Type N riparian prescriptions employs a patch-cut strategy, where a portion of the riparian stand in a Type N basin RMZ may be clearcut, providing that sensitive sites and at least 50% of the perennial stream length is buffered. CMER intended this study, along with BCIF and Soft Rock Studies, to evaluate the effectiveness of this strategy. There are no Performance Targets for stream-associated amphibians defined in Schedule L-1. Critical Questions related to the response of amphibians to the Type N prescriptions were defined by the Type N Riparian Prescriptions Rule Group in the CMER Work Plan after Schedule L-1 was finalized and approved by Policy. Projects related to answering Critical Questions are also identified in Schedule L-2 and include a test of the effectiveness of the Type N prescriptions for westside Type N streams in maintaining the long-term viability of stream-associated amphibians.

This study provides a substantial gain in multiple areas (see results and conclusions sections for each response). While previous studies may have evaluated many of the metrics we included in this study as they relate to forestry practices, the Hard Rock Study provides results in context of the specific forest practices rules for riparian prescriptions required on Type N streams in western Washington.

The BACI study design provides a more precise estimate of the response to forest harvest. The inclusion of variable buffer treatments, both more restrictive and less restrictive than the current rules, was established to provide a response curve along a gradient of buffer length.

We expanded on the knowledge base for many metrics included in the study. For example, our results tell us a lot about the baseline densities of stream-associated amphibians throughout managed forest landscapes in western Washington, and our BACI study design expanded on most previous studies that were largely retrospective. For example, previous observations had resulted in the conclusion that torrent salamanders were relatively uncommon on managed landscapes; in contrast, we found torrent salamanders to be the most abundant stream-associated amphibian species encountered both pre- and post-harvest.

We are more confident in many of our findings because we were able to utilize new technology and sampling techniques that were not previously available, because of the duration and/or intensity of sampling, and because we were able to take advantage of more recent statistical methods. For example, a new statistical method allowed us to adjust counts of amphibians by estimates of detection without the need for marking individual animals, for less biased estimates of density than for those based on count data alone.

## Technical Implications and Recommendations:

### New rule tools or field method development.

- We consistently had a difficult time detecting Coastal Tailed Frogs, especially post-metamorphs, in some sites. In one site, we encountered only a single post-metamorphic individual in a single year. Exploration of alternative methods for detecting the species, including the viability of using tools such as environmental DNA (eDNA) for occupancy and abundance, may prove invaluable for future research and monitoring of stream-associated amphibians, including at our own study sites. We could address the question: How well and under what conditions does eDNA sampling accurately and consistently identify Coastal Tailed Frog presence in headwater streams, and can it be used effectively to estimate abundance?

**Research/monitoring suggestions.**

We have several recommendations for research and/or monitoring that can help address the effectiveness of Type N riparian prescriptions for protecting and sustaining stream-associated amphibian populations. These recommendations fall into three categories: (1) analysis of existing data, (2) continued monitoring, and (3) new field studies.

*Analysis of Existing Data*

- Sensitive Site Effectiveness: Data we collected during the Type N Hard Rock Study could be used to do a preliminary evaluation of the characteristics of sensitive sites before and after harvest, under varying buffer strategies (i.e., buffered and unbuffered). While we have sufficient data for some sensitive sites (i.e., side-slope seeps, Type Np intersections and headwater springs), our data for headwall seeps is lacking (N=10) and we did not have alluvial fans in any study sites. We can also evaluate amphibian use of sensitive sites and whether use and/or density differs from that in non-sensitive site reaches and buffers. Results from this evaluation could inform the need for additional investigation in the future.
- Side-slope and Headwater Seep Characteristics: During amphibian sampling for the Type N Hard Rock Study, we collected data associated with side-slope and headwater seeps. These data could be used to answer questions about amphibian use of, and the characteristics associated with, the hydrologic footprints of seep areas. We could also address whether the current definitions for side-slope and headwall seeps are applicable to features used by amphibians? Results of this examination could inform the utility of additional investigation in the future.
- Buffered versus unbuffered Np reach-scale effectiveness: An evaluation of within-stream variability and characteristics between buffered and unbuffered reaches and between wood-obstructed and unobstructed reaches may prove informative for understanding the effects of alternative riparian buffer prescriptions. For example, based largely on retrospective studies, stream-associated amphibians were thought to be mostly absent from areas lacking overstory canopy and covered with dense matrices of wood and stored sediment; however, we found all focal amphibians, and even evidence of reproduction in the form of egg masses, in wood-obstructed reaches filled with fines and organic debris. CMER could address reach-scale effectiveness, at least in part, with existing data from the Hard Rock Study. We recommend an evaluation of reach-scale variability with existing data from this study, which could inform the utility of continued monitoring and/or future projects.

*Continued Monitoring*

- Disturbance and recovery trends over time: This study covered only the first two years after harvest, which is not enough time to evaluate fully the duration of harvest effects and the long-term trajectory of response. To understand completely the impacts of the treatments on the managed landscape one would have to monitor the response for a longer period. Substantial amounts of time and money have been invested in this study to date. Currently we have collected data through eight years post-harvest, and a report outlining those findings is in development. Data collection at existing study sites over a longer time will reduce scientific uncertainty about the duration of disturbance and the progress of

recovery in Type N riparian buffers and clearcuts. Considering the amount of time and money that would be required to re-initiate a similar study from the beginning, the best opportunity for evaluating long-term recovery is with continued monitoring in the existing study. Additional data collection may be especially important for evaluating the time to recovery to baseline conditions for amphibians, as preliminary results for amphibian demographics through eight years post-harvest reveal a significant decline in the Coastal Tailed Frog density in all three riparian buffer treatments that we did not observe in the two years immediately following harvest. Continued study for this and other related studies (see **What is the relationship between this study and any others that may be planned, underway, or recently completed**?) would result in a more confident assessment of prescription effectiveness as we monitor response to treatments over time.

*New Field Studies*

- Investigation of wood loading and amphibian use through time: Even with Forest Practices rules intended to minimize slash input into streams, we observed heavy slash loading in some stream reaches. In the two years immediately following harvest, we observed amphibian use of, and evidence of reproduction (i.e., egg masses) in, these reaches. Future evaluations could assess persistence of these wood-obstructed reaches, including overall stream coverage as a function of time since harvest. We could also address trends in amphibian density in wood-obstructed reaches through time.

**Suggested changes to rules/board manual.**

A review and evaluation of the Performance Targets for westside and eastside Type N streams, both in context of the results of these studies and other current scientific research, by CMER and the Timber, Fish and Wildlife (TFW) Policy Committee would be appropriate once the studies outlined under #5 are completed. They could propose changes to Performance Targets and/or new measures if appropriate. Specific to stream-associated amphibians, though there is an Overall Performance Goal in Schedule L-1 to support the long-term viability of covered species, there are no Performance Targets specific to stream-associated amphibians. The only target for amphibians is outlined in the CMER Work Plan as a Resource Objective to provide conditions that sustain stream-associated amphibian population viability within occupied sub-basins for covered-species. However, a definition of "viability" and metrics for evaluating viability are not provided.

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