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Ecological Condition of Western Cascades Ecoregion Streams

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an Environmental Monitoring and Assessment Program (EMAP) Report

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I. PURPOSE

The purposes of this report are to:

- Assess and report on the condition of small streams in the Western Cascades ecoregion of Oregon and Washington (**Map 1**).
- Compare the overall condition of small streams in the Western Cascades ecoregion to selected streams with minimum levels of human disturbance (reference sites).

This report summarizes data collected as part of the Regional Environmental Monitoring and Assessment Program (R-EMAP). This R-EMAP project is a cooperative effort between the Environmental Protection Agency (EPA) Office of Research and Development, EPA Region 10, the Washington Department of Ecology (Ecology), and the Oregon Department of Environmental Quality (ODEQ).

Photo: French Creek, Oregon. Courtesy of Shannon Hubler, Oregon DEQ

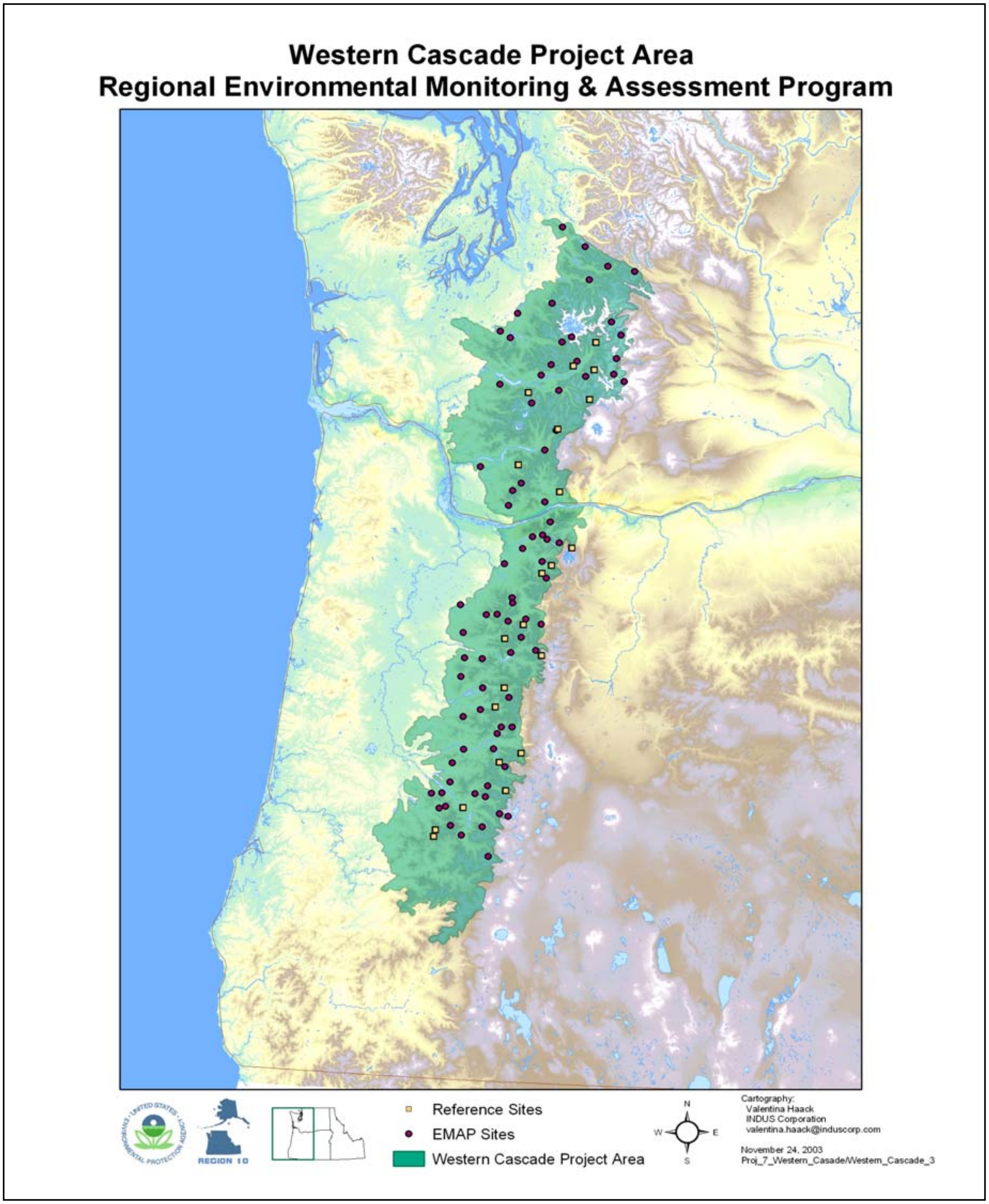
II. BACKGROUND

Ecoregions are distinct geographic areas based on topography, climate, land use, geology, soils, and naturally occurring vegetation. Ecoregions can be viewed at a variety of scales or levels. The Cascades ecoregion is a level III ecoregion (Omernik, 1987). There are 76 level III ecoregions across the conterminous United States. The Cascades ecoregion is comprised of the Cascade Mountain Range in Oregon and Washington. Most of the ecoregion is between 2,000 and 7,000 ft in elevation and is densely forested (see **Map 1**).

Each ecoregion can be further refined into sub-ecoregions, also referred to as level IV ecoregions. In this project we will be discussing two sub-ecoregions of the Cascades ecoregion, the Western Cascades Lowlands and Valleys sub-ecoregion and the Western Cascades Montane Highlands sub-ecoregion (Pater et al, 1998). **Map 2** shows the two sub-ecoregions. We will refer to these two sub-ecoregions collectively as the Western Cascades ecoregion.

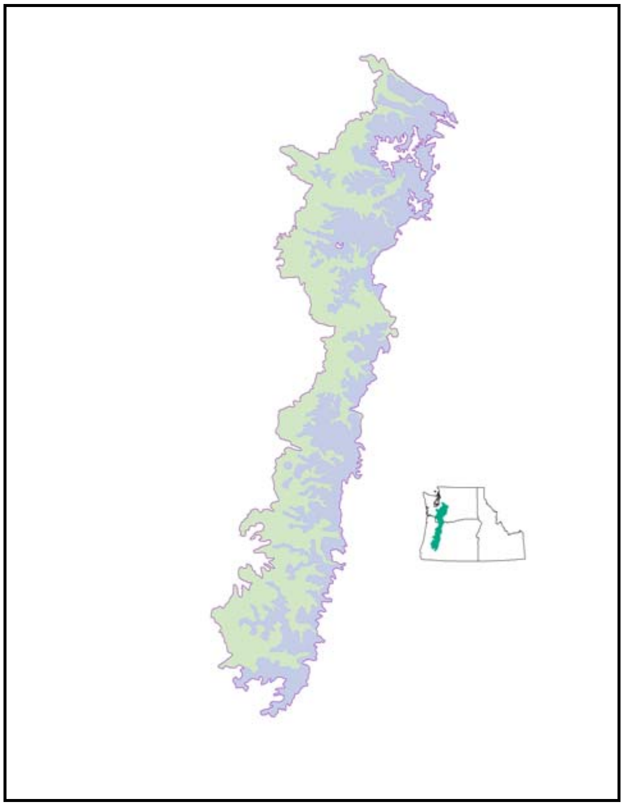
The Western Cascades ecoregion excludes all of the high Cascades and Subalpine Cascades sub-ecoregions. It also excludes all of the Cascades south of Lane County in Oregon and all of the Cascades north of about I-90 in Washington. The Western Cascades ecoregion is 10,859 square miles in area (about the size of Massachusetts) and makes up 63% of the Level III Cascades ecoregion.

The Western Cascades Lowlands and Valleys sub-ecoregion is characterized by a network of steep ridges and narrow valleys. Elevations are generally less than 3,200 ft and are the lowest in the Cascades ecoregion. The mild climate promotes lush forests that are dominated by Douglas fir and western hemlock.



Map 1. Map of Western Cascades ecoregion showing sites selected using EMAP probability design and reference sites.

The Western Cascades Montane Highlands sub-ecoregion is composed of steep, glaciated mountains that have been dissected by high gradient streams. It has lower temperatures than the Western Cascades Lowlands and Valleys sub-ecoregion and is characterized by a deep annual snow pack. It supports forest dominated by Pacific silver fir, western hemlock, mountain hemlock, Douglas fir and noble fir (Omernik, 1987).



Map 2. Western Cascades Lowlands and Valleys subecoregion in green and Western Cascades Montane Highlands subecoregion in blue.

The predominant land cover type in the Western Cascades ecoregion is forest (87%) (**Figure 1**). The next most common land cover type is transitional, which is defined as areas with sparse vegetation (<25%) that are dynamically changing from one land cover to another often due to land use activities (e.g. forestry clear cuts, construction) and natural processes (e.g. fire, flood). There is no urban land cover and very limited agriculture (1%) in the Western Cascades ecoregion.

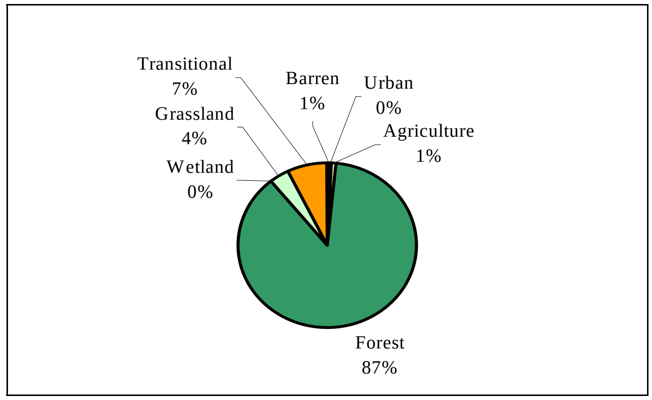


Figure 1. Percent of land in major landtype categories for the Western Cascades ecoregion.

Timber harvest is the major industry in this area. The primary land ownership is Federal, followed by private (**Figure 2**). In Washington, the federal land ownership is primarily the US Forest Service (41%) followed by the National Park Service. In Oregon, the US Forest Service (58%) is also the primary federal landowner, followed by the Bureau of Land Management.

The density of roads in Western Cascades ecoregion (road length/ecoregion area) is 1.23km/square km. The density of roads in forested portion of this ecoregion is 1.15km/square km.

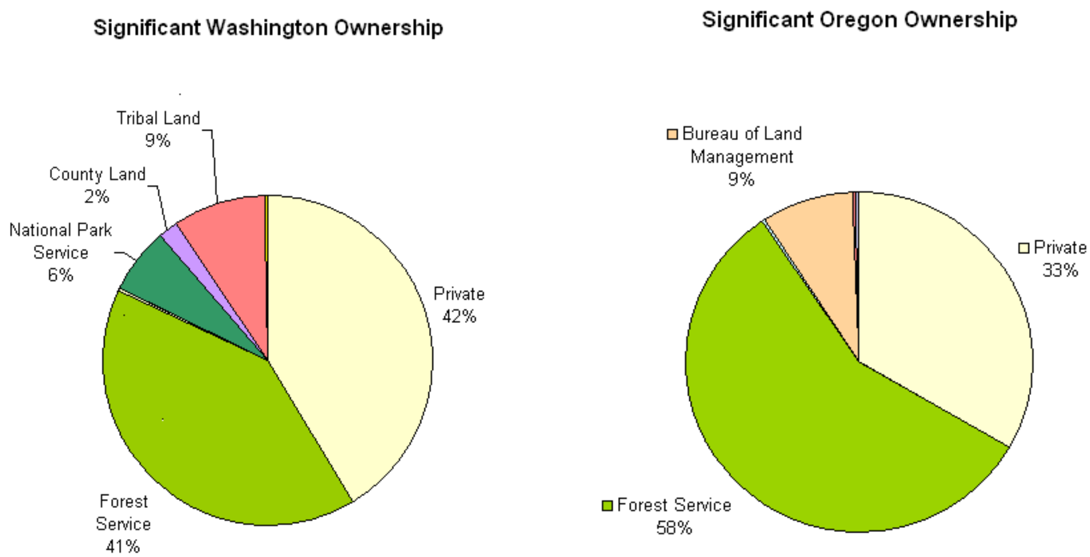


Figure 2. Percent landownership within significant categories by state in the Western Cascades ecoregion.

III. PROJECT DESCRIPTION

This document summarizes data collected in the Western Cascades ecoregion of Washington and Oregon as part of the Regional Environmental Monitoring and Assessment Program (R-EMAP). The project is a cooperative effort between the Environmental Protection Agency (EPA) Office of Research and Development, EPA Region 10, the Washington Department of Ecology (Ecology), and the Oregon Department of Environmental Quality (ODEQ). Ecology and ODEQ conducted all field sampling for this project in 1999-2000.

The Environmental Monitoring and Assessment Program (EMAP) was initiated by EPA's Office of Research and Development (ORD) to estimate the current status and trends of the nation's ecological resources and to examine associations between ecological condition and natural and human disturbances. The goal of EMAP is to develop ecological methods and procedures that advance the science of measuring environmental resources to determine if they are in an acceptable or unacceptable condition. Two major features of EMAP are:

- the use of ecological indicators, and
- the probability-based selection of sample sites.

Regional EMAP (R-EMAP) uses EMAP's indicator concepts and statistical design, and applies them to projects of smaller geographic scale and time frames. R-EMAP provides States and EPA Regional offices opportunities to use EMAP indicators to answer questions of regional interest. The following are general descriptions of the EMAP sample design and indicators.

A. Design – How to Select Stream Sites to Sample

Environmental monitoring and assessments are typically based on subjectively selected stream reaches. Peterson et al. (1998; 1999) compared subjectively selected localized lake data with probability-based sample selection and showed the results for the same area to be substantially different. The primary reason for these differences was lack of regional sample representativeness of subjectively selected sites. Stream studies have been plagued by the same problem. A more objective approach was needed to assess overall stream quality on a regional scale.

EMAP uses a statistical sampling design that views streams as a continuous resource. This allows statements to be made in terms of length of the stream resource in various conditions (Herlihy et al., 2000). Sample sites are randomly selected using a systematic grid based on landscape maps overlaid with stream traces. The EMAP systematic grid provides uniform spatial coverage, making it possible to select stream sample locations in proportion to their occurrence (Overton et al., 1990). This design allows one to make statistically valid estimations from the sample data to the entire length of stream in a study area (the Western Cascades ecoregion), such as estimates of the number of stream miles or kilometers that are in "poor" condition.

Study sites were selected from a stream population of all mapped (1:100,000 scale) 2nd and 3rd order streams in the Western Cascades ecoregion, using EMAP-Surface Water protocols (Herlihy et. al., 2000). See **Map 1** for the location of the sites.

Stream Order	Percent in Oregon	Percent in Washington	Total Percent
*0	.7	1.4	2.1
1st	31.9	31.9	63.8
2nd	7.5	9.1	16.6
3rd	4.8	5.4	10.2
>3rd	3.8	3.5	7.3

*(0 order streams are usually side channels on rivers, unconnected reaches, canals/ ditches or intermittent/ephemeral)

Table 1. Proportion of streams in the Western Cascades ecoregion in each stream order.

Although 1st through 3rd order streams are usually wadeable and therefore suitable for sampling using EMAP protocols, this project was limited to 2nd and 3rd order streams. First order streams were excluded for two primary reasons:

- Limited funding – we need to target the aquatic resource most likely to be affected by humans.
- Access issues - first order streams are more likely to be the most costly and difficult to access and have the most restrictive time frame of accessibility (snow for much of the field season).

There are approximately 19,489 total km (12,100 mi) of streams in the Western Cascades ecoregion. The 2nd and 3rd order streams represent 26.8 % or 5224 km (3,246 mi) of streams in this ecoregion.

The EMAP probability design was used to select a random sample of the target population. In this study, the "target" population is 2nd and 3rd order streams. A total of 108 sites were evaluated for field sampling. Of these, 79 were selected as "target sites" (useable sample sites). Sites determined to be useable or "target" sites if they were 2nd and 3rd order streams that were accessible, wadeable, perennial, and free of physical barriers. Reasons for excluding the remaining 29 sites are shown in **Figure 3**. "Non-target" sites were sites found to not be a 2nd or 3rd order stream, for example a wetland, when visited. The estimated stream length represented by the 79 target samples is 3,779 km of the total 5,224 km. Each of 79 sites was sampled at least once during the 1999-2000 field season. Sites were sampled July 5th through October 19th.

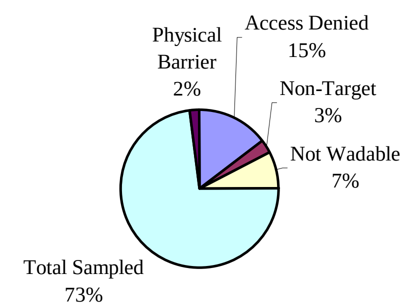


Figure 3. Status of sites initially selected for sampling following sites evaluation.

Reference condition represents the biological potential or goal for the waterbody. The reference condition establishes the basis for making comparisons and for detecting impairment. The most common way to establish the reference condition is to collect actual data from a number of sites that represent condition with minimal human disturbance. The data is then aggregated from these sites to develop a reference condition for that area, ecoregion, or class of waterbody.

For this project, in addition to the 79 sites selected using the EMAP probability design, an additional 22 reference sites were selected (**Map 1**). The reference condition for each indicator metric is the average value calculated from these 22 sites. The reference sites were selected by the state environmental agencies (Oregon DEQ and Ecology) from 2nd and 3rd order streams in the Western Cascades ecoregion to represent minimal human disturbance. The reference sites were sampled using the same field methods as the probability selected sites, which will enable us to compare the dataset from these reference sites to the probability dataset.

B. Indicators - What to Assess at Each Selected Site

The objective of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. To implement the Clean Water Act, States adopt water quality standards. These standards are designed to protect public health or welfare, enhance the quality of water, and protect biological integrity.

Biological Integrity:

> "a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley, 1981; Frey, 1977)

In general terms, a water quality standard defines the goals of a waterbody by designating the use or uses to be made of the water (such as aquatic life, coldwater biota or salmonid spawning), setting criteria necessary to protect those uses, and preventing degradation of water quality. Therefore, in order to assess the nation's waters, it is important to measure water quality (stream water parameters), physical habitat (watershed, riparian and in-stream measurements) and biological (vertebrate and invertebrates communities) condition. EMAP uses ecological indicators to quantify these conditions (Lazorchak, et al. 1998). Indicators are measurable characteristics of the environment, both abiotic and biotic, that can provide information on ecological resources.

A general list of the indicator categories used in EMAP to detect stress in stream ecosystems is provided in **Table 2**. The following section describes EMAP measurements in each of these indicator categories.

Indicator	Rationale
Stream water chemistry	Water chemistry affects stream biota. Numeric criteria are available to evaluate some water quality parameters.
Watershed condition	Disturbance related to land use affects biota and water quality.
Instream physical habitat and riparian condition	Instream and riparian alterations affect stream biota and water quality. Physical habitat in streams includes all physical attributes that influence organisms.
Biological: fish and amphibians	Fish and amphibians are meaningful indicators of biological integrity. They occupy the upper levels of the aquatic food web and are affected by chemical and physical changes in their environment. They are direct measures of aquatic life uses.
Biological: benthic macro-invertebrates	Benthic macroinvertebrates live on the bottom of streams and reflect the overall biological integrity of the stream. They are direct measures of aquatic life uses.

Table 2. General EMAP indicators.

IV. METHODS

Photo: Opal Creek, Oregon. Courtesy of Shannon Hubler, Oregon DEQ

In this section, we briefly describe the methods used for collecting stream water chemistry, physical habitat and biological data. In addition, the methods used to analyze the data are presented. EMAP field methods were primarily used and additional detailed information is available in Lazorchak et al., 1998. Any exceptions to the EMAP field methods are noted below.

A. Field Measurements

Identical field data collection methods were used for both the probability sites and reference sites for all indicators described below.

Stream Water Chemistry

Stream water chemistry characteristics influence the organisms that reside in streams. A great deal of information is available on the effects of specific chemicals on aquatic biota. Data for 11 water quality parameters were collected at most sites. Measurements of pH, dissolved oxygen (DO), stream temperature, conductivity, alkalinity, total phosphorus (TP), Nitrite-Nitrate (NO_2-NO_3), ammonia (NH_3), chloride (Cl^-), sulfate (SO_4) and total suspended solids were made. The rationale behind the selection of some of these stream water measures are presented in **Table 3**.

Water chemistry indicator	Importance to biota	Examples of human activities that influence this indicator
Stream Temperature	-Influences biological activity - Growth and survival of biota	- Riparian shade reduction - Altered stream morphology
Dissolved Oxygen (DO)	- Growth and survival of fish - Sustains sensitive benthic invertebrates - Organic material processing	- Erosion - Addition of organic matter - Riparian shade reduction - Industrial and municipal waste
pH	- Fish production - Benthic invertebrate survival	- Mining - Addition of organic matter - Fuel burning emissions (e.g., automobiles)
Conductivity	- Indicator of dissolved ions	- Agricultural returns, industrial input and mining
Nutrients - Total phosphorous (TP), Total nitrogen (TPN), Nitrite-Nitrate (NO_2-NO_3), and Ammonia (NH_3)	- Stimulates primary production -Accumulation can result in nutrient enrichment	- Erosion - Recreation, septic tanks and livestock - Stormwater runoff - Sewage, livestock waste, and agriculture - Salmon overharvest
Chloride (Cl^-)	- A surrogate for human disturbance	- Industrial discharge, fertilizer use, livestock waste, and sewage

Table 3. Stream water indicators.

Individual states also collected some additional parameters (such as dissolved organic carbon) that will not be discussed in this document.

Physical Habitat Indicators

Physical habitat in streams includes all those physical attributes that influence or provide sustenance to organisms within the stream (Kaufmann in Peck et al., 2003).

Physical habitat varies naturally, as do biological and chemical characteristics, thus expectations of habitat condition differ even in the absence of human caused disturbance. Degradation of aquatic habitats by nonpoint source activities is recognized as one of the major causes for the decline of anadromous and resident fish stocks in the Pacific Northwest (Williams et al., 1989).

Measurements of physical habitat parameters fall into one of the following three types of sampling method protocols.

1. Continuous measurements are collected along the entire length of the sample reach. Thalweg profile (a survey of depth along the stream channel), and presence/absence of soft sediments (fine gravel or smaller) were collected at either 100 or 150 equally spaced points along the stream reach. An observation of the geomorphic channel type (e.g. riffle, glide, pool) was made at each point. Crews also tally large woody debris along the reach.

2. Transect measurements are collected from 11 evenly spaced transects. Measures/ observations of bankfull width, wetted width, depth, substrate size, shade, and fish cover were taken at each transect. Measures and/or visual estimates of riparian vegetation structure, human disturbance, and stream bank angle, incision and undercut are also collected at each transect. Gradient measurements and compass bearing between each of the 11 stations are collected to calculate reach gradient and channel sinuosity.

3. Reach measurements apply to the reach as a whole. Channel morphology class for the entire reach is determined (Montgomery and Buffington, 1993) and instantaneous discharge is measured at one optimally chosen cross-section.

<u>Some Useful Definitions- Habitat:</u>

<u>Bankfull width</u> - The stream width measured at the average flood water mark.

<u>Canopy</u> - A layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand.

<u>Channel</u> - An area that contains continuously or periodically flowing water that is confined by banks and a stream bed.

<u>Large Woody Debris</u> - Pieces of wood larger than 5 feet long (1.5m) and 4 inches (10.1cm) in diameter, in a stream channel.

<u>Riparian area</u> - An area of land and vegetation adjacent to a stream that has a direct effect on the stream. This includes woodlands, vegetation, and floodplains.

<u>Sinuosity</u> - The amount of bending, winding and curving in a stream or river.

<u>Stream gradient</u> - A general slope or rate of change in vertical elevation per unit of horizontal distance of the water surface of a flowing stream.

<u>Substrate</u> - The composition of the grain size of the sediments in the stream or river bottom, ranging from rocks to mud.

<u>Thalweg</u> - The deepest part of the stream.

The major types of physical habitat indicators are channel form, substrate, riparian vegetation, large woody debris, and fish cover. The importance of each is described as follows.

Channel Form

The cross section of a stream channel (width and depth) provides information for evaluating total habitat space available for fish and other organisms. Because the data are collected in a systematically spaced approach, the means are estimates of the spatial distribution of the habitat parameters measured.

Substrate

Substrate describes the grain size of particles on the stream bottom, and ranges from rocks to mud. Substrate is an important feature of stream habitat. Stream substrate size is influenced by many factors including geology, gradient, flow and channel shape. Substrate particle size data were collected at five locations along each of the 11 evenly spaced transects at each sample site. Data were expanded to reflect the proportion of the stream channel area.

Riparian Vegetation

Riparian (stream bank) vegetation is important for several reasons: it influences channel form and bank stability through root strength; it is a source of recruitment for LWD that influences channel complexity and provides cover for fish; it provides inputs of organic matter such as leaves; and shades the stream which influences water temperature.

Expressed as a proportion of the reach, riparian cover data were collected for three vegetation layers:
1. Canopy - >5m
2. Mid level - .5m to 5 m
3. Ground cover - <.5m

Visual estimates of cover density and general structural/species vegetation classes (e.g. coniferous, deciduous) of each layer were recorded. Three types of riparian canopy (riparian vegetation >5m) cover types were considered: coniferous, deciduous, and mixed coniferous and deciduous cover.

Stream Shading

In addition to riparian vegetation presence, stream shading from riparian canopy was assessed using densiometer readings at each of the 11 transects. The amount of riparian shading influences the amount of solar radiation that reaches stream. Shade conditions were estimated for both bank and mid-channel.

Large Woody Debris (LWD)

Large woody debris (LWD), as single pieces or in accumulations (i.e. log jams), alters flow and traps sediment, thus influencing channel form and related habitat features. The quantity, type and size of LWD recruited to the channel from the riparian zone and from hillslopes can be very important to stream function. Each pieces of LWD that is at least partially in the baseflow channel is tallied by length and diameter classes.

Pools

In streams, pools are areas of deeper, slower flowing water that are important habitat features for fish. The abundance of pools and their size and depth depends on the stream's power and channel complexity. Stream size, substrate size and abundance, and the presence of larger roughness elements (e.g. LWD) all contribute to the frequency and quality of pools.

Fish Cover

Many structural components of streams are used by fish as concealment from predators and as hydraulic refuge (e.g. bank undercuts, LWD, boulders). Although this metric is defined by the likelihood of fish use, fish cover is also indicative of the overall complexity of the channel which is likely to be beneficial to other organisms.

Biological Indicators

Fish/Aquatic Vertebrate Assemblage

The physical degradation of streams can cause changes in the food web and the composition and distribution of habitats (Lonzarich, 1994). In some regions, fish are good indicators of these long-term effects and broad habitat conditions because they are relatively long-lived and mobile (Karr et al., 1986). Fish assemblages integrate various features of environmental quality, such as food abundance and habitat quality and therefore may be better indicators of land-use impacts than single salmonid species (Karr, 1981).

Some Useful Definitions - Biota

Aquatic Assemblage - an organism group of interacting populations in a given waterbody, for example, vertebrate (fish and amphibians) assemblage or a benthic macroinvertebrate assemblage.

Benthic Macroinvertebrates - animals without backbones, living in or on the sediments, and of a large enough size to be seen by the unaided eye (e.g. aquatic larvae of insects).

Amphibians are also sensitive to alterations in the environment. When amphibian data are combined with fish data, the more general term aquatic vertebrate will be used.

The objectives of the vertebrate assemblage field methods are to:
1) collect data useful for estimating relative abundance of all species present in the assemblage, and
2) collect all species except the most rare species in the assemblage.

Fish were sampled along the entire length of the reach with one-pass electro-fishing (Lazorchak, et al., 1998). All portions of the sample reach were fished. Fish were identified, counted, and measured and voucher specimens were collected for species that were difficult to identify. Only amphibians that were captured during electrofishing or found on the banks were identified and counted. Although these methods were not used to estimate absolute abundance, standardized collection techniques allow for calculation of proportionate abundance of species (Reynolds, et al, 2003).

Benthic Invertebrate Assemblage

Benthic macroinvertebrates inhabit the sediment or surface substrates of streams. The benthic macroinvertebrate assemblage reflects the overall biological integrity of the benthic community. Monitoring this assemblage is useful for assessing the status of the stream and monitoring trends. Macroinvertebrates respond to a wide array of stressors in different ways, thus it is often possible to determine the type of stress that has affected a macroinvertebrate assemblage (Klemm et al., 1990). Because many macroinvertebrates have life cycles of a year or more and are relatively immobile, the structure of the macroinvertebrate assemblage is a function of present conditions and conditions of the recent past.

Macroinvertebrates were sampled from the riffles using a D-frame kick net (500μm mesh). Riffles were defined as the portion of the stream with relatively fast currents and shallow depth. A composite sample was collected by combining five kick samples (10 ft^2 total) from separate riffles. Each composite was then sent to a laboratory that identified and counted organisms.

In the laboratory, a random subsample comprised of one sixth or more of each composite was processed for macroinvertebrate identification. For each sample, at least 300 organisms were identified to the finest practical taxonomic level. For samples with less than 300 organisms, all individuals were identified. If less than 100 organisms were identified in a sample, metrics were not calculated for that sample. This only happened in three samples that had a mean abundance of 45, as compared with the mean abundance for the remainder of the samples which was 374.

The macroinvertebrate methods used in the Western Cascades REMAP project are slightly different than that used in other EMAP studies (Lazorchak et al., 1998) where macroinvertebrate data is collected at each transect regardless of habitat type. This difference was to ensure consistency of this REMAP project with earlier State REMAP datasets.

B. Data Analysis

In this report, the primary method for evaluating indicators for sites selected using the EMAP probability design is the cumulative distribution function (CDF). A CDF is a graph that show the distribution of indicator or parameter data for the entire population. The "population" in this report is the total length of 2nd and 3rd order (wadeable) streams of the Western Cascades ecoregion. For example, **Figure 4 (CDF)** shows that approximately 50 percent of the 2nd and 3rd order stream length has an indicator value above 10 (and the other 50% of the stream length are below 10).

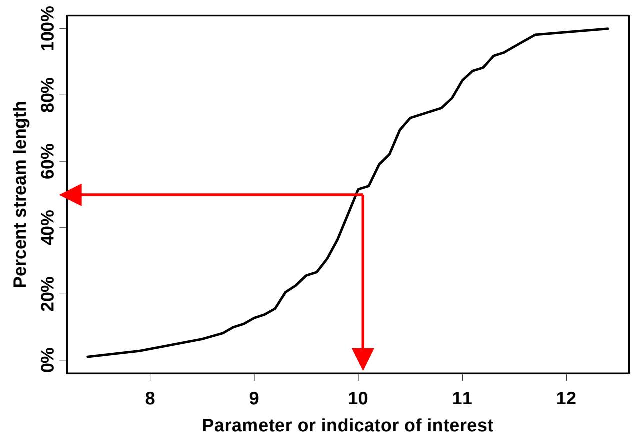


Figure 4. Example cumulative distribution function (CDF).

When data from probability sites are used in this report, they are weighted so that the results can be used to represent the entire stream length of 2nd and 3rd order streams in the Western Cascades ecoregion.

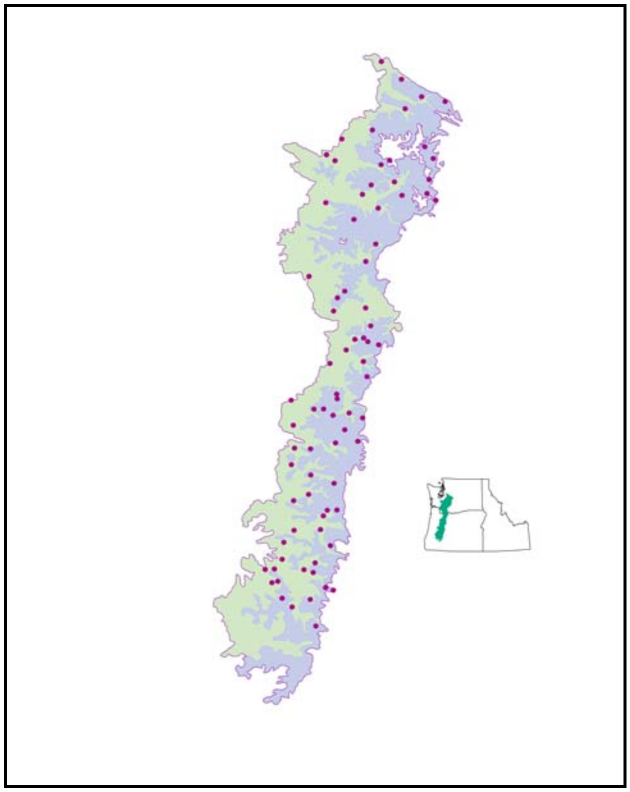
V. DESCRIPTION - of the overall condition of Western Cascades ecoregion streams

Photo: Hideaway Falls, Tumbling Creek, Oregon. Courtesy of Shannon Hubler, Oregon DEQ

A. Introduction

In this section of the report we will describe the overall condition of 2nd and 3rd order streams in the Western Cascades ecoregion of Oregon and Washington based on analysis of probability site data. These data were collected from 79 randomly selected sites in the Western Cascades ecoregion (see **Map 3**) using the R-EMAP protocols (described in Section IV). In the next section (Section VI), we will compare this assessment of overall ecoregion-wide condition, with data from the reference sites. In Sections V and VI, we present only a portion of the indicators that were generated from the field data due to the large volume of information that was collected. Additional indicators are summarized in Appendices 1-6.

There are approximately 19,489 total kilometers of streams (all stream orders) in the Western Cascades ecoregion. The results presented below are from 2nd and 3rd order streams that represent 26.8 percent of the streams in this ecoregion.



Map 3. Western Cascades ecoregion showing sites selected using the EMAP probability design.

B. Stream Water Chemistry

Data for 11 stream water indicators were collected from most sites. Summary statistics for all water chemistry indicators are available in Appendix 2. The results reported below are for only variables that most influence the biota. Data interpretation reflects a single view in time at these representative locations as sites were not continuously sampled and timing of sampling was not intended to capture the peak concentration of chemical indicators. Some aspects of stream water chemistry are temporally variable and a single measurement is of limited value for characterizing specific stream water chemistry conditions.

Dissolved Oxygen (DO)

Dissolved oxygen is the oxygen dissolved in water that is available for organisms to use in respiration. In the Western Cascades ecoregion, DO ranged from 7.4 mg/L to 12.4 mg/L, with a mean of 10 mg/L (**Figure 5**). This is an expected condition in streams with low temperature, hydraulic turbulence and low primary productivity, typical of 2nd and 3rd order streams in the Pacific Northwest.

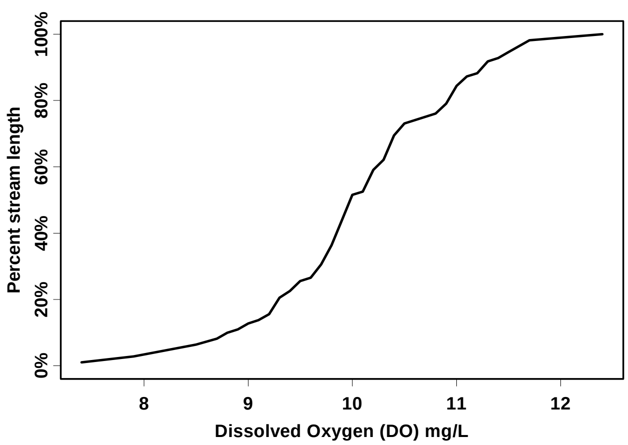


Figure 5. CDF of Dissolved Oxygen (DO).

pH

Another important stream water variable, pH, is a numerical measure of the activity of the constituents that determine water acidity. It is measured on a logarithmic scale of 1.0 (acidic) to 14.0 (basic) and 7.0 is neutral. The pH of the Western Cascades ecoregion sites ranged from 6.2 to 9 with mean 7.3 (**Figure 6**). Measurements of pH collected during the day are typically elevated, as CO_2 is depleted due to photosynthesis which effectively shifts the pH up.

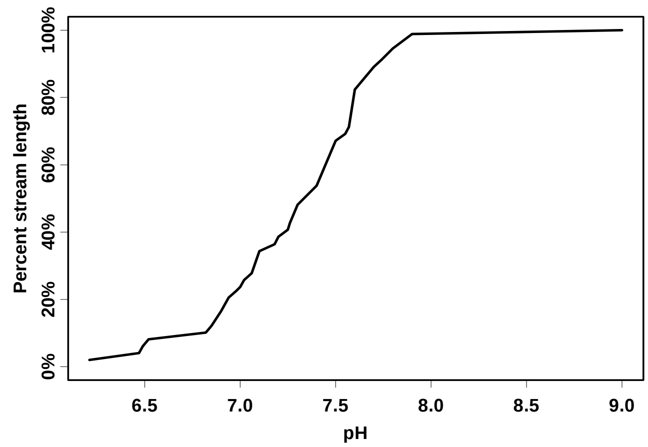


Figure 6. CDF of pH.

Temperature

Water temperature is a critical stream variable. Water temperatures ranged from 3.3°C to 17.6°C and the mean temperature was 11.2°C (see **Figure 7**). The extent of the sample period (July 5th to October 19th) is likely to influence the range of these results.

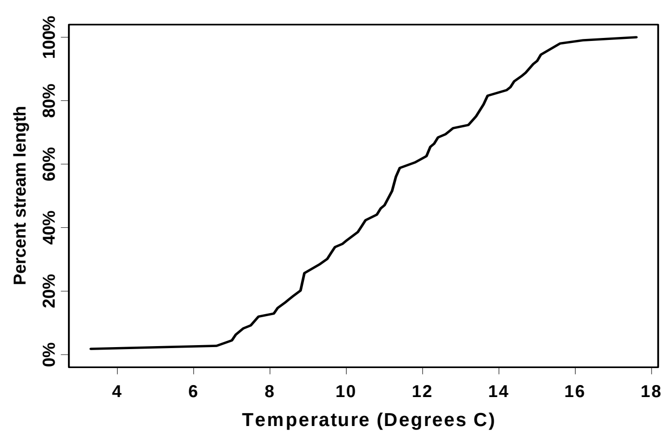


Figure 7. CDF of stream temperature.

Total Suspended Solids (TSS)

Total Suspended Solids (TSS) is a measure of the suspended organic and inorganic solids in water and is expressed in mg/L. TSS is measured by weighing the particles suspended in water which will not pass through a filter. TSS of streams in the Western Cascades ecoregion is shown in **Figure 8**. The mean value for TSS was 31mg/l and the median was 35mg/l. Approximately, 93 percent of the stream length had TSS values less than 12mg/l. Four sites had TSS levels above 275mg/l; all were glacially fed streams originating from Mount Rainier, and were in or near the Mount Rainier National Park.

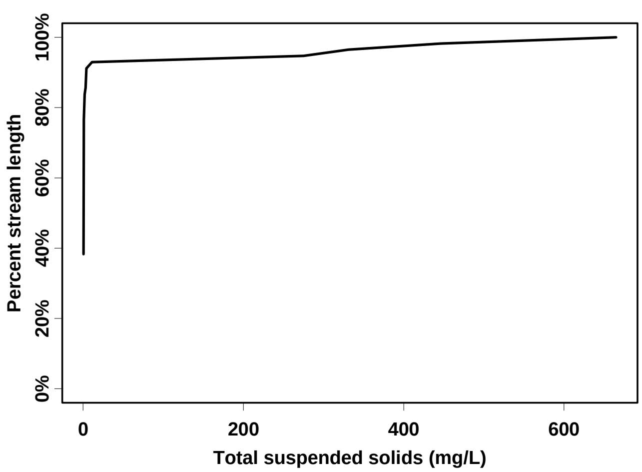


Figure 8. CDF of Total Suspended Solids (TSS).

Nutrients

Excessive nutrient inputs from human-caused sources have been shown to increase algal growth in a process called eutrophication. Alternatively, loss of nutrients from human activities can reduce stream productivity. For example, calculations by Gresh et al. (2000) indicate that only 3 percent of the marine-derived biomass once delivered by anadromous salmon to the rivers of Puget Sound, the Washington Coast, Columbia River, and the Oregon Coast, is currently reaching those streams. Results for several of the collected nutrient parameters are presented in **Table 4.**

Phosphorous

The mean phosphorus concentration from samples collected during this study was 0.04 mg/L. Mean annual phosphorus concentrations in small forested streams of the west slope of the Cascades are typically <0.06 mg/L (McDonald et al., 1991).

Because of the low phosphorous content, many streams in the Pacific northwest region are considered naturally nutrient poor and sensitive to nutrient inputs (Welch et al., 1998). The principal means of increase of phosphorous in Pacific Northwest streams are increased erosion rates and organic matter inputs.

Nutrient	Mean	Min. Value	Max. Value
Total Phosphorus	.04	.003	.52
Nitrite-Nitrate	.03	0	.5

Table 4. Nutrients, expressed as mg/L.

Nitrogen

Nitrogen is one of the most important nutrients in aquatic systems. Inorganic nitrogen which includes, ammonium (NH+4), nitrite (NO-2) and nitrate (NO-3), is the predominant form of nitrogen in flowing waters. Increased inorganic nitrogen stimulates primary production. In unpolluted streams and rivers, nitrate is the most common form. The measure of dissolved nitrogen in this project was nitrate-nitrite. The usual range in non-enriched streams is 1 - 0.5 mg/L (Welch et al; 1998). All measured values for this study were within this normal range. Low nutrients in the form of nitrate are characteristic of forest streams. This is similar to stream monitoring results from the Coast Range ecoregion (Herger and Hayslip, 2000).

C. Physical Habitat Indicators

In this section we describe the physical characteristics of streams at a broad scale using indicators such as channel form and related measures (Kaufmann, et al. 1999). We also describe the physical characteristics of streams at a finer reach scale using indicators such as substrate size and pool habitat. We focus on those indicators of greatest importance to the biota. Summary statistics for all physical habitat indicators are available in Appendix 3.

Channel Form

In the Western Cascades ecoregion, 2nd and 3rd order streams have a large range (.6% to 33.6%) of mean gradients. However most streams had a relatively moderate gradient (median 2.6%). The mean thalweg depth (the depth along the deepest part of the stream) was 48.1cm. Mean wetted stream width was 11.4 m.

Substrate

Substrate is an important feature of stream habitat in a variety of ways including; cover and protection for juvenile fish, habitat for macroinvertebrates and habitat for spawning salmonids. Excess supplies of fine sediments can decrease both the abundance and quality of this habitat by filling spaces between gravels, cobbles and boulders. Field measurements of substrate particles are used to quantify the presence of the various sizes of substrate present in streams.

The sand/fines sediment size class includes substrate particles that are less than 2 mm in diameter. This substrate size class was not common in the streams of the study area (mean 12.1%). Over 85% of the stream miles had less than 20 percent sand/fines substrates (**Figure 9**).

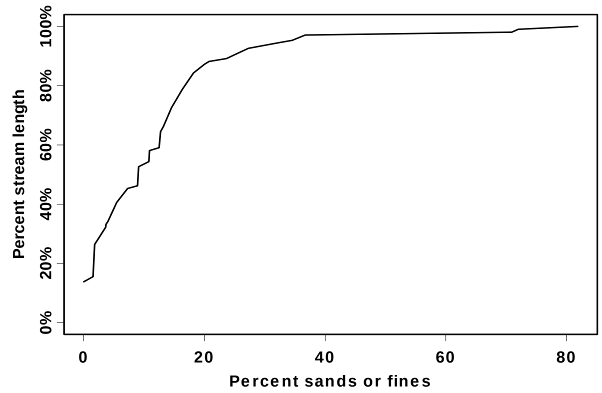


Figure 9. CDF of percent sand/fines.

Another way of looking at the substrate data is by expressing the average geometric mean substrate size on a logarithmic scale ($\log_{10}$). In this way, the range of the distribution of the various substrate size classes can be viewed on one graph. In the Western Cascades ecoregion 2nd and 3rd order streams, fine gravel or smaller (≤16mm) was the mean substrate size in 10% of the stream miles. Most streams had mean substrate size in the coarse gravel or larger size classes. A little less than half of the stream length has an estimated geometric mean diameter that is smaller than or equal to 100 mm, which is cobble size (**Figure 10**).

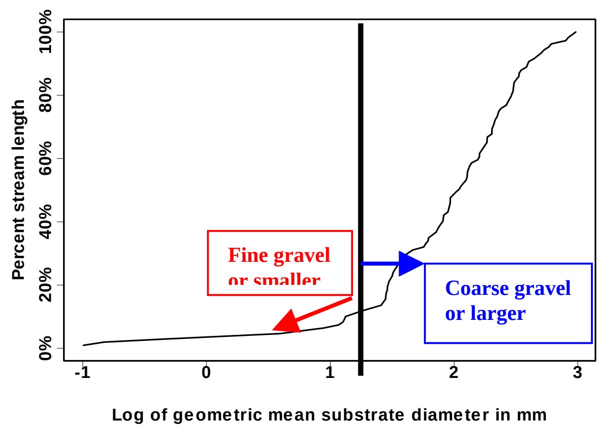


Figure 10. CDF of the log of the geometric mean particle diameter.

Riparian Vegetation

Expressed as a proportion of the reach, riparian cover data were collected for three woody vegetation layers:

1. Canopy - >5m
2. Mid level - .5m to 5 m
3. Ground cover - <.5m

Data are collected that describe the areal cover of ach of these layers. The total woody cover from the three layers could potentially be 3.0, or 300%, if the woody cover in each of the layers was 100%. In the Western Cascades ecoregion, 2nd and 3rd order streams, about 30 percent of the stream length has a combined areal cover of canopy, mid-layer, and ground layer woody vegetation cover of at less than 1.0 (**Figure 11**). Only about 20 percent of the stream miles have a combined 3-layer woody cover greater than 1.5 **(Figure 11)**.

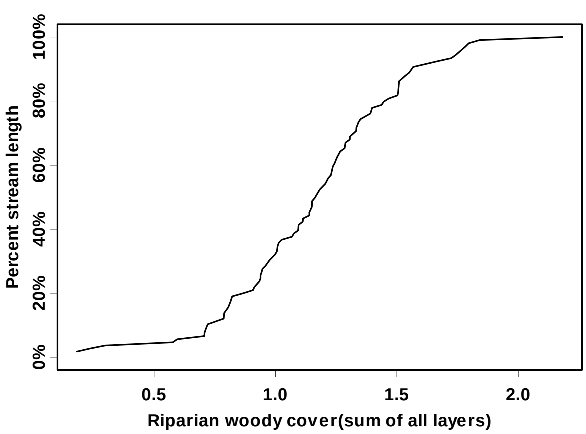


Figure 11. CDF of percent of reach with riparian woody vegetation cover (sum of all layers).

Three types of riparian canopy (riparian vegetation >5m) cover types were considered: coniferous, broadleaf deciduous, and mixed coniferous and deciduous cover. The riparian tree canopy of most streams is composed of mixed deciduous species (e.g. alder, maple) and coniferous (e.g. pine, fir). (**Figure 12**).

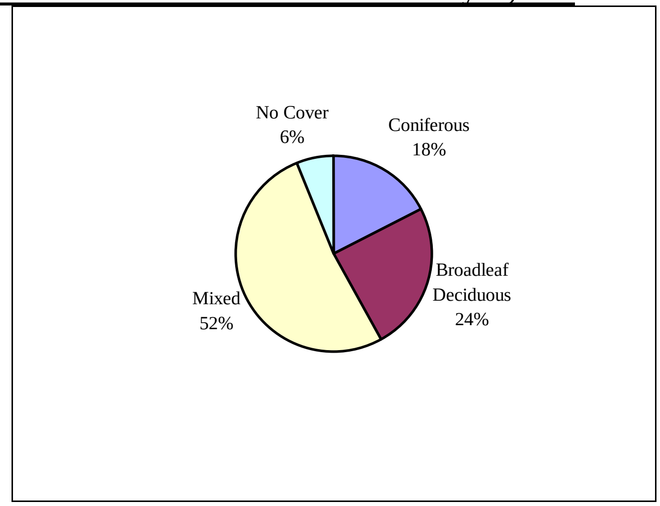


Figure 12. Pie chart of the mean percent riparian canopy cover by major species types.

Stream Shading

Overall, shade was high with mean bank shading of 86% and mean mid-channel shade of 64% **(see Figure 13).**

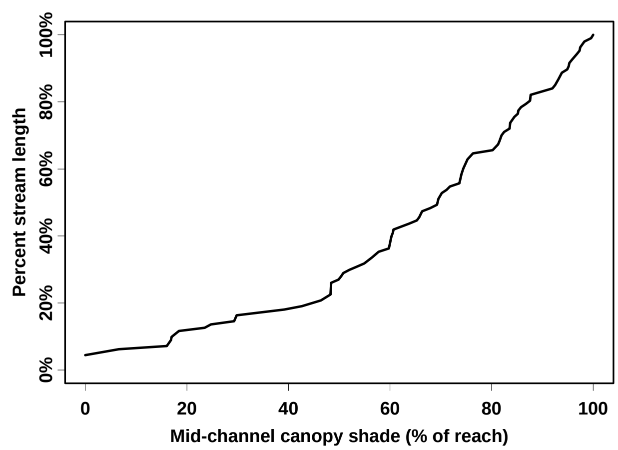


Figure 13. CDF of mid-channel shade (percent of reach).

Large Woody Debris (LWD)

Larger sized pieces of LWD have a greater ability to influence channel form than smaller pieces. Field data were categorized into five size classes (very small, small, medium, large, very large) based on the following length/diameter matrix (**Table 5**). Overall, LWD of all size classes was moderately abundant (median 13 pieces/100m) with only 1.7% of the stream length without any measurable LWD.

Diameter Class (m)	**Length Class (m)**		
	1.5 - 5	**>5 - 15**	**>15**
0.1 - 0.3	Very Small	Small	Medium
>0.3 - 0.6	Small	Medium	Large
>0.6 - 0.8	Small	Large	Large
>0.8	Medium	Large	Very Large

Table 5. Definition of five LWD size classes based on piece length and diameter.

However, analyzing the medium and larger sized pieces provides a different view of the LWD content of the streams (**Figure 14**). Larger pieces were somewhat rare. The mean frequency of very large size was .5 pieces/100m and the mean large size was 2.5 pieces/100m (**Figure 15**).

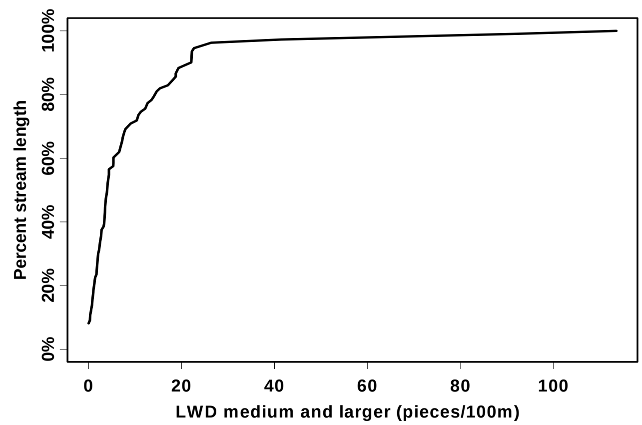


Figure 14. CDF of Large Woody Debris (LWD) quantity for the medium and large categories, expressed as pieces per 100m.

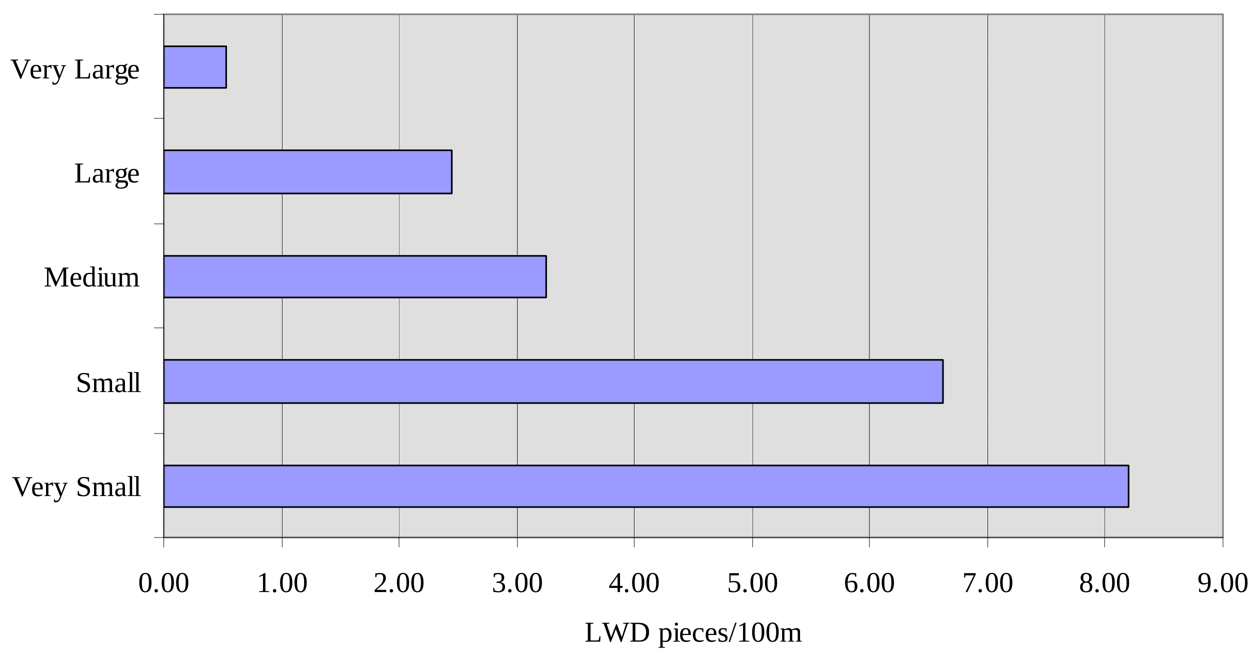


Figure 15. Mean LWD quantity (pieces per 100m) by size class. (see Table 5 for definition)

Pools

Although the pool frequency is high in the Western Cascades ecoregion (mean 1 pool per 1 channel width of stream length), most of the pools are shallow (<50cm), with mean pool depth of 19 cm (see **Figure 16**).

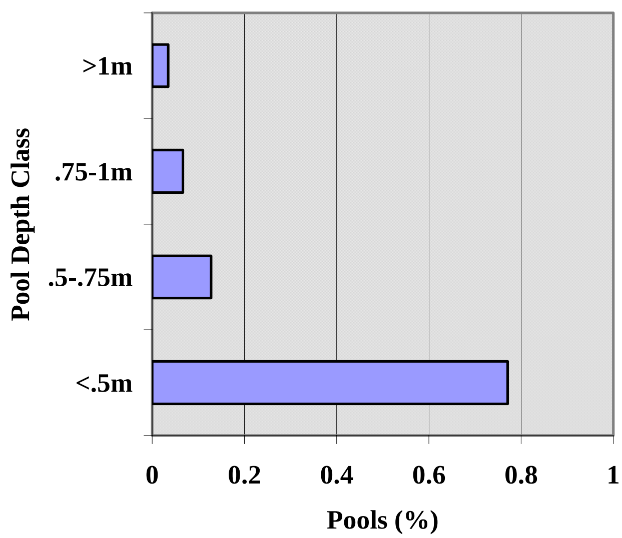


Figure 16. Frequency of pools by depth class.

Fish Cover

The presence and extent of fish concealment features consists of visual estimates of the cover class category (**Table 6**) of eight specific types of features in each of the 11 transects along each stream sample reach. Fish cover types are: filamentous algae, aquatic macrophytes, LWD, brush and small woody debris, in-channel live trees or roots, overhanging vegetation, undercut banks, boulders and artificial structures.

Fish cover category	% cover estimate
Absent	0
Sparse	0-10
Moderate	10-40
Heavy	40-75
Very Heavy	>75

Table 6. Definition of fish cover categories.

For each of these fish concealment type, field crews estimated areal cover in four classes (**Table 6**). Reach fish cover metrics are then calculated by assigning cover class midpoint values (i.e., 0%, 5%, 25%, 57.5%, and 87.5%) to each observation and then averaging those cover values across all 11 stations.

The natural fish cover metric combines several of the fish cover types in to one metric value. These cover types are large wood, brush, overhanging vegetation, boulders and undercut banks. The mean natural fish areal cover for 2nd and 3rd order streams in the Western Cascades ecoregion is 0.6 (**Figure 17**).

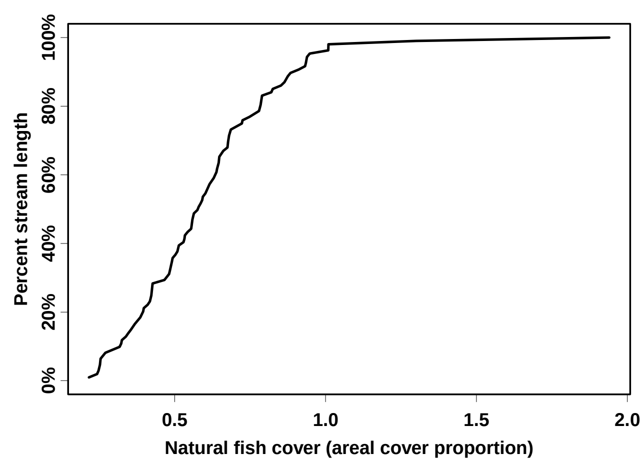


Figure 17. CDF of natural fish cover.

Riparian disturbance

Riparian disturbance data were collected by examining the channel, bank and riparian area on both sides of the stream at each of the 11 transects and visually estimating the presence and proximity of disturbance (Kaufmann and Robinson, 1998). Eleven different categories of disturbance were evaluated. Each disturbance category is assigned a value based on its presence and how close it is (proximity) to the stream (**Table 7**).

Value	Proximity to stream
1.67	in channel or on bank
1.0	within 10m of stream
0.67	beyond 10m from stream
0	not present

Table 7. Values for riparian disturbance based on proximity to stream.

Data were used to calculate a proximity-weight disturbance index (PWDI) for each reach (Kaufman et al., 1999). This index combines the extent of disturbance (based on presence or absence) as well as the proximity of the disturbance to the stream. Categories of disturbance were defined using quartile ranges of the data (**Table 8**).

All types of disturbance were observed in the riparian zones of the Western Cascades ecoregion streams. Some, such as row crops, were very rare both in overall mean and frequency of occurrence (number of sites). The most common forms of riparian disturbance were logging and roads (both 21%), followed by pavement and cleared areas (5%) (**Figure 18**).

Data Range	Level of Human Influence
0 - .4	Low
> .4 - .8	Medium
> .8 - 1.2	High
> 1.2	Very High

Table 8. Categories of human influence based on the proximity-weight disturbance index (PWDI) for each site.

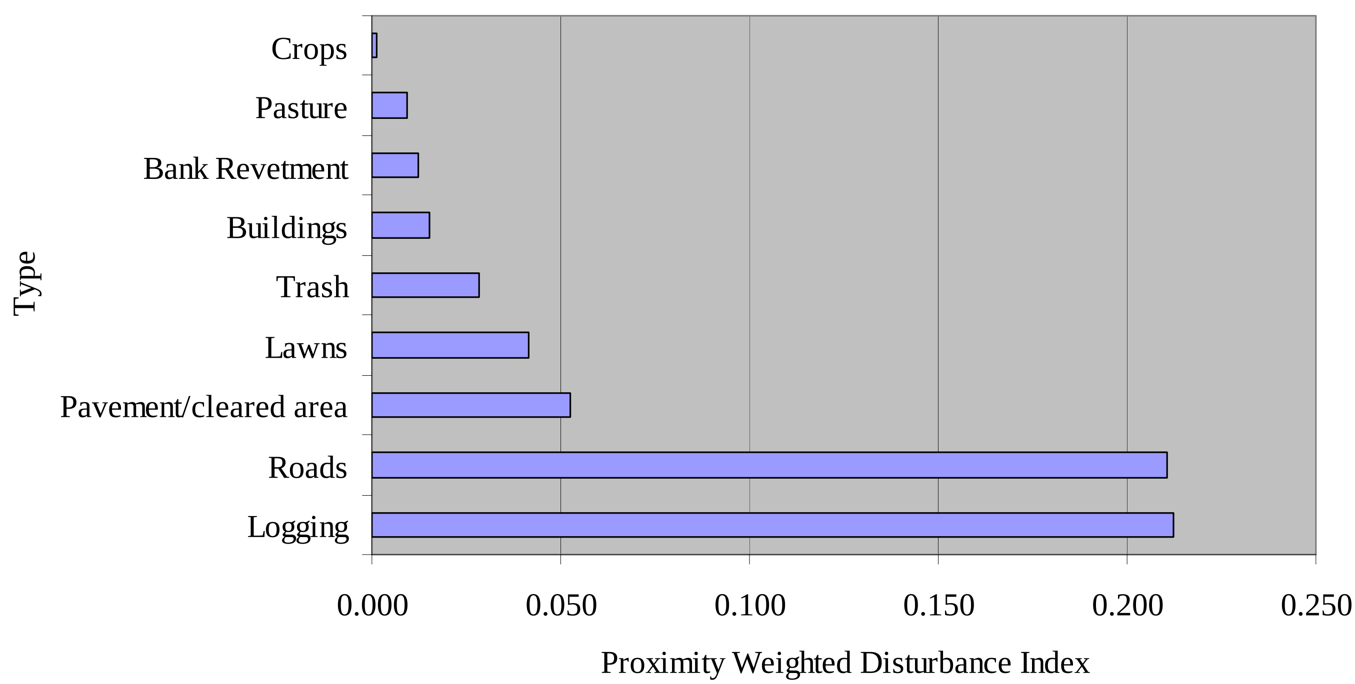


Figure 18. Mean riparian zone human influence from each of 9 disturbance categories.

D. Biological Indicators

Fish and Amphibian Resources

Aquatic vertebrates (fish or amphibians) were found at 69 sites, 86% of the randomly selected sites sampled for the project. Ten sites were not sampled due to restrictions by fisheries agencies. Of these 69 sites, fish were found at 65 sites, which represents 81% of stream km represented by the study design. Amphibians were found at 47 sites, representing 55% of stream km. A total of 23 different species were captured, 18 fish species and 5 amphibian species. Aquatic vertebrate sampling abundance is summarized in **Table 9** and species are listed in **Figure 19.** Additional information is available in Appendix 4.

Information	# of Sites	% of Stream Length[1]	Comment
Sites with fish	65	81%	Cutthroat trout was the most common species
Sites with amphibians	47	55%	Tailed frogs were the most common species
Sites with fish, but no amphibians	22	30%	
Sites with amphibians, but no fish	4	5%	
Sites with salmonids	64	80%	Cutthroat and rainbow were the most common species
Sites with non-native fish	4	7%	Brook trout was the only non-native species

[1] Based on a total of 69 sites sampled for vertebrates.

Table 9. Frequency of occurrence of aquatic vertebrates at probability sites.

Non-native species were rare in the basin's 2nd and 3rd order streams. Only 1 non-native fish species (brook trout) was encountered, and was captured at only 4 sites, representing 7% of the stream length. Although non-native species were rare, this study does not assess the presence/abundance of hatchery fish that may be planted in the streams of the sample area.

The Salmonidae family, which includes trout, salmon and whitefish, was the most broadly distributed vertebrate family in the basin, followed by the Cottidae family (sculpins). Tailed frogs were the most widely distributed single vertebrate species. Cutthroat and rainbow trout were the most broadly distributed salmonid species (see **Figure 19**).

The dominant sculpin (cottid) species are shorthead, torrent and Paiute sculpins, which are all native to both Oregon and Washington. Several fish species were found rarely (<2% of the estimated stream km). These were the prickly sculpin, longnose sucker, mountain whitefish and the threespine stickleback (**Figure 19**).

Most fish species known to occur in 2nd and 3rd order streams of the Western Cascades (Wydoski and Whitney, 2003) were captured in this study. Several species that range in the 2nd and 3rd order streams of the Western Cascades were not collected including bull trout, torrent sculpin, and mountain sucker. Bull trout and mountain suckers have limited range in the ecoregion. Two sites in Washington were not electrofished because they were designated bull trout habitat under the Endangered Species Act.

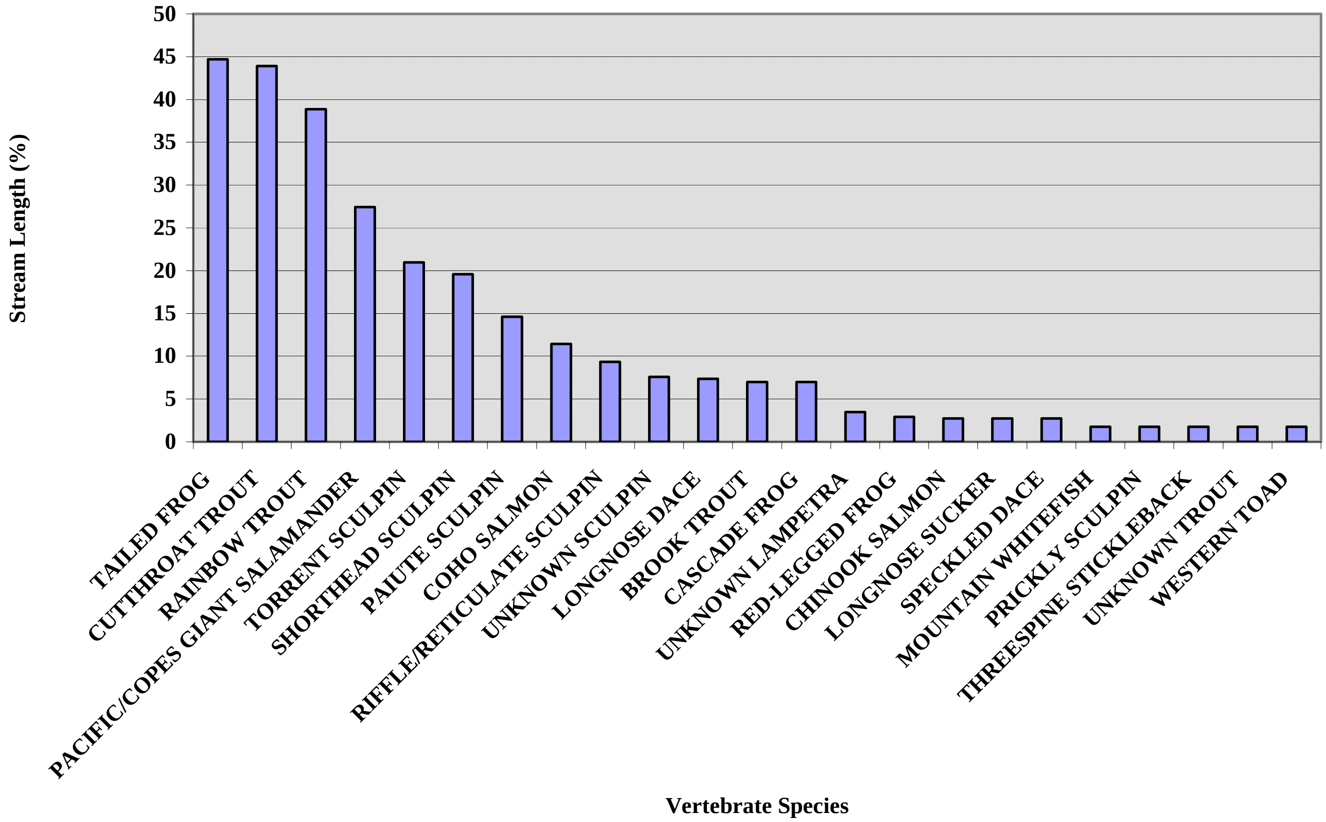


Figure 19. Aquatic vertebrate species presence.

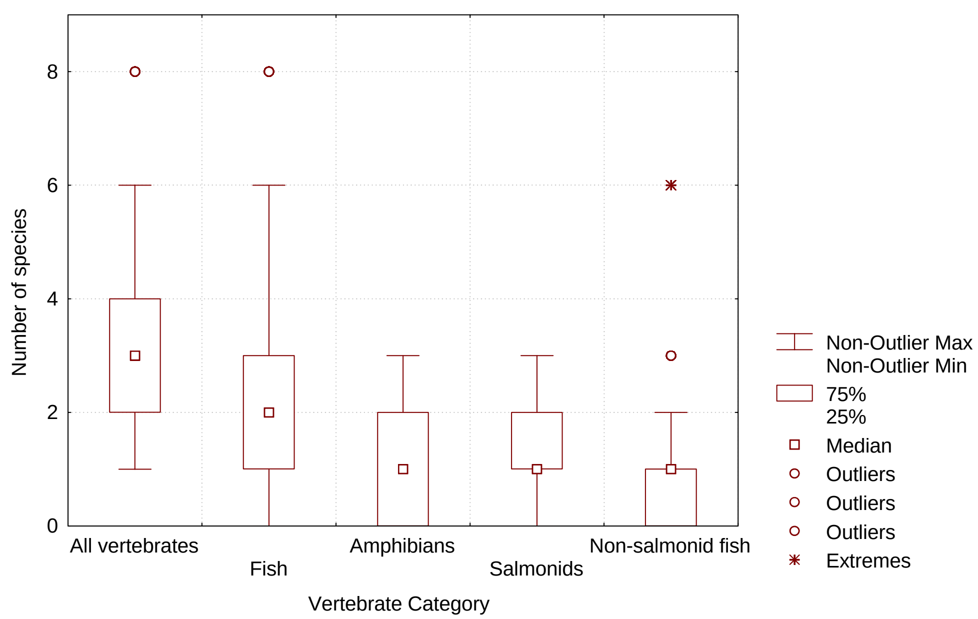


Figure 20. Aquatic vertebrate species richness.

The streams sampled typically had 1-3 fish species and 0-2 amphibian species (**Figure 20**). Most stream kilometers represented by the probability sites had at least one salmonid species as well as one non-salmonid fish species (usually a sculpin species).

Fish Guild descriptions:
The relation of fish species to their environment can be described in terms of guilds. Sensitivity guilds are used to categorize fish species by how sensitive they are to pollution. Likewise, temperature guilds are used to classify fish by their preference to various stream temperature conditions. Guild classifications are useful for describing the fish assemblage within the ecoregion. The guild classifications used for this report are from Zaroban et al. (1999). Guilds were defined as follows:

Temperature guilds - 3 classifications**;** warm, cool, and cold water preference.

Sensitivity guilds - 3 classifications**;** tolerant, intermediate, and sensitive based on species ability to tolerate pollution and human induced disturbance.

Most aquatic vertebrate species that were sampled in the ecoregion are in the sensitive category of the tolerance guild and in the cold-water temperature guild (Appendix 5). Stream length was likewise dominated by these two guilds (**Figures 21 and 22**).

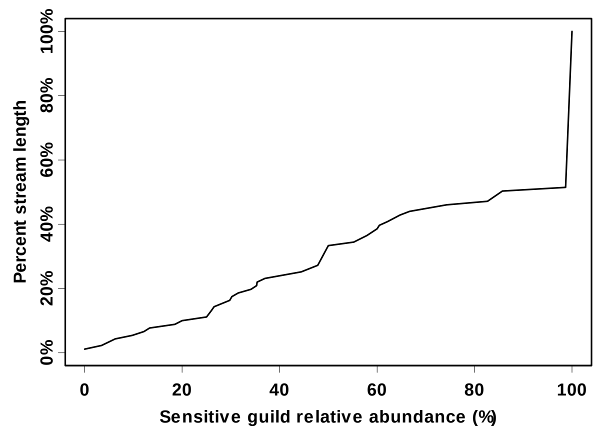


Figure 21. CDF of percent relative abundance of sensitive aquatic vertebrate guild individuals.

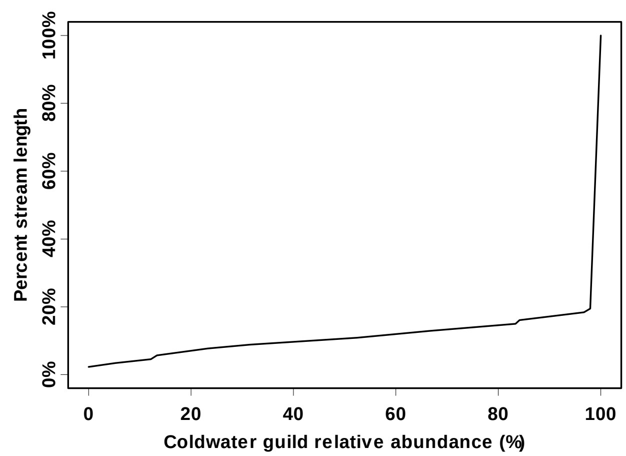


Figure 22. CDF of percent relative abundance of coldwater aquatic vertebrate guild individuals.

Macroinvertebrate Assemblage

Benthic macroinvertebrate assemblages reflect overall biological integrity of the stream and monitoring these assemblages is useful in assessing the current status of the water body as well as long-term changes (Plafkin et al., 1989).

Benthic invertebrate data collected from riffle habitats were available from 70 of the 79 randomly selected sample reaches. The benthic invertebrate data represents 3361km of streams. The following six metrics were used in this document: taxa richness, EPT taxa richness, intolerant richness, percent EPT, percent Plecoptera, and percent intolerant individuals. See **Table 10** for a more in depth description of each metric.

The metric "taxa richness" gives an overall indication of the diversity of macroinvertebrate assemblages in the Western Cascades ecoregion (**Figure 23**). The total number of taxa among sample reaches ranges from 12 to 55.

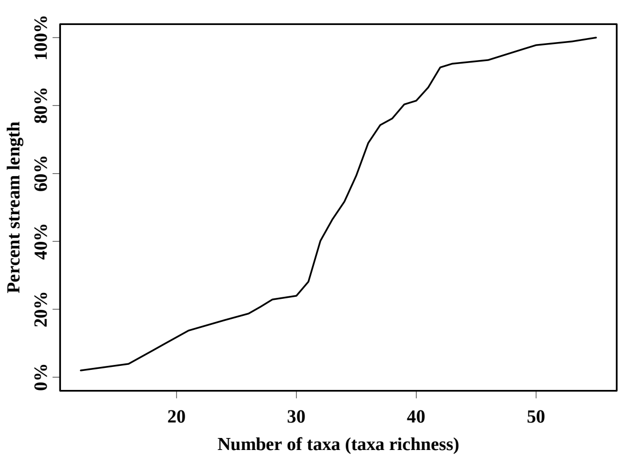


Figure 23. CDF of total macroinvertebrate taxa richness.

Metric	Description	Rationale
Taxa richness	The total number of different taxa describes the overall variety of the macroinvertebrate assemblage. Useful measure of diversity of the assemblage.	Decreases with low water quality associated with increasing human influence. Sensitive to most types of human disturbance.
% EPT	The percent of all individuals in the sample that are in the orders: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies).	In general, these taxa are sensitive to human disturbance.
EPT richness	The number of different taxa in the orders: Ephemeroptera, Plecoptera and Trichoptera.	In general, these taxa are sensitive to human disturbance.
% Plecoptera	The percent of all individuals in the sample that are in the order Plecoptera	Plecoptera are sensitive to human disturbance.
% Intolerant	The percent of all individuals in the sample that are intolerant of pollution (using designations in Wisseman, 1996).	Taxa designated as intolerant are more sensitive to human disturbance than other taxa.
Intolerant richness	The number of different taxa intolerant of pollution (Wisseman, 1996).	Taxa designated as intolerant are more sensitive to human disturbance than other taxa.

Table 10. Description of benthic macroinvertebrate metrics.
(Resh and Jackson, 1993 and Resh, 1995).

Percent EPT has been used extensively to evaluate stream condition throughout the United States. It is calculated by adding up the number of individuals that are found in three orders of aquatic insects - mayflies (**E**phemeroptera), stoneflies (**P**lecoptera) and caddis flies (**T**richoptera), by the total number of individuals. Many of the species in these three orders are sensitive to pollution and other stream disturbances (USEPA, 2000), and percent EPT is a good gauge of stream disturbance.

Most 2nd and 3rd order streams of the Western Cascades ecoregion are dominated by EPT individuals (**Figure 24**). Approximately 30% of the stream length had over 80 % of the individuals made up of EPT taxa (**Figure 24**).

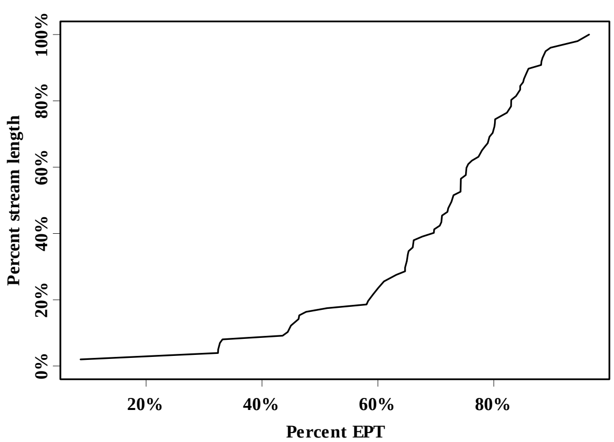


Figure 24. CDF of percent EPT.

Barbour et al (1994) found the percent of Stoneflies (Plecoptera) to be a valuable metric in Middle Rockies – Central ecoregion of Wyoming. In the Western Cascades ecoregion, over 80% of the 2nd and 3rd order stream length had over 20 percent of the individuals from the order Plecoptera (**Figure 25**).

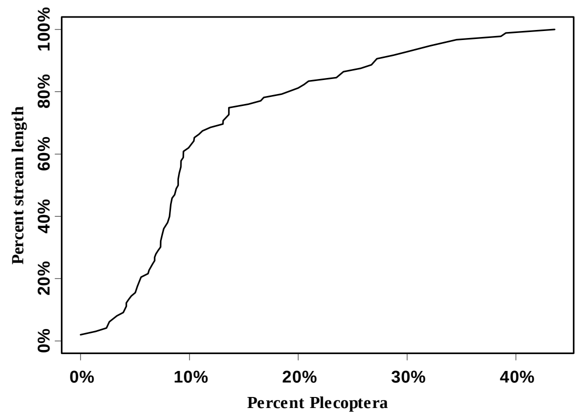


Figure 25. CDF of percent Plecoptera .

Intolerant macroinvertebrates are generally cold water adapted, sensitive to fine sediment and winter scour/sorting of substrates (Wisseman, 1996). This designation of intolerance to pollution is specifically for macroinvertebrates in western montane streams and is only for the most sensitive of species. Half of the 2nd and 3rd order stream length in the Western Cascades ecoregion have 10% or less of the macroinvertebrate assemblage made up of intolerant individuals (**Figure 26**).

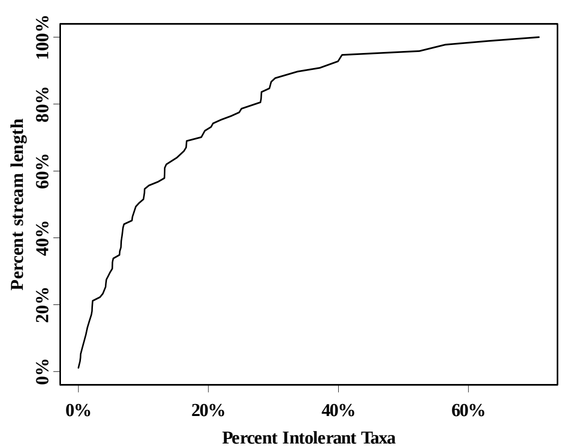


Figure 26. CDF of percent intolerant macroinvertebrates

Additional macroinvertebrate data from probability sites is available in Appendix 6.

VI. INTERPRETATION – of the ecological condition and stressors in streams of the Western Cascades ecoregion

Photo: Alec Creek, Washington. Courtesy of Glenn Merritt, Washington Department of Ecology.

A. Introduction

Most historic assessments of stream quality have focused on describing the chemical quality of streams and, occasionally, on impacts to sport fisheries. However, under the Clean Water Act, water quality standards are designed not to merely meet chemical criteria but to attain the beneficial uses of water bodies, such as aquatic life use. Therefore, the ultimate concern is the health of the biota that inhabit these streams and rivers.

In this assessment we try to address this issue by incorporating direct measurements of the biota themselves. Stream organisms integrate the many physical and chemical stressors and factors, including other ecological interactions (predation, competition, etc.), that are acting in, and on, the stream ecosystem.

Information on the stream biota is supplemented by measurements of other stream characteristics, especially those physical, chemical, or other factors that might influence or affect stream condition. These stream characteristics allow us to assess the stressors of stream condition, based on expected signals from major environmental perturbations (e.g., habitat modification, forest harvest, mine drainage, agricultural nutrients, etc.).

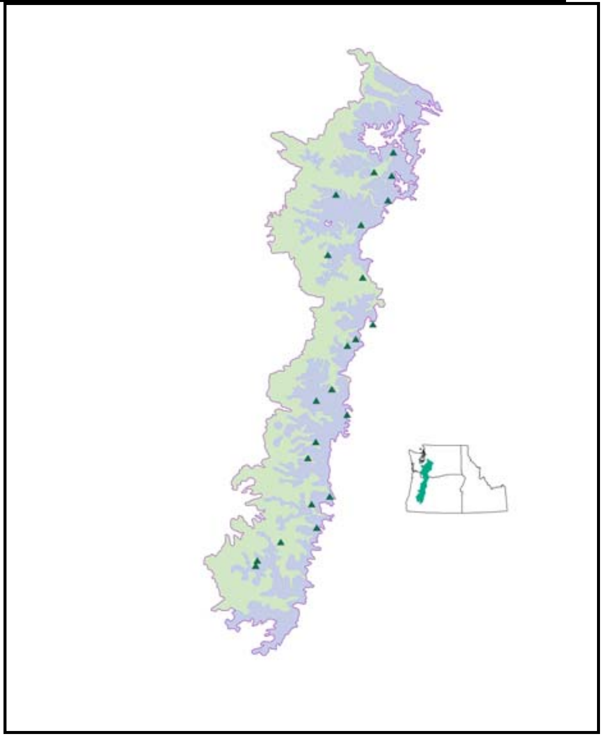
This project was designed to evaluate the overall condition of 2nd and 3rd order stream in the Western Cascades ecoregion. The data provides a large base of information, which while not necessarily designed to investigate specific activities, can be used to assess human influence on streams in the Western Cascades ecoregion. Forest is the major land cover type and forest harvest related activities are the largest source of human influence in the riparian area. Therefore, we will evaluate some indicators thought to be sensitive to forest harvest activities in the northwest (McDonald et al., 1991).

To assess whether or not a specific metric indicates good or poor condition, a benchmark, standard or target is needed for comparison (**Table 11**). For stream water chemistry, state water quality agencies, under the Clean Water Act, develop water quality criteria for many of the most important parameters. We will use these criteria, as they are developed to be protective of aquatic life.

INDICATORS OF STRESS	
Indicator	**Benchmark**
Water chemistry	Chemical and physical criteria established for aquatic life protection by the states of Oregon and Washington.
Stream channel condition	Reference condition based on data from 22 reference sites in the Western Cascades ecoregion.
Riparian habitat	Reference condition based on data from 22 reference sites in the Western Cascades ecoregion.
INDICATORS OF CONDITION	
Indicator	**Benchmark**
Fish Assemblage	Reference condition based on data from 21 reference sites in the Western Cascades ecoregion.
Macroinvertebrate Assemblage	Reference condition based on data from 18 reference sites in the Western Cascades ecoregion.

Table 11. Types of benchmarks or targets used for comparison in the Western Cascades ecoregion.

There are currently no water quality criteria for all of the other indicators (physical habitat and biological assemblages) in this project. However, they are critical for assessing the support for the goals of the Clean Water Act. For these indicators, we compare site condition with that determined from data collected at 18-22 reference sites from least disturbed sites (reference sites) from the Western Cascades ecoregion. The reference sites (**Map 4**) are all 2nd and 3rd order streams, and the data collected at these sites uses the same R-EMAP protocols as all of the other data. Due to the large number of indicators measured at each site, we will present results for only a few indicators. Additional indicators are summarized for reference conditions in Appendices 7 and 8.



Map 4. Reference sites in the Western Cascades ecoregion.

B. Reference Condition

Reference condition should be based on data from reference sites that represent the best range of environments that can be achieved by similar streams within a particular ecoregion. The two primary considerations for evaluating the suitability of reference sites are: representativeness, and minimal human disturbance.

To evaluate these factors, we compared the landscape data from the upstream contributing areas of reference sites to that of probability sites. Based on the information presented below, we concluded that the reference sites were both representative of the 2nd and 3rd order streams in the Western Cascades ecoregion and showed minimal human disturbance.

> ## Some Useful Definitions
> **Reference Sites** – a specific locality on a waterbody which is minimally impaired and is representative of the expected ecological integrity of other location on the same waterbody or nearby waterbodies (USEPA, 1996).
>
> **Reference Condition** – the overall condition of minimally impaired waterbodies characteristic of a waterbody type of a region. Often the aggregation of information gathered at reference sites.
>
> **Upstream Contributing Area** - all land above a point on a stream that drains to that point. Thus, disturbance or alteration to this land area can impact the stream.

Representativeness
Reference sites are a little higher in the watershed than probability sites (the median elevation for the contributing area were 3716 feet and 3376 feet, respectively). The slope conditions for the upstream contributing areas were similarly steep (median values of the mean slope were 22 and 19 degrees, respectively).

Stream density (defined as stream distance (km) divided by area (km^2)) was also very similar between probability and reference sites (median values of 0.71 and 0.76 km/km^2, respectively.

Land cover is primarily forested condition for both probability and reference sites: the median forest land cover was respectively 91 and 98 percent. In addition, the distribution of forest “type” was also very similar, with both data sets being comprised primarily of coniferous forest (median values of 81 and 95 percent, respectively.)

Minimal human disturbance
The Western Cascades ecoregion is a sparsely populated area. Very few people reside within these upstream contributing areas, with a vast majority of watersheds for both datasets having zero residents.

Harvest activities within the upstream contributing areas for reference sites were very sparse, and often absent (median value of zero percent). Harvest within contributing areas of the probability sites was also low (median value of 5 percent), but several of these sites had fairly high (>50%) level of past harvest activities. The GIS dataset used to calculate summaries of harvest activities had a filter of .02 square kilometers. Thus, many smaller harvest activities were not included in this dataset.

Finally, road densities were much greater within upstream contribution areas for probability sites than observed for reference sites (median of 1.3 and 0.1 km of roads per square kilometer, respectively).

C. Stream Water Chemistry
In general terms, water quality standards define the goals for a waterbody by designating the use or uses to be made of the water, setting criteria necessary to protect those uses (such as aquatic life, coldwater biota and salmonid spawning), and preventing degradation of water quality through antidegradation provisions.

Under the Clean Water Act, each State establishes water quality standards, which are approved by EPA. The States of Washington and Oregon have established water quality standards that include water quality criteria representing maximum concentrations of pollutants that are acceptable if State waters are to meet their designated uses. The stream water data from the probability sites is compared to current water quality criteria of Oregon and Washington (**Table 12**).

Indicator	Criteria for Oregon[1]	Criteria for Washington[2,3]
Dissolved Oxygen (DO)	>11.0 mg/L for salmonid spawning >8 mg/L for cold water aquatic life	>9.5 mg/L-Class AA >8 mg/L-Class A
pH	6.5 to 8.5 for all waters	6.5 to 8.5 for both Class A and Class AA Waters
Water Temperature	18°C salmonid rearing, 16°C for core rearing and 12°C for salmonid spawning	16°C - Class AA 18°C -Class A

Table 12. Table of selected freshwater criteria. ([1]Oregon Administrative Rules Chapter 340, and Washington State, 1992). [2]Streams in the Western Cascades ecoregion are either Class A or AA, which are state designated use classifications. [3]Further details for pH and temperature relating to point source pollution or unusual natural conditions are in the Washington Administrative Code Chapter 173-201A.

Dissolved Oxygen (DO)

The Washington state criteria is >9.5 mg/L for AA and >8.0 mg/L for A streams, the Oregon state criteria is >11.0 mg/L for salmonid spawning and >8 mg/L for cold water aquatic life. Approximately, 3% of the stream length in the Western Cascades ecoregion was below 8 the 8.0 mg/L criteria and 80% of the stream kilometers were below 11mg/L (see **Figure 27**).

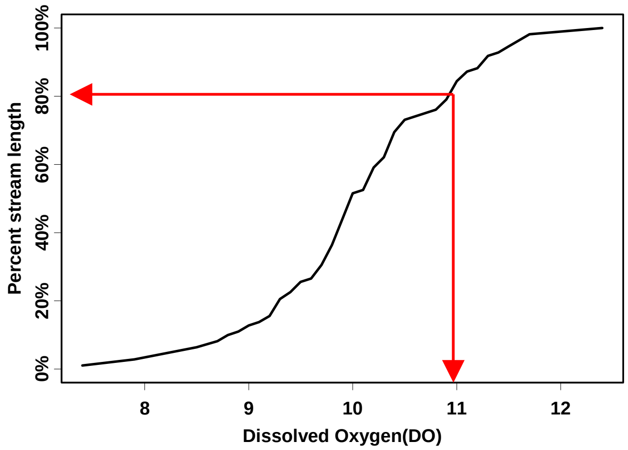


Figure 27. CDF of dissolved oxygen showing the % stream length less than 11 mg/L.

pH

The available literature indicates that pH is not sensitive to most forest management activities (McDonald et al., 1991). Most (98%) of the stream length was within the state criteria of 6.5 to 8.5. One site was below 6.5 and one site was above 8.5.

Temperature

Forest cover provides shade to streams and a reduction in the forest cover along streams can increase the solar radiation reaching the stream surface, which in turn can lead to increased stream temperatures. In this project, using a single measurement, two percent of the stream length was above 16°C (Washington's criteria for class AA waters). Most of the streams were cold, 61% were below Oregon's 12°C criteria for salmonid spawning. However, this criteria only applies during the season and location of salmonid spawning. We found a mean temperature of 11.2°C. However, using a single measurement, it is unlikely to represent peak stream temperatures. Data collected from continuous recording data loggers from 35 of the Oregon sites showed that the maximum temperature was not captured by the single measurement. However, the single measurement was similar to the mean temperature recorded over the summer by the continuous data loggers.

Nutrients

Phosphorous

Studies in the Pacific northwest indicate that forest management activities are unlikely to substantially increase phosphate concentrations in aquatic ecosystems (McDonald et al., 1991). Although there are no State criteria for phosphorus, EPA recommends a limit of <0.05 mg/L for streams that deliver to lakes and a suggested limit of 0.1 mg/L in streams that do not deliver to lakes (MacKenthun, 1973 in MacDonald et al., 1991). In 93% of the stream length phosphorus was below 0.1 mg/L (**Figure 28**).

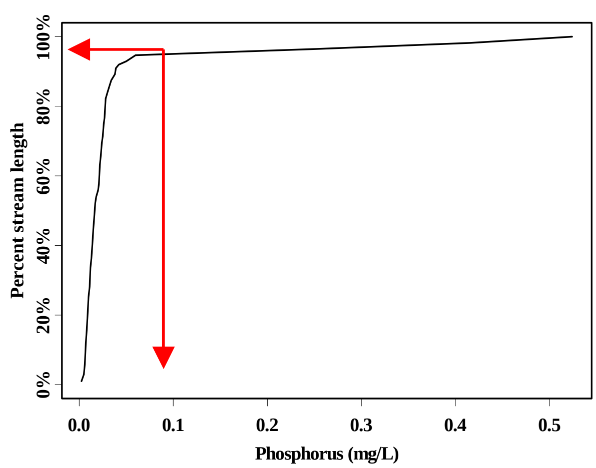


Figure 28. CDF of total phosphorus (mg/L) showing % of stream length less than .1mg/L.

Nitrite-nitrate

Forest management activities can alter many parts of the nitrogen cycle, and this makes it difficult to generalize about the effect of these activities. There is no national criterion for nitrate but concentrations of <0.3 mg/L would probably prevent eutrophication (Cline 1973, in MacDonald et al., 1991). Most (95%) of the streams have <0.3 mg/L nitrite-nitrate.

D. Physical Habitat Indicators

While there are currently no water quality criteria for physical habitat variables, they are very important for supporting designated uses and directly support the goal of the Clean Water Act. Watershed scale features (stream order, basin size, and gradient) describe the stream in the context of the overall landscape and provide context for the relationship with other physical habitat features. In this section, we compare the results of the ecoregion-wide assessment (using probability sites) of the Western Cascades ecoregion of habitat condition to the reference condition. Other relevant benchmarks or targets from the literature are also discussed.

Substrate

Stream substrate size is influenced by many factors including geology, gradient, flow and channel shape. Many human activities, both on the land and in streams, directly or indirectly alter the composition and size of stream substrates. The transport and deposition of excess sediment in streams and rivers is a major problem in waters throughout the United States. Accumulations of fine substrate particles fill the spaces between coarser streambed materials, thereby reducing habitat space and its availability for benthic fish and macroinvertebrates (Platts et al., 1983).

Substrate class distribution was similar for the two data sets (**Figure 29**). For the probability and reference sites, cobble (<64 to 250 mm) sized substrate was the most common surface substrate. For the probability sites, boulders were the next most common surface substrate. For the reference sites, the next most common substrate was coarse gravel (**Figure 29**).

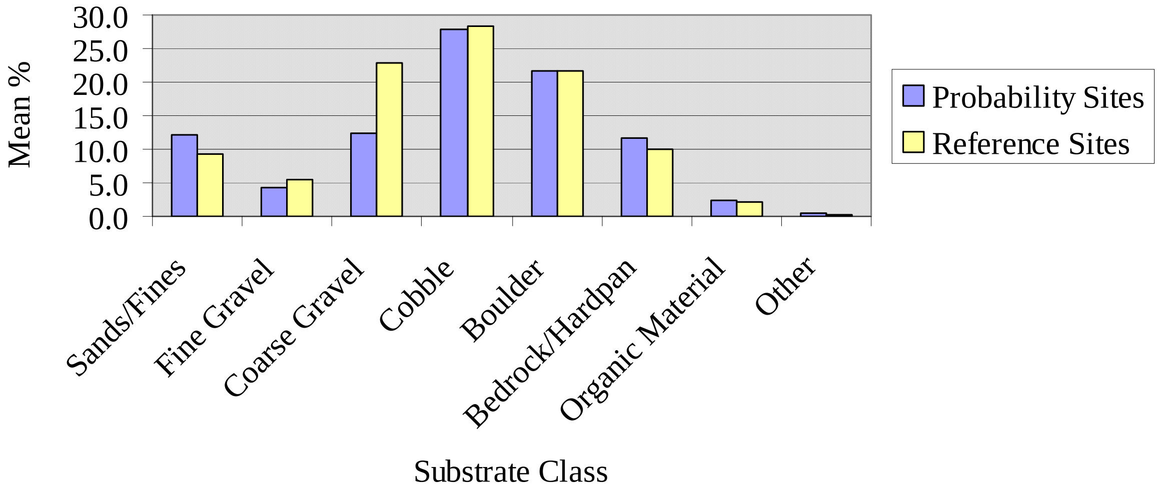


Figure 29. Bar chart of mean substrate quantity, for probability and reference sites in the Western Cascades ecoregion.

Riparian Vegetation

The primary influence of management activities on the riparian areas is the direct removal of vegetation. The removal of the riparian canopy, by increasing direct solar radiation to the stream, can cause marked increases in water temperature. Both coniferous and deciduous broadleaf species are effective in stream shading.

The amount of shade was fairly high for both the probability sites and the reference sites. The mean shading was 86% for probability and 94% for reference sites when shade was measured near the streambank (**Table 13**). Mean mid-channel shading was 64% for the probability sites and 81% for the reference sites.

Shade Parameters	Probability sites- Mean	Reference sites- Mean
Mean percent shade as measured at the banks	85.6	94.2
Mean percent shade as measured mid-channel	63.7	81.3

Table 13. Mean percent shading, for probability and reference sites in the Western Cascades ecoregion.

Three types of riparian canopy (riparian vegetation >5m) cover types were considered: coniferous, deciduous, and mixed coniferous and deciduous cover (**Figure 30**). Mixed cover was the most common type of riparian canopy cover for both reference and probability sites. For the probability sites, the next most common riparian cover was broadleaf deciduous. For the reference sites, the next most common riparian cover was coniferous. Coniferous trees provide much greater structural function in streams due to the size and decay-resistance of the wood they contribute to streams.

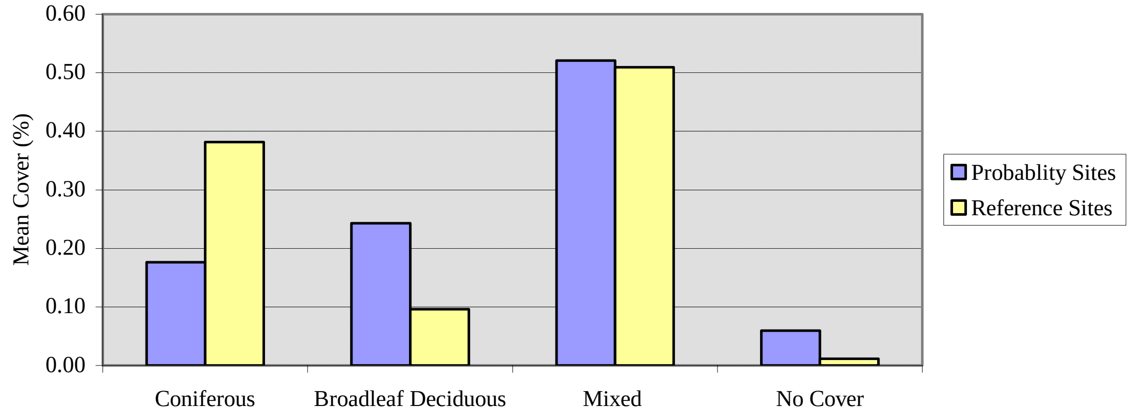


Figure 30. Mean percent riparian cover by canopy classes for probability and reference sites.

Large Woody Debris (LWD)

Loss of LWD without a recruitment source can result in long-term alteration of channel form as well as loss of habitat complexity in the form of pools, overhead cover, flow velocity variations, and retention and sorting of spawning-sized gravels. The amount of LWD in streams of the Pacific northwest has been reduced from historical levels by forest management activities.

For the west side of the Cascades, the National Marine Fisheries Service (NMFS) suggests "properly functioning" stream channels should have >80 pieces per mile (5 pieces per 100m) of LWD >24 inches (>60cm) in diameter (NMFS, 1996). For the probability sites, the mean number of pieces in this large and very large size class was 3 pieces per 100m. For the reference sites, the mean number of pieces in these two categories was 6.6 pieces per 100m. In addition, LWD was generally more prevalent in the reference sites in all categories, including the large class (**Figure 31**).

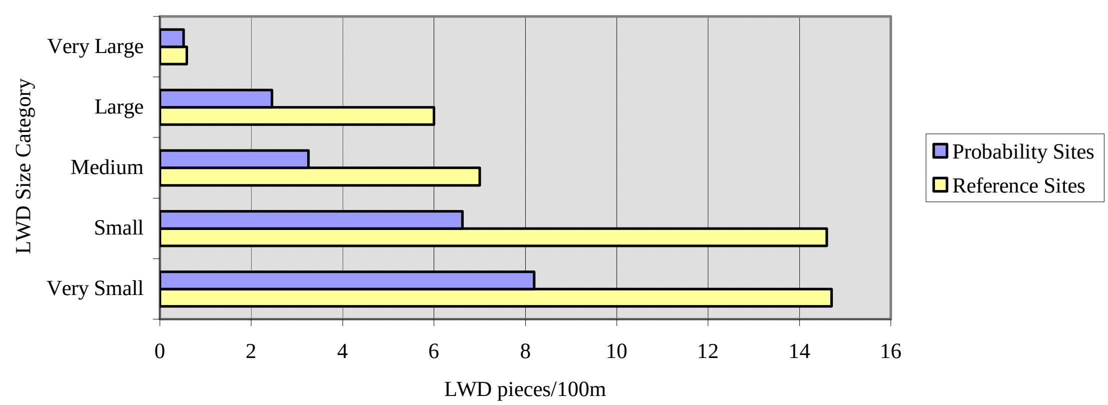


Figure 31. Mean LWD quantity (pieces per 100m) by size class for reference and probability sites. (see Table 5 for definition)

Riparian Disturbance

Removal or alteration of riparian vegetation reduces habitat quality and can result in negative effects to the stream biota.
A proximity-weight disturbance index (PWDI) for each reach (Kaufman et al., 1999). This index combines the extent of disturbance (based on presence or absence) as well as the proximity of the disturbance to the stream. Categories of disturbance were defined using quartile ranges of the data (**Table 6**).

Generally the level of human influence is low (<0.4) for all the separate categories based on mean values (see Appendices 3 & 6) for both the probability and reference sites. However, for the probability sites, when all disturbance categories are accounted for, most sites have a medium level of total human influence (mean .6 and median .4). The reference sites have a lower level of total human influence (mean .1 and median 0). This is to be expected, as reference sites were selected to represent minimal levels of human disturbance.

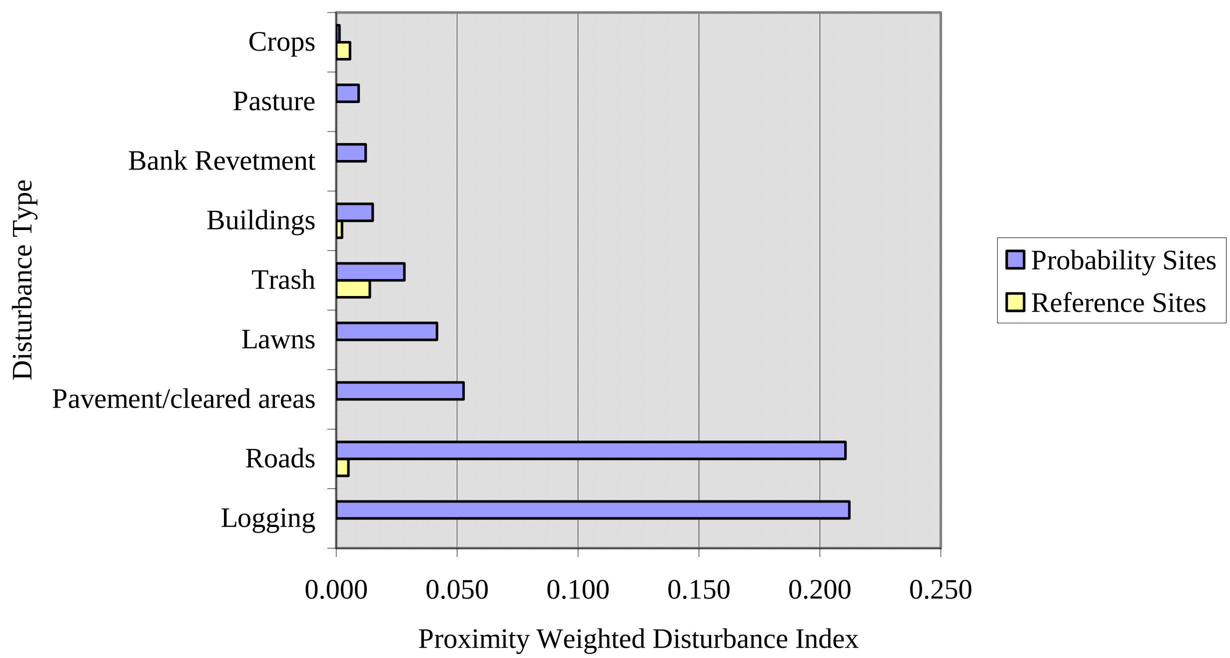


Figure 32. Mean riparian zone human influence from each of 9 disturbance categories for reference and probability sites.

E. Biological Indicators

While there are currently no numeric water quality criteria for biological indicators, measuring the condition of the biological assemblages is very important, as they provide a direct measure of the aquatic life designated use and directly support the goal of the Clean Water Act. For both macroinvertebrate and aquatic vertebrate assemblages, we compare the results of the ecoregion-wide assessment (using probability sites) to that of the reference condition.

Fish and Amphibians

Aquatic vertebrate richness calculated for the probability sites was generally similar to that of the reference condition (**Figure 19 and Figure 33**). A summary of metrics for aquatic vertebrates for reference sites is available in Appendix 8. The means and medians were similar, although the range of values was greater for the probability sites. The reference sites had higher amphibian species richness and lower fish richness that the probability sites. The ratio of fish to amphibian richness was reversed in the reference condition dataset, which had typically one fish species and two amphibian species. As with the probability dataset, salmonid species occurrence is common. Reference sites differed from the probability data in the occurrence of non-salmonids (number of species and relative abundance), which were less common.

The reference sites are dominated by sensitive and coldwater guild species. The range among reference sites was much smaller than that of the probability sites for both of these aquatic vertebrate metrics (**Figure 34 and Figure 35**).

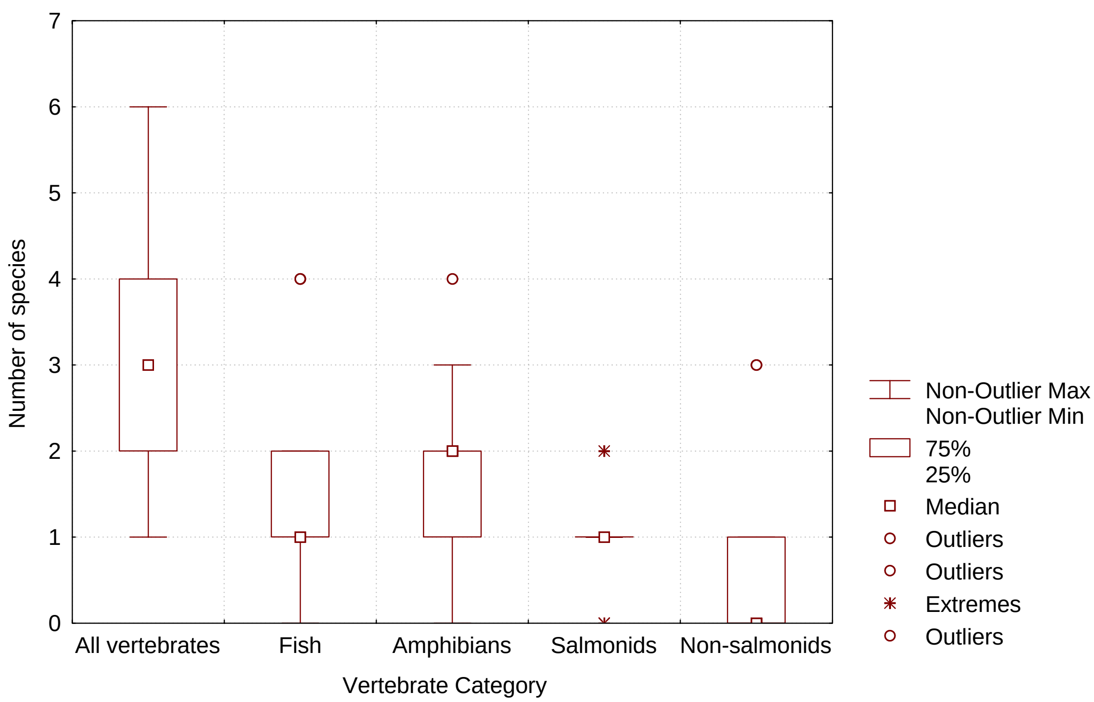


Figure 33. Aquatic vertebrate species richness in reference sites.

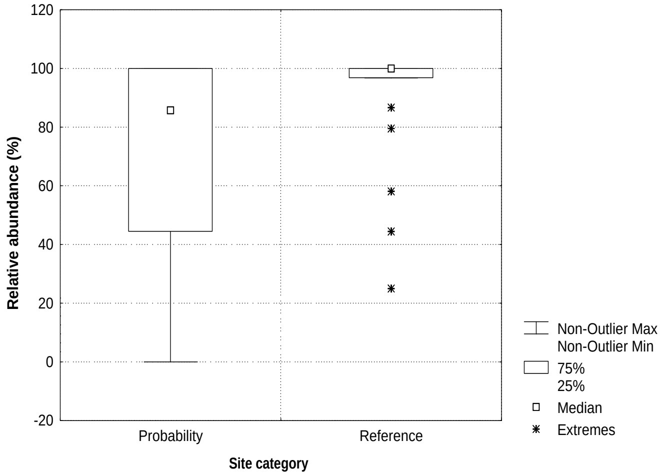


Figure 34. Comparison of relative abundance of sensitive aquatic vertebrate species guilds for the probability sites versus the reference sites.

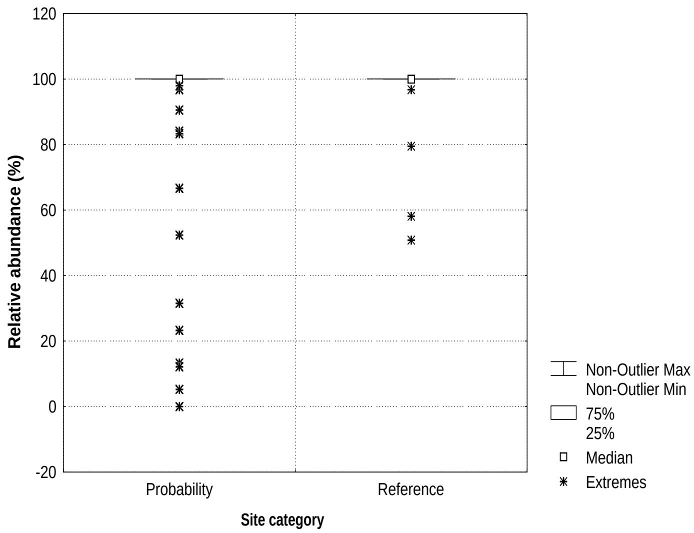


Figure 35. Comparison of relative abundance of coldwater vertebrate species guilds for the probability versus reference sites.

Overall diversity of aquatic vertebrates was characterized with the Shannon-Wiener diversity index, which incorporates not only maximum richness but 'evenness' in the abundances of species within sites. The probability sites have slightly lower diversity than the reference sites (**Figure 36**).

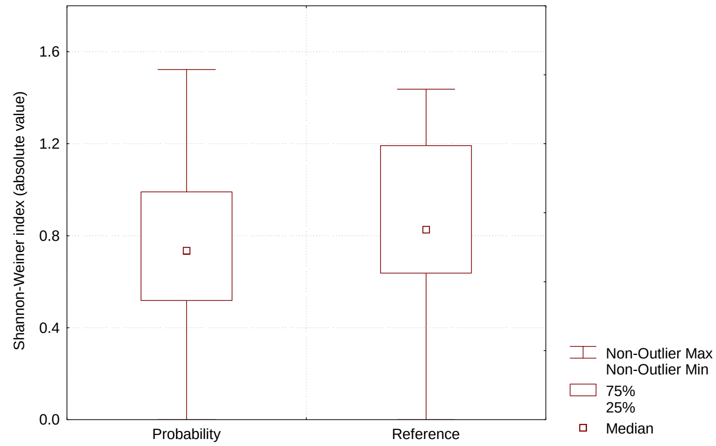


Figure 36. Comparison of Shannon-Weiner diversity index for aquatic vertebrates for the probability sites versus the reference sites.

Macroinvertebrates

Benthic macroinvertebrate data can be evaluated using a number of different attributes or metrics. Taxa richness metrics enumerate the various taxa, either singly or by groups. For the probability sites, overall macroinvertebrate taxa richness was generally similar to that of the reference condition (**Figure 37**). The means and medians were similar, although the range of values was greater for the probability sites. Taxa richness metrics for EPT, non-insect and long-lived taxa for the probability sites were also similar to that of the reference condition (Appendix 9). The reference sites had a slightly higher mean number of sensitive taxa.

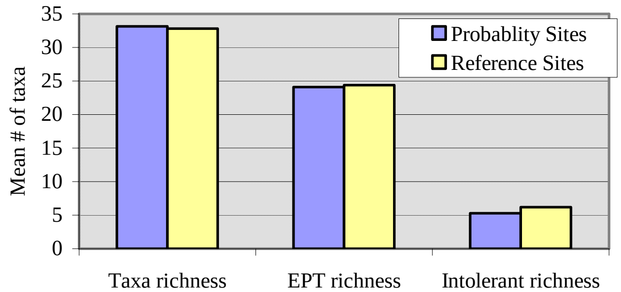


Figure 37. Comparison of macroinvertebrate taxa richness metrics calculated for the probability sites versus the reference sites.

Another type of metric for evaluating macroinvertebrate assemblages is the percent of all individuals in the sample that are in each different taxonomic or sensitivity group. For the probability sites, the percent of the individuals in the sample that were in the orders **E**phemeroptera (mayflies), **P**lecoptera (stoneflies) and **T**richoptera (caddis flies), was lower (mean 69.0%) than that of the reference condition (mean 76.9%) (**Figure 38**). The percent of the sample made up of Plecoptera, was slightly lower (mean 12%) for the probability sites as compared to that of the reference condition (mean 16%). The percent of the sample made up of sensitive insects, was lower (mean 15%) for the probability sites as compared to that of the reference condition (mean 22%).

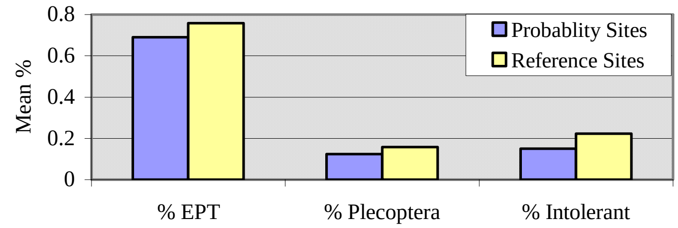


Figure 38. Comparison of selected macroinvertebrate percent metrics calculated for probability sites versus reference sites.

VII. SUMMARY

The often complex results of environmental data analyses must be communicated in a straightforward manner to water resource managers and the public. In order to determine the extent of the 2nd and 3rd order streams in the Western Cascades ecoregion that are in good, fair and poor condition, we measured chemical, physical and biological indicators in a statistical probability sample of stream reaches (probability sites). The indicator values used to designate good, fair and poor are in Appendix 10.

A. Stream Water Chemistry

For stream water chemistry indicators, we compared these results to water quality criteria for Oregon and Washington or literature values where no criteria existed (**Figure 39**). Over 90% of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "good" condition for pH, phosphorus and nitrite-nitrate. Streams were determined to be in "good" condition for pH between 6.5-8.8, below 0.1 mg/L for phosphorus and below 0.3 mg/L for nitrate-nitrite. For temperature, 61% the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "good" condition. We defined "good" as below 12°C. Thirty-seven percent of the stream length was in "fair" condition (between 12°C and 16.0°C). Only 2% of the stream length was in "poor" condition (warmer than 16°C). However, the use of a single measurement is unlikely to catch peak stream temperatures.

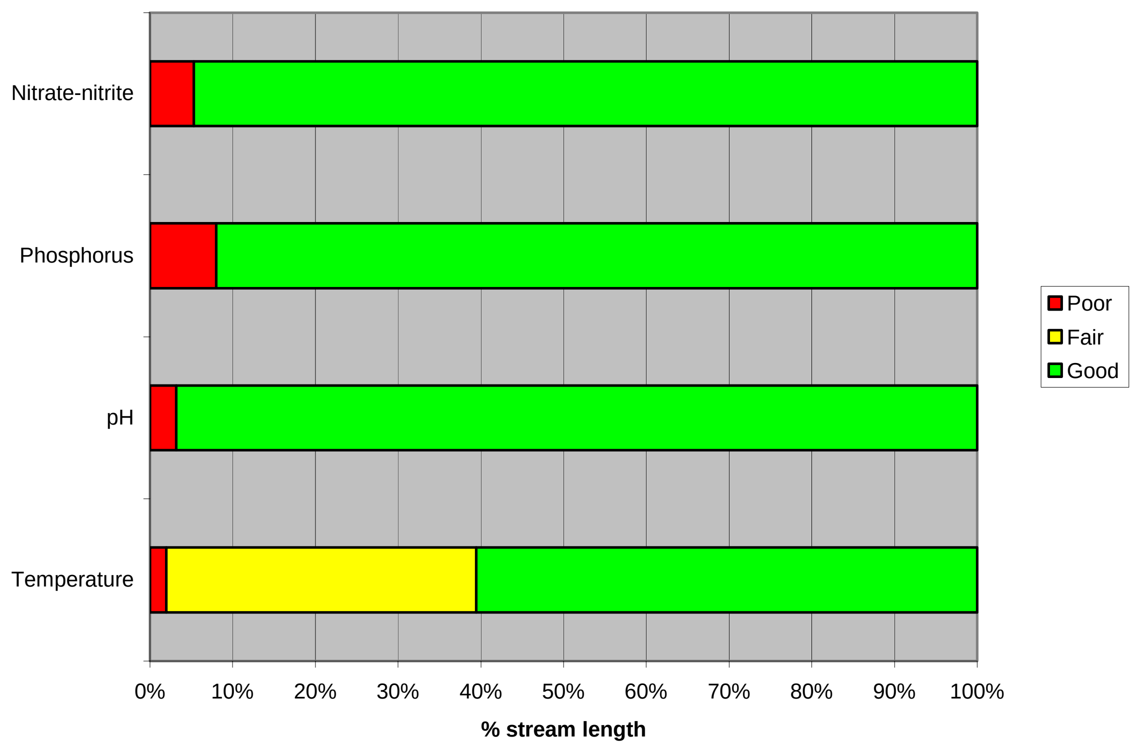


Figure 39. Selected water chemistry indicators.

B. Physical Habitat and Biological Indicators

For physical habitat and biological assemblages, we compare the results of the ecoregion-wide assessment (using probability sites) to that of the reference condition (using reference sites) as there are no applicable numeric water quality criteria. The range of scores at reference sites for each habitat and biological indicator describes a distribution that we used to define reference condition. We believe that the reference sites are minimally disturbed by human influence, however we may have included sites with some level of human disturbance as reference sites. Therefore, we have set our scoring criteria conservatively. The 25th percentile of this reference distribution is the criteria that we used to distinguish probability sites in "good" condition from those in "fair" condition (Barbour, et al. 1999). The 5th percentile value of reference separates sites in fair condition from those in "poor" condition (**Figures 39 and 40**). These criteria provide a margin of safety, as they would designate 5% of the reference sites in "poor" condition. All specific indicator values are in Appendix 10.

Generally, LWD was more prevalent in the reference sites in all categories, including the large class. For the amount of LWD in the large and very large size classes, 23% of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites. An additional, 49% of the stream length was in "fair" condition for large and very large LWD (**Figure 40**).

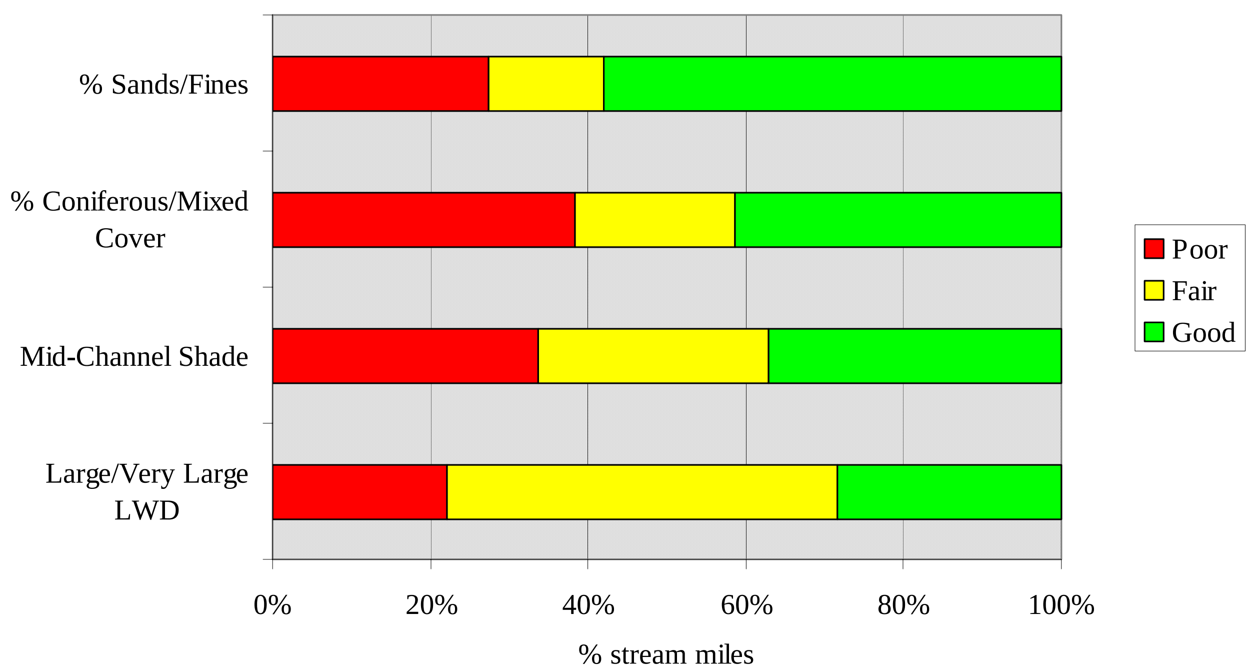


Figure 40. Selected physical habitat indicators.

The amount of mid-channel shade was fairly high for both the probability and reference sites. However, 34% percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition for percent mid-channel canopy cover as compared to the reference sites. An additional, 30% of the stream length was in "fair" condition for mid-channel shade (**Figure 40**).

Mixed cover was the most common type of riparian canopy cover for both reference and probability sites. For the probability sites, the next most common riparian cover was broadleaf deciduous. For the reference sites, the next most common riparian cover was coniferous. Thirty-seven percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites for percent coniferous plus mixed canopy cover types (**Figure 40**).

Cobble (<64 to 250 mm) sized substrate was the most common surface substrate for both the probability and reference sites. For the percent of the substrate made up of sands or fines, 27% of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites. An additional, 16% of the stream length was in "fair" condition for percent sands or fines (**Figure 40**).

Salmonids were common in both with ecoregion-wide sites having slightly higher salmonid richness. Coldwater guild species were the dominant temperature guild in both datasets. Reference sites differed from the probability sites in that they had higher amphibian species richness. For total vertebrate richness, 8% of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to reference sites (**Figure 41**). The reference sites also had higher relative abundance of sensitive aquatic vertebrate guild species. Twenty-seven percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites for sensitive aquatic vertebrate species relative abundance. Finally, using the Shannon-Weiner diversity index for aquatic vertebrates, 16% of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites (**Figure 41**).

For benthic macroinvertebrates (**Figure 41**), the percent of the individuals in the sample that were EPT, Stoneflies (Plecoptera) and sensitive insects, were lower for the probability sites as compared to that of the reference condition. For the percent of the individuals in the sample that were EPT (% EPT), 17% of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion were in "poor" condition as compared to the reference sites. Fourteen percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites for the percent of the individuals in the sample that were Stoneflies (% Plecoptera).

For the percent of individuals in the sample that are sensitive individuals, 22% of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites. An additional, 21% of the stream length was in "fair" condition for percent sensitive (**Figure 41**).

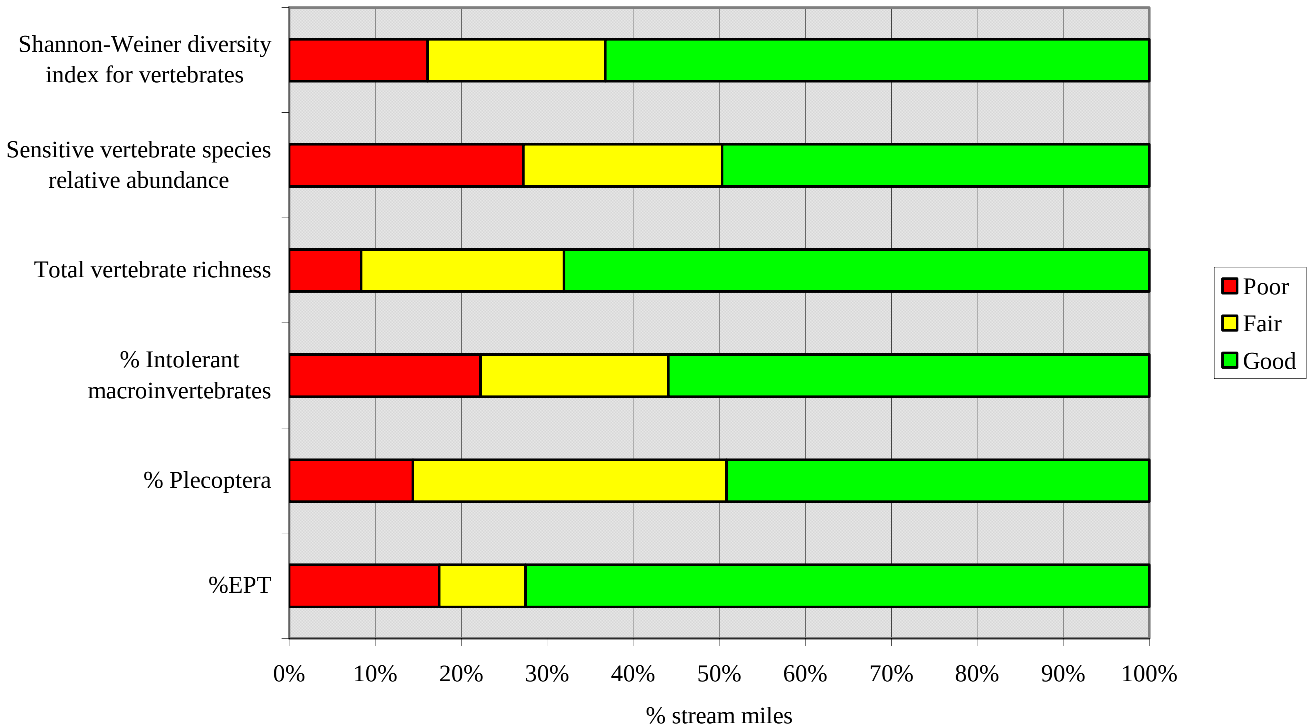


Figure 41. Selected biological indicators.

This project was designed to evaluate the overall condition of 2nd and 3rd order streams in the Western Cascades ecoregion. In this assessment we used direct measurements of the biota themselves as indicators of ecological condition. The organisms that live in a stream integrate many of the physical and chemical stressors and factors that are acting in, and on, the stream ecosystem. Information on the stream biota is supplemented by indicators of stress, which are measurements of other stream characteristics or factors that might influence or affect stream condition, especially stream water chemistry and physical habitat.

In conclusion, very few (3-8%) of the of the 2nd and 3rd order stream kilometers in the Western Cascades ecoregion were in "poor" condition using stream water indicators. However, physical habitat indicators showed a greater extent of the 2nd and 3rd order stream length in the Western Cascades ecoregion were in "poor" condition (22-38%). The biological indicators (fish, amphibians, and macroinvertebrates) are likely responding to many of these alterations in physical habitat condition, as 8-27 percent of the 2nd and 3rd order stream kilometers in the Western Cascades ecoregion were in "poor" condition using biological indicators.

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IX. APPENDICES

Appendix 1. List of probability (ecoregion-wide) sites with associated stream identification number.

Probability Site Identification Code	State	County	Site Name	7.5 (24K) Quad Map	Longitude (Decimal Degrees)	Latitude (Decimal Degrees)	Weight
R0CE99-001	WA	THURSTON	DESCHUTES R	Bald Hill	122.4010	46.79846	65.905
R0CE99-004	OR	LINN		Mill City South	122.3956	44.69910	36.778
R0CE99-007	WA	YAKIMA	CLEAR CR.N FK	Spiral Butte	121.3513	46.65625	65.905
R0CE99-008	WA	PIERCE	GREENWATER R	Greenwater	121.6287	47.15351	65.905
R0CE99-009	OR	LANE	LOOKOUT CR	McKenzie Bridge	122.2335	44.22566	36.778
R0CE99-011	WA	PIERCE	KAUTZ CR	Wahpenayo Peak	121.8448	46.74753	65.905
R0CE99-012	WA	YAKIMA	TEITON R.S FK	Pinegrass Ridge	121.2744	46.50979	65.905
R0CE99-013	WA	YAKIMA	DEEP CR	Bumping Lake	121.3201	46.80735	65.905
R0CE99-015		LANE		Rose Hill	122.6360	43.74313	36.778
R0CE99-016	WA	SKAMANIA		Gumboot Mountain	122.1424	45.83448	65.905
R0CE99-017	WA	SKAMANIA	ALEC CREEK	Quartz Creek Butte	121.8577	46.18070	65.905
R0CE99-018	WA	KING		Hobart	121.8929	47.48160	65.905
R0CE99-019	OR	MARION	BATTLE CREEK	Mother Lode Mountain	122.0718	44.84753	36.778
R0CE99-020	OR	LANE		Mount June	122.6760	43.82877	36.778
R0CE99-021	OR	MULTNOMAH	BULL RUN R	Hickman Butte	121.8883	45.48151	36.778
R0CE99-022	OR	CLACKAMAS		High Rock	121.8804	45.23331	36.778
R0CE99-025	OR	LANE	EIGHT CR	Westfir East	122.3935	43.83500	36.778
R0CE99-026	OR	MULTNOMAH	BULL RUN R	Tanner Butte	121.9329	45.50834	36.778
R0CE99-029	OR	CLACKAMAS	TABLE ROCK FK	Gawley Creek	122.3829	44.98133	36.778
R0CE99-030	OR	LANE	REBEL CREEK	Cougar Reservoir	122.1510	44.01687	36.778
R0CE99-032	WA	SKAMANIA		Bobs Mountain	122.2442	45.68818	65.905
R0CE99-033	OR	HOOD RIVER	HOOD R.W FK	Bull Run Lake	121.7811	45.46444	36.778
R0CE99-037	OR	CLACKAMAS	NORTH FORK EAGLE CR	Estacada	122.2515	45.31402	36.778
R0CE99-040	OR	LANE	JUNIPER CREEK	McCredie Springs	122.3152	43.62610	36.778
R0CE99-042	WA	SKAMANIA	GREEN R	Spirit Lake East	122.0879	46.34761	65.905
R0CE99-043	WA	KING	REX R	Cougar Mountain	121.6792	47.36246	65.905
R0CE99-044	OR	CLACKAMAS	NOHORN CR	Bagby Hot Spring	122.1923	44.94622	36.778
R0CE99-045	OR	LANE	WINBERRY CR.N FK	Saddleblanket Mountain	122.6086	43.90107	36.778
R0CE99-046	WA	LEWIS	SKATE CR	Tatoosh Lakes	121.7006	46.6289	65.905
R0CE99-047	WA	LEWIS	JOHNSON CR	Packwood Lake	121.6183	46.53533	65.905
R0CE99-048	WA	PIERCE	CARBON R	Golden Lakes	121.9501	46.99203	65.905
R0CE99-049	OR	LINN	CANYON CR	Swamp Mountain	122.3888	44.37382	36.778
R0CE99-050	OR	LANE	BOHEMIA CR	Warner Mountain	122.4864	43.56533	36.778
R0CE99-052	OR	CLACKAMAS		Mount Lowe	121.9016	44.93674	36.778

Probability Site Identification Code	State	County	Site Name	7.5 (24K) Quad Map	Longitude (Decimal Degrees)	Latitude (Decimal Degrees)	Weight
R0CE99-053	OR	LINN	CRABTREE CR	Keel Mountain	122.5722	44.57779	36.778
R0CE99-054	OR	LANE	LITTLE FALL CR	Goat Mountain	122.6016	44.02250	36.778
R0CE99-055	OR	LANE	BLACK CR	Waldo Lake	122.0999	43.69998	36.778
R0CE99-057	OR	CLACKAMAS	FISH CR	Wanderers Peak	122.1609	45.06435	36.778
R0CE99-059	OR	CLACKAMAS	TABLE ROCK FK	Rooster Rock	122.2889	44.98745	36.778
R0CE99-060	OR	LANE	WILLAMETTE R.M FK.N FK	Sardine Butte	122.2881	43.88818	36.778
R0CE99-064	OR	LINN	THOMAS CR	Snow Peak	122.5506	44.69758	36.778
R0CE99-065	OR	LANE	LOST CR	Kloster Mountain	122.7638	43.82124	36.778
R0CE99-071	OR	HOOD RIVER	EAGLE CR	Wahtum Lake	121.8684	45.59532	36.778
R0CE99-081	WA	LEWIS	LITTLE NISQUALLY R	Eatonville	122.3107	46.76024	65.905
R0CE99-082	OR	CLACKAMAS	LITTLE SANDY CR	Brightwood	122.0991	45.41619	36.778
R0CE99-084	OR	LINN	MIDDLE SANTIAM R	Yellowstone Mountain	122.3787	44.51245	36.778
R0CE99-085	OR	DOUGLAS	TUMBLEBUG CR	Rigdon Point	122.2502	43.43759	36.778
R0CE99-086	OR	MULTNOMAH	BULL RUN R	Brightwood	122.0169	45.49421	36.778
R0CE99-087	OR	CLACKAMAS	FISH CR	Wanderers Peak	122.1671	45.09738	36.778
R0CE99-088	OR	MARION	FRENCH CR	Detroit	122.1549	44.74877	36.778
R0CE99-089	OR	CLACKAMAS	BEAVER CREEK	Wilhoit	122.6127	45.03728	36.778
R0CE99-090	OR	LANE	WALL CR	Huckleberry Mountain	122.3020	43.81883	36.778
R0CE99-091	WA	LEWIS	LYNX CR	Randle	121.9329	46.59884	65.905
R0CE99-092	WA	YAKIMA	TEITON R.N FK	Pinegrass Ridge	121.3680	46.55650	65.905
R0CE99-093	WA	PIERCE	NISQUALLY R	Mount Rainier West	121.7598	46.78256	65.905
R0CE99-094	OR	LINN	BLUE R	Carpenter Mountain	122.2008	44.26785	36.778
R0CE99-095	OR	LANE	BRICE CR	Bearbones Mountain	122.5859	43.62256	36.778
R0CE99-096	WA	SKAMANIA	ROCK CR	Bonneville Dam	121.9277	45.72157	65.905
R0CE99-097	OR	CLACKAMAS	ZIGZAG R	Rhododendron	121.9218	45.33885	36.778
R0CE99-098	OR	MARION	BREITENBUSH R.S FK	Breitenbush Hot Spring	121.9383	44.76994	36.778
R0CE99-099	OR	LANE	MARTEN CR	Goat Mountain	122.5095	44.11275	36.778
R0CE99-100	OR	LANE	BLACK CR	Mount David Douglas	122.1772	43.71492	36.778
R0CE99-101	WA	CLARK	CEDAR CR	Ariel	122.5070	45.92629	65.905
R0CE99-103	WA	KING		Lester	121.4656	47.24525	65.905
R0CE99-104	OR	MARION		Lyons	122.5758	44.85975	36.778
R0CE99-106	WA	LEWIS	KIONA CR	Kiona Peak	122.0168	46.52887	65.905
R0CE99-107	WA	LEWIS		Tower Rock	121.8523	46.43783	65.905

Probability Site Identification Code	State	County	Site Name	7.5 (24K) Quad Map	Longitude (Decimal Degrees)	Latitude (Decimal Degrees)	Weight
R0CE99-108	WA	PIERCE	OHOP CR	Tanwax Lake	122.2543	46.91662	65.905
R0CE99-109	OR	LINN	WILEY CR	Farmers Butte	122.5310	44.32169	36.778
R0CE99-110	OR	LANE	LAYNG CR	Rose Hill	122.6911	43.73071	36.778
R0CE99-111	WA	LEWIS	WINSTON CR	Coyote Mountain	122.3800	46.45726	65.905
R0CE99-113	WA	YAKIMA		Norse Peak	121.4100	46.88836	65.905
R0CE99-114	OR	LINN	MIDDLE SANTIAM R	Harter Mountain	122.1469	44.46141	36.778
R0CE99-115	OR	LINN		Tamolitch Falls	122.1061	44.27184	36.778
R0CE99-116	WA	SKAMANIA	COPPER CREEK	Gumboot Mountain	122.2126	45.78460	65.905
R0CE99-117	WA	SKAMANIA	CURLY CREEK	Burnt Peak	121.9478	46.05240	65.905
R0CE99-118	WA	KITTITAS	CABIN CR	Easton	121.2238	47.21701	65.905
R0CE99-119	OR	CLACKAMAS		Bull of the Woods	122.0383	44.96758	36.778
R0CE99-120	OR	LANE		Blue River	122.2550	44.12664	36.778

Appendix 2. Summary statistics for water chemistry indicators for probability sites.

Water Chemistry – PROBABILITY SITES													
Indicator	**Units**	**N**	**Mean**	**95% Confidence**	**Median**	**Minimum**	**Maximum**	**Range**	**Variance**	**Standard Deviation**	**Standard Error**	**Total Weight**	**% Stream Miles**
Alkalinity	mg/L	78	18.623	18.841	18.000	5.430	34.500	29.070	46.458	6.816	0.111	3742.5	99.034
Chloride	mg/L	78	0.921	0.947	0.934	0.000	4.690	4.690	0.647	0.804	0.013	3742.5	99.034
Conductivity		77	3.553	44.030	44.000	13.700	81.000	67.300	218.070	14.767	0.243	3676.6	97.290
Dissolved Oxygen (DO)	mg/L	77	10.098	10.128	10.000	7.400	12.400	5.000	0.869	0.932	0.015	3676.6	97.290
Ammonia (NH3_N)	mg/L	78	0.017	0.017	0.010	0.010	0.049	0.039	0.000	0.010	0.000	3742.5	99.034
Nitrate-Nitrite (NO2_NO3)	mg/L	78	0.033	0.036	0.010	0.000	0.495	0.495	0.008	0.089	0.001	3742.5	99.034
Total Phosphorus	mg/L	78	0.039	0.042	0.017	0.003	0.524	0.522	0.008	0.089	0.001	3742.5	99.034
pH	pH units	70	7.312	7.327	7.400	6.210	9.000	2.790	0.184	0.429	0.008	3244.4	85.853
TSS	mg/L	78	31.358	35.082	1.000	0.500	665.000	664.500	13544.315	116.380	1.899	3742.5	99.034
SO4	mg/L	61	2.295	2.401	1.050	0.000	17.100	17.100	9.282	3.047	0.054	3117.3	82.490
Grab Water Temperature	deg. C	78	11.177	11.265	11.200	3.300	17.600	14.300	7.543	2.747	0.045	3742.5	99.034

Appendix 3. Summary statistics for physical habitat metrics for probability sites (see Kaufmann, et al. 1999 for further definition and method of calculation)

Physical Habitat – PROBABILITY SITES												
Type	**Indicator**	**Units**	**Code**	**Mean**	**95% Conf.**	**Median**	**Min.**	**Max.**	**Range**	**Variance**	**Standard Deviation**	**Standard Error**
channel	Reach with cascades	%	PCT_CA	2.326	2.537	0.000	0.000	49.000	49.000	43.958	6.630	0.108
channel	Reach with dry/submerged flow	%	PCT_DRS	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
channel	Reach with falls	%	PCT_FA	0.476	0.526	0.000	0.000	8.000	8.000	2.388	1.545	0.025
channel	Percent reach with fast water types	%	PCT_FAST	62.203	62.920	61.364	0.000	100.000	100.000	507.152	22.520	0.366
channel	Reach with glides	%	PCT_GL	14.546	15.068	9.000	0.000	56.000	56.000	268.366	16.382	0.266
channel	Reach with pools	%	PCT_POOL	14.830	15.239	12.000	0.000	52.000	52.000	165.155	12.851	0.209
channel	Reach with rapids	%	PCT_RA	6.081	6.529	0.000	0.000	88.000	88.000	197.673	14.060	0.228
channel	Reach with riffles	%	PCT_RI	20.417	21.108	10.000	0.000	76.000	76.000	470.518	21.691	0.352
channel	Reach with slow water types	%	PCT_SLOW	37.797	38.514	38.636	0.000	100.000	100.000	507.152	22.520	0.366
channel	Reach length	m	REACHLEN	328.959	337.246	280.000	100.000	1960.000	1860.000	67757.258	260.302	4.227
channel	Reach length/mean bankfull width	count	#CH_WID	0.158	0.162	0.138	0.000	0.667	0.667	0.016	0.125	0.002
channel	Standard deviation thalweg depth	cm	SDDEPTH	22.128	22.559	18.270	7.268	99.301	92.033	183.228	13.536	0.220
channel	Sinuosity	m/m	SINU	1.177	1.187	1.113	1.012	4.103	3.092	0.103	0.321	0.005
channel	Mean bankfull height above water surface	m	XBKF_H	1.257	1.327	0.700	0.320	13.900	13.580	4.732	2.175	0.035
channel	Mean bankfull width	m	XBKF_W	16.513	17.032	13.664	3.336	125.900	122.564	266.462	16.324	0.265
channel	Mean thalweg depth	cm	XDEPTH	48.144	48.771	47.960	12.926	98.570	85.644	387.080	19.674	0.319
channel	Mean water slope of reach	m	XSLOPE	4.137	4.270	2.640	0.645	33.570	32.925	17.312	4.161	0.068
channel	Mean undercut bank distance	m	XUN	0.026	0.027	0.014	0.000	0.152	0.152	0.001	0.036	0.001
channel	Wetted width/depth ration	%	XWD_RAT	29.019	29.798	24.308	9.499	187.843	178.344	598.471	24.464	0.397
channel	Mean wetted width	m	XWIDTH	11.402	11.903	9.275	2.505	125.188	122.683	247.940	15.746	0.256
cover	Area covered by all types but algae		XFC_ALL	0.606	0.614	0.580	0.216	1.940	1.724	0.064	0.253	0.004
cover	Area covered by large objects		XFC_BIG	0.457	0.463	0.450	0.073	1.100	1.027	0.043	0.208	0.003
cover	Area covered by natural objects		XFC_NAT	0.603	0.611	0.580	0.216	1.940	1.724	0.062	0.250	0.004
human	Agricultural human disturbance	prox. wtd. sum	W1_HAG	0.011	0.013	0.000	0.000	0.886	0.886	0.008	0.087	0.001
human	All human disturbance	prox. wtd. sum	W1_HALL	0.587	0.605	0.424	0.000	2.250	2.250	0.328	0.573	0.009

Physical Habitat – PROBABILITY SITES												
Type	**Indicator**	**Units**	**Code**	**Mean**	**95% Conf.**	**Median**	**Min.**	**Max.**	**Range**	**Variance**	**Standard Deviation**	**Standard Error**
human	Non-agricultural human disturbance	prox. wtd. sum	W1_HNOAG	0.576	0.595	0.402	0.000	2.250	2.250	0.323	0.569	0.009
human	Buildings	prox. wtd. index	W1H_BLDG	0.015	0.018	0.000	0.000	0.652	0.652	0.008	0.087	0.001
human	Row crops	prox. wtd. index	W1H_CROP	0.001	0.002	0.000	0.000	0.045	0.045	0.000	0.007	0.000
human	Landfill/trash	prox. wtd. index	W1H_LDFL	0.028	0.031	0.000	0.000	0.490	0.490	0.005	0.073	0.001
human	Logging	prox. wtd. index	W1H_LOG	0.212	0.223	0.000	0.000	1.455	1.455	0.117	0.342	0.006
human	Mines	prox. wtd. index	W1H_MINE	0.002	0.002	0.000	0.000	0.068	0.068	0.000	0.010	0.000
human	Park	prox. wtd. index	W1H_PARK	0.042	0.046	0.000	0.000	0.742	0.742	0.022	0.147	0.002
human	Pipes	prox. wtd. index	W1H_PIPE	0.002	0.002	0.000	0.000	0.094	0.094	0.000	0.011	0.000
human	Pasture	prox. wtd. index	W1H_PSTR	0.009	0.012	0.000	0.000	0.886	0.886	0.008	0.087	0.001
human	Pavement	prox. wtd. index	W1H_PVMT	0.053	0.057	0.000	0.000	0.758	0.758	0.022	0.149	0.002
human	Road	prox. wtd. index	W1H_ROAD	0.211	0.218	0.091	0.000	0.758	0.758	0.056	0.237	0.004
human	Channel revetment	prox. wtd. index	W1H_WALL	0.012	0.014	0.000	0.000	0.375	0.375	0.003	0.052	0.001
Lwd	Count large woody debris class 1	#/100m	C1WM100	21.039	21.779	13.333	0.000	160.000	160.000	541.295	23.266	0.378
Lwd	Count large woody debris class 2	#/100m	C2WM100	12.845	13.336	8.214	0.000	114.500	114.500	238.009	15.428	0.250
Lwd	Count large woody debris class 3	#/100m	C3WM100	6.226	6.528	2.708	0.000	67.500	67.500	89.836	9.478	0.154
Lwd	Count large woody debris class 4	#/100m	C4WM100	2.978	3.170	1.111	0.000	36.500	36.500	36.555	6.046	0.098
Lwd	Count large woody debris class 5	#/100m	C5WM100	0.524	0.580	0.000	0.000	10.556	10.556	3.024	1.739	0.028
Lwd	Volume large woody debris class 1	m3/m2	V1W_MSQ	0.027	0.029	0.009	0.000	0.325	0.325	0.003	0.052	0.001
Lwd	Volume large woody debris class 2	m3/m2	V2WM100	31.502	33.649	10.801	0.000	403.917	403.917	4549.176	67.448	1.095
Lwd	Volume large woody debris class 3	m3/m2	V3WM100	28.957	31.064	8.737	0.000	399.677	399.677	4380.831	66.188	1.075
Lwd	Volume large woody debris class 4	m3/m2	V4W_MSQ	0.020	0.022	0.005	0.000	0.307	0.307	0.002	0.048	0.001
Lwd	Volume large woody debris class 5	m3/m2	V5WM100	11.864	13.116	0.000	0.000	238.767	238.767	1547.249	39.335	0.639
pool	Number of residual pools	count	NRP	19.385	19.598	19.000	0.000	38.000	38.000	44.826	6.695	0.109

Physical Habitat – PROBABILITY SITES												
Type	**Indicator**	**Units**	**Code**	**Mean**	**95% Conf.**	**Median**	**Min.**	**Max.**	**Range**	**Variance**	**Standard Deviation**	**Standard Error**
pool	Number of pools, depth >100 cm	count	RPGT100	0.449	0.476	0.000	0.000	4.000	4.000	0.723	0.850	0.014
pool	Number of pools, depth >50 cm	count	RPGT50	1.991	2.049	2.000	0.000	8.000	8.000	3.355	1.832	0.030
pool	Number of pools, depth >75 cm	count	RPGT75	0.867	0.908	0.000	0.000	5.000	5.000	1.617	1.272	0.021
pool	Vertical profile of largest residual pool	m2	RPMAREA	13.167	13.650	7.490	0.000	93.233	93.233	230.119	15.170	0.246
pool	Maximum residual depth of deepest pool	cm	RPMDEP	93.395	95.646	71.440	0.000	443.470	443.470	5000.314	70.713	1.148
pool	Maximum pool volume	m3	RPMVOL	57.837	61.758	17.056	0.000	734.563	734.563	15173.540	123.181	2.000
pool	Mean residual pool area	m2	RPXAREA	2.660	2.750	1.671	0.105	14.641	14.536	7.856	2.803	0.046
pool	Mean residual pool depth	cm	RPXDEP	19.296	19.636	16.639	0.000	64.036	64.036	114.410	10.696	0.174
pool	Mean residual pool length	m	RPXLEN	11.133	11.360	9.733	0.000	33.200	33.200	51.089	7.148	0.116
pool	Mean residual pool volume	m3	RPXVOL	11.829	12.953	2.951	0.053	257.212	257.158	1226.509	35.022	0.574
pool	Mean residual pool width	m	RPXWID	3.258	3.412	2.407	0.000	38.037	38.037	23.339	4.831	0.078
riparian	Fraction of reach with coniferous dominant canopy		PCAN_C	0.176	0.185	0.045	0.000	1.000	1.000	0.081	0.284	0.005
riparian	Fraction of reach with broadleaf deciduous dominant canopy		PCAN_D	0.243	0.251	0.182	0.000	0.905	0.905	0.066	0.257	0.004
riparian	Fraction of reach with mixed canopy		PCAN_M	0.521	0.531	0.500	0.000	1.000	1.000	0.097	0.312	0.005
riparian	Fraction of reach without canopy vegetation		PCAN_N	0.060	0.063	0.000	0.000	0.682	0.682	0.014	0.117	0.002
riparian	Mean riparian canopy cover		XC	0.539	0.545	0.517	0.039	1.061	1.022	0.039	0.197	0.003
riparian	Mean canopy density left and right banks	%	XCDENBK	85.555	86.161	92.513	4.813	100.000	95.187	362.148	19.030	0.309
riparian	Mean canopy density midstream	%	XCDENMID	63.671	64.532	69.519	0.000	100.000	100.000	731.829	27.052	0.439
riparian	Fraction of reach with riparian canopy density > 0.3m DBH		XCL	0.248	0.254	0.253	0.006	0.727	0.722	0.026	0.161	0.003
riparian	Riparian cover, sum of 3 layers		XCMG	1.645	1.661	1.656	0.239	2.899	2.660	0.246	0.496	0.008
riparian	Riparian woody cover, sum of 3 layers		XCMGW	1.161	1.172	1.169	0.182	2.182	2.000	0.128	0.357	0.006

Physical Habitat – PROBABILITY SITES												
Type	**Indicator**	**Units**	**Code**	**Mean**	**95% Conf.**	**Median**	**Min.**	**Max.**	**Range**	**Variance**	**Standard Deviation**	**Standard Error**
riparian	Riparian canopy + mid-layer woody cover		XCMW	0.933	0.942	0.926	0.127	1.622	1.494	0.083	0.289	0.005
riparian	Riparian ground-layer vegetation cover		XG	0.586	0.592	0.580	0.079	1.052	0.974	0.040	0.200	0.003
riparian	Faction of reach with canopy present		XPCAN	0.940	0.943	1.000	0.318	1.000	0.682	0.014	0.118	0.002
riparian	Fraction with both canopy and understory present		XPCM	0.930	0.934	1.000	0.286	1.000	0.714	0.016	0.127	0.002
riparian	Fraction of reach with all 3 vegetation classes present		XPCMG	0.927	0.931	1.000	0.300	1.000	0.700	0.016	0.126	0.002
riparian	Faction of reach with understory present		XPMID	0.966	0.969	1.000	0.476	1.000	0.524	0.007	0.085	0.001
substrate	Log10[Relative Bed Stability]		LRBS_BW5	-0.381	-0.359	-0.276	-2.841	0.638	3.479	0.465	0.682	0.011
substrate	substrate - mean Log10 (diameter class)	mm	LSUB_DMM	1.927	1.949	2.041	-0.995	2.983	3.977	0.474	0.688	0.011
substrate	substrate bedrock class	%	PCT_BDRK	11.608	12.018	9.091	0.000	49.091	49.091	165.146	12.851	0.209
substrate	substrate > fine gravel	%	PCT_BIGR	80.417	80.966	83.636	0.000	100.000	100.000	297.078	17.236	0.280
substrate	substrate boulder class	%	PCT_BL	21.782	22.284	20.000	0.000	74.545	74.545	248.810	15.774	0.256
substrate	substrate cobble class	%	PCT_CB	27.917	28.287	27.273	0.000	56.364	56.364	135.105	11.623	0.189
substrate	substrate fines class	%	PCT_FN	7.249	7.610	2.500	0.000	65.455	65.455	129.101	11.362	0.184
substrate	substrate coarse gravel class	%	PCT_GC	12.330	12.635	9.091	0.000	36.364	36.364	91.814	9.582	0.156
substrate	substrate fine gravel class	%	PCT_GF	4.312	4.483	1.818	0.000	29.091	29.091	28.797	5.366	0.087
substrate	substrate hardpan class	%	PCT_HP	0.103	0.122	0.000	0.000	5.455	5.455	0.370	0.608	0.010
substrate	substrate wood or organic class	%	PCT_ORG	2.354	2.498	0.000	0.000	21.818	21.818	20.686	4.548	0.074
substrate	substrate other class	%	PCT_OT	0.422	0.506	0.000	0.000	20.000	20.000	7.040	2.653	0.043
substrate	substrate sand class	%	PCT_SA	4.849	5.053	1.818	0.000	23.636	23.636	41.320	6.428	0.104
substrate	substrate sand or fines	%	PCT_SAFN	12.097	12.544	9.091	0.000	81.818	81.818	196.846	14.030	0.228
substrate	substrate < coarse gravel	%	PCT_SFGF	16.607	17.085	12.727	0.000	83.636	83.636	225.252	15.008	0.244
substrate	Mean substrate embeddedness	%	XEMBED	33.665	34.130	33.364	8.615	79.012	87.636	213.358	14.607	0.237

Appendix 4. Summary statistics for aquatic vertebrate (fish and amphibian) metrics for probability sites.

Metric	Stream km	Mean	+95% Conf.	Median	Min.	Max.	Range	Variance	Standard Deviation	Standard Error
Aquatic Vertebrates – PROBABILITY SITES										
% of fish non-salmonids	3249	41.446	40.206	42.857	0.00	100.00	100.00	1299.267	36.045	0.632
% of fish salmonids	3249	53.106	51.836	50.000	0.00	100.00	100.00	1362.808	36.916	0.648
% of fish species non-salmonids	3249	31.482	30.566	50.000	0.00	100.00	100.00	708.664	26.621	0.467
% of fish species that are salmonids	3249	63.070	62.049	50.000	0.00	100.00	100.00	880.804	29.678	0.521
# of amphibian individuals	3249	6.977	6.560	2.000	0.00	79.00	79.00	146.453	12.102	0.212
% relative abundance of amphibian individuals	3249	22.228	21.191	7.692	0.00	100.00	100.00	908.284	30.138	0.529
# amphibian species	3249	1.035	1.004	1.000	0.00	3.00	3.00	0.836	0.914	0.016
% amphibian species	3249	33.595	32.560	33.333	0.00	100.00	100.00	905.236	30.087	0.528
# of coldwater individuals	3249	40.558	39.299	32.000	0.00	196.00	196.00	1340.396	36.611	0.642
% relative abundance of coldwater individuals	3249	89.986	89.106	100.000	0.00	100.00	100.00	654.695	25.587	0.449
% coldwater species	3249	91.580	90.882	100.000	0.00	100.00	100.00	411.997	20.298	0.356
% relative abundance of coolwater individuals	3249	10.907	9.980	0.000	0.00	100.00	100.00	725.301	26.931	0.472
# of coolwater individuals	3249	5.436	4.752	0.000	0.00	123.00	123.00	395.649	19.891	0.349
% coolwater species	3249	7.281	6.670	0.000	0.00	100.00	100.00	315.967	17.775	0.312
# of fish individuals	3249	40.075	38.771	32.000	0.00	176.00	176.00	1436.154	37.897	0.665
# of fish species present	3249	2.212	2.159	2.000	0.00	8.00	8.00	2.351	1.533	0.027
% relative abundance of intermediate sensitive individuals	3249	28.534	27.406	14.286	0.00	100.00	100.00	1075.167	32.790	0.575
% intermediate sensitive species	3249	22.244	21.400	20.000	0.00	100.00	100.00	602.009	24.536	0.430
intermediately sensitive individuals	3249	14.848	13.964	1.000	0.00	123.00	123.00	660.562	25.701	0.451
# non-salmonid fish individuals	3249	21.700	20.713	10.000	0.00	123.00	123.00	823.442	28.696	0.503
% relative abundance of non-salmonid fish	3249	37.335	36.144	38.235	0.00	100.00	100.00	1198.821	34.624	0.607
% all species that are non-salmonids	3249	27.913	27.041	33.333	0.00	100.00	100.00	642.661	25.351	0.445
# non-salmonid fish species	3249	0.970	0.931	1.000	0.00	6.00	6.00	1.242	1.115	0.020
Shannon-Weiner diversity index (absolute value)	3249	0.743	0.730	0.784	0.00	1.52	1.52	0.133	0.365	0.006
# salmonid individuals	3249	18.334	17.467	11.000	0.00	176.00	176.00	634.868	25.197	0.442
% relative abundance of salmonid individuals	3249	38.993	38.026	40.000	0.00	100.00	100.00	790.507	28.116	0.493
# salmonid species	3249	1.242	1.220	1.000	0.00	3.00	3.00	0.402	0.634	0.011
% salmonid species	3249	41.641	40.871	33.333	0.00	100.00	100.00	500.915	22.381	0.393
# of sensitive individuals	3249	31.038	29.904	22.000	0.00	196.00	196.00	1088.586	32.994	0.579
% relative abundance of sensitive individuals	3249	71.290	70.158	85.714	0.00	100.00	100.00	1081.954	32.893	0.577
% sensitive species	3249	77.079	76.209	80.000	0.00	100.00	100.00	639.151	25.281	0.444
# of all vertebrate individuals	3249	47.051	45.701	36.000	1.00	196.00	195.00	1540.554	39.250	0.689
# of vertebrate species present	3249	3.247	3.198	3.000	1.00	8.00	7.00	2.020	1.421	0.025

Appendix 5. Species characteristics classification for aquatic vertebrate species. Classification based on Zaroban et al. (1999).

Family/Species	Common Name	Tolerance	Habitat	Temperature	Feeding
Fish Species					
Catostomidae					
Catostomus catostomus	longnose sucker	intermediate	benthic	cold	invertivore
Cottidae					
Cottus rhotheus	torrent sculpin	intermediate	benthic	cold	invert/ piscivore
Cottus beldingi	Paiute sculpin	intermediate	benthic	cold	Invertivore
Cottus asper	prickly sculpin	intermediate	benthic	cool	invert/ piscivore
Cottus perplexus	reticulate sculpin	intermediate	benthic	cool	invertivore
Cottus gulosus	riffle sculpin	intermediate	benthic	cool	invertivore
Cottus confuses	shorthead sculpin	sensitive	benthic	cold	invertivore
Cyprinidae					
Rhinichthys cataractae	longnose dace	intermediate	benthic	cool	invertivore
Rhinichthys osculus	speckled dace	intermediate	benthic	cool	invertivore
Gasterosteidae					
Gasterosteus aculeatus	threespine stickleback	tolerant	hider	cool	invertivore
Salmonidae					
Oncorhynchus tshawytscha	chinook salmon	sensitive	water column	cold	invertivore
Oncorhynchus kisutch	coho salmon	sensitive	water column	cold	invertivore
Oncorhynchus clarki	cutthroat trout	sensitive	water column	cold	invert/ piscivore
Oncorhynchus mykiss	rainbow trout	sensitive	hider	cold	invert/ piscivore
Salvelinus fontinalis	brook trout	intermediate	hider	cold	invert/ piscivore
Prosopium williamsoni	mountain whitefish	intermediate	Benthic	cold	invert/ piscivore

Family/Species	Common Name	Tolerance	Habitat	Temperature	Feeding
Amphibians					
Leiopelmatidae					
Ascaphus truei	tailed frog	sensitive	benthic/ hider	cold	invert/ carnivore
Ranidae					
Rana aurora	red-legged frog	intolerant	edge	none	invert/ carnivore
Rana cascadae	Cascade frog				
Bufonidae					
Bufo boreas	western toad	sensitive	lentic	none	invert/ carnivore
Dicamptodontidae					
Dicamptodon copei	Copes giant salamander	intolerant	hider	cold	invert/ carnivore
Dicamptodon tenebrosus	Pacific giant salamander	intolerant	benthic/ hider	cold	invert/ carnivore

Appendix 6. Summary Statistics for selected benthic macroinvertebrate metrics for probability sites.

Benthic Macroinvertebrates – PROBABILITY SITES									
Metric	**Mean**	**95% Conf.**	**Median**	**Minimum**	**Maximum**	**Range**	**Variance**	**Standard Deviation**	**Standard Error**
Taxa richness	33.134	33.424	34.000	12.000	55.000	43.000	73.722	8.586	0.148
Total count (abundance)	373.769	378.422	345.000	100.000	1220.000	1120.000	19002.082	137.848	2.374
Ephemeroptera richness	9.125	9.256	9.000	2.000	27.000	25.000	15.127	3.889	0.067
% Ephemeroptera	0.427	0.433	0.441	0.015	0.856	0.841	7.886	2.808	0.048
Plecoptera richness	6.700	6.795	6.000	0.000	13.000	13.000	0.009	0.095	0.002
% Plecoptera	0.124	0.127	0.090	0.000	0.436	0.436	0.012	0.107	0.002
Trichoptera richness	8.256	8.371	9.000	0.000	19.000	19.000	58.998	7.681	0.132
%Trichoptera	0.139	0.143	0.103	0.000	0.482	0.482	1.942	1.394	0.024
EPT richness	24.082	24.341	24.000	9.000	52.000	43.000	0.011	0.104	0.002
% EPT	0.690	0.696	0.731	0.087	0.964	0.877	0.007	0.086	0.001
Non-insect richness	2.333	2.380	2.000	0.000	7.000	7.000	11.397	3.376	0.058
% Non-insect	0.060	0.064	0.028	0.000	0.676	0.676	0.010877	0.104294	0.001796
Long-lived richness	3.272	3.344	3.000	0.000	12.000	12.000	4.632041	2.152218	0.037058
% Long-lived	0.073	0.076	0.049	0.000	0.401	0.401	0.007344	0.085696	0.001476
Intolerant richness	5.288	5.402	4.000	0.000	15.000	15.000	11.39652	3.375873	0.058127
% Intolerant	0.151	0.156	0.093	0.000	0.708	0.708	0.023367	0.152863	0.002632

Appendix 7. Summary Statistics for physical habitat for reference sites (n=22) (see Kaufmann, et al. 1999, for further definition and method of calculation)

Physical habitat – REFERENCE SITES										
Type	Indicator	Units	Code	Mean	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
channel	Reach with cascades	%	PCT_CA	5.153	0.667	0.000	44.000	97.623	9.880	2.017
channel	Reach with dry/submerged flow	%	PCT_DRS	2.444	0.000	0.000	35.000	65.987	8.123	1.658
channel	Reach with falls	%	PCT_FA	0.613	0.000	0.000	6.667	2.702	1.644	0.336
channel	Reach with fast water types	%	PCT_FAST	61.777	71.167	15.000	88.000	419.429	20.480	4.180
channel	Reach with glides	%	PCT_GL	15.992	11.028	0.000	35.000	138.652	11.775	2.404
channel	Reach with pools	%	PCT_POOL	19.787	19.500	2.000	40.000	86.765	9.315	1.901
channel	Reach with riffles	%	PCT_RI	45.539	45.000	0.000	84.000	496.901	22.291	4.550
channel	Reach with rapids	%	PCT_RA	10.472	0.000	0.000	71.000	372.714	19.306	3.941
channel	Reach with slow water types	%	PCT_SLOW	35.779	28.833	12.000	60.667	269.174	16.407	3.349
channel	Reach length	m	REACHLEN	214.400	150.000	150.000	600.000	14372.327	119.885	24.471
channel	Standard deviation thalweg depth	cm	SDDEPTH	16.516	13.524	6.900	48.760	79.451	8.914	1.819
channel	Sinuosity	m/m	SINU	1.215	1.120	1.042	1.755	0.036	0.191	0.039
channel	Mean bankfull height above water surface	m	XBKF_H	0.622	0.615	0.336	0.964	0.034	0.183	0.037
channel	Mean bankfull width	m	XBKF_W	9.816	8.282	4.373	25.282	32.469	5.698	1.163
channel	Mean thalweg depth	cm	XDEPTH	32.115	26.560	9.787	63.680	254.648	15.958	3.257
channel	Mean water slope of reach	m	XSLOPE	6.231	5.358	1.200	17.860	17.740	4.212	0.860
channel	Mean undercut bank distance	m	XUN	0.027	0.017	0.000	0.112	0.001	0.032	0.007
channel	Wetted width/depth ratio	%	XWD_RAT	24.316	22.358	11.525	61.407	114.124	10.683	2.181
channel	Mean wetted width	m	XWIDTH	5.816	4.402	1.980	16.845	16.296	4.037	0.824
cover	Area covered by all types but algae		XFC_ALL	0.775	0.760	0.132	1.359	0.090	0.301	0.061
cover	Area covered by large objects		XFC_BIG	0.587	0.589	0.109	1.102	0.066	0.257	0.052
cover	Area covered by natural objects		XFC_NAT	0.775	0.760	0.132	1.359	0.090	0.301	0.061
human	Agricultural human disturbance	prox. wd. sum	W1_HAG	0.000	0.000	0.000	0.000	0.000	0.000	0.000
human	All human disturbance	prox. wtd. sum	W1_HALL	0.124	0.000	0.000	1.530	0.131	0.362	0.074
human	Non-agricultural human disturbance	prox. wtd. sum	W1_HNOAG	0.124	0.000	0.000	1.530	0.131	0.362	0.074

Physical habitat – REFERENCE SITES										
Type	Indicator	Units	Code	Mean	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
human	Buildings	prox. wtd. index	W1H_BLDG	0.014	0.000	0.000	0.333	0.005	0.068	0.014
human	Row crops	prox. wtd. index	W1H_CROP	0.000	0.000	0.000	0.000	0.000	0.000	0.000
human	Landfill/trash	prox. wtd. index	W1H_LDFL	0.002	0.000	0.000	0.030	0.000	0.008	0.002
human	Logging	prox. wtd. index	W1H_LOG	0.006	0.000	0.000	0.091	0.000	0.020	0.004
human	Mines	prox. wtd. index	W1H_MINE	0.076	0.000	0.000	1.500	0.097	0.311	0.063
human	Park	prox. wtd. index	W1H_PARK	0.000	0.000	0.000	0.000	0.000	0.000	0.000
human	Pipes	prox. wtd. index	W1H.PIPE	0.005	0.000	0.000	0.121	0.001	0.025	0.005
human	Pasture	prox. wtd. index	W1H_PSTR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
human	Pavement	prox. wtd. index	W1H.PVMT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
human	Road	prox. wtd. index	W1H_ROAD	0.021	0.000	0.000	0.318	0.005	0.068	0.014
human	Channel revetment	prox. wtd. index	W1H.WALL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lwd	Count large woody debris class 1	#/100m	C1WM100	42.888	30.000	5.609	182.000	1639.566	40.492	8.265
Lwd	Count large woody debris class 2	#/100m	C2WM100	28.213	18.000	2.003	126.000	843.062	29.036	5.927
Lwd	Count large woody debris class 3	#/100m	C3WM100	13.567	8.174	0.000	51.333	202.734	14.238	2.906
Lwd	Count large woody debris class 4	#/100m	C4WM100	6.633	4.273	0.000	24.000	52.839	7.269	1.484
Lwd	Count large woody debris class 5	#/100m	C5WM100	0.592	0.000	0.000	3.333	0.859	0.927	0.189
Lwd	Volume large woody debris class 1	m3/m2	V1W.MSQ	0.073	0.040	0.003	0.241	0.006	0.078	0.016
Lwd	Volume large woody debris class 2	m3/m2	V2WM100	55.534	35.881	2.039	199.037	3594.092	59.951	12.237
Lwd	Volume large woody debris class 4	m3/m2	V4W.MSQ	0.056	0.024	0.000	0.211	0.004	0.066	0.013
Lwd	Volume large woody debris class 3	m3/m2	V3WM100	50.511	32.653	0.000	188.487	3208.529	56.644	11.562
Lwd	Volume large woody debris class 5	m3/m2	V5WM100	13.383	0.000	0.000	75.400	439.298	20.959	4.278
pool	Number of residual pools	count	NRP	25.208	25.000	0.000	39.000	87.216	9.339	1.906
pool	Number of pools, depth >100 cm	count	RPGT100	0.083	0.000	0.000	1.000	0.080	0.282	0.058
pool	Number of pools, depth >50 cm	count	RPGT50	1.625	1.000	0.000	5.000	2.505	1.583	0.323
pool	Number of pools, depth >75 cm	count	RPGT75	0.583	0.000	0.000	4.000	1.210	1.100	0.225
pool	Vertical profile of largest residual pool	m2	RPMAREA	6.000	2.670	0.000	63.122	157.680	12.557	2.563

Physical habitat – REFERENCE SITES										
Type	Indicator	Units	Code	Mean	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
pool	Maximum residual depth of deepest pool	cm	RPMDEP	66.979	59.626	0.000	241.896	2002.523	44.750	9.134
pool	Maximum pool volume	m3	RPMVOL	23.635	3.611	0.000	390.822	6222.259	78.881	16.102
pool	Mean residual pool area	m2	RPXAREA	1.189	0.561	0.159	8.242	3.305	1.818	0.379
pool	Mean residual pool depth	cm	RPXDEP	14.273	12.391	0.000	32.512	54.494	7.382	1.507
pool	Mean residual pool length	m	RPXLEN	5.801	3.516	0.000	25.350	32.563	5.706	1.165
pool	Mean residual pool volume	m3	RPXVOL	3.256	0.597	0.087	39.215	69.459	8.334	1.738
pool	Mean residual pool width	m	RPXWID	1.788	1.395	0.000	5.480	1.672	1.293	0.264
riparian	Fraction of reach with coniferous dominant canopy		PCAN_C	0.381	0.239	0.000	1.000	0.159	0.398	0.081
riparian	Fraction of reach with broadleaf deciduous dominant canopy		PCAN_D	0.096	0.045	0.000	0.409	0.015	0.122	0.025
riparian	Fraction of reach with mixed canopy		PCAN_M	0.509	0.564	0.000	1.000	0.137	0.370	0.076
riparian	Fraction of reach without canopy vegetation		PCAN_N	0.011	0.000	0.000	0.091	0.001	0.027	0.006
riparian	Mean riparian canopy cover		XC	0.604	0.624	0.240	0.864	0.025	0.158	0.032
riparian	Mean canopy density at left and right banks	%	XCDENBK	94.239	96.925	75.668	100.000	50.135	7.081	1.445
riparian	Mean canopy density midstream	%	XCDENMID	81.280	86.163	37.166	98.128	256.278	16.009	3.268
riparian	Fraction of reach with riparian canopy density > 0.3m DBH		XCL	0.309	0.296	0.016	0.643	0.028	0.169	0.034
riparian	Riparian cover, sum of 3 layers		XCMG	1.684	1.699	0.876	2.484	0.140	0.374	0.076
riparian	Riparian woody cover, sum of 3 layers		XCMGW	1.108	1.096	0.644	1.730	0.081	0.285	0.058
riparian	Riparian canopy + mid-layer woody cover		XCMW	0.916	0.916	0.463	1.394	0.062	0.250	0.051
riparian	Riparian ground-layer vegetation cover		XG	0.604	0.609	0.313	0.997	0.028	0.167	0.034
riparian	Faction of reach with canopy present		XPCAN	0.989	1.000	0.905	1.000	0.001	0.028	0.006
riparian	Fraction with both canopy and understory present		XPCM	0.981	1.000	0.762	1.000	0.003	0.055	0.011
riparian	Fraction of reach with all 3 vegetation classes present		XPCMG	0.979	1.000	0.762	1.000	0.003	0.055	0.011
riparian	Faction of reach with understory present		XPMID	0.989	1.000	0.864	1.000	0.001	0.034	0.007

Physical habitat – REFERENCE SITES										
Type	Indicator	Units	Code	Mean	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
substrate	Log10[Relative Bed Stability]		LRBS_BW5	-0.392	-0.371	-1.582	0.584	0.234	0.483	0.099
substrate	substrate - mean Log10 (diameter class	mm	LSUB_DMM	1.961	2.048	0.318	2.956	0.327	0.572	0.117
substrate	substrate bedrock class	%	PCT_BDRK	9.842	0.000	0.000	52.727	313.414	17.703	3.614
substrate	substrate > fine gravel	%	PCT_BIGR	82.557	83.636	47.273	100.000	109.225	10.451	2.133
substrate	substrate boulder class	%	PCT_BL	21.723	20.000	0.000	49.091	220.980	14.865	3.034
substrate	substrate cobble class	%	PCT_CB	28.245	29.091	0.000	58.182	172.390	13.130	2.680
substrate	substrate fines class	%	PCT_FN	5.398	3.636	0.000	29.091	42.522	6.521	1.331
substrate	substrate coarse gravel class	%	PCT_GC	22.746	16.364	3.636	70.909	215.923	14.694	2.999
substrate	substrate fine gravel class	%	PCT_GF	5.461	4.545	0.000	16.667	17.875	4.228	0.863
substrate	substrate hardpan class	%	PCT_HP	0.152	0.000	0.000	1.818	0.264	0.513	0.105
substrate	substrate wood or organic class	%	PCT_ORG	2.247	1.818	0.000	10.909	7.194	2.682	0.547
substrate	substrate other class	%	PCT_OT	0.221	0.000	0.000	3.636	0.645	0.803	0.164
substrate	substrate sand class	%	PCT_SA	3.965	3.636	0.000	16.364	17.353	4.166	0.850
substrate	substrate sand or fines	%	PCT_SAFN	9.362	7.273	0.000	45.455	77.398	8.798	1.796
substrate	substrate < coarse gravel	%	PCT_SFGF	14.823	14.545	0.000	45.455	89.238	9.447	1.928
substrate	Mean substrate embeddedness	%	XEMBED	30.235	31.000	6.909	50.364	133.302	11.546	2.357

Appendix 8. Summary statistics for aquatic vertebrate (fish and amphibian) metrics for reference sites (n=21).

Aquatic vertebrates – REFERENCE SITES									
Metric	Mean	+95% Conf.	Median	Min.	Max.	Range	Variance	Standard Deviation	Standard Error
% of fish non-salmonids	19.910	7.397	0.000	0.00	79.17	79.17	837.241	28.935	6.033
% of fish salmonids	67.047	50.411	90.909	0.00	100.00	100.00	1480.021	38.471	8.022
% of fish species non-salmonids	21.739	9.411	0.000	0.00	75.00	75.00	812.747	28.509	5.944
% of fish species that are salmonids	65.217	49.005	50.000	0.00	100.00	100.00	1405.632	37.492	7.818
# of amphibian individuals	60.696	21.043	15.000	0.00	310.00	310.00	8408.221	91.696	19.120
% relative abundance of amphibian individuals	40.578	27.389	33.333	0.00	100.00	100.00	930.304	30.501	6.360
# amphibian species	1.783	1.392	2.000	0.00	4.00	4.00	0.814	0.902	0.188
% amphibian species	55.072	43.086	50.000	0.00	100.00	100.00	768.303	27.718	5.780
# of coldwater individuals	118.130	53.687	34.000	1.00	600.00	599.00	22208.391	149.025	31.074
% relative abundance of coldwater individuals	95.009	89.153	100.000	50.79	100.00	49.21	183.363	13.541	2.824
% coldwater species	94.638	89.342	100.000	60.00	100.00	40.00	149.989	12.247	2.554
% relative abundance of coolwater individuals	4.991	-0.864	0.000	0.00	49.21	49.21	183.363	13.541	2.824
# of coolwater individuals	4.913	-1.859	0.000	0.00	70.00	70.00	245.265	15.661	3.266
% coolwater species	5.362	0.066	0.000	0.00	40.00	40.00	149.989	12.247	2.554
# of fish individuals	68.565	34.334	29.000	0.00	290.00	290.00	6266.166	79.159	16.506
# of fish species present	1.478	1.029	1.000	0.00	4.00	4.00	1.079	1.039	0.217
% relative abundance of intermediate sensitive individuals	9.108	0.281	0.000	0.00	75.00	75.00	416.680	20.413	4.256
% intermediate sensitive species	9.275	1.627	0.000	0.00	60.00	60.00	312.835	17.687	3.688
intermediately sensitive individuals	5.435	-1.449	0.000	0.00	70.00	70.00	253.439	15.920	3.319
# non-salmonid fish individuals	20.652	5.289	0.000	0.00	115.00	115.00	1262.237	35.528	7.408
% relative abundance of non-salmonid fish	13.864	4.610	0.000	0.00	60.22	60.22	457.956	21.400	4.462
% all species that are non-salmonids	14.203	5.612	0.000	0.00	60.00	60.00	394.664	19.866	4.142
# non-salmonid fish species	0.565	0.178	0.000	0.00	3.00	3.00	0.802	0.896	0.187
Shannon-Weiner diversity index (absolute value)	0.852	0.700	0.826	0.00	1.44	1.44	0.123	0.351	0.073
#salmonid individuals	47.913	21.980	20.000	0.00	175.00	175.00	3596.447	59.970	12.505
% relative abundance of salmonid individuals	45.558	32.771	45.455	0.00	100.00	100.00	874.277	29.568	6.165
# salmonid species	0.913	0.733	1.000	0.00	2.00	2.00	0.174	0.417	0.087
% salmonid species	30.725	21.606	25.000	0.00	100.00	100.00	444.653	21.087	4.397
# of sensitive individuals	119.478	53.955	34.000	1.00	600.00	599.00	22958.806	151.522	31.594
% relative abundance of sensitive individuals	90.892	82.065	100.000	25.00	100.00	75.00	416.680	20.413	4.256
% sensitive species	90.725	83.076	100.000	40.00	100.00	60.00	312.835	17.687	3.688
# of all vertebrate individuals	129.261	63.020	44.000	1.00	600.00	599.00	23464.474	153.181	31.940
# of vertebrate species present	3.261	2.736	3.000	1.00	6.00	5.00	1.474	1.214	0.253

Appendix 9. Summary statistics for benthic macroinvertebrate metrics for reference sites (n=18).

Benthic Macroinvertebrates – REFERENCE SITES							
Metric	Mean	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
Taxa richness	32.833	32.000	21.000	49.000	49.676	7.048	1.661
Total count (abundance)	318.222	298.000	146.000	580.000	9749.830	98.741	23.274
Ephemeroptera richness	8.611	9.000	5.000	12.000	4.840	2.200	0.519
% Ephemeroptera	0.443	0.462	0.085	0.719	8.801	2.967	0.699
Plecoptera richness	7.722	7.500	4.000	16.000	0.009	0.097	0.023
% Plecoptera	0.158	0.136	0.040	0.347	0.013	0.113	0.027
Trichoptera richness	8.056	8.000	3.000	12.000	26.487	5.147	1.213
% Trichoptera	0.158	0.135	0.017	0.546	2.212	1.487	0.351
EPT richness	24.389	23.500	18.000	38.000	0.002	0.049	0.011
% EPT	0.759	0.766	0.523	0.976	0.006	0.075	0.018
Non-insect taxa richness	2.278	3.000	0.000	5.000	9.007	3.001	0.707
% Non-insect	0.047	0.032	0.000	0.175	0.002	0.049	0.011
Long-lived richness	3.222	3.000	0.000	5.000	2.654	1.629	0.384
% Long-lived	0.060	0.033	0.000	0.332	0.006	0.075	0.018
Intolerant richness	6.222	6.000	2.000	13.000	9.007	3.001	0.707
% Intolerant taxa	0.222	0.158	0.034	0.761	0.035	0.187	0.044

Appendix 10. Metric values used for figures 38-40.

INDICATOR	POOR	FAIR	GOOD
Nitrate-nitrite	≥.3mg/l	n/a	<.3mg/l
Phosphorus	≥.1mg/l	n/a	< .1mg/l
pH	<6.5 or >8.8	n/a	6.5 - 8.8
Temperature	≥ 16.0 °C	Between 12°C and 16.0°C	< 12°C
Percent sands/fines	> 16%	Between 12% and 16%	< 12%
% Coniferous/mixed cover	< 66%	Between 66% and 82%	> 82%
Mid-channel shade	< 57%	Between 57% and 75%	> 75%
Large/very large LWD	< .001 m3/m2	Between .001 and .009 m3/m2	>.009 m3/m2
% EPT	< 56%	Between 56% and 63%	> 63%
% Plecoptera	< 4%	Between 4% and 9%	> 9%
% Intolerant macroinvertebrates	< 4%	Between 4% and 7%	> 7%
Total vertebrate richness	1 species	2 species	3 species or more
% Relative abundance of sensitive vertebrate species	< 44%	Between 44% and 95%	> 95%
Shannon-Weiner index (absolute value)	< .37	Between .37 and .64	> .64