Headwater Stream Smart Buffer Pilot Project:
Study Design

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Background

In May 2019 TFW Policy agreed that the temperature response findings from the Np buffer effectiveness study (i.e., Hard Rock Study; McIntyre et al. 2018) warranted an adaptive management action. Therefore, Policy recommended to the Forest Practices Board (FPB) that a technical workgroup of scientific and operational experts develop alternative Type Np riparian management zone (RMZ) recommendations that meet a suite of resource protection, feasibility, and economic objectives. The workgroup was charged with reviewing findings from CMER Type N related projects and other relevant science to inform the adaptive management process. The initial focus of the RMZ recommendations is for water temperature protection and potentially other riparian functions (e.g., large wood supply) may be addressed.

The retention of RMZs on Type Np waters (headwater streams) is required by the Washington forest practice rules (WAC 222-12-045(2)(a)). The rules require 50 foot fixed-width, no-cut buffer strips on both sides of the stream for at least 50% of the length, beginning at the lower portion of Type Np waters and around adjacent sensitive sites. Additional buffers are retained in areas with unstable slopes. Specific knowledge about the effectiveness of buffers on headwater streams outside of the CMER studies, is limited, despite the recent inclusion of headwaters into riparian protection strategies (e.g., Richardson and Danehy 2007). Most studies of buffer effectiveness have investigated buffers along fish-baring streams (Everest and Reeves 2007). Further, the implementation of uniform buffers (e.g., fixed width forest stands on both sides of a channel) has been the dominant paradigm in watershed management including on both federal (FEMAT 1993) and on state and private lands (Murphy 1995, Ice 2005). Uniform buffers are generally not designed to account for riparian functions that are highly variable involving; for example, thermal loading, wood recruitment, erosion, and biological productivity (Naiman et al. 1992, Everest and Reeves 2007). A site-specific approach offers an alternative to prescriptive uniform buffers and may be more protective of ecological functions and more cost effective in forestry and watershed management. Despite potential benefits, few experiments have been done to test the efficacy of buffers that are tailored to site-specific or landscape characteristics (Richardson et al. 2012).

Retaining riparian vegetation that attenuates incoming solar radiation (direct and diffuse) is the primary objective for conserving water temperature in Np streams. Direct-beam solar radiation on the water's surface is the dominant source of heat energy that may be absorbed by the water column and streambed. Absorption of solar energy is greatest when the solar angle is greater than 30° (i.e., 90 to 95 % of energy is absorbed as heat; Moore et al. 2005) and solar heating of a stream from direct beam radiation is most significant during mid-day (Beschta et al. 1987) as the sun travels from southeast to southwest (azimuths 135° to 225°). Therefore, riparian vegetation that blocks direct solar radiation along the sun's pathway across the sky is the most effective for reducing radiant energy available for stream heating (Moore et al. 2005). Research shows that the attenuation of direct beam radiation by riparian vegetation is a function of canopy height, vegetation density, and buffer width (Beschta et al., 1987, Sridhar et al. 2004, DeWalle 2010). Light attenuation increases with increasing canopy height and increasing buffer density as a result of the increased solar path and extinction of energy. Buffer width has a variable influence on light attenuation depending on stream azimuth (e.g., effective buffer widths for E-W streams may be narrower than for N-S streams due to shifts in solar beam pathway from the sides to the tops of the buffers; Dewalle 2010).

This study design describes a pilot study to test the effectiveness of implementing alternative buffering schemes (i.e., smart buffer designs) along Np streams to maintain shade and minimize changes in water temperature. Because experimental studies are limited, we are uncertain if smart buffer designs are a viable option to the standard rules. Therefore, we expect the initial design process to be a learning exercise for all involved. Also, we expect this process will result in developing tools and deriving guidelines for different situations where the development of smart buffer prescriptions will be feasible and cost-effective. Similarly, we will likely identify situations where smart buffers are not worth the effort.

Purpose, Goals, and Objectives

The purpose of this project is to evaluate the effectiveness of riparian smart buffer design strategy for maintaining shade and minimizing changes in water temperature that may be the result of forest management. The working hypothesis is that buffer locations, widths, and stand densities can be configured to improve effective shading of Np streams equal to or greater than that provided by Np fixed-width RMZs. Also, that effective shading can be achieved by a cost-effective planning process and strategic allocation of the RMZ buffer area. The intent is to examine the effectiveness and practicality of implementing alternative buffer designs (e. g., variable width and thinning) that are tailored to site-specific conditions and include considerations for slope stability and sensitive sites.

The project goals are to determine where smart buffer designs are implementable, to measure their effectiveness, and to provide proof of concept. To achieve these goals, we propose to:

1. Implement alternative buffering configurations (e. g., variable width and stand density) that are designed to optimize for the reduction in solar insolation (energy reaching the stream) and allocation of retained riparian stands (i.e., buffered areas) along Np streams.
2. Examine smart buffer designs in a range of different harvest unit sizes and locations (e.g., entire Np basin, imbedded within Np basin) that are commonly implemented on Np streams.
3. Measure the effectiveness of smart buffer designs to reduce solar insolation and minimize changes in water temperature exported from harvest units.
4. Evaluate how watershed characteristics (i.e., aspect, topography) and harvest unit configuration influences effective shade, solar insolation, and air temperature within harvest area.
5. Evaluate how watershed and hydrology attributes (e.g., surface flow, substrate composition, slash cover, gradient, geology, elevation) may influence temperature response to treatment.
6. Evaluate how riparian stand forestry metrics (e.g., basal area, tree height, density) can be used as guidance for developing smart buffer design.

Approach

The study will use a BACI approach for assessing the relative effectiveness of smart buffer designs to maintain shade and minimize changes in water temperature. Shade, temperature, and covariates will be monitored before and after riparian shade retention treatments at a sample of Np study basin/reaches that are typical of timber harvest on industrial forest lands in Western Washington.

Several reference basins will be monitored to help distinguish changes in temperature and shade that may be associated with treatments from changes due to inter-annual variability (e.g., warm or cool summers) or natural disturbance events (e.g., wind storms). Monitoring will occur one- to two years before treatment and two years after the harvest treatments. The intent is to measure the maximum potential response in shade and temperature resulting from the treatments which generally occurs within 2-years after harvest (Arismendi and Groom 2019).

Strategically locating and retaining riparian timber stands to attenuate direct solar radiation is the most effect and feasible management strategy for conserving water temperature in headwater streams. Therefore, measures of effective shade will be the primary metric used for assessing treatment effectiveness. Effective shade is defined as the fraction of total possible solar radiation that is blocked by riparian vegetation (Teti and Pike 2005, Allen and Dent 2001). Effective shade is a function of the spatial relationships among sun position, location and orientation of stream reach, hiIlslope topography, and riparian vegetation buffers (Chen et al. 1998). Effective shade differs from canopy closure or canopy cover which are commonly used terms to express the percentage of open sky that is obscured by overhead vegetation.

Research demonstrates that light attenuation in forest stands can be predicted with high confidence using common forestry metrics (Sonohat et al. 2004, Hale 2003, Drever and Lertzman 2003). For example, Groom et al. (2011) found that shade was best predicted by basal area and tree height of riparian stands in western Oregon. Because we are interested in evaluating how riparian stand metrics can be used as guidance for developing smart buffer designs, we will conduct surveys of riparian stand composition. Pre-treatment surveys will be used for guiding buffer designs and post-treatment survey data will be used for evaluating relationships between shade and stand metrics.

Water and air temperature will be measured before and after harvest to evaluate temperature responses that may be associated with the harvest treatments. However, shade from riparian vegetation is not the only factor influencing stream temperature. Research shows that temperature response from timber harvest is variable and is highly dependent on multiple physical factors including stream flow, substrate composition, groundwater inflow, and surface/subsurface water exchange (i.e., hyporheic exchange) (Moore et al. 2005). For example, Janisch et al. (2012) found that spatially intermittent headwater streams with short surface-flowing extent above a monitoring station and characterized by coarse-textured streambed tended to be thermally unresponsive. Whereas, streams with longer surface-flowing extent and with fine-textured streambeds were thermally responsive. The CMER studies similarly observed temperature and surface flow correlations (McIntyre et al. 2018, Ehinger et al. In review). The amount of stream coverage by slash and forest debris is another factor confounding temperature response to overhead shade reduction (Kibler et al. 2013, Janisch et al. 2012, Jackson et al. 2001). Therefore, to account for physical modifiers of temperature response, we plan to collect data on a suite of local attributes to be used as covariates in our analyses; including surface water extent, substrate size composition, and channel coverage by slash and debris.

Study Sites

We know that valley aspect, topography and stream size are key factors affecting insolation and thermal loading of streams. Therefore, it would be desirable to have a range of study basins with different aspects, valley confinement, and size. Also, given variability in topography and stand composition, we wanted to examine the range of harvest unit configurations in terms of size and location (e.g., harvest of entire Np basin or harvest unit imbedded within Np basin). The intent is to collect sufficient data to explore how well we can design buffers given the typical range of conditions on industry lands. Therefore, we asked WFPA participant companies to identify suitable Np harvest units that fit the following criteria:

- units with one or more Np stream reaches,
- units with minimal unstable slope buffers and no recent channel disturbances (e.g., debris flows)
- units that could be harvested during the fall-winter 2020-2021 period.

Five WFPA member companies offered to participate in the smart buffer design study (Table 1). Company searches and field reconnaissance surveys resulted in 29 viable study sites, of which 21 are to be treated with smart buffer design prescriptions and 8 will be unharvested reference sites. The treatment sites include 14 km of Np streams with 34 stream reaches averaging 376 m long (Table 2). The study treatment and reference sites are geographically widespread among four DNR regions and have a diversity of stream orientations with single and multiple reach configurations (Tables 1 and 2).

In addition to the treatment sites, five sites with standard Np buffers will be monitored on Weyerhaeuser lands in the Pacific Cascade region (Figure 1). Also, one reference that is currently being monitored by the CMER Soft Rock study (i.e., REF2; Ehinger et al. In review) and is located near the study sites (Figure 1), will be incorporated with the study reference sites. The longer record of temperature data at Site REF2 (2013 through 2020) will be helpful in the BACI analysis as it provides temporal context for assessing annual variability in the study area.

Table 1. Number of study sites by company, region, treatment, and valley orientation.

		Treatment orientations				Reference orientations			
Company	**DNR region**	**N-S**	**E-W**	**NE-SW NW-SE**	**All**	**N-S**	**E-W**	**NE-SW NW-SE**	**All**
HFM	Pac. Casc.	0	2	3	5	0	0	0	0
PB	Puget Sound	0	1	1	2	0	0	0	0
ROC	Olympic	1	1	3	5	0	0	2	2
SPI	Northwest	1	0	3	4	0	1	0	1
WC	Pac. Casc.	1	1	3	5	2	2	1	5
All	All	3	5	13	21	2	3	3	8

Table 2. Study treatment reach length statistics by company.

		Reach length (m) statistics			
Company	**Number reaches***	**Sum**	**Mean**	**Minimum**	**Maximum**
HFM	5	1482	296	161	443
PB	2	602	301	201	401
ROC	7	1974	282	158	441
SPI	5	2543	509	301	832
WC	15	7384	492	215	771
All	34	13985	376	158	832

*Some sites have multiple reaches; thus, number of reaches is greater than sites.

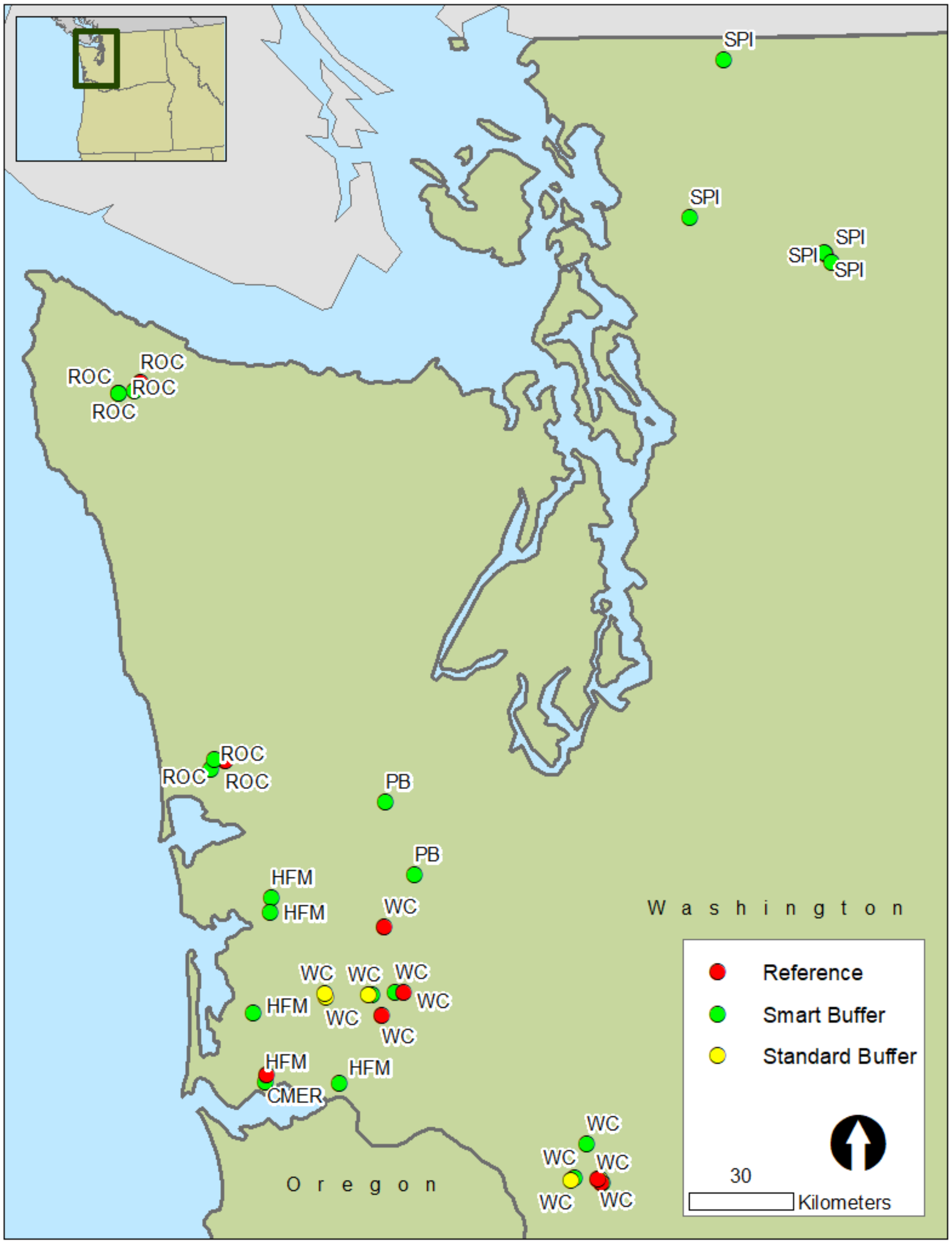

Figure 1. Location of smart buffer study sites.

Designing Smart Buffers

The process of developing smart buffer designs will be an iterative and multi-step procedure that will involve interaction among project scientists, forest engineers, and industry policy representatives. The field data will facilitate an empirically derived site-specific design with options for retaining effective shade. The initial design will be evaluated by forest engineers and potentially modified to incorporate operational concerns (roads, yarding) and consideration for cost-effectiveness. Also, stand retention for sensitive sites, equipment exclusion zones, and large wood will be allocated in buffer designs. Finally, or maybe jointly, industry policy input on shade targets and other concerns may be explored. For example, there are no specific shade targets for Np streams other than that provided by buffering (two-sided, 50-ft wide) at least 50% of stream length. Therefore, a key driver will be the retention of shade that is sufficient to meet some specified target. We plan to examine the shade and temperature data from CMER studies (e.g., Hardrock and Softrock) along with this study to inform the smart design process.

The proposed approach for developing the smart buffer designs is as follows:

- First, riparian stand and location-specific data will be used to delineate and map the riparian zone area providing effective shade. For this study, the riparian zone area that provides effective shade is referred to as a "ShadeShed." The size of shadeshed varies by location as a function of tree height, stream orientation, and solar altitude which varies by time-of-year as the sun moves across the sky (Figure 2). Thus, the shadeshed delineates a polygon-shaped area of effective shade that varies in width along the stream in relation to channel orientation (Figure 2). The shadeshed polygon will be designed to provide maximum shade during the mid-summer period when air temperatures are high and water temperature is known to be most sensitive to shade loss (Moore et al. 2005). Therefore, we use the sun path and solar altitude geometry for August 1st to compute the shadesheds. Also, the shadeshed size will be configured to block peak mid-day direct-beam radiation which occurs two hours before and after solar noon as the sun moves from east to west (azimuth 135°- 225°). This approach provides maximum effective shade (shadeshed) during the mid-day period when solar heating of a stream from direct-beam radiation is most significant (Beschta et al. 1987).

- Second, we will use the surface flow data (left panel; Figure 3) to identify reaches with contiguous surface flow that are potentially thermally sensitive to shade loss (e.g., Janisch et al. 2012). Headwater tributaries with seasonal flow (Ns) or dry headwater reaches that are thermally less sensitive would not require a shadeshed. Therefore, the shadeshed location and length may be adjusted in relation to patterns of summer surface flow (right panel; Figure 3).

- Third, the relative effectiveness of various buffer configurations to retain effective shade will be evaluated using estimates of thermal loading. Pre-harvest effective shade is estimated from the hemi-photo data and the associated riparian stand composition from the riparian surveys. Therefore, using published models of light attenuation/shade loss in relation to riparian stand metrics (Teply et al. 2014, Groom et al. 2011, Sonohat et al. 2004) we can estimate the potential effective shade for various levels of stand retention. This approach facilitates designing for an optimal solution.

- Fourth, additional stand retention for sensitive sites and large wood (LW) supply may be added depending on the location and extent of buffering for shadesheds. For example, only one-sided shadesheds would occur along east-west streams. Therefore, an RMZ on the north side could be retained for large wood supply, equipment limitation, and sensitive site buffering, if necessary (right panel, Figure 3). The width and density of RMZs will depend on location in relation to other buffers and vulnerability to windthrow. For example, in Np streams most post-harvest LW recruitment from buffers occurs from windthrow (e.g., Schuett-Hames and Stewart 2019, McIntyre et al. 2018) and most LW is derived within 10 m (30 ft) (Schuett-Hames and Stewart 2019) of the stream.

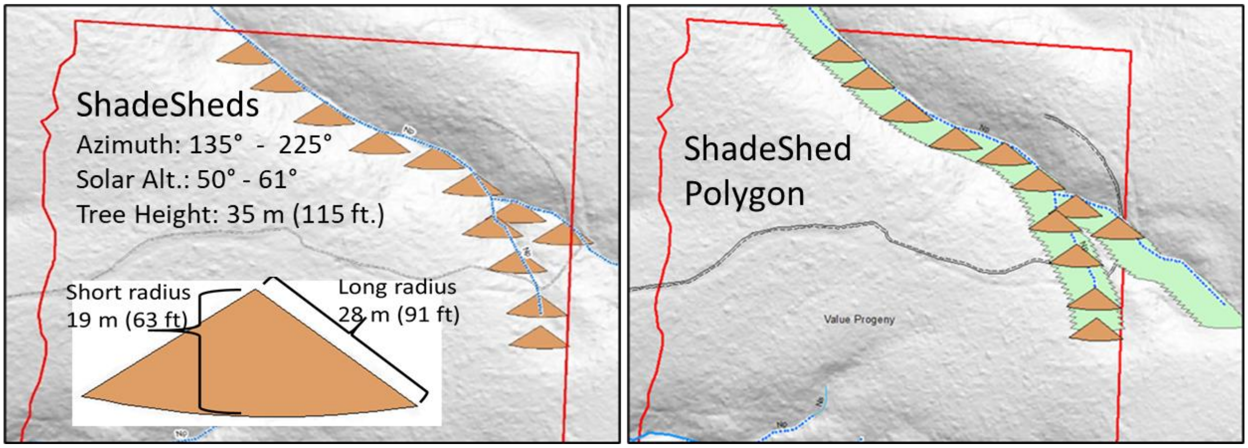

Figure 2. Example of how shadesheds (left) are used to delineate the zone of effective shading (green polygon; right) on Np stream. Example is based on sun path and solar altitude for mid-day period on August 1st for a stream near Olympia, WA.

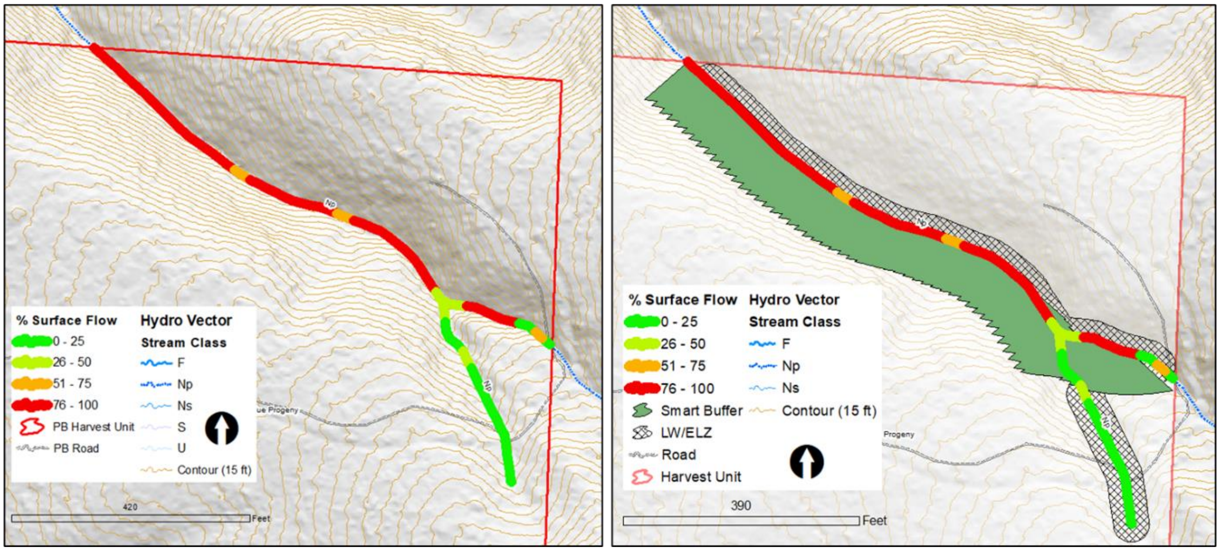

Figure 3. Summer surface flow distribution (left) and zone of effective shading (green polygon; right) in relation to stream reaches with contiguous surface flow. Right panel also includes potential RMZ for large wood (LW) and equipment limitation zone (ELZ)

Field Methods

Measuring Effective Shade

Digital hemispherical photography (DHP) will be used to measure canopy closure and estimate solar insolation for each study site. The DHP will be collected during the summer low stream flow and leaf-on period (i.e., mid-July to mid-September). Hemispherical imaging is a time-tested and reliable method to quantify riparian canopy characteristics which can produce accurate and repeatable estimates of stream solar exposure (Davies-Colley and Payne, 1998; Ringold et al., 2003). For the purpose of this study, our analysis will focus on three metrics; canopy closure which is calculated directly from canopy imagery, direct-beam radiation, and effective shade which will be calculated as the ratio of direct-beam solar radiation below the canopy to direct-beam solar radiation above the canopy. The Gap Light Analyzer (GLA) imaging software (Frazer et al. 1999) will be used to extract gap light transmission data for computing shade metrics for the mid-day period of August 1st (see Designing Smart Buffers). Shade estimates for this date/time are less affected by topography and more related to light attenuation by riparian vegetation given the high sun angle (ranges 47° to 60°).

Hemispherical photos will be collected in the mainstem and all tributary channels that occur within the harvest unit. Canopy images will be collected at a height of 1.5 m (5 ft) above the stream bed in the center of the channel. This camera elevation provides an image of the forest canopy and minimizes view-obstructions by shrubs. In the mainstem channel, photos will be taken at 50-m (164-ft) intervals; starting at the lower end of the harvest unit boundary (i.e., distance 0 m) and consecutively upstream, and ending at either the upper harvest unit boundary or perennial initiation point (PIP). In tributaries, photos will be taken at 50-m intervals, starting at 50 m upstream of the tributary/mainstem junction and ending at either the upper harvest unit boundary or PIP. Camera settings and methods will follow the new pixel thresholding method developed by Zhao and He (2016) that provides an optimal threshold value for separation of sky and plant pixels. Photos will be taken during time periods to avoid glare. Canopy images will be collected with digital camera with a high-quality sensor and hemispherical lens (not fisheye) that captures a 180-degree angle of view. The camera will be mounted on a monopod with self-leveling and stabilizer.

Because the DHP is labor intensive and best suited for research, we also plan to measure shade at each photo station using a spherical ACD (angular canopy density) meter (Teti 2001) which is a simple user-friendly device that provides estimates of effective shade that are comparable to DHP (Teti and Pike, 2005). Our intent is to evaluate the practicality and utility of using the ACD meter for potential future use by forester.

A hip-chain will be used to establish photo stations at 50-m intervals. Each camera station will be flagged and GPS coordinates will be recorded with a high-accuracy GPS receiver (e.g., Trimble R-1).

Temperature Monitoring

Water and air temperature monitoring will occur during the summer season (June 1 to September 30) during the pre- and post-harvest study periods. Temperature will be measured with temperature sensors having an accuracy of less than or equal to ± 0.5° C and with a precision of ± 0.1°C. The accuracy of all sensors will be examined with a National Institute of Standards and technology certified thermometer before and after each monitoring season.

A minimum of two sensors will be located within the lower portion of the Np study reach. One sensor will be placed at or close to the downstream end of the study reach and a second one will be placed 50 m (150 ft) upstream. This location scheme provides: 1) potential to detect and correct for temperature anomalies due to spatially variable temperature (e.g., groundwater input) within the lower Np zone of response, and 2) redundancy in case we have a faulty or dewatered sensor. Ambient air temperature will be monitored at the 50-m point and located 1 m (3 ft) above the stream-bank elevation. This sensor will provide local ambient air temperature which is an important factor influencing water temperature and will help in evaluating stream thermal sensitivity to changes in shade.

If the harvest unit is located on an Np stream reach with unharvested timber and stream flow upstream, a third sensor will be located just upstream of the unit within the unharvested stand. Similarly, if more than one channel with flowing water enters the study area from outside the unit, a sensor will be located in each stream. Knowing the temperature of incoming water will enable us to determine the change in temperature as it flows through the study reach.

Sensors will be placed in the main channel (most flow) where there is complete mixing and installed just above the channel bed. Water temperature sensors will be secured inside a 5-cm (2”) diameter PVC pipe to minimize temperature bias from exposure to direct solar radiation (e.g., after harvest). The air temperature sensor will be deployed in a housing that functions as a solar shield and rain protection while still allowing free flow of air to the sensor (Holden et al. (2013).

Physical Characteristics

Data on the physical channel characteristics, spatial patterns of flow/dry channel, and the proportion of channel covered (obscured) by debris/log-jams will be collected during the low-flow period each year of study. Channel bank full width (BFW) will be measured (nearest 0.05 m) at each photo station. Flow type, wetted width, debris-obscured bed, and substrate will be classified within 10-m (33 ft) segments in between each photo station. Surface flow within each 10-m segment will be classified into one or more of the following four categories: obscured, unbroken surface flow, saturated flow, or dry (Hunter et al. 2005). The proportions of segment length within each category will be estimated to nearest 10% (i.e., sum of obscured and flow type proportions = 100% of segment length). The obscured category applies where the stream bed or flow type is not visibly discernable because of coverage by dense slash, debris jams, or stream is subterranean. Flow types will be classified within the unobscured (stream bed visible) portion of the 10-m segment. Unbroken surface water is defined as any continuous water surface unbroken by mineral substrate (typically pools or narrow riffles); saturated includes any discontinuous wet surface broken by substrate; and dry where neither applies. Three wetted widths will be measured (nearest 0.05 m) within each 10-m segment, but only if and where the unbroken flow type occurs. These data will be used to calculate an average width for the unbroken flow type.

The dominate and sub dominate substrate composition within the unobscured portion will be classified as: fines/sand, gravel, cobble, and boulder/bedrock. Dominant substrate refers to the size category that covers the greatest proportion of bankfull channel area and subdominant is the category with second-most coverage.

Riparian Timber Stand Composition

An inventory of riparian timber stand composition will be performed using the strip-plot method developed by Marquardt (2010). Marquardt (2010) examined several methods and found that rectangular strip plots out performed several different inventory methods for estimating BA and density in riparian stands. Also, they found that narrow-width plots (i.e., 12-ft wide) performed better than wider plots and that a 10% sample provided a good estimate of riparian stand characteristics. Given these findings a 12-ft wide by 75-ft long strip plot (horizontal distances) located perpendicular to the channel on each side is proposed for our inventory. The 75-ft plot will be subdivided into three subplots (i.e., 0-25, 25- 50, 50-75) to provide estimates of stand variability with distance from the stream. The number of plots will be based on a 10% sample of the study reach length within a harvest unit. Plots will be equally spaced along the study reach. Measurements of species, DBH, total height, and live crown height will be taken from all live trees ≥ 6” dbh.

Data Analysis

Shade Treatment Effects

The primary objective is to evaluate any change in shade that can be attributed to harvest impact. The magnitude of the pre- to post-harvest shade impact will be estimated using a statistical model predicting shade at each sampled location as a function of a fixed effect of treatment period (pre, post year 1, post year 2) and a random reach effect to account for repeated measures within sites. Standard diagnostics of residuals from this model will be used and transformations performed as necessary. The relative importance of treatment effect in describing differences in shade will be evaluated using small sample AIC methods (Burnham and Anderson 2002), and the magnitude of the treatment effect will be estimated with confidence intervals.

Temperature

Estimates of temperature treatment effects will be based on statistical models similar to those used by Gomi et al. (2006). Reference reaches appropriate to each study reach will be selected based upon the fit of pre-treatment regression models predicting summer maximum daily temperature at treatment reaches from maximum daily temperature at reference reaches. Following Gomi et al. (2006) generalized least-squares regression will be used to model autocorrelation among daily measurements in all models. An additional model component for within-year temperature trends may also be included in the model, depending upon the stationarity of residuals from initial model fits. For example, there may be a linear increase in daily max from June through August, or the trend may be curvilinear. The autocorrelation structure and form of the model will then be used to predict all observations (i.e., including post-harvest observations) with the addition of a fixed effect for treatment period (pre-, post year 1 and post year 2). The improvement to model fit over the model with no treatment effect will be assessed using small sample AIC methods. The magnitude of pre to post-harvest temperature changes will be reported with confidence intervals.

Environmental Predictors of Shade and Temperature

Following Groom et al (2011), we will fit a limited set of a priori models predicting shade retention from environmental and physical reach covariates including basal area, tree height, crown ratio, tree density, buffer width, and channel orientation. As for the treatment effect, a random effect of reach will be included to account for correlation of measurements within reaches, and the treatment period will also be included as a covariate in the full (overfit model). Residuals will be tested for adherence to assumptions and transformations or revised modeling approaches will be used if necessary.

We will also evaluate the environmental and physical factors that best predict summer maximum stream temperature conditions in these stream reaches using statistical models. One approach will be to model daily maxima using generalized least squares modeling to account for autocorrelation. Another approach will be to average summer daily maximum temperatures and predictors to provide one sample per reach per year, following Groom et al (2011). The daily temperature approach can allow for more precision in results, but the autocorrelation can be difficult to fit well. Since most predictors will not have daily values, the annual average approach may provide clearer results. Predictors for the temperature model will include shade, air temperature, surface flow extent, and substrate size composition.

Implementation Schedule

The implementation schedule (Table 3) lists project tasks and activities during 2019 through 2022; including one or two years of pre-harvest and two years of post-harvest monitoring. Data collected during pre-harvest will be used to inform the development of smart buffer designs during late summer 2020. Unit harvesting and treatment implementation is scheduled for the late fall and winter period of 2020 – 2021 pending approval of FPAs. An evaluation of early response trends in temperature and shade will be developed during winter 2022 and a final report of the two-year post treatment findings will be prepared in late 2022. Continued monitoring after 2022 may occur pending funding and study findings.

Table 3. Implementation schedule.

Year	Period	Task
2019	Jun - Sep	Temperature monitoring
	Jun - Sep	Shade and stream channel survey
	Oct - Dec	Data processing
2020	Jan - Feb	FPB draft proposal and petition
	Mar - Apr	Finalize study design
	Apr - May	Submit AMP proposal and pilot rule petition
	Jun - Sep	Temperature monitoring
	Apr - Jul	Riparian plot survey
	Jul - Aug	Shade and stream channel survey; data processing
	Aug - Sep	Collaborate and design proposed site-specific treatments
	Sep - Oct	Companies submit FPA with alternative prescriptions
	Nov - Dec	Implement smart buffer treatments
2021	Jan - Apr	Implement smart buffer treatments
	Jan - Apr	Pre-treatment data processing
	Jun - Sep	Temperature monitoring
	Apr - Jul	Riparian plot survey
	Jul - Aug	Shade and stream channel survey
	Oct - Dec	Post-treatment data processing
2022	Jan - Feb	Access effectiveness of smart buffer treatments
	Feb - Mar	Prepare initial findings progress report
	Apr - Sep	Repeat monitoring and surveys
	Oct - Dec	Analyses and final reporting

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