Comparison of Standard F&F Eastside Riparian Prescriptions with No Shade Removal Within 75-ft Prescription (bull trout overlay) –Study Plan–

Prepared by:

Jeff Light, Plum Creek Timber Company
Bob Conrad, Northwest Indian Fisheries Commission
Bill Ehinger, Washington Dept. of Ecology

Prepared for:

The Bull Trout Scientific Advisory Group of the TFW Cooperative Monitoring, Evaluation, and Research Committee

Introduction

Riparian timber harvest prescriptions in eastern Washington differ depending on whether a stream is located inside or outside of the mapped distribution of bull trout (*Salvelinus confluentus*). In what is known as the bull trout overlay (WAC 222-16, Figure 1), "all available shade must be retained within 75-ft of bankfull width or CMZ of the (Type F) stream" (WAC 222-30-040). The "no shade removal" prescription of the bull trout overlay (BTO) is based on the assumption that standard Forests and Fish (FF) riparian prescriptions are inadequate to maintain the cold water temperatures required by bull trout, and that a 75-ft buffer width is sufficient for maintaining stream temperatures. Elsewhere in eastern Washington, removal of trees within 75-ft of fish-bearing waters may be constrained by the need to leave sufficient shade to maintain stream temperatures within water quality standards.

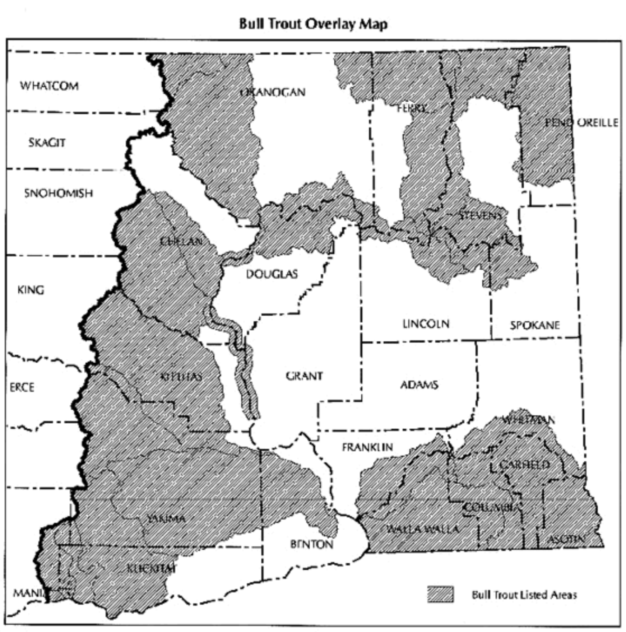


Figure 1. The Bull Trout Overlay in eastern Washington (from Washington Forest Practices Board Manual, section 1).

Problems arise during implementation of the bull trout overlay. Because knowledge of the current and potential distribution of the species is imprecise, large areas of forestland in eastern Washington are currently enveloped by the bull trout overlay. Where bull trout do not, and likely will not occur, forestlands may be inappropriately restricted with the "all available shade" provision. In these situations, the resulting riparian conditions may limit the intent of the eastside riparian strategy[1], and may cause landowners to forego harvest opportunities. Conversely, if neither the BTO nor the FF riparian prescriptions provide adequate stream temperature protection, other FF goals will not be met.

Goals and Objectives

The goal of this project is to determine whether the riparian prescriptions for the bull trout overlay and the standard FF prescriptions provide comparable protection for stream temperatures and whether the prescriptions maintain riparian conditions that will meet water quality standards for temperature and bull trout thermal preferences.

Specific objectives are to:

1. Quantify and compare differences in post-harvest canopy cover levels achieved by standard Forests and Fish riparian prescriptions and by prescriptions prohibiting shade removal within 75-ft of Type F (fish habitat) streams.
2. Quantify and compare differences in stream temperature effects of standard Forests and Fish riparian prescriptions and prescriptions prohibiting shade removal within 75-ft of Type F (fish habitat) streams.
3. Quantify each treatment prescription for achieving water quality standards for temperature and bull trout thermal preferences.
4. Use the information from objectives 1, 2, and 3 to develop recommendations to the Timber/Fish/Wildlife Cooperative Monitoring, Evaluation, and Research Committee (CMER) regarding the relative performance of each prescription for meeting water quality standards and bull trout thermal preferences.

An associated study entitled "Study Plan to Evaluate the Effectiveness of the Current TFW Shade Methodology for Measuring Attenuation of Solar Radiation to the Stream" will supplement this study with measurements of solar radiation actually reaching the stream. The solar radiation study will only occur at sites addressing the "all available shade" rule, not the standard eastside riparian rules. The RFP for the solar radiation study is out for bid concurrently with the BTO Shade/Temp study (reference RFP #02—189).

Experimental Design

A before/after, control/impact design will be used to test for effectiveness and differences in performance of the two prescriptions (treatments). True controls (randomly selected, independent) are not used, therefore the unmanaged reaches upstream of each treatment reach will be used and referred to as "reference reaches."

Canopy cover and stream temperatures will be measured for at least one summer before and two summers after streamside harvesting. Two years of pre-harvest monitoring and two or more years of post-harvest monitoring is the goal and will be conducted where possible. Each replicate (site) will consist of a reference reach with no harvest activity upstream of a treatment reach where one of the two prescriptions is applied. The reference reach will have no management

[1] One of the goals of the FF eastside riparian management strategy is to mimic forest conditions that occurred before widespread fire-suppression efforts.

within the RMZ (Core, Inner and Outer Zones) and will have stream and riparian conditions that closely match those in the treatment reaches. The treatment reach will be located downstream and adjacent to the reference reach, and will be harvested using one of the two (randomly assigned) prescriptions. The length of each treatment and reference pair will be a minimum of 600-m (300 m for the reference and 300 m for the treatment). Continuous temperature recorders will be placed in the stream at 150-m intervals between the upper boundary of the reference reach and the lower boundary of the treatment reach (Figure 2). Air temperature dataloggers will be placed at the midpoints of the reference and treatment reaches, suspended 2-m over the stream channel. There will be 20 total study sites for each treatment, with 10 replicates of each treatment in sites with 50-70% pre-harvest canopy levels, and 10 replicates of each treatment in sites with >70% pre-harvest canopy levels.

Data Analysis

The results from analyses of both individual sites and combinations of sites will be used to examine the effect of BTO and FF prescriptions on canopy closure and stream temperatures. In this way, we expect to be able to gain an understanding of what happens "on average" and also gain insight into the specific site conditions that produce a given outcome. For temperature, analysis of data for individual sites also allows us to determine if the prescription was effective at that site and to assess whether effectiveness of the prescription is affected by the conditions at

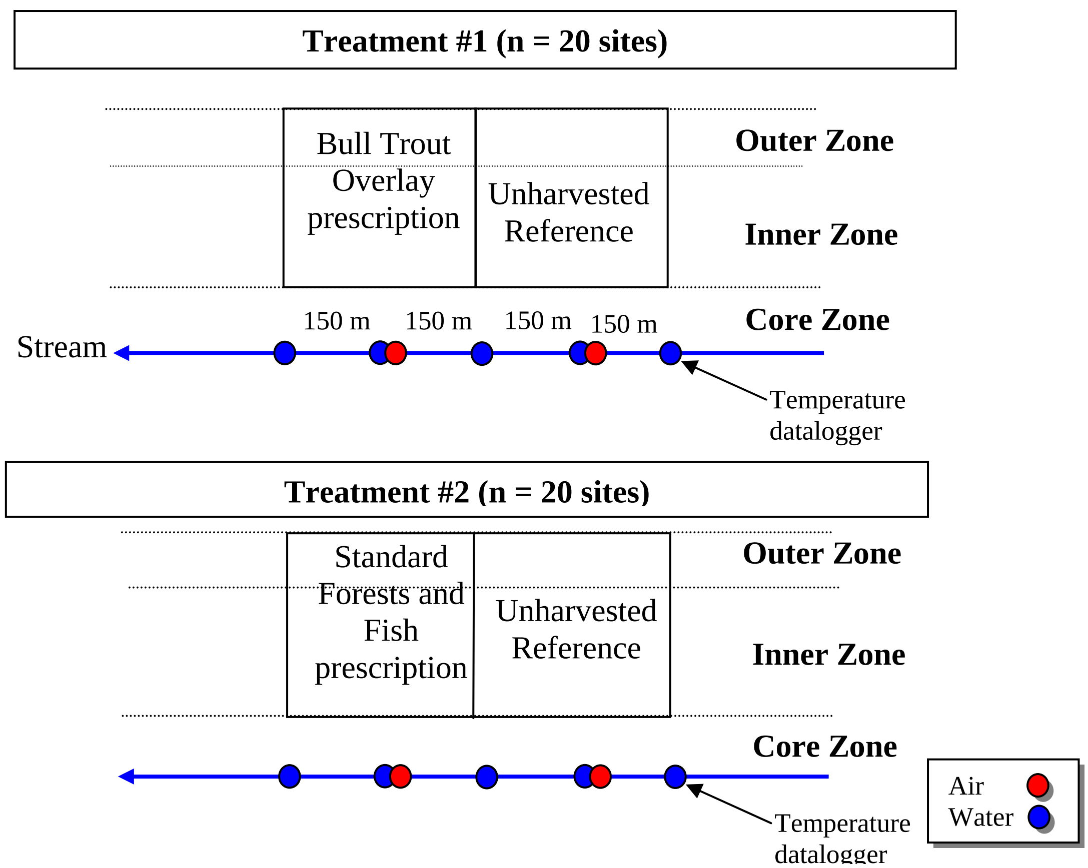


Figure 2. Illustration of thermograph placement in relationship to harvest unit boundaries (modified from McGowan et al. 2000). Harvest units must border both sides of the stream.

the site (i.e. elevation, aspect, etc.).

Site-specific evaluations

Each study site offers valuable information about the effects of the riparian timber harvest prescriptions on canopy and stream temperature. Also, since it is unlikely that the experiment will begin in the same year for all study sites, analysis of individual sites is the quickest way to obtain meaningful information. For canopy, any measured pre- and post-harvest differences will be interpreted using simple measures of pre- and post-harvest riparian stand conditions. For stream temperature, graphical and regression analyses will be used to examine treatment effects. An illustration of the graphical output for stream temperature is shown in Figure 3. This is simply a plot of the longitudinal array of thermographs showing pre- and post harvest temperatures (in this case, using MWMT). The peak annual air temperatures for the site are shown for context (air temperature data at each site should also be graphed and assessed for differences). Another simple way to illustrate

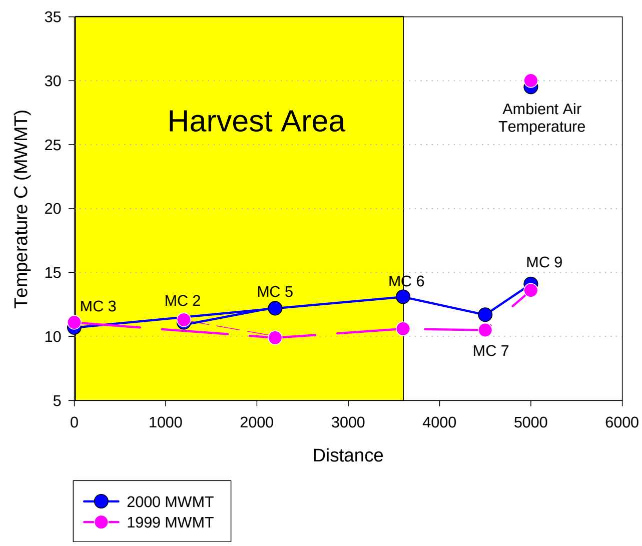


Figure 3. Illustration of pre- and post-harvest temperatures along the length of a stream at an example study site.

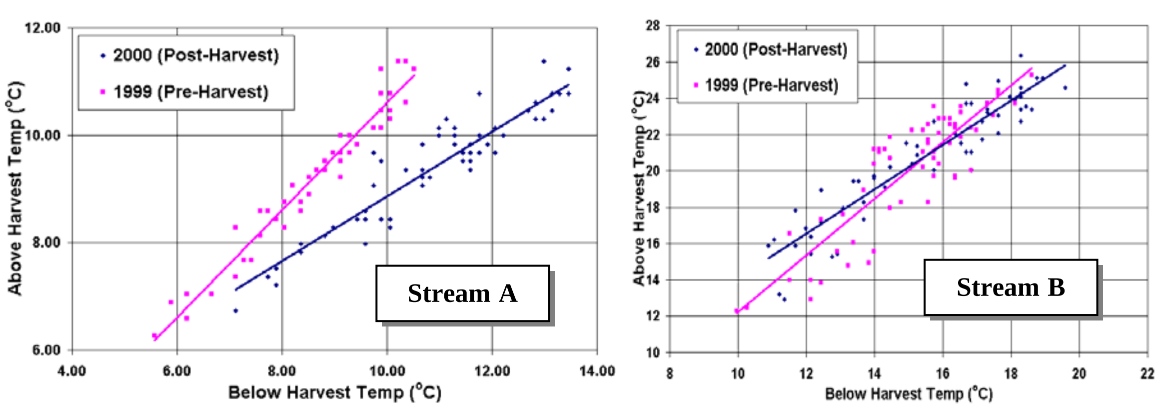


Figure 4. Example comparison of pre- and post-harvest stream temperatures using daily data from paired (upstream-downstream) monitoring stations. With comparable climates in both years, significant post-harvest differences appear likely in stream A, but not stream B.

differences is to plot daily temperature data of the individual paired upstream and downstream stations for comparable monitoring periods before and after harvest (Figure 4). In these exploratory plots, care must be taken to properly account for yearly climatic differences.

Changes in the maximum daily water temperature (or other temperature metrics) in the treatment reach from pre- to post-harvest will also be assessed with multiple linear regression. The approach compares the temperature variables in the treatment and reference reaches with respect to their *relationship* before and after harvest. For example, using the model below, we can control for water temperature as it leaves the reference reach and account for typical seasonal variation in water temperature that is unrelated to harvest.

$$T_{trmt} = b_0 + b_1 * T_{reference} + b_2 * \sin(2\pi * time) + b_3 * \cos(2\pi * time)$$

Where,

T_{trmt} = maximum daily temperature at the bottom of the treatment reach,

$T_{reference}$= maximum daily temperature at the bottom of the reference reach,

Sin(2π∗time) and cos(2π∗time) = terms to account for seasonal variation in water temperature (time is expressed in years), b_0, b_1, b_2, and b_3 are the regression coefficients. Significant difference in stream temperature will be evaluated by testing for differences in b_1, the slope of downstream vs. upstream stream temperature, and differences in b_0, the y-intercept, between pre- and post-harvest periods**.** The specific hypotheses tested will be:

1) $H_{0\text{-y-intercept}}$: $B_{0\ \text{pre-harvest}} = B_{0\ \text{post-harvest}}$ The pre- and post-harvest regression lines have different y-intercepts.

2) $H_{0\text{-slope}}$: $B_{1\ \text{pre-harvest}} = B_{1\ \text{post-harvest}}$ The pre- and post-harvest regression lines have different slopes.

If either of these hypotheses is rejected, then significant post-harvest changes in water temperature have probably occurred. However, the rejection of $H_{0\text{-y-intercept}}$ must be interpreted with caution. By definition, differences in the y-intercept are evaluated at x (reference reach water temperature) = zero, requiring extrapolation well beyond the expected range of x values. Instead, the y-intercept will be evaluated at the lower range of measured reference reach temperature by constructing confidence bands about the regression lines.

Since significant correlation often exists between consecutive measurements of serially collected (time series) data, the assumption of independent observations is violated. This can be avoided by including terms to account for the seasonality of the data and by increasing the interval between consecutive measurements (Helsel and Hirsch 1992) or by including a lag 1 autocorrelation term in the regression model (Hostetler 1991). Either method works well, but one should be selected and used at all sites in order to keep the sample sizes similar among sites to facilitate comparison of the results among sites.

This same regression technique should be used to evaluate post-harvest changes in the temperature metrics listed below in the Methods section. Rates of warming (or cooling) will also be examined for before vs. after harvest differences.

Further exploratory data analysis will be used to identify under what conditions each prescription was effective. This may be as simple as tabulating the experimental results if they are consistent across experimental units. However, it is more likely that this will entail searching for correlation between the experimental results (significant vs. non-significant, the magnitude of post-harvest change, or other indicators) and site-specific environmental variables (air temp, elevation, reference reach water temperature, canopy cover, stream size, stream morphology, etc.) or differences in how prescriptions were implemented. Graphical analysis will also be used to look for interactions among variables.

Pooled Site Evaluations

A primary goal of this study is to determine the *average* and site specific differences between the BTO and FF prescriptions when applied in the mixed conifer zone of eastern Washington. This analysis will require data from all forty study sites. The canopy and temperature data will be analyzed as follows.

Canopy Closure

The difference between the mean canopy closure measured in the reference and treatment reaches will be used for subsequent analyses (***D*** = upstream mean canopy closure – downstream mean canopy closure). The difference between sub-units is used assuming the two means in a sample unit are not independent (i.e., the mean of the downstream sub-unit is probably not independent of the mean of the upstream sub-unit). We do not expect longitudinal trends in canopy closure (i.e., we don't expect canopy closure to consistently increase or decrease as we move downstream), therefore we expect the mean of these differences over *n* streams to be zero. This is a hypothesis that can be tested.

Hypothesis Tests. If the treatment (harvest under a prescription) has no effect on canopy closure then we expect that, for a sample unit, the difference between sub-units pre-harvest ($\boldsymbol{D_{Pre}}$) would be the same as the difference post-harvest ($\boldsymbol{D_{Pst}}$). If post harvest, the difference between the sub-units has increased then the harvest prescription has probably had a negative effect on canopy closure (there has been a decrease in canopy closure in the downstream sub-unit relative to the upstream sub-unit). If we define the effect of the prescription on a stream (sample unit) relative to the upstream sub-unit, then the dependent variable used to measure the effect of the prescription is (see Figure 5):

$$E_i = D_{iPre} - D_{iPst} ,$$

where the *i* subscript refers to an individual stream.

We can then calculate the mean effect ($\overline{E}$) for all streams in the prescription. If $\overline{E}$ is 0 or greater then the prescription has had no effect or a positive effect on canopy closure. If the mean effect is less then 0 there has been a decrease in canopy closure, on average, in the downstream sub-unit with respect to what was seen pre-treatment. Because we are concerned only about mean effects less than 0, we test using the one-sided hypothesis:

$$H1_o : \overline{E}^{BTO} \geq 0$$

$$H1_A : \overline{E}^{BTO} < 0 .$$

Comparing Prescriptions. The same analysis will be conducted for the FF prescription with the same caveats. For example, all FF sample units must receive harvest on both sides of the stream, and canopy measurements should occur at approximately the same time of the year as the pre-harvest measurements were conducted to control for seasonal changes in canopy closure. Hypothesis H1 above will be tested to examine whether the FF treatment had a significant effect on canopy closure. In addition, the following one-sided hypothesis will be tested to determine if the effects of the two prescriptions on canopy closure are the same:

$$H2_o : \overline{E}^{FF} \geq \overline{E}^{BTO}$$

$$H2_A : \overline{E}^{FF} < \overline{E}^{BTO} .$$

Data Analysis. Because canopy closure data is expressed as proportions or percentages, and proportional data typically do not have a normal distribution, non-parametric tests not requiring the normally distributed data or equal variance assumptions will be used.

Bull Trout Overlay Prescription

		Pre-harvest			Post-harvest		
		Upstream	Downstream		Upstream	Downstream	
Stream:	1	$\boxed{C_{1U}}$	$\boxed{C_{1D}}$	$D_{1Pre} = C_{1U}-C_{1D}$	$\boxed{C_{1U}}$	$\boxed{C_{1U}}$	$D_{1Pst} = C_{1U}-C_{1D}$
Stream:	2	$\boxed{C_{2U}}$	$\boxed{C_{2D}}$	$D_{2Pre} = C_{2U}-C_{2D}$	$\boxed{C_{2U}}$	$\boxed{C_{2U}}$	$D_{2Pst} = C_{2U}-C_{2D}$
Stream:	3	$\boxed{C_{3U}}$	$\boxed{C_{3D}}$	$D_{3Pre} = C_{3U}-C_{3D}$	$\boxed{C_{3U}}$	$\boxed{C_{3U}}$	$D_{3Pst} = C_{3U}-C_{3D}$
					$\vdots$		
Stream:	n	$\boxed{C_{nU}}$	$\boxed{C_{nD}}$	$D_{nPre} = C_{nU}-C_{nD}$	$\boxed{C_{nU}}$	$\boxed{C_{nU}}$	$D_{nPst} = C_{nU}-C_{nD}$

Data for analysis is: $D_{1Pre} - D_{1Pst} = E_1^{BTO}$

$D_{2Pre} - D_{2Pst} = E_2^{BTO}$

$\vdots$

$D_{nPre} - D_{nPst} = E_n^{BTO}$

Test hypothesis 1: $H1_o : \overline{E}^{BTO} \leq 0$ to test for effect of harvest prescription.

Figure 5. Schematic of the experimental design for analysis of canopy closure for a single prescription and a two-year study design.

Hypothesis 1: The observations tested are the differences in canopy closure between the upstream and downstream sub-units of a stream. Since we have paired observations (measurements are made on the same sample units pre-treatment and post-treatment), Hypothesis 1 can be tested using the non-parametric Wilcoxon signed ranks test (Conover 1980). Using a paired test is more powerful than a non-paired test such as a regular t-test or the non-parametric Mann-Whitney test comparing mean differences or mean ranks of the differences, respectively.

Hypothesis 2: The observations tested are still differences in canopy closure between sub-units of a stream. The observations are no longer paired since we are analyzing differences between prescriptions. Since there are only two groups in the analysis (BTO versus FF), the appropriate non-parametric test is the Mann-Whitney test (Conover 1980). This is the non-parametric equivalent of the standard t-test.

Analysis of multiple (>1) years of pre-treatment and post-treatment data. Having two years of pre- and post- data allows for an examination of the between-year variation in differences between upstream and downstream sub-sections under pre-treatment and treatment conditions. If the null hypothesis for the previously described two-year study design is not rejected, having this information will permit a better understanding of the power of the experiment. A more detailed description of a possible four-year (two years pre-harvest and two years post-harvest) study design is included in the stream temperature section that follows.

Stream Temperature

The core design will use the information from three thermographs in each sample unit to compare harvest treatments: (1) one at the upstream boundary of the upstream (reference) sub-unit; (2) one at the boundary between the upstream and downstream (treatment) sub-units, and (3) one at the downstream boundary of the downstream sub-unit. The thermographs placed at midpoints between these (Figure 2) will be used to examine the rates of warming in each sub-unit before and after harvest.

Pre-harvest Data Collection and Dependent Variable for Analysis. In year 1 of the study (pre-harvest), data from each sample unit will be collected and recorded separately for each sub-unit (300-m section) within the selected sample units. For any temperature dependent variable measured, the measurement for each sub-unit will be the difference between the upstream and downstream thermographs in the sub-unit. This measurement reflects the change in temperature (Δ_T) as the stream flows through the sub-unit. The difference in Δ_T between the two sub-units (upstream sub-unit – downstream sub-unit) will be used for subsequent analyses that define the dependent variable for analysis. The difference in Δ_T between sub-units is used because the temperature measurements in a sample unit are not independent (i.e., the temperature observed in the downstream sub-unit is most likely not independent of the temperature observed in the upstream sub-unit). We expect longitudinal trends in stream temperature; stream temperatures should increase as you move downstream (absent any extraneous inputs).

Application of Treatment (harvest prescription) and Post-harvest Data Collection. The sample unit dependent temperature variables calculated will be the same as above, i.e., the differences in Δ_T between the upstream sub-unit and downstream sub-unit. The experimental design issues discussed in the canopy closure section are pertinent here, also.

Hypothesis Tests. If the treatment (harvest under a prescription) has no effect on stream temperature then we would expect that, for a sample unit, the difference in Δ_T between sub-units pre-harvest (Δ_{TPre}) would be the same as the difference post-harvest (Δ_{TPst}) when subjected to a similar air temperature regime. Because pre-treatment and post-treatment measurements will be made in different years, an additional complication with the stream temperature analysis that must be accounted for is the effect of the annual air temperature regime and its influence on stream temperatures. Therefore, air temperature will be considered a covariate that is controlled for in any analysis comparing stream temperatures between years.

If post harvest, the difference in Δ_T between the sub-units in a stream has increased (after adjusting for differences in the air temperature regime) then the harvest prescription has had a negative effect on stream temperature (there has been an increase in stream temperature in the downstream sub-section that exceeds that seen pre-harvest). If we define the effect of the prescription on a stream (sample unit) relative to the upstream sub-unit, then the dependent variable used to measure the effect of the prescription is (Figure 6):

$$E_i = \Delta_{Ti\,Pre} - \Delta_{TiPst},$$

where the *i* subscript refers to an individual stream.

We can then calculate the mean effect ($\overline{E}$) for all streams in the prescription. If $\overline{E}$ is zero or greater then the prescription has had no effect or a positive effect on the stream temperature dependent variable. If the mean effect is less than zero there has been an increase in the stream temperature dependent variable, on average, in the downstream sub-unit with respect to what was seen pre-treatment. Because we are concerned only about mean effects less than zero, we test using the one-sided hypothesis:

$$H3_o : \overline{E}^{BTO} \geq 0$$

$$H3_A : \overline{E}^{BTO} < 0$$

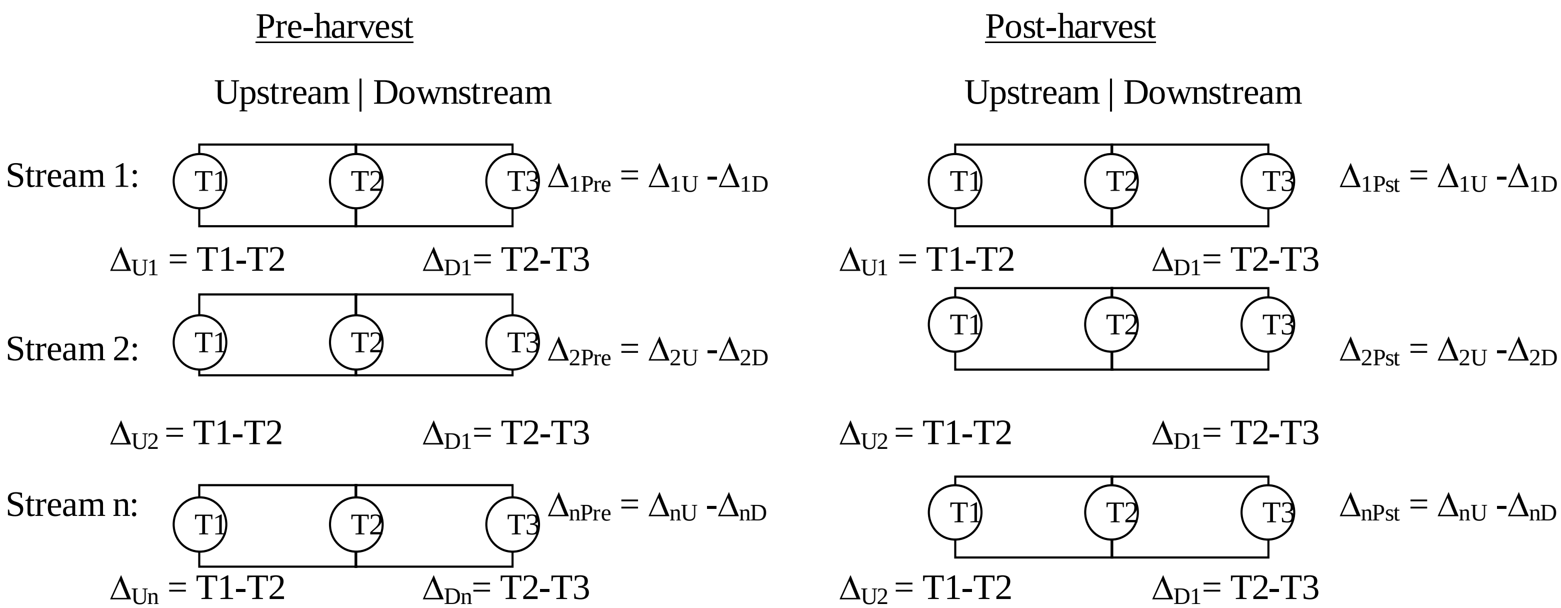
Comparing Prescriptions. The same analysis can be conducted for the FF prescription. Hypothesis H3 above will be tested to examine whether the FF treatment had a significant effect on the stream temperature dependent variable. In addition, the following one-sided hypothesis can be tested to determine if the effects of the two prescriptions on the stream temperature dependent variable are the same:

$$H4_o : \overline{E}^{FF} \geq \overline{E}^{BTO}$$

$$H4_A : \overline{E}^{FF} < \overline{E}^{BTO}.$$

Data Analysis. The stream temperature Δ_T data will be tested to see if it is normally distributed and if the equal variance assumption between groups is met. Whether the paired t-test and independent samples t-test, or the non-parametric equivalents discussed in the canopy closure section will be used for the analysis will be determined by the outcome of these tests. In

Bull Trout Overlay Prescription



Data for analysis is: $\Delta_{1Pre} - \Delta_{1Pst} = E_1^{BTO}$

$\Delta_{2Pre} - \Delta_{2Pst} = E_2^{BTO}$

$\vdots$

$\Delta_{nPre} - \Delta_{nPst} = E_n^{BTO}$

Figure 6 Schematic of the experimental design for analysis of stream temperature for a single prescription and a two-year study design.

addition, an analysis of covariance will be conducted to determine if air temperature (or other variables) is a significant covariate influencing the stream temperature dependent variable that needs to be accounted for in any analysis.

Hypothesis 1: The observations tested are the differences in Δ_T between the upstream and downstream sub-units of a stream. If air temperature (or flow) is not a significant covariate, then the analysis can be conducted similarly to the canopy closure analysis. Since we have paired observations (measurements are made on the same sample units pre-treatment and post-treatment), Hypothesis 3 can be tested using either a paired t-test or its non-parametric equivalent, the Wilcoxon signed ranks test (Conover 1980). Using a paired test is more powerful than a non-paired test such as a regular t-test or the non-parametric Mann-Whitney test comparing mean differences or mean ranks of the differences, respectively. If air temperature (or flow) is a significant covariate, a single-factor ANOVA will be conducted using air temperature (or flow) as a covariate (Milliken and Johnson 1995). The factor will be treatment (with 2 levels, pre-harvest and post-harvest). The ANOVA analysis will be conducted using the Δ_{iPre} and Δ_{iPst} data.

Hypothesis 2: The observations tested are still differences in Δ_T between sub-units of a stream. The observations are no longer paired since we are analyzing differences between prescriptions. If air temperature (or flow) is not a significant covariate, then the analysis will be similar to that conducted for the canopy closure analysis. Since there are only two groups in the analysis (BTO versus FF), the appropriate test is the standard t-test or its non-parametric equivalent, the Mann-Whitney test (Conover 1980). If air temperature (or flow) is a significant covariate, a two-factor ANOVA will be conducted using air temperature (or flow) as a covariate (Milliken and Johnson 1995). The factors will be treatment (with 2 levels, pre-harvest and post-harvest) and prescription (with two levels, BTO and FF). The ANOVA analysis will be conducted on the Δ_{iPre} and Δ_{iPst} data. If the ANOVA is significant, multiple comparison tests will be used to determine which groups are significantly different.

Analysis of multiple (>1) years of pre-treatment and post-treatment data. Having two years of data pre- and post- data will allow the between-year variation in Δ_T between upstream and downstream sub-sections to be examined under pre-treatment and post-treatment conditions. With this experimental design, a standard two-factor ANOVA will be used for analysis using air temperature as a covariate if it is significant. The second year of data (pre-treatment or post-treatment) would be used to better estimate between year variability. The data structure will be similar to the following:

Stream	Prescription	Pre-treatment Year 1	Pre-treatment Year 2	Post-treatment Year 1	Post-treatment Year 2
A1	BTO	D_{1111}	D_{1121}	D_{1211}	D_{1221}
A2	BTO	D_{2111}	D_{2121}	D_{2211}	D_{2221}
A3	BTO	D_{3111}	D_{3121}	D_{3211}	D_{3221}
:	:				
An	BTO	D_{n111}	D_{n121}	D_{n211}	D_{n221}
B1	FF	D_{1112}	D_{1122}	D_{1212}	D_{1222}
B2	FF	D_{2112}	D_{2122}	D_{2212}	D_{2222}
B3	FF	D_{3112}	D_{3122}	D_{3212}	D_{3222}
:	:				
Bn	FF	D_{n112}	D_{n122}	D_{n212}	D_{n222}

$D_{ijkl} = \Delta_{iU} - \Delta_{iD}$ where *i* = stream; *j* = pre-harvest (1) or post-harvest (2); *k* =year (1 or 2); and *l* = prescription (1 = BTO, 2= FF).

Study Sites

Study sites will be selected from available commercial forestlands in the mixed conifer habitat type (2500-5000 ft elevation) in eastern Washington. Sites will be volunteered by landowners, and need not be located within the boundaries of the Bull Trout Overlay. Harvest treatments will be randomly assigned to each study site.

Site Selection Criteria

- A study reach at least 600-m long on a small (<15-ft bankfull width) fish-bearing stream.
- A relatively consistent stand of timber with sufficient basal area to meet the minimum requirements for commercial harvest under the Forests and Fish rules.
- Pre-harvest canopy closure levels >50%.
- Absence of tributaries that enter or influence the study reaches.
- Absence of a channel migration zone.
- Limited amounts of unforested areas (i.e., pastures). Generally, unforested areas should not occur within the riparian zone, especially within the core or inner zone. Sites with > 10% of the inner zone occupied by nonforested areas will require special review and approval by the Bull Trout Scientific Advisory Group (BTSAG) to be considered for inclusion in the study.
- Limited amounts of wetlands, beaver ponds, or other secondary surface water bodies.

- Ideally, none should be present; however, inclusion of a limited amount of these areas may be acceptable. If secondary surface waters occupy greater than 10% of the riparian area at a site then review and approval by BTSAG will be required.

- Continuous surface flow during the monitoring period (no intermittent sections within the study reaches).
- Absence of stream-adjacent roads within the riparian zone.
  -Road crossings within the sample area will be avoided if possible, however, a sample site with a road crossing will not automatically be removed from consideration. Any stream-adjacent roads or road crossings will require review and approval by BTSAG.
- Absence of significant groundwater inputs within the study reaches.
  -Sites will be examined for groundwater influence using spot temperature checks throughout the sample reach and by discharge measurements at the upper and lower boundaries of the reference and treatment reaches. Sites with noticeable differences in groundwater influence between treatment and reference reaches must be reviewed by BTSAG for inclusion.
- Absence of recent major disturbance
  - from debris torrents
  - from livestock grazing that has significantly altered stream morphology or bank vegetation
  - from other channel disturbance.
- Committed landowner.
  - The landowner must be willing to design the timber harvest unit to fit the experimental design and be willing to maintain the reference site in an unmanaged condition for at least 3 years (and preferably longer).
  - Landowner must agree to harvest along both sides of the stream
  - Timber harvest and related activities must comply with Forests and Fish rules and have the maximum allowable volume removed during harvest.

Methods

Riparian Timber Harvest
Harvest specifications for Fish Habitat (Type F) streams in the mixed conifer zone of eastern Washington are described in the Washington Forest Practices Rulebook *(WAC 222-30-022*). This is available via the Internet at: http://www.wa.gov/dnr/htdocs/fp/fpb/rules.html. Details of special regulations for the Bull Trout Overlay are also listed (see *WAC 222-30-040).*

Canopy Cover
The mean canopy cover in the treatment and reference reaches will be estimated from the canopy cover readings taken along the harvest and reference reaches for all pre- and post-harvest years included in the study. Canopy should be measured during full leaf-out, and for a given site the pre- and post-harvest measurements should be taken at approximately the same time of year. Canopy cover will be measured using a forest densiometer every 25 m, according to the methodology described below (from section 1 of the Washington Forest Practices Board Manual, 2000):

> "Hold the instrument level 12" - 18" in front of your body at elbow height. You should see the reflection of your head just outside of grid in the mirror. Assume four equal spaced dots in each square and systematically count dots equivalent to quarter-square canopy openings. Repeat this procedure four times per plot taking measurements while facing upstream, downstream, and at the right and left banks. Average the four dot counts per plot to get the percent canopy opening for the plot. Multiply the average number of dots by 1.04 and subtract the results from 100 to obtain the percent of area occupied by canopy. [For canopy openings greater than 50%, it may be easier to directly count the area covered by canopy.]..."

When possible, begin measuring at the downstream end of a study reach and work upstream.

Stream and Air Temperatures

Thermographs to be used in this study are StowAway TidBit™ digital temperature loggers manufactured by Onset Computer Corporation (Pocasset, MA). These thermographs have a range of –0.5 ^{o}C to +37 ^{o}C, and have a rated accuracy of ± 0.2 ^{o}C at +21 ^{o}C. Prior to deployment, individual thermograph performance will be verified in an ice bath. If possible, all loggers should be set with a delayed launch for midnight of a particular day (e.g., July 14), to facilitate data processing.

Temperature loggers will be deployed from July 1st to September 15 for a given monitoring year. Based on local experience with stream temperature regimes, this should ensure that annual maximum temperatures are captured. All thermographs will be programmed to record every half-hour through the monitoring period. Stream temperature loggers will be placed in a location in the stream where the water column is well mixed and deep enough to submerge the datalogger during low flows. Temperature loggers will be shielded from direct solar radiation to eliminate any potential warming of the instrument housing. If needed, this can be accomplished by covering the thermograph with an inconspicuous rock cairn. Each logger must be strapped to a weight (e.g., a rock or a 1 ½" to 2" galvanized pipe conversion joint) using plastic zip ties. The weight must then be tethered to a sturdy tree, root, or rock using 12 gage hay wire. The tether line should be well concealed to prevent tampering. The location of the tether tie-off location should be marked with blue spraypaint.

Air temperature will be measured continuously (half-hourly intervals) at two locations per study site. One site will be located in the center of the treatment reach, and one will be located in the center of the reference reach. The air temperature data loggers are to be suspended 2 m above the surface of the stream. This can be accomplished by attaching the device directly to overhanging vegetation or by attaching it to a nylon cord that has been tied to vegetation on opposing banks. An inverted paper cup should be placed over each data logger to shield it from direct solar radiation. Tether the air temperature data loggers and mark their locations as needed (these are not likely to be washed away during a high runoff event).

Pink flagging with black polka dots or a similarly unusual pattern must be hung over the stream at the location of each thermograph. The serial number of each thermograph should be recorded during deployment, and detailed notes of the thermograph location should be taken. Record the time of deployment and retrieval. Keep an inventory to track the status of all thermographs.

After retrieval, the raw temperature data should be downloaded from the Tidbit data loggers and stored as ".dtf" files using the serial number as the label (e.g., 235679.dtf). These raw data should then be converted to a text file for import into Excel. Save the file as before with the serial number for a label, and a ".txt" suffix (e.g., 235679.txt). When importing to Excel, be sure to place the date and time in separate fields (columns). Once in Excel, trim any extraneous data (e.g., from the period between launch and deployment, or retrieval and downloading) and save as an Excel file. Use the serial number and the year as a filename (e.g., 235679_2002.xls).

From the raw thermograph data, the following temperature metrics will be compiled for each summer at each survey site:

- **Maximum Daily Average Temperature (MDA)—**This is the warmest daily average water temperature recorded during a given year or survey period.
- **Maximum Daily Maximum Temperature (MDM)—**This is the warmest daily maximum water temperature recorded during a given year. This metric will be used to compare the effects of the two treatments.
- **Maximum Weekly Average Temperature (MWAT)—**This is the mean of daily average water temperatures measured over the warmest consecutive 7-day period.
- **Maximum Weekly Maximum Temperature (MWMT)—**This is the mean of daily maximum water temperatures measured over the warmest consecutive 7-day period. This metric will also be used for comparison of the two treatments.
- **Minimum Weekly Average Temperature (MinWMT) —** This is the mean of daily *minimum* water temperatures measured over the warmest consecutive 7-day period
- **Diurnal Flux —**This is the average of the daily difference between the highest and lowest temperatures measured over the warmest consecutive 7-day period.

Covariate Data Collection. A variety of covariate data will be collected as part of this study. Except where noted, measurements will be taken at three locations in each 300-m reach (canopy stations 2, 6, and 10) during the pre-harvest period only:

- Elevation of stream (m) – This will be estimated off maps for each thermograph location.
- Azimuth of stream (^{o}) – This is the general direction in which the stream is flowing relative to true north (0^o-360^o)
- Drainage area (nearest hectare, calculated from topographic maps or GIS)
- Distance from divide (nearest 0.1 km, calculated from topographic maps or GIS)
- Valley features (general morphology [confined, unconfined, etc.], slope angle to horizon)
- Ecoregion (Omernik and Gallant [1986], or more recent version)
- Site Class – Riparian forest site class should be determined from state soil maps.
- Stream gradient (%) – Average stream gradient will be measured to the nearest whole % with an abney or hand level in the reference and treatment reaches.

- Stream substrate – visual estimate of the dominant and subdominant particle size in the treatment and reference reaches
  - sand, silt, clay, organic or other fine material
  - Gravel 2-64 mm (0.1” – 2.5”)
  - Cobble 64-130 mm (2.5” – 5.0”)
  - Boulder >130 mm (5.0”)
  - Bedrock
- Bankfull and wetted stream width and depth – These will be measured to the nearest 0.1 m at the same three locations where discharge is measured (see below). Measurements will be made in each year of the study.
- Discharge – nearest whole CFS, using a method appropriate for very low flows, such as a salinity tracer, see Pleus (1999) and Rantz et al. (1982). To be measured during summer baseflow conditions, ideally in the last week of July or the first week of August, *in all years of the study*. Discharge should be measured at three locations: (1) the upstream end of the reference reach; (2) the boundary between the reference and treatment reaches; and (3) the lower end of the treatment reach.
- Air temperature – Measured to the nearest 0.1º C, and expressed using the same metrics described above for water temperature. Measured in all years of the study.

Riparian Stand Characteristics. Change in riparian stand structure attributes (e.g., % harvest removal, change in basal area, trees per acre, etc. in each zone and for the stand as a whole) will be estimated via sub-sampling the riparian zones along the reference and harvest reaches. Stand conditions will be measured in the year before harvest (reference and treatment reaches) and the year after harvest (treatment reach only).

- Standard forestry cruise methods will be used to measure characteristics of vegetation on both sides of each study reach. The methods consist of surveying five 20-ft strips oriented perpendicular to the channel and spaced uniformly throughout the minimum 100-ft x 2000-ft riparian area at each study site. Data are to be collected separately for the CMZ (if present), core zone (edge of bankfull channel or CMZ, whichever is greater, to 30-ft upslope), inner zone (30-ft to 75-ft), and outer zone (75-ft to ~100-ft). The site class, per WAC 222-30-022 will determine the width of the outer zone. All stems in each strip greater than 1-in dbh are to be measured within the core zone. All stems greater than 4-in dbh will be measured in the inner and outer zone.

Data measured for each stem in each strip are:
(1) Diameter breast height (dbh) in 1" classes
(2) Species
(3) Height
(4) Height to live crown (can be estimated, with measurements on a few trees per strip)

Data to be summarized and reported for each portion of each strip, and for the stand overall, are:
(1) Trees per acre
(2) Basal Area per acre
(3) Average % hillslope angle for each zone in each strip (measured in the field with a clinometer)

The Forest Vegetative Series is to be described for the overall riparian area based on the DNR's Vegetation Classification System for eastside forests.

Deliverables

1) annual reports summarizing the work conducted each year and the plan for the following year;

2) annual submission of data (after QA) in spreadsheet files;

3) A final report describing the results of the statistical and other analyses contained in this study plan shall be prepared and presented to the Bull Trout Scientific Advisory Group of CMER.

Annual reports should summarize work in each year, and identify any problems (e.g., malfunctioning data loggers, dry streams) that might affect study results or plans for the coming year(s). These reports are due by February of each year. Spreadsheet files containing all error-checked data collected and used in the analyses will be delivered to BTSAG. All reports will be subject to review by BTSAG. Publication of the final report will not be allowed until after peer review by the Scientific Review Committee and final approval from BTSAG and CMER.

Time Frame

- March 2002 (refine study plan, develop RFP)
- April-May (release RFP, interview and select contractor)
- June (study site selection)
- mid-June to July (deploy thermographs, measure site characteristics)
- mid- to late-September (retrieve thermographs).
- October, 2002- February 2003 (process data, report on pre-treatment conditions, study site characteristics).
- mid-September 2003 through June 2004. Conduct harvest treatments.
- 2003, 2004, etc. (same schedule as 2002, except skip site selection step, add more analysis and reporting, yearly reports ready for review by bull trout scientific advisory group in March of the following year).

Acknowledgments

This study plan was greatly improved by input from the following individuals: Kate Benkert, Bob Beschta, Sondra Collins, Scott Craig, Liz Dent, Larry Dominguez, Brian Fransen, Tracy Hillman, Mark Hunter, Terry Jackson, Mike Newton, Jim Matthews, Roger Peters, Blake Rowe, and Steve Toth.

References

Cohen, J. 1988. *Statistical Power Analysis for the Behavioral Sciences* (Second Edition). Lawrence Erlbaum Associates, Publishers, Hillsdale, New Jersey.

Conover, W. J. 1980. *Practical Nonparametric Statistics* (Second Edition). John Wiley and Sons, New York.

Helsel, D.R. and R.M. Hirsch. 1992. Statistical Methods in Water Resources. Elsevier Science B.V. Amsterdam, Netherlands.

Hostetler, S.W. 1991. Analysis and modeling of long-term stream temperatures on the Steamboat Creek basin, Oregon: Implication for land use and fish habitiat. Water Resour. Bull. 27: 637-647.

Milliken, G. A. and D. E. Johnson. 1995. *Analysis of Messy Data: Volume III Analysis of Covariance*. Kansas State University. Draft text.

Omernik, J.M. and A.L. Gallant. 1986. Ecoregions of the Pacific Northwest. U.S. EPA. EPA/600/3-86/033. Corvallis, Oregon. 39 pp.

Pleus, A.E. 1999. TFW Monitoring program method manual for the wadable stream discharge method. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-009. DNR#111.

Rantz, S.E. et al. 1982. Measurement and computation of streamflow: volume 1. Measurement of stage and discharge. Geological Survey Water-Supply Paper 2175. US Dept. of the Interior. US Gov't. Printing Office, Washington D.C.