# Extensive Riparian Status and Trends Monitoring Program-Stream Temperature Phase I: Eastside Type F/S Monitoring Project
# Final Report

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WASHINGTON STATE DEPARTMENT OF
**Natural Resources**
Peter Goldmark - Commissioner of Public Lands

Cooperative Monitoring
Evaluation & Research

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**Washington State Forest Practices Adaptive Management Program**
**Cooperative Monitoring, Evaluation, and Research Committee (CMER)**
**Report**

# Extensive Riparian Status and Trends Monitoring Program-Stream Temperature Phase I: Eastside Type F/S Monitoring Project Final Report


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**Prepared for the**

**Cooperative Monitoring, Evaluation, and Research (CMER) Committee**
**Washington State Forest Practices Board**
**Adaptive Management Program**
**Washington State Department of Natural Resources**
**Olympia, WA**


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**Washington State Forest Practices Adaptive Management Program**

The Washington State Forest Practices Board (FPB) has established an Adaptive Management Program (AMP) by rule in accordance with the Forests & Fish Report (FFR) and subsequent legislation. The purpose of this program is to:

> *Provide science-based recommendations and technical information to assist the FPB in determining if and when it is necessary or advisable to adjust rules and guidance for aquatic resources to achieve resource goals and objectives. The board may also use this program to adjust other rules and guidance.* (Forest Practices Rules, WAC 222-12-045(1)).

To provide the science needed to support adaptive management, the FPB established the Cooperative Monitoring, Evaluation and Research (CMER) committee as a participant in the program. The FPB empowered CMER to conduct research, effectiveness monitoring, and validation monitoring in accordance with WAC 222-12-045 and Board Manual Section 22.

**Report Type and Disclaimer**

This technical report contains scientific information from research or monitoring studies that are designed to evaluate the effectiveness of the forest practices rules in achieving one or more of the Forest and Fish performance goals, resource objectives, and/or performance targets. The document was prepared for the Cooperative Monitoring, Evaluation and Research Committee (CMER) and was intended to inform and support the Forest and Fish Adaptive Management program. The project is part of the Type F Riparian Prescriptions Rule Group Extensive Riparian Status and Trends Monitoring Program, and was conducted under the oversight of the Riparian Scientific Advisory Group (RSAG).

This document was reviewed by CMER and was assessed through the Adaptive Management Program's independent scientific peer review process. CMER has approved this document for distribution as an official CMER document. As a CMER document, CMER is in consensus on the scientific merit of the document. However, any conclusions, interpretations, or recommendations contained within this document are those of the authors and may not reflect the views of all CMER members.

**Proprietary Statement**



**Full Reference**

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# Executive Summary

We used a probability sampling design to sample maximum stream temperature and canopy closure on Type F streams on land managed under the Forest Practices rules in eastern Washington. Four hundred seventy-one sites were evaluated (Figure 2) for use in the study. Sites were drawn sequentially to maintain spatial balance, and screened with high- resolution orthophotos to establish candidate sites. Parcel ownership was determined from county tax records. As permission to access the sites was obtained, sites were sampled until we reached a total of 50 sites which were monitored over the summers of 2007 and 2008.

Two difficulties encountered during the implementation were:

1. Nearly 33% (155) of the 471 sites evaluated were non-target waters, i.e. were not Type F streams.
2. Very low participation rates from small forest land owners. We obtained access to only 1%, 3 of the 295 sites evaluated, on small forest land owner property.

Cumulative distribution function (CDF) plots with 95% confidence limits are presented and the estimated 25, 50, and 75% CDF values for stream temperature are presented in tabular form.

In spite of the difficulties in implementation, the design was sensitive enough to detect a difference in the regional stream temperature distribution between 2007 and 2008 due to higher summer air temperatures in 2007.

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# Introduction

Several decades of stream temperature research have shown forest streams can be thermally sensitive to forest management (Brown and Krygier, 1970; Moore et al., 2005a). Stream temperature response to forest management has, however, not always been predictable (e.g., Groom et al., 2011). For example, temperature response drivers are believed to differ by stream order, with influence of riparian shade decreasing as channel width increases (e.g., Poole and Berman, 2001; Webb et al., 2008). Stream temperature is affected by several interrelated factors in addition to canopy cover. These can vary widely across the landscape (e.g. aspect, bankfull width, wetted width, depth, elevation, groundwater input, hyporheic flow) and may only be indirectly affected by forest practices (stream flow and air temperature) (Hewlett and Fortson, 1982; Bilby, 1984; Beschta et al., 1987; Webb and Zhang, 1999; Poole and Berman, 2001; Isaak and Hubert, 2001; Johnson, 2004; Moore et al., 2005b).

Washington state regulates forest practices within riparian buffers in order to limit the loss of canopy cover and mitigate the effects of forest harvest on stream temperature. Several studies are currently underway to evaluate the effectiveness of riparian buffer requirements on westside non fish-bearing streams (Hayes, et al. 2006, Ehinger, et al. 2011) and on eastside fish-bearing streams (Light, et al. 2003). This study is intended to provide a landscape-level assessment of the status of temperature of Type F/S streams on forest lands in eastern Washington. These data will complement the effectiveness monitoring projects and enable the state to estimate the proportion of streams meeting specific water quality criteria.

We use a probability sampling design to provide a robust statistical inference to the landscape or regional scale. Probability sampling also offers a consistent approach to sampling statewide resources (e.g., Overton et al., 1990; Diaz-Ramos et al., 1996). To date, sampling of water temperature and canopy cover condition in Washington state has not been sufficiently comprehensive to characterize stream temperature on the millions acres of private and public forest lands .

## *Context for Extensive Monitoring and Adaptive Management*

In 2001, the Washington State Forest Practice Board (WFPB) approved a comprehensive set of new forest practice rules (WFPB, 2001), based on the Forest and Fish Report (FFR, 1999), to regulate forest management activities on non-federal forest lands (This does not include state or private forest land managed under an approved Habitat Conservation Plan.) using principles of adaptive management. These rules were intended to:

- Provide compliance with the federal Endangered Species Act for aquatic and riparian-dependent species on non-federal forest lands.
- Restore and maintain riparian habitat on non-federal forest lands to support a harvestable supply of fish.
- Meet the requirements of the federal Clean Water Act (1977) for water quality on non-federal forest lands.
- Keep the timber industry economically viable in Washington State.

The Forest and Fish Report calls for both effectiveness and trend monitoring to inform the adaptive management program, with a 10-year time window to begin to assess water quality trends. A monitoring framework was developed (Benkert, et al., 2002) to guide FFR monitoring and research efforts at different spatial scales. The recommendations included:

*Prescription monitoring* - reach or harvest unit scale monitoring to evaluate the effectiveness of individual FFR prescriptions under a range of different physiographic conditions and evaluate alternative treatments for meeting resource objectives.

*Intensive monitoring* - watershed scale monitoring designed to address the cumulative effects of multiple forest practices and biotic effects by conducting concentrated monitoring and research efforts in a single location.

*Extensive monitoring* **-** landscape scale monitoring to estimate the current status and future trends of key indicators of input processes and habitat conditions statewide.

The WFPB also formally established the Cooperative Monitoring, Evaluation, and Research Committee (CMER) to provide scientific expertise to guide the adaptive management process. The adaptive management feedback loops are informed by three additional monitoring tiers (e. g., Noss and Cooperrider, 1994; Stadt et al., 2006 (Figure 1)):

- *compliance*[1] evaluates consistency between rules and management actions
- *effectiveness* evaluates whether resource conditions are achieved
- *validation* relates biotic response to management action (Noss and Cooperrider, 1994; Lindenmayer and Franklin, 2002)

The Extensive Riparian Status and Trend (ERST) program is an implementation of extensive and effectiveness monitoring[2].

## Purpose

The purpose of the ERST monitoring program is to:

- provide data needed to evaluate landscape-scale effects of implementing the FFR forest practices riparian prescriptions, and
- provide data needed by regulatory agencies to evaluate progress toward meeting Clean Water Act requirements and riparian resource objectives.

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[1] Only validation monitoring establishes causality

[2] Establishing causality is necessary to close the feedback loop between data and policy, but establishing causality is not the role of effectiveness monitoring. Appropriate hypotheses for a causal approach would be: H1- *Water temperature regimes across landscapes will be altered by forest practices in Washington state?* or H2- *By what mechanism are these changes in temperature being propagates from the landscape to the stream?* Instead this question is being evaluated: *Are water temperature regimes changing?*

## Program Organization

The ERST monitoring program is organized into four separate projects (Appendix A) and two phases. The projects stratify Washington state by geographic region (eastside/westside) and by stream type (Type F/S—fish-bearing, Type Np—perennial non fish-bearing). The phases refer to the status (Phase I) and trend (Phase II) components of the monitoring design.

## Goals and Objectives

The goal of the four projects in the ERST monitoring program is to document the status and trends of key resource condition indicators, and specifically to seek to provide unbiased estimates of two key riparian indicators—water temperature and riparian canopy cover—for Type F/S and Type Np streams within lands regulated as FFR lands.

This report summarizes results of Phase I for eastside Type F/S streams. The objectives are threefold:

- Describe the frequency distribution of water temperature metrics (maximum summer stream temperature and 7-day mean maximum daily water temperature) and canopy cover in fish-bearing streams on FFR lands in eastern Washington.
- Estimate frequency distributions of several descriptive non-temperature variables.
- Provide the data with which Ecology can compare current and future stream temperature conditions.

# Methods

## *Study Design*

In 2006, a Generalized Random Tessellation Stratified (GRTS) survey design for a linear resource was used to establish a statewide probability master sample[3] (Table 1)[4]. See Appendix B for a discussion of the survey design. To optimize flexibility, no multi-density categories, over sample, panels, or stratifications were imposed. Only reverse hierarchical ordering was retained (applied simultaneously statewide) so that any consecutive subset of sites is spatially balanced. For the master sample, both inclusion probability and survey design weight are approximately 1.0 (i.e. expected master sample size approximately one site per km of stream length in the sample frame[5]). Each sample site consists of a latitude-longitude coordinate pair along a Type F/S stream.

In 2007, the master sample was partitioned to meet the selection criteria for a target lands domain[6] in

[3] The master sample consists of approximately 380,000 points, drawn by EPA from compiled 1:24k stream coverages at the WRIA scale. For a summary of probability sample features see Appendix B.

[4] See table for hydrography layer definition. National Hydrographic Data and FRAMEWORK layers were rejected as either subsets of the hydrography of interest, or as not containing suitable stream classification fields.

[5] A sample frame consists of a list, map, or other description of the units of the population to be sampled. (OECD, http://stats.oecd.org/glossary/about.asp).

[6] the target domain is used to describe the spatial extent of the target population, or ‘the set of elements about which information is wanted and estimates are required (OECD, http://stats.oecd.org/glossary/about.asp)

eastern Washington (Table 1) (hereafter referred to as the target lands domain). This target lands domain (i.e. land regulated under the Forest and Fish rules) was defined by four criteria:

- Forested land cover, (based on USGS LandSat-derived 'Forest Land' classification)
- Not federally-owned
- Not part of a Habitat Conservation Plan
- Not included in an Urban Growth Area

Forested land not explicitly excluded by one of the last three criteria was considered part of the target lands domain and any Type F/S streams within the domain were candidates to be sampled.[7]

Several GIS coverages, as available in 2007, were merged and filtered to construct the target lands domain. These included a coverage describing lands that Forest Practices regulates well as Washington state legal cadastral data (personal communication, J. Black). The CMER lands coverage (http://www.dnr.wa.gov/Search/Results.aspx?k=cmerlands ) was itself a product of several coverages:

- Forest lands (USGS Land use land cover)
- Federal and tribal lands (Washington DNR major public lands)
- HCP lands (USFWS)
- Urban growth areas (U.S. Census (Tiger))

The target lands domain includes three ownership classes:

- private industrial timberlands (IND),
- private small forest landowner (SFLO), and
- non-federal public lands (PUB)

Hydrographic length of streams classified as Type F on the hydro layer was calculated, taking into account partitioning to the target lands domain. The result was 7224 potential sampling sites (i.e., a sample frame length of 7224 km) on Type F/S surface waters (Table 1). Greater than 90% of the hydrographic length and associated sampling sites corresponded to modeled water sub-type F1 (Table 2). Because stream temperature is an issue in all streams, regardless of size, no stratification by stream size or Strahler order (Horton, 1945; Strahler, 1957) was imposed. Probability of a stream reach of any specific order being selected was thus in approximate proportion to stream order occurrence in the hydrographic layer.

To achieve a base sample of 50[8] sites, four hundred seventy-one sites were evaluated (Figure 2) for use in the study. Sites were drawn sequentially to maintain spatial balance, and screened with high- resolution orthophotos to establish candidate sites. Parcel ownership was determined from county tax records.

[7] Imperfections in stream classification in the hydrologic layers result in a list of candidate sites consisting of a mixture of both target and non-target sites. The target population is thus typically a sub-set of the candidate sites.

[8] To balance level of precision and sampling effort, GRTS designs often are variations on sampling 50 sites. This equates to +/- 10% precision and 90% confidence. Sample size is to some degree design dependent and can either be established prior to the sample draw and used to fix design factors, or open-ended and determined by adequate representation of sub-populations or strata (see http://www.epa.gov/nheerl/arm/surdesignfaqs.htm#manysamples). Alternative ways to gain precision and reduce effort such as repeated, year-over-year sampling using modest sized sequential random samples, are possible.

Landowner contact (i.e., permission to visit candidate sites) was made in person, where feasible, or by phone call or letter. Where public access was available some sites were first inspected to determine if the stream met the landuse and stream type criteria prior to contacting the landowner. Sites determined to be non-target (not Type F/S) waters in the sample frame, or on non-target lands (not forestry land use) were replaced by adhering to the GRTS sequence order and site replacement process. Seven categories of site replacement were observed (Table 3) and are discussed later.

If permission to access was granted, a hand-held GPS device was used to navigate to the site coordinates, the location was monumented with a semi-permanent marker driven into the soil near the stream, the marker flagged, and relationship of the marker to the stream sample point described. Later, a second crew installed temperature monitors and record the non-temperature variables (see below).

## Assumptions and Constraints

A number of assumptions were made regarding the target population, how it was identified, and the indicators measured. Some apply to GRTS, in general, and others, specifically to this study.

Assumptions

GRTS[9]

- Landowner class does not influence response.
- Spatial balancing variable (hydrography) is correlated with response.
- Excluded sites have the same statistical properties as monitored sites (i.e., missing completely at random).
- Indicators integrate the disturbances being assessed.
- Biologically-meaningful trends (Phase II) are detectable, over implementation timeframes.

ERST

- Errors in hydrography and water typing are recognized and corrected to the extent possible.
- The sample describes landscape-scale variability.
- Streams listed at Type F on the hydrolayer that met the physical criteria for fish-bearing streams, were Type F streams. We did survey streams to verify stream type.
- Variability can be adequately quantified by GRTS probability approach.
- Meaningful (to regulatory community) changes in stream temperature regimes, driven by forest practices, will be expressed as changes in maximum temperature.
- Changes in stream temperature driven by forest practices are large enough to be detected.[10]

Known Constraints

- Hydrography is of variable density (updated for forest lands (Table 1)). National Map Accuracy Standard is ± 12.19 m (40 ft). Source scale is 1:24,000.

[9] See Appendix B

[10] At least three views of stream temperature drivers are possible: a) anthropogenic disturbances such as logging practices dominate; b) natural causes dominate; c) the preceding two causes contribute equally. ERST however is not intended to establish causality.

- The sample frame changes over time. Hydrography is continuously updated thru the Timber, Fish, and Wildlife Agreement water type modification process. In any given year, the modifications represent a very small proportion of the entire fish-bearing network, but over several decades, the change could be substantial.
- Fish presence /absence breakpoints were derived from a mix of model predictions, fish presence/absence surveys, and previous water type classification. The modeling approach was DEM-based logistic regression. Derived terms include gradient, elevation, and average annual precipitation. Source DEM: USGS, 10 m (origination year 2000).

## *Variables measured*

This study considered a subset of stressor variables with special emphasis on water temperature and riparian canopy cover. Water temperature is one of the most commonly violated water quality standards in Washington State (Butkus, 2002) and riparian shade (via riparian buffer requirements) is the regulatory means of meeting Forests and Fish targets for stream temperature. Other non-temperature variables were also measured or derived to provide context for the water temperature results and are described below.

## Non-Temperature Variables

GIS-derived variables

Three study variables−elevation, basin area, and basin slope, were GIS-derived from readily available statewide, public data. These provide background for the temperature and habitat results (see below) from the base sample (*n* = 50 sites). Definitions for these variables and their source GIS layers are in Table 5.

Measured variables

A limited survey was undertaken to quantify several easily-measured descriptors of study reaches (Table 5). Study reaches were evaluated using six transects, each perpendicular to stream flow and equal in length to its associated bankfull channel width, at upstream distances of 0, 60, 120, 180, 240, and 300 m relative to the established downstream temperature-monitoring station. Methods were adapted from Peck et al. (2003) and Schuett-Hames et al. (1999a, 1999b), and simplified for efficiency, ease of use, and repeatability.

Eleven variables were measured: 1) bankfull width, 2) wetted width, 3) wetted depth, 4) channel gradient, 5) channel aspect, 6) riparian canopy closure, 7) thalweg depth, 8) $LWD_{downed}$, 9) $LWD_{suspended}$, 10) $LWD_{jams}$, and 11) riparian overstory type. Variables 1-7 were included to assess reach-scale correlation with temperature. LWD recruitment is a Forests and Fish resource objective and so was also measured and reported. Overstory type provides a categorical backdrop for other results. Year of data collection was 2007. These are referred to hereafter collectively as habitat variables.

## Temperature Variables

Stream temperature was measured at 30-minute intervals at the upper and lower end of each 300 m reach with *in situ* Tidbit data loggers (Onset Computers, 2004) using the methods described in Schuett-Hames et al. (1999a). Data loggers were attached to iron rebar driven into the stream bed then suspended in the water column using zip ties and shielded from direct sun using perforated white PVC tubing. The intent was to install all temperature data loggers by June 30, 2007[11] in order to observe each stream's annual thermal peak. However, at some sites installation of data loggers was delayed until mid-July (Figure 3) so it is possible that the 2007 thermal peak was missed at some sites

During installation of the stream temperature data loggers, air temperature data loggers were deployed adjacent to the lower monitoring station, approximately 30cm above the water surface, when possible, and shielded from direct sun (Schuett-Hames et al., 1999). Height and distance from the stream varied when necessary to protect the data logger from direct sun.

Data were downloaded in September 2007. To obtain a more complete record of the July-August temperature monitoring period, data loggers were immediately redeployed after downloading and remained in place until retrieved in September 2008.[12]

Temperature metrics were calculated for those sample sites with at least 30 days of data over the period July 1 through August 31 (Appendix E). Metrics for water were:

- maximum water temperature (Tmax, upstream and downstream),
- maximum seven-day average of daily maximum temperature (7Tmax, upstream and downstream),
- temperature change along reach (downstream minus upstream) for Tmax as (D_Tmax), and
- temperature change along reach (downstream minus upstream) for 7Tmax (D_7Tmax).

Metrics for air were:

- maximum air temperature (air_Tmax), and
- maximum seven-day average of daily maximum temperature (air_7Tmax)[13].

## Quality Assurance

Prior to deployment, temperature loggers were compared to a National Bureau of Standards (NBS) thermometer at 0 and ~18 °C. Monitors outside the manufacturer's specified tolerance (0.2 °C for water temperature, 0.4 °C for air temperature) were replaced.

[11] Gaining permission to access sites was slow so temperature data loggers were still being deployed the third week of July, 2007 (Figure 3). To better target the annual critical thermal period, a second year of data was collected.

[12] GRTS design allows repeated measures. Because the panel is fixed (i.e., no year-over-year change in sites) the panel is analogous to a traditional study's control. Differences between successive continuous distribution functions (CDFs) estimate year-to-year variation.

[13] Maximum stream temperature is a logical starting point in ERST investigations because the 7-day average maximum water temperature is used to express state water quality standards for temperature and because stream temperature is the most commonly violated water quality standard. ESRT studies can however be keyed to other criteria.

During the study data loggers at several monitoring locations were exposed to the air as water level dropped or the streams dried. These data were identified and excluded from analysis. First, field notes were used to flag sites and general time periods when specific data loggers may have been exposed. Second, both water and air temperature data for each site were examined to determine the date and time when a data logger may have become exposed. Typically, both upstream and downstream water temperature records were closely correlated. As a submerged data logger becomes exposed to the air, the water temperature record, especially daytime temperatures, more closely track air temperature. Because of the typically large difference between afternoon air and water temperature, it was usually apparent when the data logger became exposed. In cases where full or partial exposure of a data logger was indicated, the affected data were excluded from the analysis. For a summary of major data gaps, see Appendix E (Tables E1, E2). Full data filtering procedures are documented in the study quality assurance plan, Ecology publication #10-03-105; http://www.ecy.wa.gov/biblio/eap2010.html.

# Analysis

Statistical and Analytical methods where based on those of the Environmental Protection Agency's (EPA) Environmental Mapping and Assessment Program (EMAP) (Peck et al., 2003).

## *GRTS Design*

Two of the categories of site replacement were significant to the sampling:

a) No response from landowner (NR). This was highly skewed toward small forest landowners rather than the industrial or public landowners. This unintended stratification changed the study design from equi-probability to variable-probability (see below). As this was not determined until after sampling, an alternative form of the Horvitz-Thompson π-weighted estimator (Horvitz and Thompson, 1952; Thompson 2002) was incorporated during analysis to adjust initial weight for stratification by ownership. The rationale to account for potential biases introduced by differential loss of sites during evaluation—that is, loss other than completely at random - is described by Stevens and Jensen (2007).

b) Non-target (other) waters (OW). Nearly 33% of the sites' water type classification was incorrect (e.g. stream was not Type F/S). This exerted a moderately uniform effect (18-38% total sample) across ownership classes (Table 4).

As a consequence, adjustment of site weights and a step-wise approach taking into account various assumptions (see remainder of report, below) was incorporated in the analysis.

## *Temperature and non-temperature variables*

Data for the analysis was summarized from the July 1-August 31st period in 2007 and 2008. This period corresponded to the regional annual thermal peak and to minimum annual stream discharge, conditions under which stream temperatures were expected to be at maximum.

Results were calculated using the GRTS spatial survey design and analysis package (*spsurvey*, v. 2.2; Kincaid and Olson, 2011) and the accessory package *sp* (Pebesma and Bivand, 2011). This package provides overview, survey design, and analysis for areal, finite, and linear resources, and also automates plotting and confidence band estimation by calling continuous distribution functions (CDF). Currently, these flexible, non-standard functions only exist for R, an open-source implementation of the S statistical language developed at Bell Laboratories. See Ihaka and Gentleman (1996) for the original published description of the R Project. For development of S, see Becker et al. (1988).

Initial per site weight for the sample domain and target population was 15.338. Final weights per site, taking into account post-sampling stratification by ownership and the number of sites of indeterminate status as target or non-target waters (i.e., site access not feasible) were:

- Industrial landowners (IND) = 33.781,
- Public ownership (PUB) = 34.944, and
- Small forest landowners (SFLO) = 58.008 (personal communication, P. Larson and T. Olson, E.P.A.).

Because SFLO were under represented in the sample, the weight assigned per site is much higher relative to the other landowner classes.

Latitude and longitude were transformed to Albers projection, spheroid Clarke 1866 (Snyder, 1987), consistent with the original sample draw. Transformation functions were called from *spsurvey*.

Results are reported as:

- CDFs and mean catchment-scale characteristics of base sample.
- CDFs and mean reach-scale characteristics of base sample.
- CDFs and associated mean temperature metrics.
- Pearson correlations between maximum-daily downstream temperature and habitat variables.
- Only sites with both downstream water temperature and air temperature were used for the correlations. Correlation *p*-values are reported as both Bonferroni-corrected and uncorrected for multiple comparisons.

The analysis pathway defines vectors for sites, sub-populations, design, and variables of interest, then calls functions to write results as percentiles and associated estimates and overall means, and plots CDFs. Confidence bands are reported in figures at the 95% level. While mean values are more intuitive to resource managers, they may be biased. The percentile estimates are not biased. Both are reported for the reader.[14].

The function, *cont.cdftest*, with *spsurvey* (R package) was used to compare temperature CDFs between years 2007 and 2008. The test statistic reported is Wald F, with associated *p*-value.

To evaluate the relationship of temperature results to regional climatic influences, the historical mean of daily maximum air temperature for July was downloaded for three sites in eastern Washington: Chewelah

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[14] Resource status estimators from GRTS-based designs remain unbiased in the presence of missing data if reported as percentiles or proportions of cumulative distributions. Estimators expressed as area, length or other quantities are biased (Diaz-Ramos et al., 1996).

(Stevens Co.), Pomeroy (Garfield Co.), and Winthrop (Okanogan Co.). These sites were selected because of close proximity to nearby FFR lands in northeast, southeast, and north-central Washington, and because of their long data record. The time period of these data was 1958-2008.

# Results

## *Non-Temperature Variables*

Overall mean percent canopy closure was 76% which included two sites with either burned or grassy riparian vegetation (percent canopy at each <10%). Range of percent canopy closure for the conifer, deciduous, or shrub riparian vegetation types were similar (Figure 5).

The GIS-derived catchment characteristics showed relatively narrow distributions (Table D1; Figure D1). An estimated 75% of catchment areas were less than 2800 ha (mean: 2751 ha). Seventy-five percent of downstream station elevations were less than 1300 m (mean: 844 m). Mean catchment slope was 4.8 % (SD: 1.7), increasing by about 1% at the 75% CDF value for the sample.

Habitat variables were also relatively uniform (Table D1; Figures D1, D2). Only channel gradient and counts of LWD jams had ratios of the 95% CDF to mean value > 2.5 (i.e., 2.5x the mean value). CDFs and summary statistics are compiled in Appendix D.

## *Temperature Variables*[15]

The median value for Tmax at the downstream locations was 16.7 $^{o}$C and 15.9 $^{o}$C in 2007 and 2008, respectively (Table 6; Figure 6). The 7Tmax values were slightly less with a median of 16.1 $^{o}$C and 14.9 $^{o}$C in 2007 and 2008, respectively. Water temperature in 2007 was slightly warmer at both the upstream and downstream sites, with the more pronounced difference at the downstream site. Mean 7Tmax was 0.7 $^{o}$C warmer in 2007 than 2008 at the upstream location ($p > 0.29$) and 1.30 $^{o}$C warmer at the downstream location ($p < 0.05$, Table 7).

The median D_Tmax, difference in Tmax between upstream and downstream monitors, was 0.4$^{o}$C in 2007 and 0.2$^{o}$C in 2008. D_7Tmax values, the upstream-downstream difference in the 7Tmax, were similar to D_Tmax with median values of 0.4°C and 0.2°C in 2007 and 2008, respectively. No significant difference ($p > 0.05$) between 2007 and 2008 was seen in either metric (Table 7).

Mean Air_Max was 1.7 °C higher ($p < 0.01$) in 2007 and mean Air_7Tmax was 1.8 °C higher ($p < 0$ .05) in 2007 than 2008 (Tables 6 and 7).

Air temperature data collected (1958-2008) from Chewelah, Pomery, and Winthrop show that 2007 was warmer than 2008 at all three locations and that July temperatures exceeded the 75percentile of the historical record at both Chewelah and Winthrop. The average maximum daily July air temperature at Chewelah, Pomeroy, and Winthrop ranged from 3.0 to 6.7 $^{o}$C higher in 2007 than 2008 (Figure 8).

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[15] CDFs for upstream 7Tmax, downstream 7Tmax, and D_Tmax were similar to the corresponding CDFs for Tmax and so are omitted to limit the number of figures.

Both Tmax and 7Tmax at the downstream location were significantly ($p < 0.05$) correlated with air temperature and canopy cover. Negative correlations were also observed between stream temperature and two measures of LWD, and a positive correlation was observed with catchment area. No other significant ($p<0.05$) correlations with stream temperature were observed.

# Discussion

## *Stream temperature*

In 2007, the observed landscape-scale, mean maximum daily stream temperature at the downstream stations was 16.7 °C (95% CI: 16.0-17.4 °C). In 2008, a climatically cooler year, mean maximum daily stream temperature at the same monitoring locations declined to 15.7 C (95% CI: 15.1- 16.4 °C). A Wald F test indicated a significant change in the CDF. Study reaches overall showed a tendency to be warmer in 2007 but no significant difference between years was seen in the in the CDFs of the degree of warming ($p > 0.05$). The intent of the study was not to tie climate to stream temperature, but results suggest a climatically warm year has the potential to influence average stream temperature by at least 1°C.

The finding that temperature metrics and descriptive non-temperature variables were generally uncorrelated suggests that upstream reaches may not have been characterized adequately, methods used to measure habitat variables may have been overly simplified, or that the metrics measured have little effect on stream temperature at the reach-scale. Again, the correlation of stream temperature with non-temperature variables was not a goal of the study. The analysis was requested by a reviewer during the project development.

## *Implementation*

The rate of site rejection was high relative to other studies (Hayslip, et al., 2004; Herger and Hayslip, 2000; Merritt et al., 1999). However GRTS designs allows rejection rates to vary. What is critical is that randomization and matching between spatial dispersion of the target population and the sample be maintained.

As the results show, GRTS offers robust methods permitting inference in the presence of errors to the sampling frame. However, both study design and scope of inference were weakened by unanticipated difficulties in implementation; the former by disturbance of the design-based spatial balance of the target population (Figure 9a), and the latter from bias introduced against sampling SFLO lands, which dominate the sample (Figure 9b). In this particular application of GRTS, the largest landowner class in the population (small forest landowners) rarely agreed to participate in the study (Figure 9b). Without re-sampling, complete correction is not possible. The remedy, in future efforts, is to replace excluded sites on an ownership-for-ownership basis until the target sample size is reached. However, if access to SFLO parcels is restricted, then access inherently constrains random sampling approaches to characterize Forest Practices regulated lands by GRTS methods or otherwise. A separate effort may be necessary to adequately sample SFLO lands. If the appropriate stratification is by ownership or management regime, approximate surrogates such as elevation do not really help. Also to consider is whether SFLO lands within the FFR lands domain meet the FFR land definition because many are mixed (forestry and agriculture) land use. However, this was beyond the scope of this project to evaluate.

Several other sources of uncertainty interfere with inference to the target population, but differ in their impact (Table 9). Misclassification of ownership, for example, can occur if parcels mix land uses (e.g. agricultural and forest lands), if parcels are undergoing transfer of ownership, or if gaps exist in the data derived from tax records. With careful review this error can be minimized. The impact on inference to a non-stratified target population would be slight. Misclassification of waters as Type N, or Type N waters as Type F, is also a possibility. This error, which can be introduced both before and during sampling, can alter the scope of inference. However its impact is also expected to be slight given on-site stream type evaluations. Potentially of much greater impact is inclusion of non-target waters in the sample frame (Table 3). This is likely to affect the length of stream within the sample frame rather than the areal extent of the sample frame. Conversely, how many Type F waters were excluded by the target population definition is unknown. No design can evaluate resource fractions excluded from sample frames.

Several analysis options for this study are possible, depending somewhat on underlying assumptions one is willing to accept (Table 9). Key in this study is whether the SFLO class is sufficiently unique in its management effects or position on the landscape to differ in the conditions of the stream and channel variables studied. If not, then the near complete non-participation by SFLOs can be overcome. That is, ownership is an irrelevant stratification imposed on an underlying uniform resource. However, differential loss of sites can also potentially disturb the underlying design-based spatial dispersion of the sample relative to the target population. Taken together, all ownerships combined (Figure 9a) might seem to approximate the distribution of the target population. Taken ownership by ownership, the impact of undersampling the SFLO class becomes apparent—near 100% loss of the majority lands class (Figure 9b). This population inference best applies to PUB and IND ownership classes.

Also of significance is how to treat the 161 sites of indeterminate target status because they could not be visited. Ratios derived from sampling can be used to estimate the proportion of indeterminate sites which are actually part of the target population. This is the route used to arrive at the final scope of inference.

Using the hydrologic definition developed from available linework for a sampling frame consisting of Type F/S streams on eastern Washington FFR lands (Table 2), the frame length was 7224 km (Table 9, Case 1). This assumed that all sites were target. However, sampling established that at least 155 sites in the sample were misclassified and were actually non-target (i.e.were misclassified as Type F/S). Accounting for these sites reduced the scope of inference (estimate of actual Type F stream kilometers) to 4747 km (Case 2). This would hold if there were no other cases of non-target sites in the sample. However, there were 161 indeterminate sites. Case 3 factors in these indeterminate sites by using ratios of target:non-target sites determined during the sampling to estimate the proportion of the full sample which are actually part of the target population. This reduces the scope of inference to 2284 km (Case 3). Case 4 takes the process one step further by incorporating stratification by ownership, i.e. uses analogous calculations to estimate the proportion of target sites by ownership class. The scope of inference for Case 4 is 1786 km, or approximately 25% of the original sample frame of 7224km. Case 4 can be viewed as a conservative estimate and GRTS allows that such stratification can be accounted for in calculations of inference.

# Conclusions

Study objectives were thus only partially met. CDFs were estimated for stream temperature, in-channel physical variables, and canopy cover. The estimate of kilometers of Type F/S streams was reduced from 7224 to 4747 km because of misclassified stream segments on the hydrography layer. Target population inference was reduced in scope to 1786 km due largely to lack of permission to access study sites on small forest landowner properties (Table 9). The scope of inference (1786 km of stream) is 37% of the estimated actual stream length and is weakened by lack of access to a large proportion of the target streams. Though the distinction between areal extent of the target population (eastside FFR lands) vs. length of target population (length of fish-bearing stream) should be noted, the scope of inference is a function of the underlying assumptions.

However, it is noted that GRTS, despite implementation errors, was sensitive enough to detect a shift in the regional stream temperature distribution due to higher summer temperatures in 2007.

## *Recommendations*

1. Better communication with and cooperation from small forest landowners will be needed to gain access to these streams in a timely manner.

2. Strict adherence to the site selection protocols during implementation.

3. EPA should guide the planning, implementation, and analysis of any future application of probability sampling to fully realize the potential of GRTS designs.

# References

Becker, R. A., J.M. Chambers, and A. R. Wilks. 1988. The new S language: A programming environment for data analysis and statistics. Wadsworth and Brooks/Cole, Advanced Books and Software. Pacific Grove, CA.

Benkert, K., B. Bilby, W. Ehinger, P. Farnum, D. Martin, S. McConnell, R. Peters, T. Quinn, M. Raines, S. Ralph, and D. Schuett-Hames. 2002. Monitoring design for the forestry module of the Governor's salmon recovery plan. http://www.dnr.wa.gov/Publications/fp_am_mdt_report_20020718.pdf

Beschta, R. L., R. E. Bilby, G. W. Brown, L. B. Holtby, and T. D. Hofstra. 1987. Stream temperature and aquatic habitat: Fisheries and forestry interactions. *In* E. O. Salo and T. W. Cundy (eds.), Streamside Management: Forestry and Fisheries Interactions. Institute of Forest Resources, University of Washington. pp. 191-232.

Bilby, R. 1984. Characteristics and frequency of cool-water areas in a Western Washington stream. Journal of Freshwater Ecology 2: 593-602.

Brown, G. W. and J. T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resources Research 6: 1133-1139.

Diaz-Ramos, S., D. L. Stevens, Jr., and A. R. Olsen. 1996. EMAP statistical methods manual. EAP/620/R-96/XXX. Corvallis, OR: U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory.

Clean Water Act. 1977. 33 U.S.C. § 1251 et seq. Amendment to Federal Water Pollution Control Act of 1972. USA.

Dent, L., D. Vick, K. Abraham, S. Schoenholz, and S. Johnson. 2008. Summer temperature patterns in headwater streams of the Oregon coast range. Journal of the American Water Resources Association 44: 803-813. doi: 10.1111/j.1752-1688.2008.00204.x

Ehinger, W., S. McConnell, D. Shuett-Hames, and J. Black. 2007. Draft study plan: Extensive riparian status and trend monitoring program. Prepared for CMER's Riparian Scientific Advisory Group.

Endangered species Act. 1973. 16 U.S.C. § 1531. et seq.

Environmental Protection Agency Office of Water, Washington, DC. 2010. TMDL program results analysis fact sheet No. EPA841-F-10-002.

FFR, 1999. Forests and Fish Report. April 29, 1999. Available online at: http://www.wa.gov/dnr/htdocs/fp/fpb/forests&fish.html

Groom, J. D., L. Dent, L. J. Madsen, and J. Fleuret. 2011. Response of western Oregon (USA) stream temperatures to contemporary forest management. Forest Ecology and Management 262: 1618-1629. doi: 10.1016/j.foreco.2011.07.012.

Hansen, M. H., W. G. Madow, and B. J. Tepping. 1983. An evaluation of model-dependent and probability sampling inferences in sample surveys. Journal of the American Statistical Association 78: 776-760.

Hayslip, G.A., L.G. Herger, and P. T. Leinenbach. 2004. Ecological Condition of Western Cascades Ecoregion Streams. EPA 910-R-04-005. U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

Herger, L.G. and G. Hayslip. 2000. Ecological condition of streams in the Coast Range ecoregion of Oregon and Washington. EPA-910-R-00-002. U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

Hewlett, J. D. and J. C. Fortson. 1982. Stream temperature under an inadequate buffer strip in the Southeast Piedmont. Water Resources Bulletin 18: 933-988.

Horton, R. E. 1945. Erosional development of streams and their drainage basins: hydro-physical approach to quantitative morphology. Geological Society of America Bulletin 56: 275-370.

Horvitz, D. G. and D. J. Thompson. 1952. A generalization of sampling without replacement from a finite universe. Journal of the American Statistical Association 47: 663-685.

Ihaka, R., and R. Gentleman. 1996. R: A language for data analysis and graphics. Journal of Computational and Graphical Statistics 5: 299-314.

Isaak, D. J. and W. A. Hubert. 2001. A hypothesis about factors that affect maximum summer stream temperatures across montane landscapes. Journal of the American Water Resources Association 37: 351-366. doi: 10.1111/j.1752-1688.2001.tb00974.x

Johnson, S. L. 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. Canadian Journal of Fisheries and Aquatic Sciences 61: 913-923.

Kincaid, T. and T. Olsen. 2011. Spatial Survey Design and Analysis, v. 2.2. Library for R.

Light, J., B. Conrad, W. Ehinger. 2003. Comparison of Standard F&F Eastside Riparian Prescriptions with No Shade Removal Within 75-ft Prescription (bull trout overlay) −Study Plan. The Bull Trout Scientific Advisory Group of the TFW Cooperative Monitoring, Evaluation, and Research Committee. Olympia, WA.

Lindenmayer, D. B., and J. F. Franklin. 2002. Conserving forest biodiversity: a comprehensive multi-scaled approach. Island Press, Washington, D. C.

Merritt, G., B. Dickes and J. S. White. 1999. Biological Assessment of Small Streams in the Coast Range Ecoregion and the Yakima River Basin. Washington State Department of Ecology, Environmental Assessment Program. Olympia, Washington Pub. No. 99-302.

.Moore, R. D., D. L. Spittlehouse, and A. Story. 2005a. Riparian microclimate and stream temperature response to forest harvest: a review. Journal of the American Water Resources Association 41: 813-834.

Moore, R. D., P. Sutherland, T. Gomi, and A. Dhakal. 2005b. Thermal regime of a headwater stream within a clear-cut, coastal British Columbia, Canada. Hydrological Processes 19: 2591-2608. doi: 10.1002/hyp.5733.

Noss, R. F. and A. Y. Cooperrider. 1994. Saving nature’s legacy: protecting and restoring biodiversity. Island Press, Washington D.C.

Onset Computers, 2004. 470 MacArthur Blvd., Bourne, MA 02532.

Overton, W. S., D. White, and D. L. Stevens, Jr. 1990. Design report for EMAP, Environmental Monitoring and Assessment Program. EAP 600/3-91/053. Corvallis, OR: U.S. Environmental Protection Agency, Environmental Research Laboratory.

Pebesma, E. and R. Bivand. 2011. Classes and Methods for Spatial Data, v. 0.9-83. Library for R.

Peck, D., A. T. Herlihy, B. H. Hill, R. M. Hughes, P. R. Kaufmann, D. J. Klemm, J. M. Lazorchak, F. H. McCormick, S. A. Peterson, P. L. Ringold, T. Magee, and M. Cappaert. 2006. Environmental Monitoring and Assessment Program-Surface waters: Western pilot study: Field operations manual for wadeable streams. EPA/620/R-06/003. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. http://www.epa.gov/wed/pages/publications/authored/EPA620R-06003EMAPSWFieldOperationsManualPeck.pdf

Poole, G. C. and C. H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanism of human-caused thermal degradation. Environmental Management 27: 787-802.

Schuett-Hames, D., A. E. Pleus, E. Rashin, and J. Matthews. 1999a. TFW Monitoring Program manual for the stream temperature survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. Rep. No. TFW-AM9-99-005. DNR # 107. Washington Dept of Natural Resources, Olympia, WA.

Schuett-Hames, D., A. E. Pleus, J. Ward, M. Fox, and J. Light. 1999b. TFW Monitoring Program method manual for the large woody debris survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. Rep. No. TFW-AM9-99-004. Washington Dept of Natural Resources, Olympia, WA.

Smith, T. M. F. 1976. The foundations of survey sampling: a review. Journal of the Royal Statistics Society, Series A 139, No. 2, pp. 183-204.

Snyder, J. P. 1987. Map projections—A working manual. U. S. Geological Survey Professional Paper 1395. 383 pp.

Stadt, J. J., J. Schieck, and H. A. Stelfox. 2006. Alberta biodiversity monitoring program: monitoring effectiveness of sustainable forest management planning. Environmental Monitoring and Assessment 121: 33-46.

Stevens, D. L., Jr. 1994. Implementation of a national environmental monitoring program. Journal of Environmental Management 42: 1-29.

Stevens, D. L., Jr. and A. R. Olsen. 2001. Spatially-balanced sampling of natural resources in the presence of frame imperfections. Joint Statistical Meetings, Atlanta, GA, August 2001.

Stevens, D. L., Jr. and S. F. Jensen. 2007. Sample design, execution, and analysis for wetland assessment. Wetlands 27: 515-523.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38: 913-920.

Thompson, S. K. 2002. Sampling. Wiley, New York, NY, U.S.A.

USGS. 2000. DEM factsheet 040-00. http://egsc.usgs.gov/isb/pubs/factsheets/fs04000.html

Washington Forest Practices Board (WPFB). 2001. Washington Forest Practices Rules, Board Manual, Forest Practices Act. Washington Department of Natural Resources. Forest Practices Division. Olympia.

Webb, B. W. , and Y. Zhang. 1999. Water temperatures and heat budgets in Dorset chalk water courses. Hydrological Processes 13: 309-321.

Webb, B. W., D. M. Hannah, R. D. Moore, L. E. Brown, and F. Nobilis. 2008. Recent advances in stream and river temperatures research. Hydrological Processes 22: 902-918. doi: 10.1002/hyp.6994

# Tables

Table 1: GIS layers and definitions used in development of the GRTS-based, statewide master sample drawn by U.S. EPA, NEERL, for Washington state in 2006, and its application to surface waters east of the Cascade Crest, Washington, characterized as Type F/S .

| Characteristic | Master Sample | Partition | |
|---|---|---|---|
| | | 1 | 2 |
| target population | all digitized streams and rivers | all digitized streams and rivers | Type F waters[d] |
| domain | statewide | Eastern Washington[b], FFR Lands[c] | Eastern Washington[b], FFR Lands[c] |
| sample frame | 1:24,000 linework[a] | same | same |
| hydrographic length, km | 387,235 | 37,428 | 7,070 |
| no. of sites | 387,237 | 37,695 | 7,224 |
| inclusion probability | ~1 (range 0.999-1.001) | -- | -- |
| hydrographic density | varies[e] | varies[e] | varies[e] |
| | | no. sites evaluated | 471 |
| | | initial weighting | 15.338 |

[a]WRIA and county shapefiles, as known 2005
[b]east-west dividing line, 1999 (DNR); revised and incorporated in forest practices rules, 2002
[c]result of combining CMER lands, state legal cadastral coverage, and other coverages, as known 2007
[d]forest practices model export (FP_MDLEXP_CD), Type F1-F8, as known 2006
[e]base linework: USGS 7.5 minute topo quads statewide; forest lands linework updated from aerial photography, 1990s

Table 2: Percent of total stream length within the target domain vs. percent of initial sample points, by waters sub-type, showing that after sampling proportions of Type F sub-types were largely preserved. Stream types were summarized from Washington hydrography GIS data. The target population was Type F/S waters within the FFR lands domain east of the Cascade Crest, Washington state.

| Sub-type | definition | % stream length, Eastern WA FFR Lands, Type F | % initial sample, Eastern WA FFR Lands |
|---|---|---|---|
| F1 | fish habitat | 91.7 | 92.5 |
| F2 | unmodeled; no DEM-to-stream match; field survey/former water type indicates fish use/habitat | 0.9 | 0.7 |
| F3 | interior arc of Type F impoundment | 1.6 | 1.5 |
| F4 | mapping anomaly such as irrigation canal; former water type indicated fish use/habitat | 0.2 | 0.2 |
| F5 | diversion waters or former Type 2 waters | 4.8 | 4.4 |
| F6 | fish use/habitat, added after type model implementation | 1.0 | 0 |
| F7 | model override; data indicate fish use/habitat upstream of modeled end-of-fish habitat | <0.1 | 0.7 |
| F8 | outside of modeled area; former water type was fish use/habitat | <0.1 | 0 |

Source: Metadata, Washington State Water Course Hydrography

Table 3: Counts and percentages of the evaluated sample ($n$=471) associated with reasons for rejection or inclusion as GRTS-derived, randomly selected stream temperature-monitoring sites. The target population was Type F/S waters within the FP regulated lands domain east of the Cascade Crest, Washington state. Data collected during initial implementation of Extensive Riparian Status and Trends, 2007.

| Reason code | no. of sites | % evaluated sample | Definition |
|---|---|---|---|
| ID | 28 | 5.9 | landowner not identified |
| LD | 11 | 2.3 | landowner declines |
| NR | 113 | 24.0 | no response from landowner |
| OL | 59 | 12.5 | other (non-FFR, non-forest) lands |
| OW | 155 | 32.9 | non-target (non-Type F) waters |
| TN | 48 | 10.2 | target not sampled |
| TS | 50 | 10.6 | target sampled |
| UK | 7 | 1.5 | reason for rejection unknown |
| Total | 471 | | |

Table 4: Summary of sites in the evaluated sample (*n*=471) by reason for rejection or inclusion, and by land ownership class, showing differential loss of sites in the SFLO class. The target population was Type F/S waters within the FFR lands domain east of the Cascade Crest, Washington state. Data collected during initial implementation of Extensive Riparian Monitoring and Trends, 2007.

| Reason code | | PUB | IND | SFLO | Note |
|---|---|---|---|---|---|
| ID | | 4 | 5 | 19 | |
| LD | | 0 | 0 | 11 | |
| NR | | 3 | 3 | 107 | Affects SFLO class, mainly |
| OL | | 15 | 5 | 39 | |
| OW | | 14 | 29 | 112 | Affects all ownership classes |
| TN | | 22 | 23 | 3 | |
| TS | | 21 | 26 | 3 | |
| UK | | 0 | 6 | 1 | |
| | Sum | 79 | 97 | 295 | |
| | % of sample | 16.8 | 20.6 | 62.6 | |
| | Success rate | 27% | 27% | 1% | |

Table 5: Definitions of catchment-scale and reach-scale non-temperature variables used by the Extensive Monitoring application of the statewide GRTS master sample to eastern Washington, 2007.

| Variable | Definition | Source | Metric analyzed (per catchment) |
|---|---|---|---|
| basin area | modeled planographic runoff area (ha) above downstream sampling point; Model: Hydrologic Modeling Extension, Spatial Analyst, ArcView 3.2 | 30 m DEM WA hydrography | as defined |
| basin slope | modeled cell slope (%) of catchment surface above downstream sampling point; Model: Surface tool, Spatial Analyst, ArcView 3.2; extent is basin area. | 30 m DEM, WA hydrography | average |
| elevation | value of grid cell (m) at downstream sample point | 30 m DEM | as defined |
| bankfull width[5] | horizontal distance (m) either between upper scour lines on opposite banks or tops of banks, perpendicular to flow | on site | mean[1] |
| wetted width[5] | horizontal distance (m) between points on opposite banks, perpendicular to flow, at which substrate particles are no longer surrounded by free water | on site | mean[1] |
| wetted depth[5] | vertical distance (cm) between substrate and stream surface, perpendicular to substrate | on site | mean[2] |
| thalweg depth | maximum wetted depth (cm) | on site | mean[1] |
| gradient | gradient (%) measured between successive transects using a clinometer and flagged height pole | on site | mean[3] |
| aspect | direction (degrees) perpendicular to valley floor slope as determined by compass at downstream sample point | on site | as defined |
| canopy cover | no. of quarter concave densiometer cells >50% center-shaded, as read at center of bankfull channel | on site | mean[4] |
| riparian vegetation | category of dominant riparian vegetation: CONIF= coniferous; DECID=deciduous; SHRUB=shrub; GRASS=grass; BURNED=recent fire | on site | Category |
| large woody debris[5] | no. of dead, non-self supporting pieces of wood >10cm diameter and >2 m length, intersecting the bankfull zone. DOWNED=modifying flow at bankfull; SUSPENDED=above flow at bankfull; JAM=10+ grouped, touching pieces of qualifying wood | on site | count / 100 m |

[1] 6 transects, 1 measurement each
[2] 6 transects, 5 equally spaced measurements per transect: left bank, left center, center, right center, right bank
[3] 5 sub-reaches, 1 measurement each
[4] 6 transects, 4 readings per transect: river left, river right, upstream, downstream; corrected to percent
[5] adapted from Schuett-Hames et al., 1999a, 1999b

Table 6: Estimated 25%, 50%, and 75% CDF values for several temperature metrics, along with associated means as calculated using the R package *spsurvey*, where *n* = number of cases associated with a given percentile of the CDF and a given metric. Means (SE) are also reported. The annual period of analysis was July and August. The target population was Type F waters within the FFR lands domain east of the Cascade Crest, Washington state. Data were collected from GRTS-derived, randomly-selected monitoring stations during the Phase I implementation of Extensive Riparian Status and Trends.

| year of data collection | matrix | metric | no. of responses | mean (SE) | minimum | estimate, 25% (CDF) | estimate, 50% (CDF) | estimate, 75% (CDF) | maximum |
|---|---|---|---|---|---|---|---|---|---|
| 2007 | air | air_Tmax | 47 | 31.0 (0.5) | 15.2 | 27.5 (*n*=12) | 32.1 (*n*=24) | 33.3 (*n*=34) | 44.5 |
| | | air_7Tmax | 47 | 28.3 (0.5) | 14.5 | 25.4 (*n*=12) | 28.9 (*n*=23) | 31.1 (*n*=34) | 40.6 |
| | water | upTmax | 43 | 15.9 (0.3) | 8.0 | 14.3 (*n*=10) | 16.0 (*n*=22) | 17.7 (*n*=32) | 22.6 |
| | | up7Tmax | 43 | 15.4 (0.3) | 7.7 | 13.7 (*n*=11) | 15.6 (*n*=22) | 17.0 (*n*=32) | 21.5 |
| | | dsTmax | 43 | 16.7 (0.4) | 8.7 | 15.0 (*n*=11) | 16.7 (*n*=22) | 18.7 (*n*=32) | 22.7 |
| | | ds7Tmax | 43 | 16.1 (0.3) | 8.4 | 14.3 (*n*=11) | 16.1 (*n*=22) | 17.8 (*n*=32) | 21.5 |
| | | D_Tmax | 39 | 0.8 (0.2) | -1.0 | 0.1 (*n*=9) | 0.4 (*n*=19) | 0.8 (*n*=29) | 6.5 |
| | | D_7Tmax | 39 | 0.7 (0.2) | -1.0 | -0.04 (*n*=9) | 0.4 (*n*=19) | 0.7 (*n*=29) | 6.4 |
| 2008 | air | air_Tmax | 37 | 29.3 (0.7) | 17.9 | 26.4 (*n*=9) | 29.0 (*n*=19) | 31.9 (*n*=28) | 48.9 |
| | | air_7Tmax | 37 | 26.6 (0.7) | 16.2 | 23.4 (*n*=9) | 26.2 (*n*=19) | 29.3 (*n*=28) | 43.4 |
| | water | upTmax | 41 | 15.5 (0.3) | 7.5 | 14.1 (*n*=10) | 15.8 (*n*=21) | 17.2 (*n*=31) | 21.3 |
| | | up7Tmax | 41 | 14.6 (0.3) | 7.4 | 13.0 (*n*=10) | 14.9 (*n*=21) | 16.2 (*n*=31) | 20.6 |
| | | dnTmax | 45 | 15.7 (0.3) | 8.3 | 14.2 (*n*=11) | 15.9 (*n*=23) | 17.2 (*n*=34) | 21.0 |
| | | dn7Tmax | 45 | 14.8 (0.3) | 8.0 | 13.2 (*n*=11) | 14.9 (*n*=23) | 16.3 (*n*=34) | 19.9 |
| | | D_Tmax | 39 | 0.3 (0.2) | -2.4 | -0.03 (*n*=8) | 0.2 (*n*=18) | 0.5 (*n*=29) | 4.2 |
| | | D_7Tmax | 39 | 0.3 (0.1) | -1.5 | 0.01 (*n*=9) | 0.2 (*n*=19) | 0.5 (*n*=29) | 3.7 |

Table 7: Between-year comparisons of cumulative distribution functions for selected water temperature metrics. Data collection years were 2007 and 2008. The annual period of analysis was July and August. The target population was Type F/S waters within the FFR lands domain east of the Cascade Crest, Washington state.

| matrix | station location | metric | change in means* | Wald F | *p*-value |
|---|---|---|---|---|---|
| water | upstream | Tmax | 0.46 | 0.788 | 0.459 |
| | | 7Tmax | 0.73 | 1.136 | 0.327 |
| | downstream | Tmax | 0.99 | 1.250 | 0.292 |
| | | 7Tmax | 1.25 | 3.219 | 0.045 |
| | difference | D_Tmax | 0.49 | 1.924 | 0.154 |
| | | D_7Tmax | 0.43 | 1.286 | 0.283 |
| air | downstream | air_Tmax | 1.69 | 5.062 | 0.009 |
| | | air_7Tmax | 1.79 | 4.183 | 0.019 |

*informational detail from Table 6 and not given by the test

Table 8: Summary of significant correlations between temperature metrics studied and non-temperature variables. Correlations are Pearson correlations, reported with and without Bonferroni correction for multiple comparisons. Data were collected during initial implementation of Extensive Riparian Status and Trends, Washington state, 2007.

| temperature metric[a] | correlate | correlation coefficient | *p*-value[b] | *n* | *p*-value |
|---|---|---|---|---|---|
| Tmax | air_Tmax | 0.59 | <0.001 | 42 | <0.001 |
| | percent canopy | -0.44 | 0.060 | 42 | 0.004 |
| | LWD, suspended | -0.31 | 0.783 | 42 | 0.046 |
| | jams | -0.40 | 0.138 | 42 | 0.008 |
| | catchment area | 0.34 | 0.449 | 42 | 0.026 |
| 7Tmax | air_Tmax | 0.59 | <0.001 | 42 | <0.001 |
| | percent canopy | -0.43 | 0.075 | 42 | 0.004 |
| | LWD, suspended | -0.31 | 0.831 | 42 | 0.049 |
| | jams | -0.40 | 0.143 | 42 | 0.008 |
| | catchment area | 0.34 | 0.500 | 42 | 0.029 |

[a] downstream stations
[b] Bonferroni correction for multiple comparisons

Table 9: Casewise consideration of how assumptions can influence scope of inference (km of stream) in GRTS-based designs, using data from ERST Type F, 2007. Data were collected during Phase I implementation of Extensive Riparian Status and Trends, Washington state.

| Properties | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| Sample frame | 7224 km | 7224 km | 7224 km | 7224 km |
| Conditions | all sites are target | mix of target and non-target | mix of target and non-target | mix of target and non-target |
| | no loss of sites | loss of sites completely at random | loss of sites completely at random | differential loss of sites |
| | no ownership strata | no ownership strata | no ownership strata | strata by ownership |
| | | if non-target = 155 sites in sample, then reduction in sample frame: | if target = 98 sites in sample, then estimated number of indeterminate sites that were target: | estimated target sites using similar calculation for PUB, IND, and SFLO separately: |
| | | | 98/310*161 = 50.897 | |
| | | | estimated target: 98 + 50.9 = 148.9 | 116.5 |
| Inference scope[a] | | (471-155)/471 * 7224 | 148.9/471 * 7224 | 116.5/471 * 7224 |
| | 7224 km | 4847 km | 2284 km | 1786 km |
| | 100% of original sample frame | 67% of original sample frame | 32% of original sample frame | 25% of original sample frame |

[a] spatial scope of domain and length or type of resource .

# FIGURES

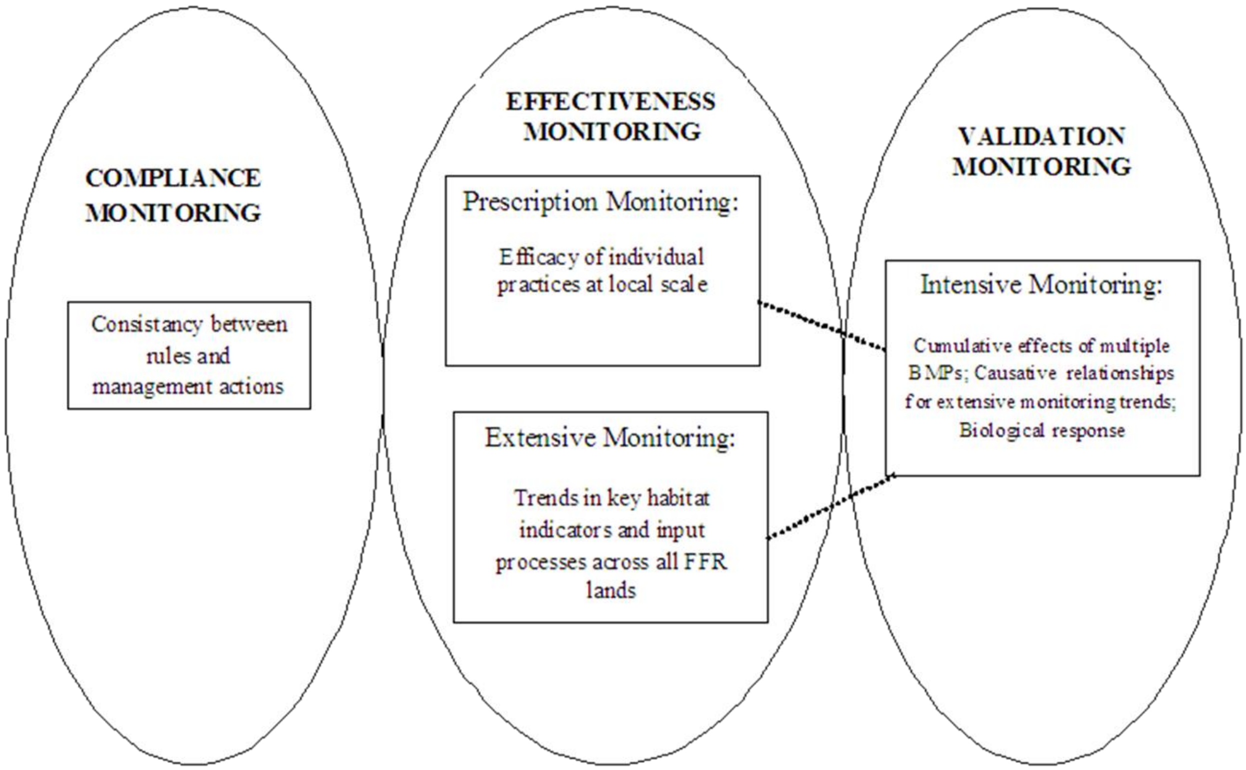
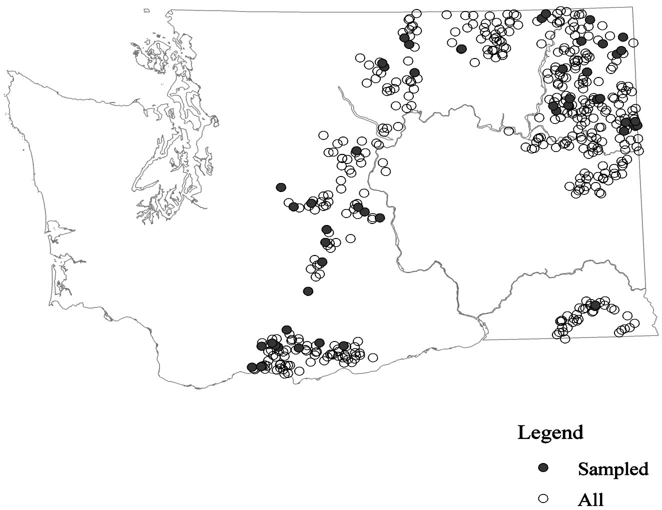
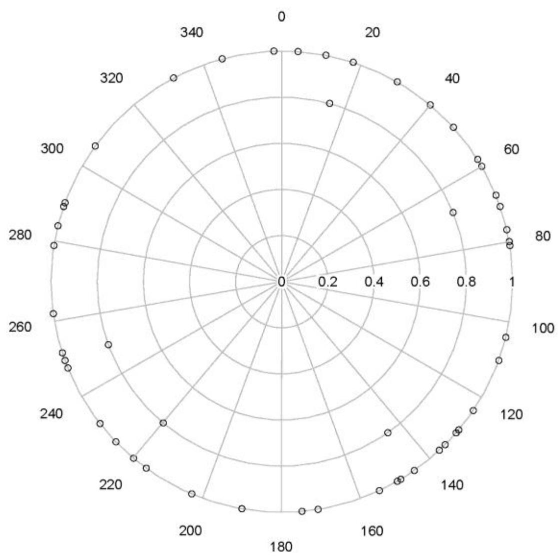



Figure 1: Relationships among components of compliance, effectiveness, and validation monitoring tiers. Intensive monitoring links (shown as dotted lines) fine-scale information determined from individual prescriptions and large-scale, long-term trends in resource conditions determined by extensive monitoring (modified from Benkert et al., 2002).




a)




b)

Figure 2: a) Spatial dispersion of sampling sites evaluated during implementation of ERST Eastside Type F, Phase I, 2007. Shaded symbols correspond to sites which were sampled ($n$ = 50). Unshaded symbols correspond to sites which were rejected ($n$ = 421); b) Associated aspects of study reaches. Each unique aspect value is represented by a point plotted at radial distance = 1. Cases in which a given aspect was common to more than one study reach are represented by points plotted at radial distance = 0.8. Sample source: Generalized Random Tessellation Stratified (GRTS) probability sample draw for Washington State.

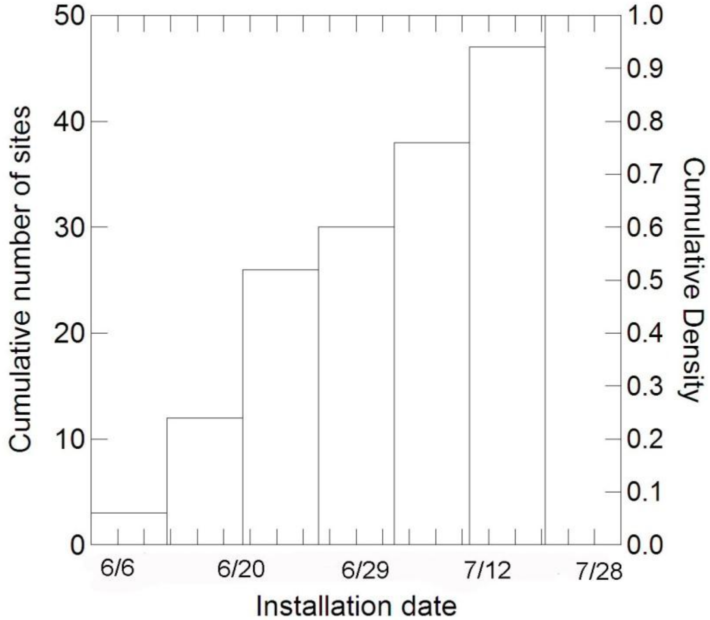



Figure 3: Date range of temperature monitoring station installations, 2007. Nineteen sites were sampled after June 30, the planned date for full deployment.

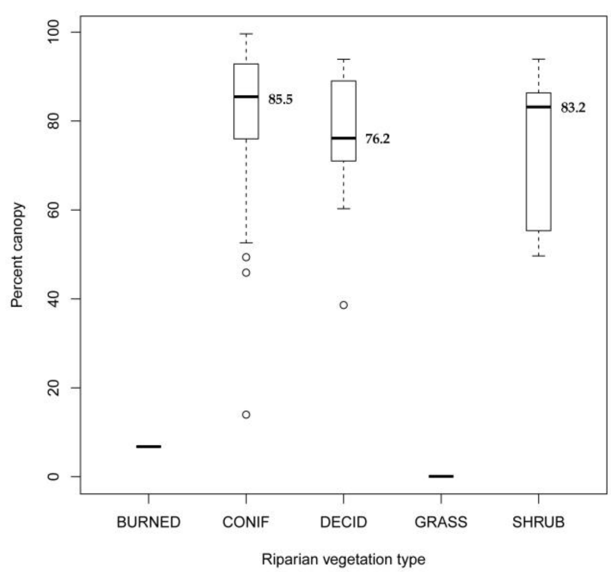



Figure 4: Percent riparian canopy by category of riparian vegetation encountered along study reaches above 50 GRTS-derived, randomly selected temperature monitoring stations. Box plots show medians, extremes, quartiles, and outliers. Riparian canopy levels were similar among coniferous, deciduous hardwood, and shrub vegetation categories. The target population was Type F/S waters within the FFR lands domain east of the Cascade Crest, Washington state.

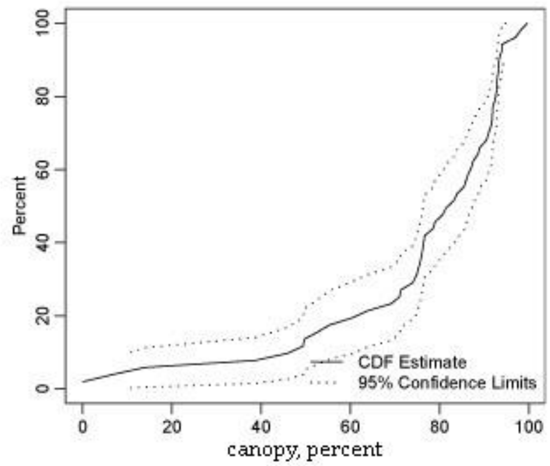
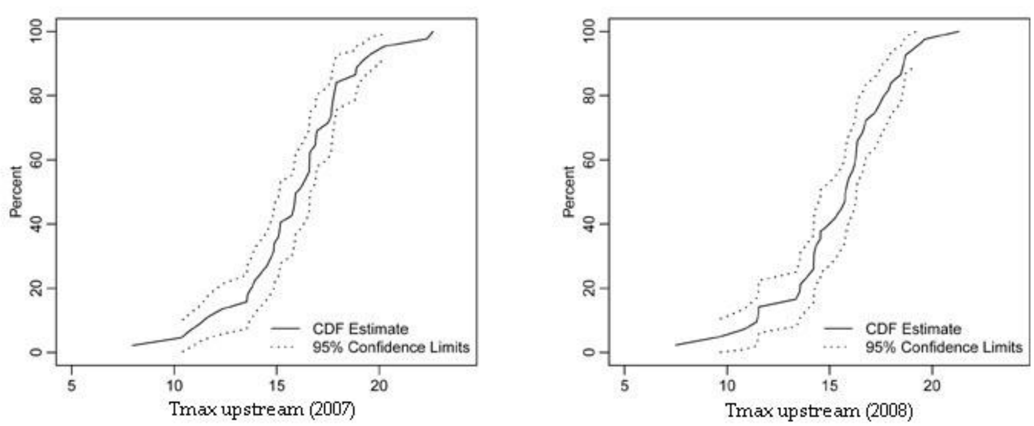
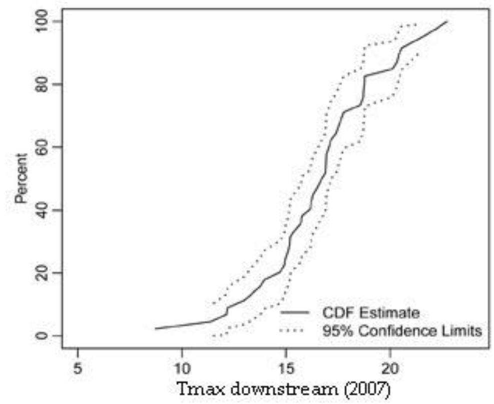


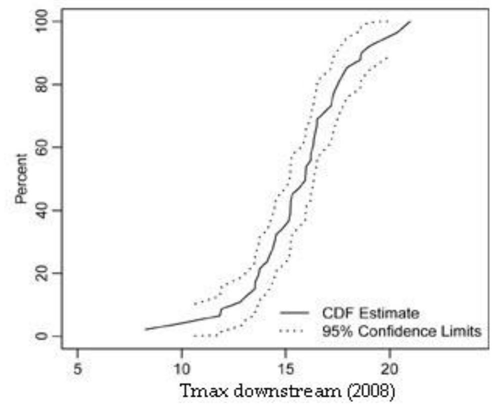

Figure 5: Cumulative distribution function and confidence limits for percent riparian canopy cover measured along ~300 m study reaches above 50 GRTS-derived, randomly selected temperature monitoring stations. The target population was Type F/S waters within the FFR lands domain east of the Cascade Crest, Washington state.



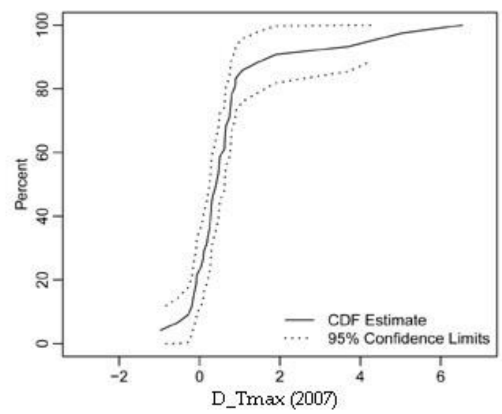

a) b)



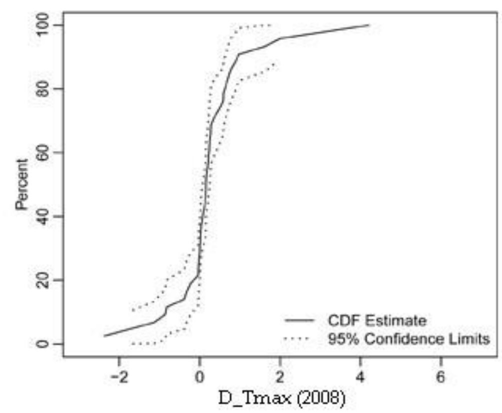

c)




d)




e)




f)

Figure 6: Cumulative distribution functions and 95% confidence limits for water temperature metrics from GRTS-derived, randomly selected stream temperature monitoring stations. Panels a) and b) show daily maximum temperature at the upstream end of ~300 m study reaches. Panels c) and d) show daily maximum temperature at the downstream end of study reaches. Panels e) and f) show differences (per site) between upstream and downstream daily maximum temperatures. The target population was Type F/S waters within the FFR lands domain east of the Cascade Crest, Washington state.

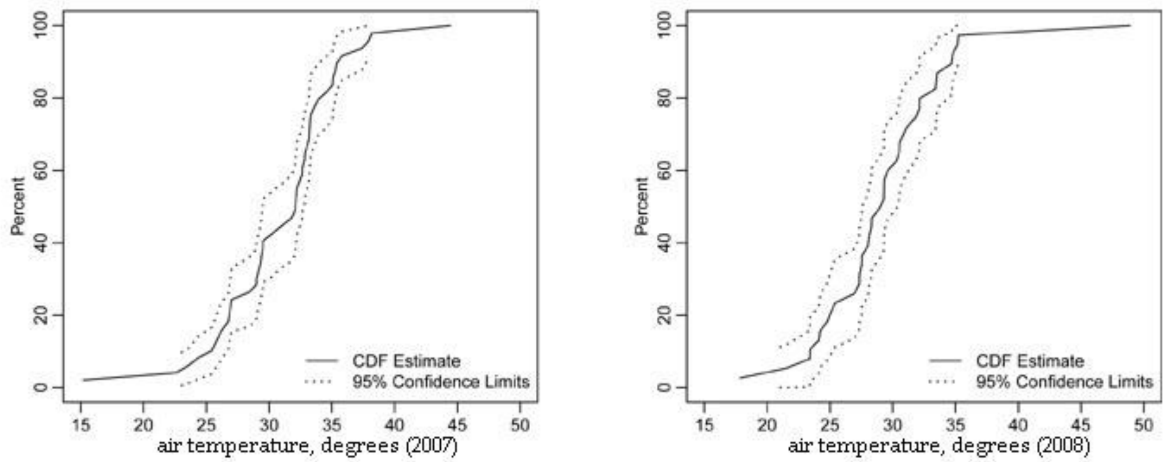



Figure 7: Cumulative distribution functions and 95% confidence limits for July-August air temperatures from GRTS-derived, randomly selected monitoring stations. Data are: a) mean maximum air temperature in 2007 ($n$ = 47), and b) mean maximum air temperature in 2008 ($n$ = 37). The target population was Type F/S waters within the FFR lands domain east of the Cascade Crest, Washington state.

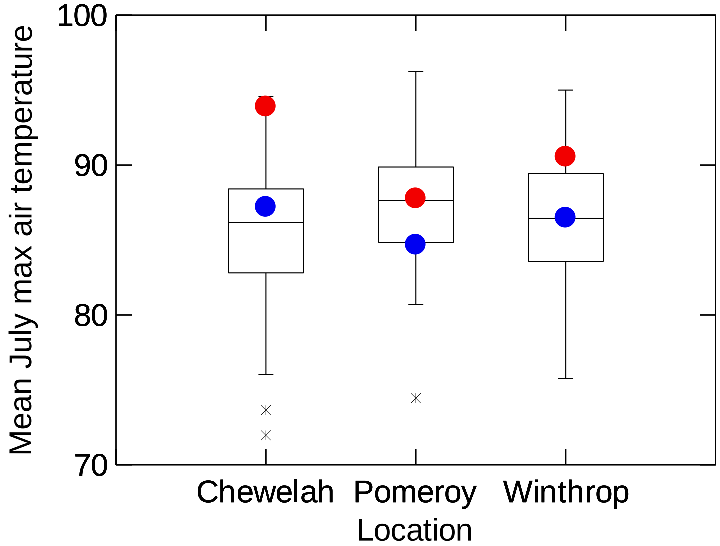
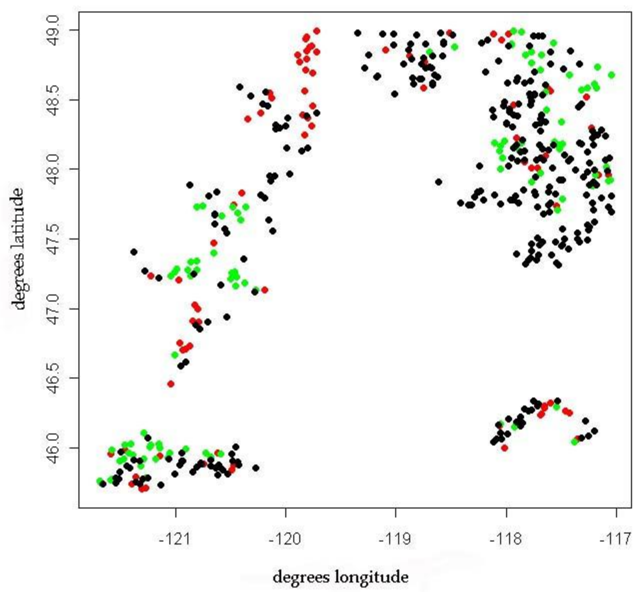
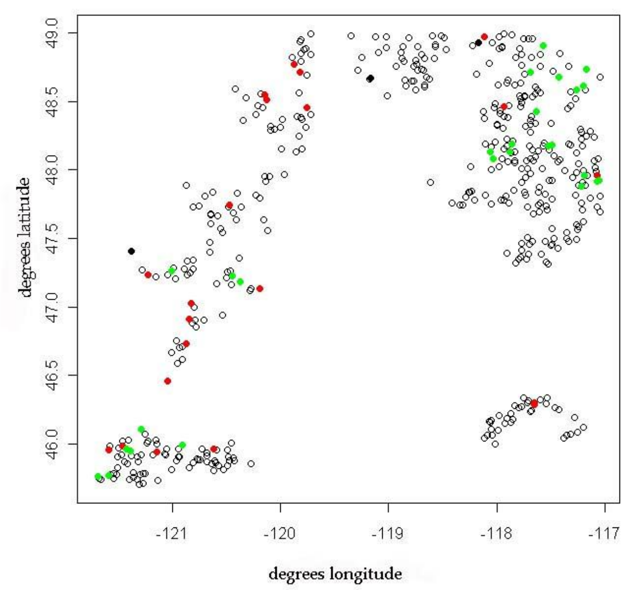



Figure 8: Distribution of mean values of the maximum July air temperatures, 1958-2008, for three locations in Eastern Washington. Red dots indicate July 2007 mean daily maximum air temperatures for these locations. Blue dots indicate July 2008 mean daily maximum air temperatures for these locations. July 2007 was warmer than July 2008, exceeding the seventy-fifth percentile of the historic record at Chewelah and Winthrop.




a)




b)

Figure 9: Effect on spatial dispersion of sampling sites evaluated due to differential loss of SFLO holdings during implementation of ERST Type F/S, Phase I, 2007-08, showing: a) the evaluated sample (*n*=471) and b) sites of data collection (*n* = 50). Data are color-coded by ownership: red = public (PUB), green= industrial (IND), black = small forest landowner (SFLO). Unshaded symbols in b) correspond to sites which were not sampled (*n* = 421).

# Appendix A: ERST timeline and modules

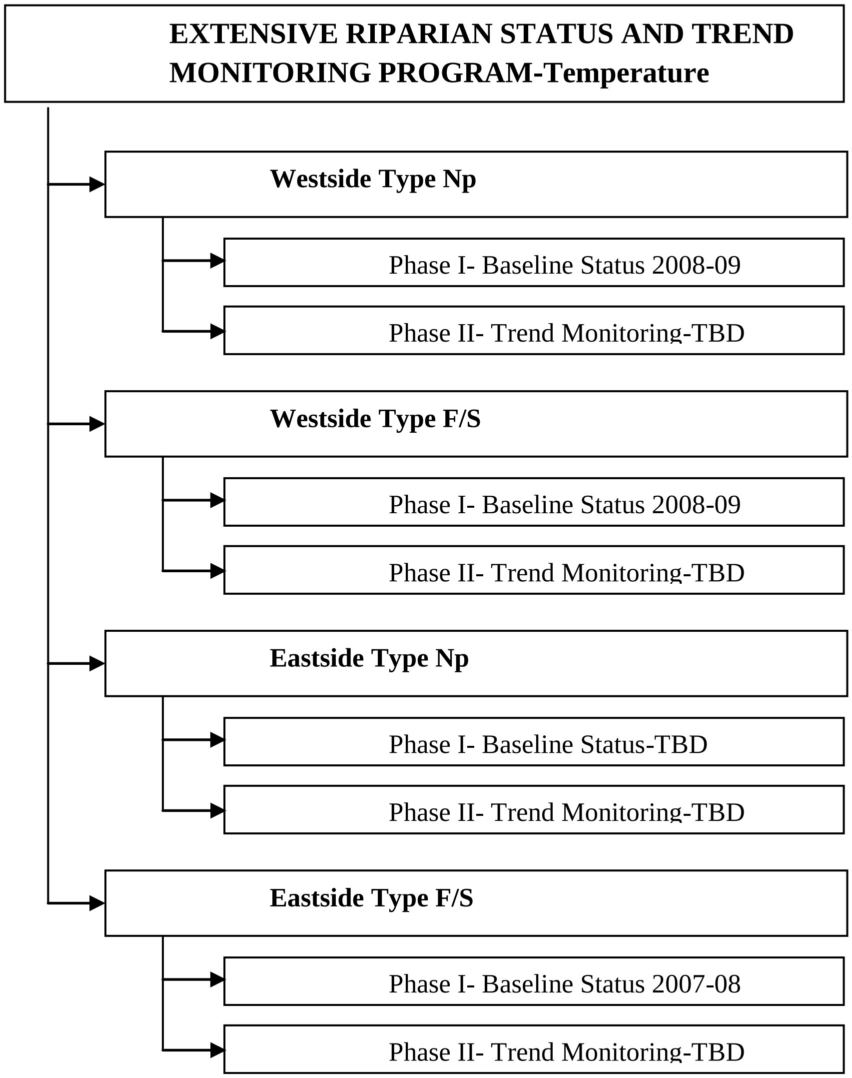



Figure A1: Project implementation schedule. Data collection for westside Type F/S and Type Np ERST began spring 2009 and was completed spring 2010. The eastside Type Np project is not scheduled at this time. Phase II monitoring implementation has not yet begun. Water types: F = fish bearing, S = shorelines, Np = non-fish-bearing and perennial (from Ehinger et al., 2007)

# Appendix B: Overview, Generalized Random Tessellation Stratified (GRTS) survey design and sampling frame construction

The generalized random tessellation stratified (GRTS) probability sampling developed by U.S. EPA for the Environmental Mapping and Assessment Program (EMAP; see http://www.epa.gov/nheerl/arm/designing/design_intro.htm) treats variability as intrinsic to natural resource indicators. Rather than attempt to remove or control for this variability, GRTS reports proportions of the resource, relative to the range of variability observed, as cumulative frequency distributions (CDFs). Also, significantly, this means GRTS is not constrained by a need for experimental controls. Instead, analogously, a single application of GRTS describes the resource, as currently known, with associated confidence bands. Trend in resource condition follows from subsequent implementations of GRTS, as change between successive CDFs[16]. As would be anticipated, GRTS easily adjusts to evaluating inter-annual variation: repeated monitoring at fixed sub-sets of sites.

Probability samples have the following distinct features:

- each member of a target population has an inclusion probability > 0 (Stevens and Jensen, 2007);
- randomization allows statistically valid inferences from samples to populations (Overton et al., 1990; Diaz-Ramos et al., 1996);
- inference to population results from design rather than statistical model (e.g. Smith, 1976; Hansen et al., 1983);
- apply to any point (i.e., discrete), linear, or areal (i.e., extensive) natural resource at a range of spatial scales (Diaz-Ramos et al., 1996);
- translates population definition into a population frame;
- estimate status, trend, or change in selected indicator with known confidence (Overton et al., 1990; Stevens, 1994);
- estimates are free from selection bias if implemented as designed (e.g., Stevens and Jensen, 2007);
- theoretical justification for estimates is well-established Horvitz-Thompson Theorem (Horvitz and Thompson, 1952);
- Can be very specific with respect to what and where to sample and how to analyze the data (i.e., probability structures of sampling and analysis must match (Diaz-Ramos et al., 1996)).

Probability samples, implemented as designed, are representative of target populations, free of sampling bias, and useful for describing status and trends of resources at various spatial scales. These strengths are realized with sequential implementations of GRTS, which, if successful, offers additional advantages:

1) effectively increase sample size and trend detection power,

2) more precise estimates than equally-sized simple random sample because it incorporates the target population spatial structure (i.e., spatial balancing) (Stevens and Jensen, 2007);

3) alternative to modeling for scaling stream temperature to landscapes;

4) informs the need for states to periodically report status of impaired surface waters (EPA, 2010);

5) analyses adaptable from equi-probability to variable probability after sampling is complete. Loss of a

[16] Sensitivity of resource evaluation methods used and whether detected changes are ecologically meaningful are external to GRTS.

sampling site, common to natural resource studies, may thus be overcome[17];

6) the spatial density pattern of sample is matched to that of the resource (i.e., reverse hierarchical ordering; Stevens and Olsen, 2001).

Conversely, there are tradeoffs. Population frame and sampling frame (see Appendix B) definitions must be sufficiently rigorous to minimize bias or contamination of estimates. That is, inclusion probabilities for undetected elements of a target population are zero. Also, sampling effort rises geometrically with increasing study complexity—a consideration even without stratification as random selection from the target population does not guarantee normal distributions of other associated variables. And, notably, what resulting data, such as stream temperature, represent must be considered, as do sample size and evaluation methods for sufficient precision and confidence in the resource estimate to match study objectives. Lastly, data must be analyzed with the R[18] statistical package.

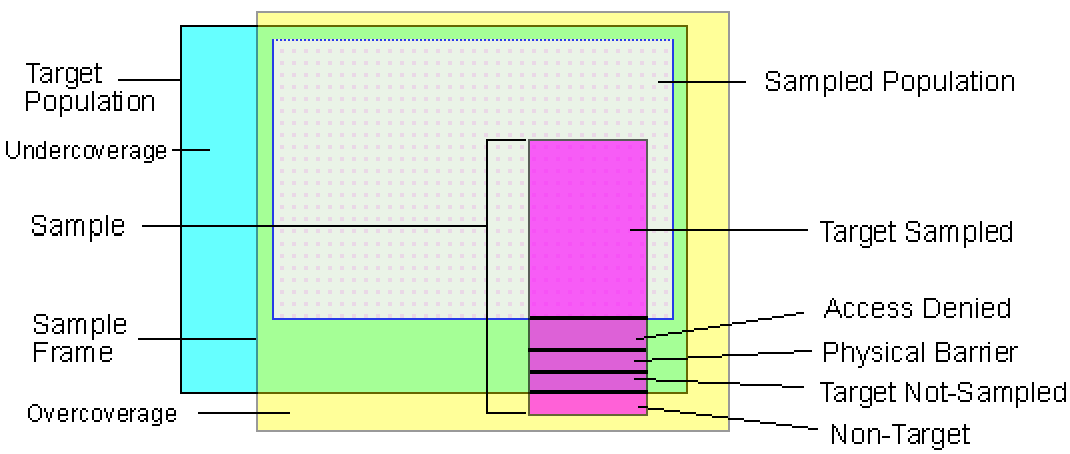



Figure B1: Generalized GRTS sampling frame construction showing relationship of the target population to frame and sampling imperfections[19].

GRTS Assumptions[20]

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[17] Non-target sites in a GRTS sample can be replaced by evaluating each next site in the sequence (assuming a sufficient oversample) until base sample size is achieved. Random spatial dispersion is thus maintained. However site replacement must be sufficiently described to a) correctly adjust survey design weights, b) account for any resulting selection stratification, c) account for any resulting unequal probability of selection. Inaccuracies will affect computation of estimates of characteristics for target populations.

[18] www.r-project.org

[19] http://www.epa.gov/nheerl/arm/designpages/monitdesign/targetpopframe.htm

[20] Aquatic Resources Monitoring, U.S. EPA, accessed 09 August 2011 http://www.epa.gov/nheerl/arm/analysispages/analysisadjwts.htm

- estimates from sampled sites apply to sampled population with no additional assumptions
- estimates from sampled population apply to remainder of target population within sample frame only if candidate sites are skipped independent of site characteristics (missing completely at random)
- remainder of target population outside sample frame of same characteristics as sampled population

Under these conditions initial design weights need no adjustment unless base sample size and design sample size differ.

# Appendix C: ERST archive content, Phase 1 Type F/S Eastern WA

Location: Washington Dept. of Ecology, Olympia, WA

Recipient: Environmental Assessment Program

Retention: compliance with agency policies

Contact:

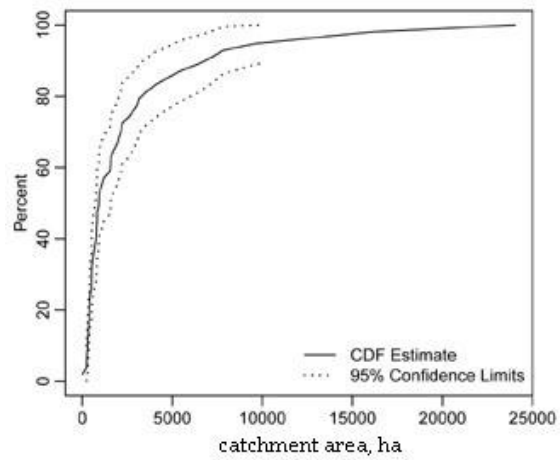
Archive content. Includes available meta-data.

| **Category** | **Description** | **Format** | **Author** |
|---|---|---|---|
| GRTS sample draw | | | |
| | design | .pdf | EPA |
| | WA hydrography, 24k | arc | DNR |
| | statewide master sample | .shp | EPA |
| Evaluated sample | | | |
| | CMER/ FFR lands, East | .shp | mixed |
| | WA east-west divide | .shp | DNR |
| | Site list | spreadsheet | mixed |
| | Site evaluation orthos | .pdf | mixed |
| | Site validation forms | spreadsheet | mixed |
| | Type F/S (*n*=471) | .shp | ECY |
| | Scanned data sheets, per site | .pdf | ECY |
| Analysis and Results | | | |
| | all raw data, temperature, 2007-2008 | .mdb | ECY |
| | all raw data, other variables, 2007-2008 | .mdb | ECY |
| | results summary | .syd | ECY |
| Misc | | | |
| | method development | varies | mixed |

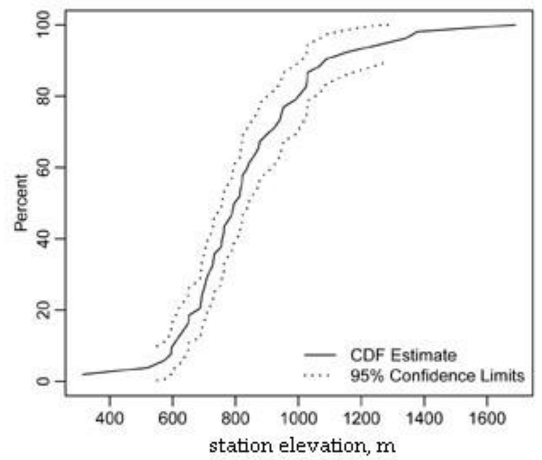
## Appendix D: Secondary results, including general catchment characteristics and habitat variables

Table D1: Estimated 25%, 50%, 75%, and 95% CDF values for catchment-scale and habitat variables, with number of cases in parentheses, as calculated by the R package *spsurvey*, where *n* = number of cases associated with a given percentile of the CDF and a given variable, Type F/S. Means (se) are also reported. Data were derived from GIS layers and 300 meter study reaches above 50 GRTS-derived, randomly-selected temperature monitoring stations. Data were collected during the initial implementation of Extensive Riparian Status and Trends, Washington state.

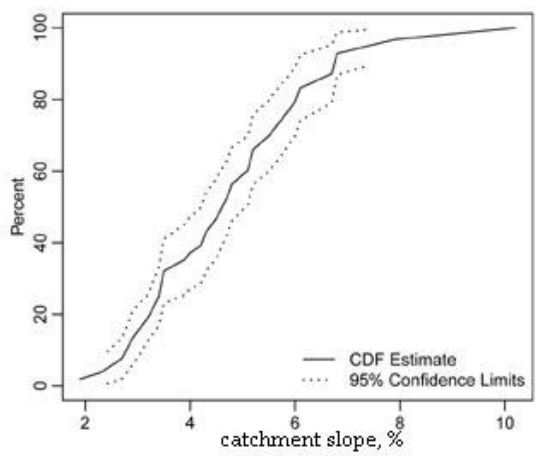
| variable | no. of responses | mean | minimum | estimate, 25% (CDF) | estimate, 50% (CDF) | estimate, 75% (CDF) | estimate, 95% (CDF) | maximum |
|---|---|---|---|---|---|---|---|---|
| catchment area, ha | 50 | 2751 (567) | 17 | 471 (*n*=13) | 917 (*n*=25) | 2706 (*n*=38) | 10031 (*n*=48) | 24041 |
| station elevation, m | 50 | 845 (25.7) | 314 | 696 (*n*=12) | 796 (*n*=24) | 946 (*n*=36) | 1284 (*n*=47) | 1690 |
| catchment slope, % | 50 | 4.8 (0.2) | 1.9 | 3.4 (*n*=13) | 4.6 (*n*=23) | 5.8 (*n*=36) | 7.4 (*n*=47) | 10.2 |
| bankfull width, m | 50 | 7.7 (1.6) | 1.9 | 3.1 (*n*=12) | 4.3 (*n*=25) | 7.3 (*n*=37) | 18.4 (*n*=47) | 87.7 |
| channel gradient, % | 50 | 6.0 (0.7) | 0.0 | 1.6 (*n*=12) | 4.0 (*n*=24) | 8.3 (*n*=37) | 18.0 (*n*=47) | 24.4 |
| thalweg, m | 50 | 0.23 (0.02) | 0.0 | 0.14 (*n*=12) | 0.22 (*n*=23) | 0.31 (*n*=37) | 0.42 (*n*=47) | 0.60 |
| wetted width, m | 50 | 3.0 (0.3) | 0.6 | 1.5 (*n*=12) | 2.2 (*n*=24) | 3.1 (*n*=37) | 7.6 (*n*=47) | 13.9 |
| LWD, down | 50 | 27.8 (2.7) | 0.3 | 14.2 (*n*=12) | 22.2 (*n*=24) | 30.5 (*n*=37) | 64.8 (*n*=47) | 124.7 |
| LWD, suspended | 50 | 5.7 (0.8) | 0.0 | 1.0 (*n*=11) | 3.9 (*n*=24) | 7.8 (*n*=37) | 12.8 (*n*=47) | 48.0 |
| LWD, jams | 50 | 1.2 (0.2) | 0.0 | 0 (*n*=23) | 0.3 (*n*=23) | 1.8 (*n*=36) | 4.0 (*n*=47) | 5.7 |
| LWD, total | 50 | 33.5 (3.1) | 0.3 | 16.8 (*n*=12) | 27.6 (*n*=23) | 38.5 (*n*=37) | 71.7 (*n*=47) | 134.0 |




a)

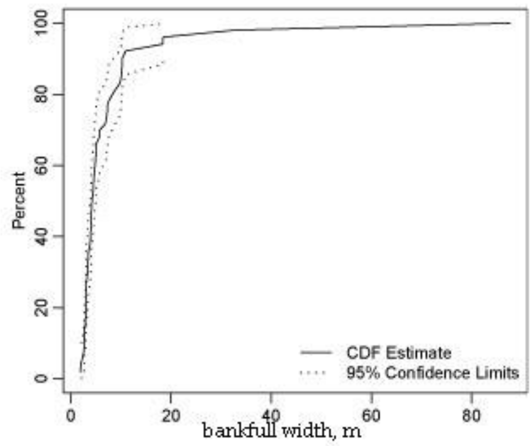



b)

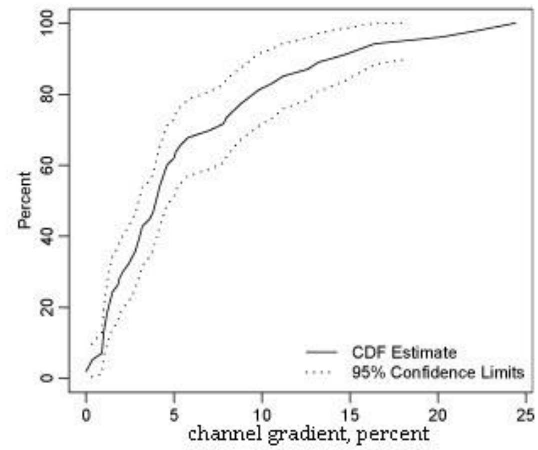



c)

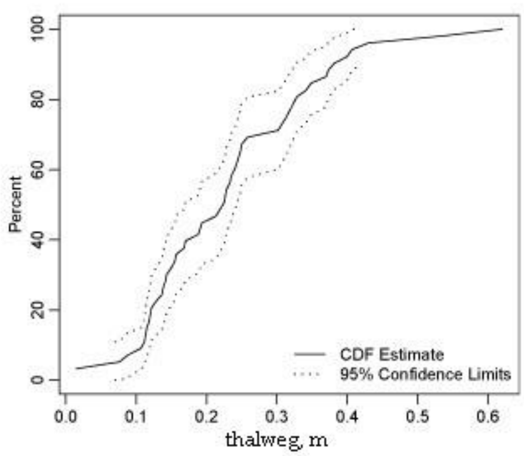
Figure D1: Cumulative distribution functions and 95% confidence limits of characteristics above or at 50 GRTS-derived, randomly selected temperature monitoring stations. The target population was Type F/S waters within the FP regulated forestlands domain east of the Cascade Crest, Washington state. Data are: a) planographic catchment area above monitoring station locations, b) elevation estimated from coordinates of the monitoring station using a 30 m DEM, and c) mean catchment slope of catchment area upstream of monitoring station locations. Estimates were calculated using R v. 2.12 and the R package spsurvey. Years of data collection were 2007 and 2008.


Percent
0
20
40
60
80
100
bankfull width, m
CDF Estimate
95% Confidence Limits

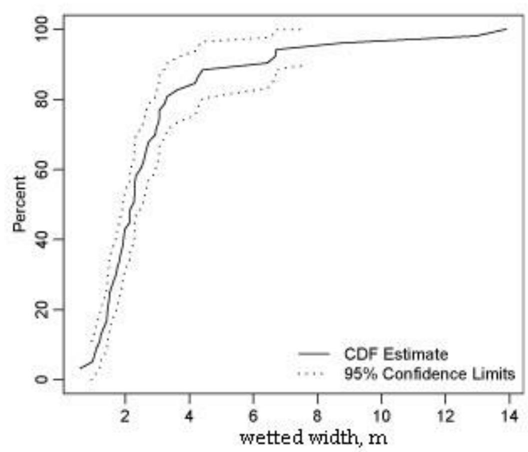
a)


Percent
0
5
10
15
20
25
channel gradient, percent
CDF Estimate
95% Confidence Limits

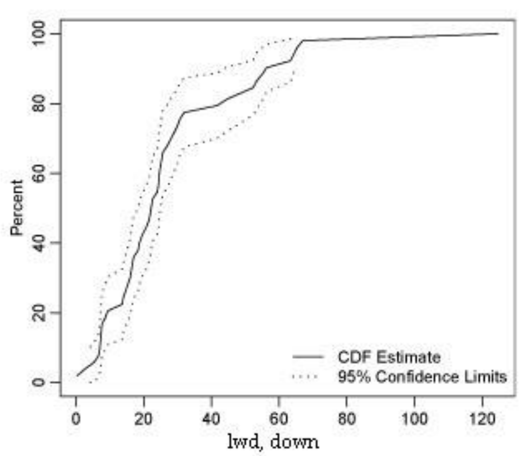
b)


Percent
0.0
0.1
0.2
0.3
0.4
0.5
0.6
thalweg, m
CDF Estimate
95% Confidence Limits

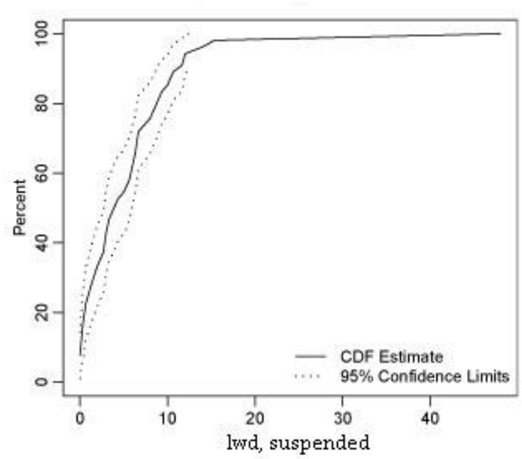
c)


Percent
2
4
6
8
10
12
14
wetted width, m
CDF Estimate
95% Confidence Limits

d)


Percent
0
20
40
60
80
100
120
lwd, down
CDF Estimate
95% Confidence Limits

e)


Percent
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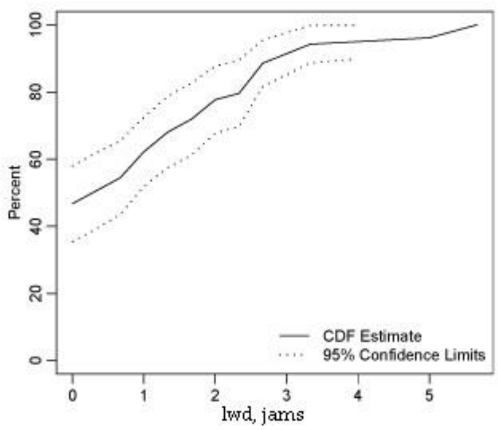
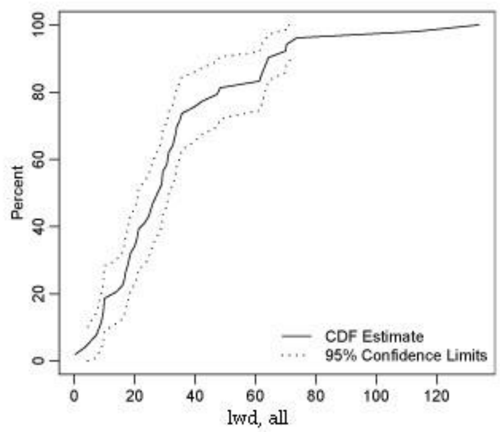
10
20
30
40
lwd, suspended
CDF Estimate
95% Confidence Limits

f)




g)




h)

Figure D2: Cumulative distribution functions and confidence limits for habitat variables measured along 300 m study reaches above 50 GRTS-derived, randomly selected temperature monitoring stations. The target population was Type F/S waters within the FP regulated forestlands domain east of the Cascade Crest, Washington state. Data are: a) mean bankfull width, b) mean channel gradient, c) mean thalweg depth, d) wetted width, e) mean count of down, large in-channel wood, f) mean count of suspended, large in-channel wood, g) mean count of in-channel, large wood jams, h) mean count of all categories of in-channel large wood inventoried. Years of data collection were 2007 and 2008.

# Appendix E: Inventory of temperature data gaps and data summaries

Table E1: Inventory of data gaps for temperature monitoring locations. Locations with < 30 days data, from a) July 1-Aug 31, 2007, or b) July 1-August 31, 2008, are marked with '**X**', followed by the reason for the data gap. Locations missing some data from this period are marked with '**x**', followed by the reason for the data gap.

a)

| Site # | Air Temperature | Water Temperature | |
|---|---|---|---|
| | | Downstream | Upstream |
| 1441 | X- missing | X- missing | X- dry channel |
| 2014 | | | X- low flow |
| 3256 | X- missing | X- dry channel | x- dry channel |
| 4132 | | X- dry channel | X- dry channel |
| 4179 | | X- dry channel | X- no channel |
| 4348 | X- missing | X- low flow | |
| 4718 | | x- dry channel | x- dry channel |
| 13153 | | X- dry channel | X- dry channel |
| 13534 | | X- low flow | |
| 15327 | | x- low flow | |
| 15440 | | X- low flow | |
| 16380 | x- found in water | | X- low flow |
| 20020 | x- found in water | | X- low flow |
| 23562 | | | x- dry channel |
| Total locations with ≥30 days data | 47 | 43 | 43 |

b)

| Site # | Air Temperature | Water Temperature | |
|---|---|---|---|
| | | Downstream | Upstream |
| 217 | X- missing | | |
| 1220 | X- malfunction | | |
| 1441 | X- missing | | X- dry channel |
| 1729 | X- download error | | |
| 2014 | | | X- dry channel |
| 2290 | | | X- vandalized |
| 3256 | | X- dry channel | X- dry channel |
| 4132 | | X- dry channel | X- dry channel |
| 4179 | | X- dry channel | |
| 5008 | x- download error | | |
| 5748 | x- download error | | |
| 7567 | | x- low flow | |
| 13145 | x- missing | X- missing | |
| 13153 | | X- dry channel | x- dry channel |
| 13534 | | | X- missing |
| 13866 | | | X- missing |
| 14156 | x- download error | | |
| 15073 | X- missing | | |
| 15327 | X- missing | | |
| 18556 | X-malfunction | | |
| 20020 | X-malfunction | | |
| 23455 | X-malfunction | | |
| 23562 | | | X-sensor buried |
| Total locations with >30 days data | 41 | 45 | 42 |

Table E2: Site-level stream temperature metrics for data collected July and August, 2007 and 2008, Type F/S.

| | 2007 | | | | | | | | 2008 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site Number** | **AirTmax** | **Air7Tmax** | **Upstrm Tmax** | **Upstrm 7Tmax** | **DownstrmTmax** | **Downstrm 7Tmax** | **D_Tmax** | **D_7Tmax** | **AirTmax** | **Air7Tmax** | **Upstream Tmax** | **Upstrm 7Tmax** | **DownstrmTmax** | **Downstrm7 Tmax** | **D_Tmax** | **D_7Tmax** |
| 000217 | 38.2 | 35.9 | 22.6 | 21.5 | 22.7 | 21.5 | 0.1 | 0.0 | * | * | 19.6 | 18.9 | 19.6 | 18.9 | 0.0 | 0.0 |
| 001088 | 29.0 | 26.3 | 13.5 | 13.4 | 13.8 | 13.4 | 0.2 | 0.0 | 28.3 | 23.5 | 13.5 | 12.8 | 13.8 | 13.0 | 0.2 | 0.2 |
| 001220 | 35.4 | 33.5 | 17.5 | 17.4 | 17.7 | 17.2 | 0.2 | -0.2 | | | 16.4 | 15.9 | 17.3 | 16.4 | 1.0 | 0.5 |
| 001263 | 24.3 | 22.8 | 14.9 | 14.6 | 15.8 | 15.4 | 0.9 | 0.8 | 21.5 | 19.7 | 14.6 | 13.6 | 15.1 | 14.2 | 0.6 | 0.6 |
| 001441 | * | * | * | * | 16.3 | 15.6 | * | * | * | * | * | * | 15.7 | 14.8 | * | * |
| 001729 | 22.6 | 20.4 | 10.8 | 10.5 | 12.2 | 11.8 | 1.4 | 1.3 | * | * | 11.5 | 11.3 | 13.1 | 12.4 | 1.6 | 1.2 |
| 002014 | 37.9 | 31.8 | * | * | 18.6 | 17.7 | * | * | 35.2 | 29.6 | * | * | 16.5 | 15.8 | * | * |
| 002290 | 32.2 | 29.7 | 18.9 | 18.7 | 18.7 | 18.1 | -0.2 | -0.5 | 34.8 | 31.8 | * | * | 18.6 | 17.7 | * | * |
| 002624 | 33.2 | 31.1 | 16.6 | 16.2 | 21.6 | 20.7 | 5.0 | 4.5 | 33.5 | 30.6 | 16.8 | 16.2 | 21.0 | 19.9 | 4.2 | 3.7 |
| 002785 | 31.0 | 28.6 | 15.9 | 15.2 | 16.2 | 15.6 | 0.3 | 0.5 | 30.3 | 27.4 | 16.2 | 15.3 | 16.2 | 15.3 | 0.0 | 0.0 |
| 003233 | 29.3 | 26.4 | 11.3 | 10.7 | 15.0 | 14.4 | 3.7 | 3.7 | 27.0 | 25.3 | 10.8 | 10.3 | 12.8 | 12.3 | 2.0 | 2.0 |
| 003256 | * | * | 17.7 | 16.1 | * | * | * | * | 27.4 | 25.2 | * | * | * | * | * | * |
| 004132 | 32.8 | 31.1 | * | * | * | * | * | * | 28.9 | 27.4 | * | * | * | * | * | * |
| 004156 | 27.0 | 25.0 | 15.1 | 14.7 | 15.4 | 15.0 | 0.3 | 0.3 | 25.1 | 23.3 | 14.2 | 13.4 | 14.5 | 13.6 | 0.3 | 0.2 |
| 004179 | 33.3 | 29.7 | * | * | * | * | * | * | 31.1 | 31.1 | * | * | * | * | * | * |
| 004271 | 25.7 | 23.8 | 16.9 | 16.5 | 17.2 | 16.7 | 0.3 | 0.2 | 24.1 | 21.6 | 16.6 | 15.6 | 16.4 | 15.5 | -0.2 | -0.1 |
| 004348 | * | * | 14.9 | 14.3 | * | * | * | * | 28.1 | 24.9 | 14.2 | 13.1 | 14.4 | 13.3 | 0.2 | 0.2 |
| 004352 | 33.6 | 31.5 | 16.2 | 15.8 | 16.9 | 16.1 | 0.7 | 0.3 | 23.4 | 21.0 | 15.8 | 14.9 | 15.9 | 15.0 | 0.2 | 0.2 |
| 004718 | 29.4 | 26.8 | 15.1 | 14.4 | 15.7 | 15.2 | 0.6 | 0.8 | 28.0 | 25.3 | 15.6 | 14.4 | 15.2 | 14.5 | -0.3 | 0.1 |
| 004961 | 37.4 | 33.7 | 19.2 | 18.7 | 20.1 | 19.3 | 0.9 | 0.6 | 32.1 | 29.4 | 18.7 | 17.9 | 19.0 | 18.2 | 0.3 | 0.3 |
| 005008 | 29.5 | 27.1 | 17.9 | 16.9 | 18.7 | 17.9 | 0.8 | 1.0 | * | * | 17.6 | 15.6 | 15.2 | 14.1 | -2.4 | -1.5 |
| 005748 | 26.9 | 25.3 | 14.7 | 14.4 | 15.2 | 14.8 | 0.5 | 0.4 | * | * | 14.2 | 13.4 | 14.9 | 13.9 | 0.6 | 0.5 |

| | 2007 | | | | | | | | 2008 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site Number** | **AirTmax** | **Air7Tmax** | **Upstrm Tmax** | **Upstrm 7Tmax** | **DownstrmT max** | **Downstrm 7Tmax** | **D_Tmax** | **D_7Tmax** | **AirTmax** | **Air7Tmax** | **Upstream Tmax** | **Upstrm 7Tmax** | **DownstrmT max** | **Downstrm7 Tmax** | **D_Tmax** | **D_7Tmax** |
| 007567 | 32.4 | 29.4 | 19.6 | 19.0 | 20.4 | 19.7 | 0.8 | 0.6 | 29.6 | 26.7 | 18.0 | 17.1 | 17.2 | 15.8 | -0.8 | -1.3 |
| 007692 | 32.9 | 30.4 | 18.8 | 18.6 | 18.8 | 18.3 | -0.1 | -0.2 | 29.3 | 27.6 | 17.9 | 17.1 | 18.0 | 17.1 | 0.1 | 0.0 |
| 007755 | 15.2 | 14.5 | 13.6 | 13.2 | 13.4 | 13.0 | -0.2 | -0.3 | 17.9 | 16.2 | 13.6 | 13.0 | 13.5 | 13.0 | 0.0 | 0.0 |
| 009409 | 23.6 | 21.2 | 8.0 | 7.7 | 8.7 | 8.4 | 0.8 | 0.7 | 24.2 | 22.7 | 7.5 | 7.4 | 8.3 | 8.0 | 0.8 | 0.7 |
| 010629 | 26.0 | 22.2 | 14.5 | 13.7 | 14.9 | 13.9 | 0.4 | 0.2 | 23.4 | 21.4 | 15.0 | 14.1 | 15.2 | 14.4 | 0.2 | 0.3 |
| 010804 | 32.1 | 29.8 | 15.9 | 15.6 | 16.5 | 16.2 | 0.6 | 0.6 | 27.5 | 26.1 | 15.7 | 14.9 | 16.5 | 15.5 | 0.8 | 0.6 |
| 013145 | 34.5 | 31.8 | 22.3 | 21.3 | 22.2 | 21.2 | -0.1 | -0.1 | * | * | 19.2 | 18.5 | * | * | * | * |
| 013153 | 44.5 | 40.5 | * | * | * | * | * | * | 48.9 | 43.4 | 21.3 | 20.6 | * | * | * | * |
| 013261 | 35.3 | 32.1 | 10.3 | 10.0 | 11.4 | 11.1 | 1.1 | 1.1 | 33.4 | 30.1 | 9.6 | 9.3 | 10.2 | 9.9 | 0.6 | 0.6 |
| 013520 | 29.5 | 26.8 | 12.4 | 11.7 | 13.0 | 12.2 | 0.6 | 0.5 | 30.6 | 26.4 | 11.4 | 10.5 | 11.9 | 11.0 | 0.5 | 0.4 |
| 013534 | 32.6 | 30.2 | 15.8 | 15.1 | * | * | * | * | 35.2 | 32.2 | * | * | 14.1 | 13.4 | * | * |
| 013866 | 35.1 | 32.2 | 16.9 | 16.5 | 18.8 | 18.3 | 1.9 | 1.8 | 29.3 | 27.0 | * | * | 16.9 | 15.8 | * | * |
| 014156 | 33.9 | 31.3 | 16.4 | 15.5 | 16.9 | 16.1 | 0.5 | 0.6 | * | * | 15.9 | 14.7 | 16.0 | 14.9 | 0.0 | 0.2 |
| 014862 | 26.3 | 24.9 | 15.8 | 15.0 | 16.2 | 15.2 | 0.3 | 0.2 | 27.3 | 24.7 | 16.3 | 15.1 | 16.3 | 15.3 | 0.0 | 0.2 |
| 015009 | 29.3 | 27.4 | 17.7 | 17.1 | 17.8 | 17.2 | 0.0 | 0.1 | 28.3 | 25.8 | 17.4 | 16.4 | 17.8 | 16.7 | 0.4 | 0.2 |
| 015073 | 29.0 | 25.6 | 14.0 | 13.4 | 14.7 | 13.9 | 0.7 | 0.5 | * | * | 13.4 | 12.5 | 14.2 | 13.2 | 0.9 | 0.7 |
| 015252 | 32.2 | 30.1 | 17.7 | 17.2 | 17.4 | 17.1 | -0.3 | -0.1 | 31.8 | 28.7 | 17.2 | 16.3 | 17.2 | 16.4 | 0.0 | 0.1 |
| 015327 | 26.8 | 24.8 | 16.6 | 16.0 | 17.1 | 16.5 | 0.5 | 0.5 | * | * | 15.3 | 14.3 | 15.3 | 14.3 | 0.0 | 0.0 |
| 015440 | 28.4 | 27.0 | 17.0 | 16.5 | * | * | * | * | 25.4 | 23.0 | 15.8 | 15.4 | 16.0 | 15.4 | 0.2 | 0.1 |
| 016380 | 32.7 | 29.0 | * | * | 17.5 | 17.1 | * | * | 30.5 | 24.2 | 16.3 | 15.5 | 16.4 | 15.6 | 0.1 | 0.1 |
| 016412 | 30.3 | 28.3 | 11.7 | 11.4 | 12.1 | 11.9 | 0.4 | 0.4 | 27.6 | 25.1 | 11.6 | 11.1 | 11.8 | 11.4 | 0.3 | 0.3 |
| 016888 | 32.1 | 29.3 | 16.6 | 16.1 | 16.7 | 16.2 | 0.1 | 0.2 | 29.3 | 27.5 | 16.1 | 15.0 | 16.2 | 15.2 | 0.1 | 0.1 |
| 018556 | 33.2 | 27.2 | 17.9 | 17.1 | 16.9 | 16.2 | -1.0 | -1.0 | * | * | 18.7 | 18.1 | 17.6 | 16.8 | -1.1 | -1.3 |
| 020020 | 35.9 | 33.5 | * | * | 15.2 | 14.8 | * | * | * | * | 14.3 | 13.4 | 14.5 | 13.6 | 0.2 | 0.2 |

| | 2007 | | | | | | | | 2008 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site Number** | **AirTmax** | **Air7Tmax** | **Upstrm Tmax** | **Upstrm 7Tmax** | **DownstrmTmax** | **Downstrm 7Tmax** | **D_Tmax** | **D_7Tmax** | **AirTmax** | **Air7Tmax** | **Upstream Tmax** | **Upstrm 7Tmax** | **DownstrmTmax** | **Downstrm7 Tmax** | **D_Tmax** | **D_7Tmax** |
| 022188 | 35.1 | 32.7 | 20.3 | 19.6 | 20.6 | 19.9 | 0.3 | 0.3 | 34.7 | 31.0 | 18.5 | 17.5 | 18.6 | 17.7 | 0.2 | 0.1 |
| 023455 | 26.9 | 24.3 | 15.2 | 14.5 | 15.1 | 14.3 | -0.1 | -0.2 | * | * | 14.6 | 13.2 | 13.7 | 12.6 | -0.9 | -0.5 |
| 023502 | 25.4 | 22.8 | 14.5 | 13.8 | 14.0 | 13.3 | -0.5 | -0.5 | 24.8 | 21.3 | 13.9 | 12.8 | 13.5 | 12.5 | -0.4 | -0.3 |
| 023562 | 31.8 | 29.6 | 13.8 | 13.2 | 20.3 | 19.5 | 6.5 | 6.4 | 32.1 | 27.9 | * | * | 20.3 | 18.5 | * | * |

*: indcates data sets with less than 30 days of data, July through August, of the associated year

Table E2: Site-level catchment, canopy, and channel descriptions, Type F/S.

| Site number | Canopy cover | Dom riparian veg | Reach length (m) | Basin Area (ha) | Dist. to divide (m) | Basin slope (%) | Mean depth (m) | Mean thalweg depth (m) | Wetted width (m) | Bankfull width (m) | Channel gradient (%) | LWD, down | LWD, susp. | LWD, jams | Elev., (m) | Channel azimuth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00217 | 64 | CONIF | 300 | 17 | 840 | 7.9 | 0.09 | 0.17 | 1.5 | 2.0 | 1.0 | 2.7 | 0.7 | 0.0 | 694 | 4 |
| 001088 | 93 | CONIF | 300 | 3586 | 9500 | 6.8 | 0.19 | 0.34 | 4.4 | 5.7 | 7.8 | 16.0 | 7.3 | 5.7 | 701 | 290 |
| 001220 | 83 | SHRUB | 300 | 955 | 5800 | 5.5 | 0.05 | 0.14 | 2.3 | 2.9 | 3.6 | 56.3 | 8.0 | 0.0 | 952 | 289 |
| 001263 | 97 | CONIF | 300 | 234 | 2200 | 5.2 | 0.03 | 0.12 | 1.4 | 2.7 | 10.6 | 24.7 | 4.3 | 0.0 | 901 | 332 |
| 001441 | 84 | CONIF | 300 | 521 | 4100 | 2.7 | 0.02 | 0.08 | 1.1 | 3.5 | 7.0 | 21.7 | 9.0 | 0.0 | 1028 | 220 |
| 001729 | 90 | CONIF | 300 | 296 | 2800 | 2.7 | 0.05 | 0.12 | 1.5 | 3.0 | 8.8 | 65.3 | 48.0 | 5.0 | 520 | 48 |
| 002014 | 76 | DECID | 304 | 296 | 2600 | 6.0 | 0.23 | 0.33 | 2.2 | 32.8 | 0.0 | 124.7 | 9.3 | 1.0 | 694 | 358 |
| 002290 | 46 | CONIF | 300 | 7219 | 16100 | 4.8 | 0.20 | 0.41 | 6.7 | 11.0 | 5.8 | 17.0 | 0.7 | 2.0 | 688 | 81 |
| 002624 | 92 | DECID | 301 | 533 | 4500 | 3.9 | 0.10 | 0.25 | 2.0 | 5.0 | 16.4 | 52.3 | 12.0 | 2.7 | 623 | 175 |
| 002785 | 93 | CONIF | 300 | 390 | 3500 | 3.0 | 0.06 | 0.14 | 1.4 | 3.0 | 11.2 | 13.7 | 3.0 | 0.0 | 595 | 130 |
| 003233 | 53 | CONIF | 300 | 402 | 4300 | 3.5 | 0.27 | 0.62 | 13.0 | 18.4 | 2.4 | 67.0 | 3.0` | 1.3 | 764 | 104 |
| 003256 | 0 | GRASS | 300 | 1944 | 7700 | 5.2 | 0.15 | 0.33 | 2.3 | 87.7 | 1.5 | 0.3 | 0.0 | 0.0 | 822 | 149 |
| 004132 | 77 | CONIF | 300 | 6449 | 11400 | 5.8 | 0.13 | 0.31 | 2.7 | 3.9 | 1.0 | 5.3 | 0.0 | 0.0 | 730 | 60 |
| 004156 | 71 | DECID | 300 | 4078 | 8400 | 4.7 | 0.21 | 0.37 | 4.2 | 8.9 | 1.9 | 30.7 | 4.3 | 3.3 | 924 | 232 |
| 004179 | 77 | DECID | 600 | 3053 | 9700 | 10.2 | 0.02 | 0.02 | 0.6 | 10.3 | 0.4 | 21.0 | 0.3 | 0.0 | 788 | 252 |
| 004271 | 89 | DECID | 300 | 588 | 5000 | 4.3 | 0.07 | 0.12 | 1.2 | 2.7 | 4.2 | 24.3 | 15.3 | 0.0 | 757 | 345 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 004348 | 81 | CONIF | 299 | 5471 | 9700 | 6.1 | 0.25 | 0.53 | 6.4 | 9.8 | 12.6 | 63.3 | 10.3 | 2.7 | 1249 | 145 |
| 004352 | 93 | CONIF | 299 | 1743 | 6700 | 4.7 | 0.15 | 0.30 | 3.3 | 5.0 | 9.8 | 22.3 | 6.7 | 1.3 | 844 | 250 |
| 004718 | 100 | CONIF | 298 | 421 | 3700 | 4.8 | 0.13 | 0.23 | 2.3 | 4.2 | 2.8 | 44.7 | 2.7 | 1.0 | 813 | 68 |
| 004961 | 50 | SHRUB | 300 | 3168 | 9600 | 2.3 | 0.20 | 0.38 | 2.1 | 4.6 | 1.3 | 7.0 | 0.3 | 0.7 | 571 | 137 |
| 005008 | 7 | BURNED | 300 | 759 | 5900 | 4.5 | 0.13 | 0.25 | 2.6 | 3.0 | 4.6 | 18.7 | 14.0 | 1.0 | 1690 | 40 |
| 005748 | 93 | CONIF | 298 | 342 | 3100 | 5.6 | 0.08 | 0.17 | 1.6 | 2.3 | 8.8 | 32.0 | 10.7 | 0.0 | 952 | 171 |
| 007567 | 75 | CONIF | 300 | 1187 | 7600 | 4.2 | 0.08 | 0.19 | 2.0 | 3.6 | 3.8 | 6.7 | 3.3 | 0.0 | 726 | 203 |
| 007692 | 75 | CONIF | 300 | 4762 | 12000 | 3.5 | 0.11 | 0.24 | 3.0 | 5.7 | 2.1 | 19.3 | 6.7 | 0.7 | 597 | 155 |
| 007755 | 69 | DECID | 300 | 796 | 5300 | 6.7 | 0.10 | 0.26 | 3.6 | 4.5 | 14.6 | 55.0 | 6.3 | 0.3 | 989 | 155 |
| 009409 | 88 | CONIF | 300 | 333 | 3300 | 4.7 | 0.11 | 0.23 | 3.2 | 7.3 | 5.1 | 53.3 | 8.7 | 3.3 | 638 | 135 |
| 010629 | 87 | DECID | 300 | 1587 | 9700 | 3.2 | 0.13 | 0.24 | 1.9 | 4.1 | 3.1 | 22.7 | 6.3 | 3.3 | 652 | 68 |
| 010804 | 91 | CONIF | 300 | 260 | 3400 | 5.8 | 0.10 | 0.16 | 1.0 | 7.2 | 0.9 | 15.3 | 5.3 | 0.0 | 733 | 11 |
| 013145 | 14 | CONIF | 300 | 24041 | 34100 | 7.9 | 0.13 | 0.40 | 13.9 | 18.4 | 1.0 | 14.0 | 0.0 | 0.0 | 713 | 18 |
| 013153 | 49 | CONIF | 299 | 924 | 4900 | 3.2 | 0.04 | 0.09 | 1.2 | 5.0 | 24.4 | 7.7 | 1.3 | 0.0 | 314 | 220 |
| 013261 | 76 | CONIF | 300 | 779 | 6800 | 3.4 | 0.22 | 0.35 | 2.3 | 3.1 | 13.2 | 41.7 | 6.7 | 5.7 | 1154 | 77 |
| 013520 | 71 | DECID | 300 | 819 | 4900 | 5.1 | 0.16 | 0.33 | 3.1 | 4.2 | 1.2 | 27.0 | 2.3 | 0.0 | 1341 | 216 |
| 013534 | 60 | DECID | 297 | 9627 | 16700 | 4.3 | 0.18 | 0.43 | 8.8 | 10.2 | 1.2 | 24.0 | 2.0 | 0.0 | 1068 | 220 |
| 013866 | 55 | SHRUB | 300 | 525 | 5800 | 3.4 | 0.11 | 0.24 | 2.5 | 4.8 | 1.8 | 18.3 | 0.3 | 1.0 | 1029 | 145 |
| 014156 | 98 | CONIF | 284 | 1096 | 28700 | 6.7 | 0.11 | 0.23 | 2.3 | 4.0 | 22.4 | 64.3 | 6.0 | 0.0 | 873 | 262 |
| 014862 | 94 | SHRUB | 300 | 1527 | 9300 | 5.1 | 0.05 | 0.13 | 2.6 | 4.5 | 5.0 | 30.0 | 5.7 | 2.0 | 821 | 150 |
| 015009 | 91 | CONIF | 300 | 630 | 5000 | 1.9 | 0.07 | 0.12 | 1.5 | 3.4 | 2.6 | 24.7 | 0.0 | 0.0 | 651 | 131 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 015073 | 93 | CONIF | 298 | 818 | 5500 | 2.9 | 0.05 | 0.11 | 1.1 | 1.9 | 9.8 | 8.7 | 100 | 0.0 | 1088 | 279 |
| 015252 | 92 | DECID | 300 | 2616 | 8900 | 6.8 | 0.12 | 0.23 | 2.7 | 3.8 | 3.2 | 25.0 | 8.7 | 2.7 | 755 | 284 |
| 015327 | 81 | CONIF | 300 | 389 | 3200 | 5.9 | 0.07 | 0.14 | 1.9 | 4.0 | 8.0 | 28.0 | 3.0 | 2.0 | 940 | 190 |
| 015440 | 79 | CONIF | 300 | 2171 | 8000 | 5.5 | 0.10 | 0.23 | 2.9 | 6.9 | 4.0 | 25.7 | 3.7 | 1.7 | 763 | 58 |
| 016380 | 89 | DECID | 300 | 692 | 5800 | 2.9 | 0.06 | 0.14 | 2.2 | 4.3 | 20.2 | 25.3 | 6.0 | 2.3 | 706 | 110 |
| 016412 | 92 | CONIF | 300 | 1576 | 9500 | 6.1 | 0.15 | 0.21 | 1.4 | 3.0 | 5.4 | 16.7 | 3.3 | 1.3 | 877 | 306 |
| 016888 | 94 | DECID | 300 | 2042 | 8800 | 3.4 | 0.08 | 0.16 | 1.8 | 2.6 | 1.4 | 9.3 | 0.7 | 0.0 | 815 | 30 |
| 018556 | 86 | SHRUB | 300 | 16056 | 25700 | 3.5 | 0.08 | 0.19 | 3.1 | 3.4 | 3.0 | 7.7 | 2.0 | 0.0 | 796 | 250 |
| 020020 | 93 | CONIF | 300 | 239 | 2600 | 6.8 | 0.04 | 0.11 | 1.6 | 2.7 | 4.6 | 22.0 | 11.7 | 0.0 | 1008 | 248 |
| 022188 | 39 | DECID | 300 | 7833 | 14600 | 4.0 | 0.15 | 0.31 | 6.7 | 8.0 | 1.2 | 16.7 | 0.3 | 0.3 | 836 | 124 |
| 023455 | 79 | CONIF | 300 | 914 | 4900 | 5.2 | 0.119 | 0.37 | 4.3 | 10.1 | 3.9 | 29.0 | 5.0 | 2.7 | 1024 | 71 |
| 023502 | 85 | CONIF | 300 | 469 | 4000 | 2.9 | 0.04 | 0.15 | 1.7 | 3.1 | 4.6 | 14.7 | 1.3 | 0.0 | 1377 | 226 |
| 023562 | 74 | DECID | 297 | 2229 | 8500 | 4.4 | 0.06 | 0.12 | 1.8 | 7.4 | 4.2 | 7.7 | 1.3 | 1.7 | 861 | 80 |