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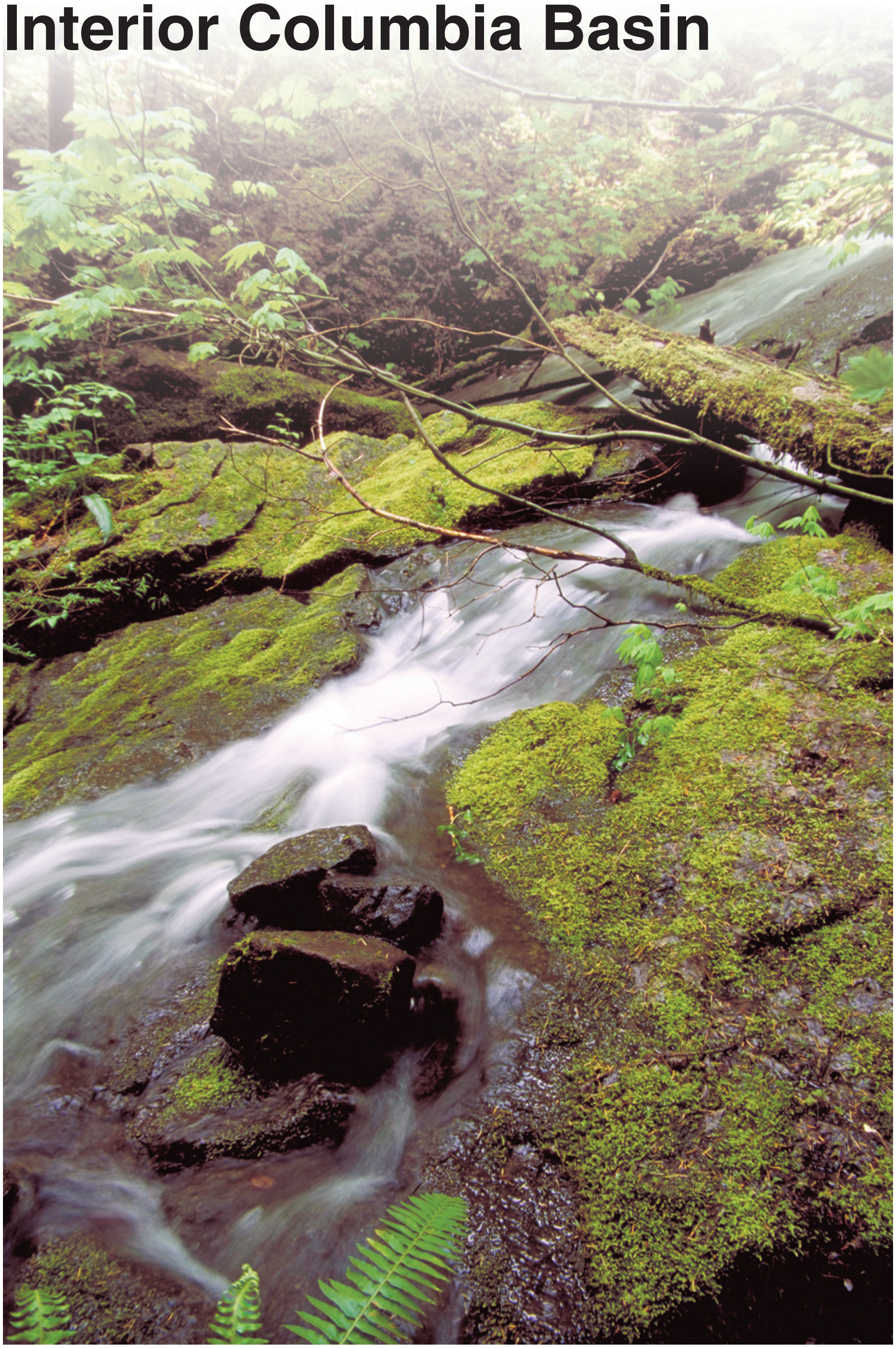
Ecological Condition of Wadeable Streams of the Interior Columbia Basin



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Ecological Condition of Wadeable Streams of the Interior Columbia River Basin

An EPA Environmental Monitoring and Assessment Program Report

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Table of Contents

List of Figures

List of Tables

List of Maps

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Abstract

The Environmental Monitoring and Assessment Program (EMAP) was developed by EPA to assess the condition of the nation's ecological resources. EMAP employs a statistical design that makes it possible to describe the proportion of the resource in good, fair or poor condition relative to reference condition. In 2000, the EMAP began a five-year effort to monitor and assess the ecological condition of rivers and streams across the West. This report uses a subset of the data from this large project and data from other EMAP projects to assess the ecological condition of the wadeable streams of the Interior Columbia River basin. Approximately 75,000 km of the 109,000 km of wadeable streams of the Basin were assessed for most indicators. In general, most streams of the basin are in fair or good condition based on the results of the metrics that could be analyzed. Primary stressors in terms of both extent and risk to biota are excess fine sediment, riparian disturbance from grazing/crops, sulfate, and phosphorous levels.

Purpose

This ecological assessment of the Interior Columbia River Basin has three purposes:

Report on the ecological condition of wadeable streams of the Interior Columbia Basin using direct measures of biological assemblages.

Identify and rank the relative importance of potential stressors affecting stream condition by using supplemental measures of chemical, physical and biological habitat to answer the following questions:

--How wide-spread/common are these stressors?
--What is the “risk” to stream biota related to these stressors?

Demonstrate the usefulness of the EMAP- type study design and analysis for assessing regional waterbody condition, which could potentially be implemented as part of state surface waters monitoring programs.

Introduction

EMAP (Environmental Monitoring and Assessment Program) was initiated by EPA to estimate the status and trends of the nation's ecological resources and examine associations between ecological condition and natural and anthropogenic influences. The surface water component of EMAP is based on the premise that the condition of stream biota can be addressed by examining biological and ecological indicators of stress. The long-term goal of EMAP is to develop ecological methods and procedures that permit the measurement of environmental resources to determine if they are in an acceptable or unacceptable condition relative to a set of environmental or ecological values. Two major features of EMAP are the use of ecological indicators and probability-based selection of sample sites.

We use the EMAP data collected as part of EPA’s Westwide pilot project to assess the biotic condition by focusing on the direct measurements of the biota in relation to the physical and chemical condition through the use of biological indicators. This approach utilizes the fact thattream biota integrate many of the physical and chemical stressors and other biota (such as non-native species) that affect the aquatic ecosystem in which they reside.

An **Ecological Assessment** can be performed in a variety of ways such as a description of the extent of a resource or an enumeration of the abundance and distribution of biota in an ecosystem. This Ecological Assessment of the Interior Columbia Basin evaluates two critical components of aquatic ecosystems: 1) the condition of the biota, and 2) the relative importance of human-caused stressors.

The first component of this ecological assessment is based on the fact that biological communities are adapted to local habitat (the combination of physical, chemical, and spatial elements) and therefore the ecological condition of wadeable streams is reflected by the quality/health of the biotic communities. In other words, the biotic communities integrate the many human disturbances that we are interested in assessing. Maintaining the biotic communities is also one of the pillars of the Clean Water Act "…. Supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat."

The second component of this ecological assessment evaluates **ecological stressors**. Stressors are defined as the pressures or disturbances exerted on aquatic systems. These are the chemical, physical, and biological components of the ecosystem that have the potential to degrade the biotic integrity of the aquatic system. This ecological assessment will identify stressors and describe their extent as well as their relative importance in terms of risk to the biotic integrity of the Interior Columbia Basin wadeable streams.

EMAP Western Pilot

The EMAP Western Pilot was a five-year effort to collect data across the twelve western states and to report on the ecological condition of this area (Stoddard et al. 2005a and Stoddard et al. 2005b). Consistent field, lab, and data analytical methods were used across the area and across stream types. All sites were selected using a probabilistic design. Collectively, the sites are a statistical representation of the target population of flowing waters of the western states.

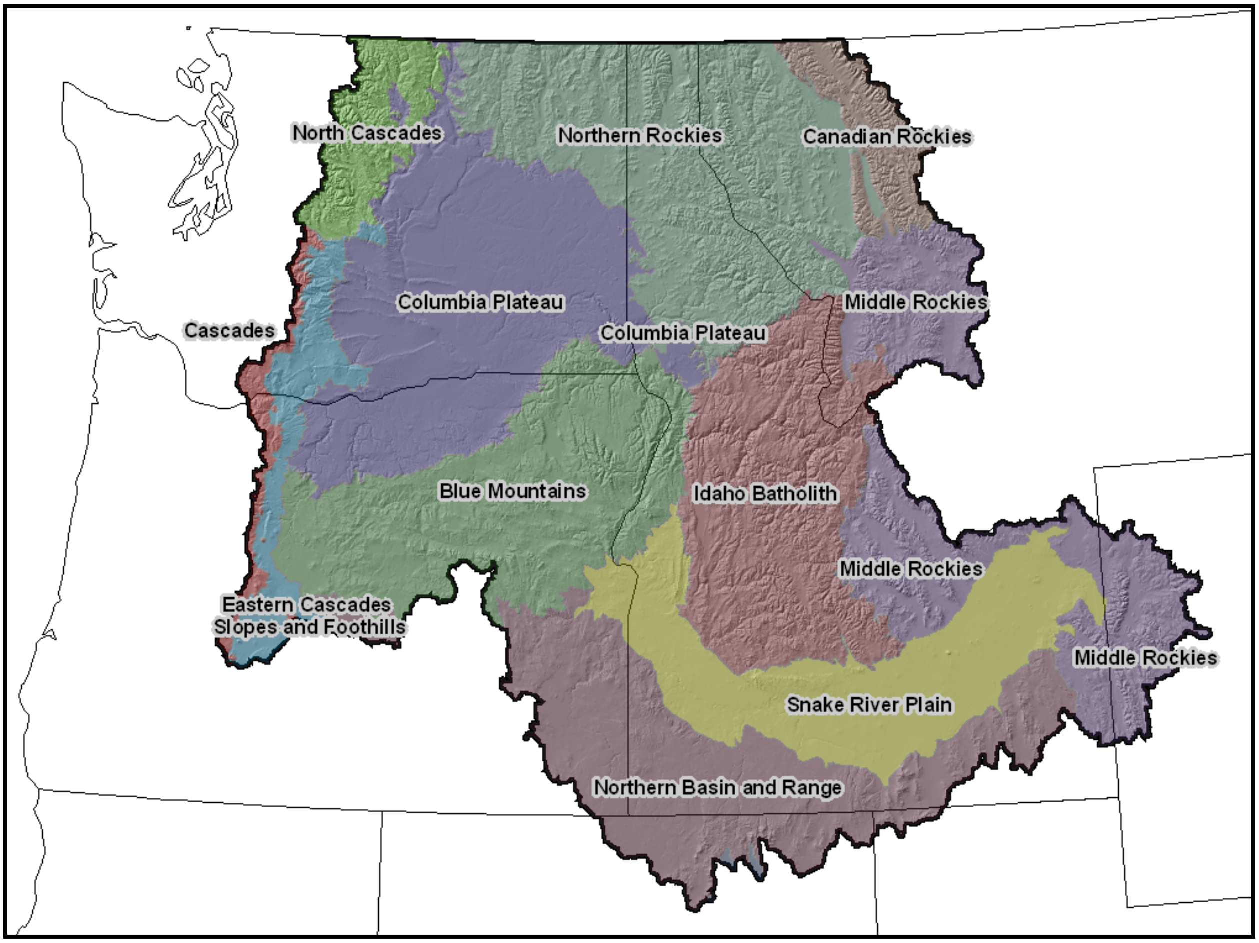
This report uses data collected as part of the Western Pilot. The Interior Columbia was selected by Region 10 as the study area because:

- The Columbia River is one of the seven Region 10 Strategic Planning Priorities.
- The basin comprises a major portion of the Region 10 geographical range.
- Region 10 has previously reported on stream condition in other major portions of the Region using EMAP data (Hayslip et al. 2004, Herger et al. 2003, Hayslip et al. 2001, and Herger et al. 2000). This is the first time extensive data have been available for reporting on the ecological condition of streams in this area.

Additional EMAP data were available from other regional EMAP projects in whole or in part conducted within the Interior Columbia Basin. These additional data provide the opportunity to refine the ‘quality thresholds’ for the analysis of the Interior Columbia Basin and generate a more robust analysis than we have previously been able to conduct using EMAP data.

The Interior Columbia Basin

The Columbia River is the second largest river in the United States based on discharge. The U.S. portion of the Columbia River Basin encompasses almost all of Idaho, large portions of Washington and Oregon, and small areas of Montana, Utah, Wyoming, and Nevada (Map 1). The basin is 202,705 square miles in area (slightly smaller than France). The Columbia River originates in Canada and drains south through Washington State. Major tributary rivers include the Snake and Clearwater rivers which originate in Idaho and drain to the west and the Deschutes and John Day rivers which originate in Oregon and drain to the north.



Map 1. Level III ecoregions of the Interior Columbia Basin (USEPA 2003a).

Ecological Regions

The Columbia River Basin ecosystem has diverse physiological, climatic, and floral and faunal characteristics as evident by the inclusion of all or portions of 11 different ecological regions (**ecoregions**) within its boundary (USEPA 2003a). Ecoregions are areas that are relatively homogenous with respect to ecological systems (Omernik 1995). The diversity of the UCB includes large expanses of high xeric plateau, steep mountains, and extensive forested areas. The basin has two major climatic regions, xeric and mountainous areas. The xeric portion of the basin is represented by the aggregation of the Columbia Plateau, North Basin Range, and Snake River Plain ecoregions. The aggregates of the remaining ecoregions comprise the mountainous climatic region. The following are brief descriptions of the Level III Ecoregions of the Basin shown on Map 1 (excerpts from Bryce 1997).

Blue Mountains (1): This ecoregion is distinct from the neighboring Cascades and Northern Rockies ecoregions because the Blue Mountains are generally not as high and are considerably more open. Like the Cascades, but unlike the Northern Rockies, the region is mostly volcanic in origin. Only the few higher ranges, particularly the Wallowa and Elkhorn Mountains, consist of intrusive rocks that rise above the dissected lava surface of the region. Unlike the bulk of the Cascades and Northern Rockies, much of this ecoregion is grazed by cattle.

Cascades (4): This mountainous ecoregion is underlain by Cenozoic volcanics and has been affected by alpine glaciations. It is characterized by steep ridges and river valleys in the west, a high plateau in the east, and both active and dormant volcanoes. Elevations range up to 4,390 meters. Its moist, temperate climate supports an extensive and highly productive coniferous forest. Subalpine meadows occur at high elevations.

Eastern Cascade Slopes and Foothills (9): The Eastern Cascade Slopes and Foothills ecoregion is in the rain-shadow of the Cascade Mountains. Its climate exhibits greater temperature extremes and less precipitation than ecoregions to the west. Open forests of ponderosa pine and some lodgepole pine distinguish this region from the higher ecoregions to the west where fir and hemlock forests are common, and the lower drier ecoregions to the east where shrubs and grasslands are predominant. The vegetation is adapted to the prevailing dry continental climate and is highly susceptible to wildfire. Volcanic cones and buttes are common in much of the region.

Columbia Plateau (10): The Columbia Plateau is an arid sagebrush steppe and grassland, which is surrounded by moister, predominantly forested, mountainous ecological regions. This region is underlain by basalt up to two miles thick. It is covered in some places by loess soils that have been extensively cultivated for wheat, particularly in the eastern portions of the region where precipitation amounts are higher.

Snake River Plain (12): This portion of the xeric intermontane basin and range area of the western United States is considerably lower and more gently sloping than the surrounding ecoregions. Mostly because of the available water for irrigation, a large percent of the alluvial valleys bordering the Snake River are in agriculture, with sugar beets, potatoes, and vegetables being the principal crops. Cattle feedlots and dairy operations are also common in the river plain. Except for the scattered barren lava fields, the rest of the plains and low hills in the ecoregion are characterized by sagebrush steppe vegetation. The natural vegetation is now used for cattle grazing.

Northern Rockies (15): The high, rugged Northern Rockies ecoregion is mountainous and lies east of the Cascades. Despite its inland position, climate and vegetation are, typically, marine-influenced. Douglas fir, subalpine fir, Englemann spruce, and ponderosa pine and Pacific indicators such as western red cedar, western hemlock, and grand fir are found in the ecoregion. The vegetation mosaic is different from that of the Middle Rockies which is not dominated by maritime species. The Northern Rockies ecoregion is not as high or as snow- and ice-covered as the Canadian Rockies although alpine characteristics occur at highest elevations and include numerous glacial lakes. The presence of granitics and associated management problems are less extensive than in the Idaho Batholith.

Idaho Batholith (16): This ecoregion is a dissected, partially glaciated, mountainous plateau. Many perennial streams originate here and water quality can be high if basins are undisturbed. Deeply weathered, acidic, intrusive igneous rock is common and is far more extensive than in the Northern Rockies or the Middle Rockies. Soils are sensitive to disturbance especially when stabilizing vegetation is removed. Land uses include logging, grazing, and recreation. Mining and related damage to aquatic habitat is widespread. Grand fir, Douglas-fir and, at higher elevations, Engelmann spruce, and subalpine fir occur; ponderosa pine, shrubs, and grasses grow in very deep canyons. Maritime influence lessens toward the south and is never as strong as in the Northern Rockies.

Middle Rockies (17): The climate of the Middle Rockies lacks the strong maritime influence of the Northern Rockies. Mountains have Douglas-fir, subalpine fir, and Engelmann spruce forests and alpine areas; Pacific tree species are never dominant. Forests can be open. Foothills are partly wooded or shrub- and grass-covered. Intermontane valleys are grass- and/or shrub-covered and contain a mosaic of terrestrial and aquatic fauna that is distinct from the nearby mountains. Many mountain-fed, perennial streams occur and differentiate the intermontane valleys from the Northwestern Great Plains. Granitics and associated management problems are less extensive than in the Idaho Batholith. Recreation, logging, mining, and summer livestock grazing are common land uses.

Canadian Rockies (41): This ecoregion straddles the border between Alberta and British Columbia in Canada and extends southeastward into northwestern Montana. The region is generally higher and more ice-covered than the Northern Rockies. Vegetation is mostly Douglas fir, spruce, and lodgepole pine at lower elevations and alpine fir at middle elevations. The higher elevations are treeless alpine. A large part of the region is in national parks where tourism is the major land use. Forestry and mining occur on the non-park lands.

North Cascades (77): The terrain of the North Cascades is composed of high, rugged mountains. It contains the greatest concentration of active alpine glaciers in the conterminous United States and has a variety of climatic zones. A dry continental climate occurs in the east and mild, maritime, rainforest conditions are found in the west. It is underlain by sedimentary and metamorphic rock in contrast to the adjoining Cascades which are composed of volcanics.

Northern Basin and Range (80): This ecoregion contains arid tablelands, intermontane basins, dissected lava plains, and scattered mountains. Non-mountain areas have sagebrush steppe vegetation; cool season grasses are more common than in the hotter-drier basins of the Central Basin and Range which are dominated by sagebrush, shadscale, and greasewood. Rangelands are generally covered in mountain sagebrush, mountain brush, and Idaho fescue at lower and midelevations; Douglas-fir, and aspen are common at higher elevations. Overall, the ecoregion is drier and less suitable for agriculture than the Columbia Plateau and higher and cooler than the Snake River Plain. Rangeland is common and dryland and irrigated agriculture occur in eastern basins.

Land Management

As in the rest of the West, rapid population growth and competing uses for water are ongoing management issues in the Interior Columbia basin. Water has always been the scarce resource and agriculture, livestock grazing, and timber harvest are the primary land uses. Dominant land cover types are forest (37%), shrublands (33%), and agriculture (13%) (Map 2). Urban land use is sparse (<1%). Land ownership is mostly public. The basin includes large areas of interior plains and plateaus with annual precipitation of 7-20 inches. Portions of the basin are mountainous and the median elevation is 1354 m.

Description of Ecological Assessment

Survey Design

This ecological condition assessment is presented at the basin-wide scale. The main body of the report describes ecological condition in terms of extent of and risk to the ecological resources for the Interior Columbia Basin. The aquatic resource assessed in this report is the network of all wadeable perennial streams within the Interior Columbia River Basin boundary (Map 1). Assessing a very large and diverse basin requires a study design that can adequately capture the variation across the landscape and be descriptive of the entire resource of wadeable streams. There are various options for collecting the data in order to describe the ecological condition of this **target population**. A census method, where data are collected from every stream, is impractical (if not impossible). EMAP uses a sample survey approach (similar to a public opinion poll) where data are collected from a subset of the streams. This information is then used to determine summary characteristics of the ‘target population’. A **probability-based** sampling method is used to select sites that are statistically representative of the target population. In a probability sample, every stream segment of the target population has a known, non-zero probability of being selected. This feature has two advantages in that 1) it guards against site selection bias and 2) it allows one to make scientifically valid inferences to characteristics of the entire target population.

The target population was sampled in a spatially-restricted manner so that the distribution of the sample sites has approximately the same spatial distribution as the target population. This is achieved by using an unequal probability sample method to insure distribution of samples of sites by stream size (Strahler order), State, and major ecoregion types (humid and arid). For example, 3rd order streams had a four times higher probability of being selected than a 1st order stream. This method effectively increases the probability of having 3rd order streams selected for the sample so that the sample is not dominated by 1st order streams, which are much more common. This variable selection probability by stream orders is accounted for when making the regional estimates by using site weighting factors. Each site is assigned a weight, based on the occurrence of its type in the stream database. First order streams have a smaller weighting factor than higher order streams. Therefore, there is not a one-to-one relation of sample sites to the stream length each site represents, and any inferences based on the unweighted set of sites to the entire target population would be inaccurate.

Ecological indicators

This analysis uses **indicators** to quantify both ecological condition (condition indicators) and stressor condition (stressor indicators) (Hughes et al. 2000). Indicators are ecological measurements, metrics, or indices that quantify physical, chemical, biological condition, habitat, or stressors (Hughes 1993). Condition indicators used to quantify ecological condition are developed from data on the various aquatic biological assemblages including benthic macroinvertebrates, vertebrates (fish and amphibians) and periphyton. Each of these assemblages has specific characteristics that make them useful for quantifying ecological condition. Single metrics used to describe ecological condition include measures of overall species richness, diversity measures such as the Shannon Index, or quantification of sensitive taxa such as 'number of Ephemeroptera, Plecoptera, or Trichoptera taxa' (EPT taxa). Multimetric indices are also used as ecological indicators (Barbour et al. 1995). These **indices of biological integrity** (IBIs) incorporate various metrics of a particular aquatic assemblage into a single metric. IBIs are commonly developed for benthic macroinvertebrate assemblages. IBIs are robust as they incorporate various ecological aspects of the assemblage that are informative of the overall condition of the assemblage such as species diversity and occurrence of tolerant taxa.

The benthic macroinvertebrate assemblage was selected for assessing the relationship of environmental condition to the response of the biological community. The macroinvertebrate metric that provides an estimate of the taxa completeness, and therefore is a measure of the 'biotic quality', was the **Observed to Expected macroinvertebrate taxa** metric (O/E metric). This metric describes the loss of macroinvertebrate biological diversity (Hawkins et al. 2000) and is a direct measure of how many taxa are missing at a site. The Observed to Expected macroinvertebrate taxa presence metric is the number of macroinvertebrate taxa observed in the sample divided by the taxa that are expected to occur. This metric was selected for the analysis because it could be calculated for all of the EMAP probability sample sites in the Basin as well as the additional reference sites that were incorporated into the study. Data for the development of IBIs for both vertebrates and invertebrates were either insufficient or not compatible across all of the reference sites to be useable as a basin-wide aquatic condition indicator.

Aquatic Stressor Indicators

Ecological stressors are chemical, physical, and biological effects that are 'stressful' to the aquatic ecosystem and have the potential to directly affect the stream biotic assemblages. Stressor indicators can be directly measured either in the stream or in the riparian area. Direct stressors are often the result of human alteration of land cover or the result of land management.

The data collected at the EMAP stream sites are used to generate hundreds of metrics that have potential use as indicators of stress. This report examines the most relevant metrics for indicating the stressors affecting the ecological condition. These metrics comprise a short list of those which had adequate data both in the Interior Columbia EMAP probability data set and in the reference site data, and where we were able to establish relations of quality across the ecoregions. By comparing the data for specific stressor metrics between the reference sites and the probability sites by ecoregion we are able to establish the range of condition from good to poor for these specific metrics. Besides being useful for quantifying the extent of ecological stress, these metrics can be associated with the ecological condition established from the condition indicators to assess ecological risk (the severity of stress on biological condition). Stress indicators are presented in four categories: water chemistry, riparian zone, in-channel habitat complexity, and sediment.

Setting Expectations

In order to describe the ecological condition of the wadeable streams of the Interior Columbia Basin, we must have an expectation of the ecological condition in a relatively ‘undisturbed’ state. This benchmark for determining ecological condition is commonly referred to as the **reference condition**. A reference condition can have many meanings. For instance, it could mean a ‘pre-settlement condition’, a ‘desired condition’, or an ‘acceptable current condition’ which implies some level of human disturbance. Setting reasonable expectations for each of the indicators of ecological condition is therefore a challenge. For this assessment, reference condition is developed from the analysis of carefully selected sites that represent the best attainable (or least disturbed) watershed condition, habitat structure, water quality and biological parameters (Hughes 1995, Stoddard et al. 2006). Deviation from the reference condition is a measure of the effect of stressors on the ecosystem. A site is considered to be in ‘good’ condition if it is in the condition we would expect to see if it were minimally exposed to the stressors of concern (i.e., if it is equivalent to reference condition). Thus, ‘good’ condition is defined relative to our expectations for a particular system rather that against an absolute benchmark of ecosystem attributes (Bailey et al. 2004).

The diversity in the physical, chemical, and biological characteristics of the wadeable streams of the Interior Columbia Basin must be considered when defining reference condition and calculating stream ecological condition. For example, a stream with finer-sized substrate and low riparian structure may be typical of an undisturbed stream in one ecoregion while those same characteristics may represent a more disturbed condition in a forested/mountainous ecoregion. The method used to rate stream condition in a way that accounts for natural geophysiological condition is to compare sites within each ecoregion to a set of reference sites from that same ecoregion. Because ecoregions have similar characteristics in terms of soil, climate, geology, and vegetation, it follows that the streams of an ecoregion would have similar stressors as well as similar responses to those stressors. Although ecoregions do not necessarily account for all natural variation they do provide a template for refining the expected condition of streams throughout a broad and variable area. Methods for establishing reference condition are discussed in the next section.

Methods

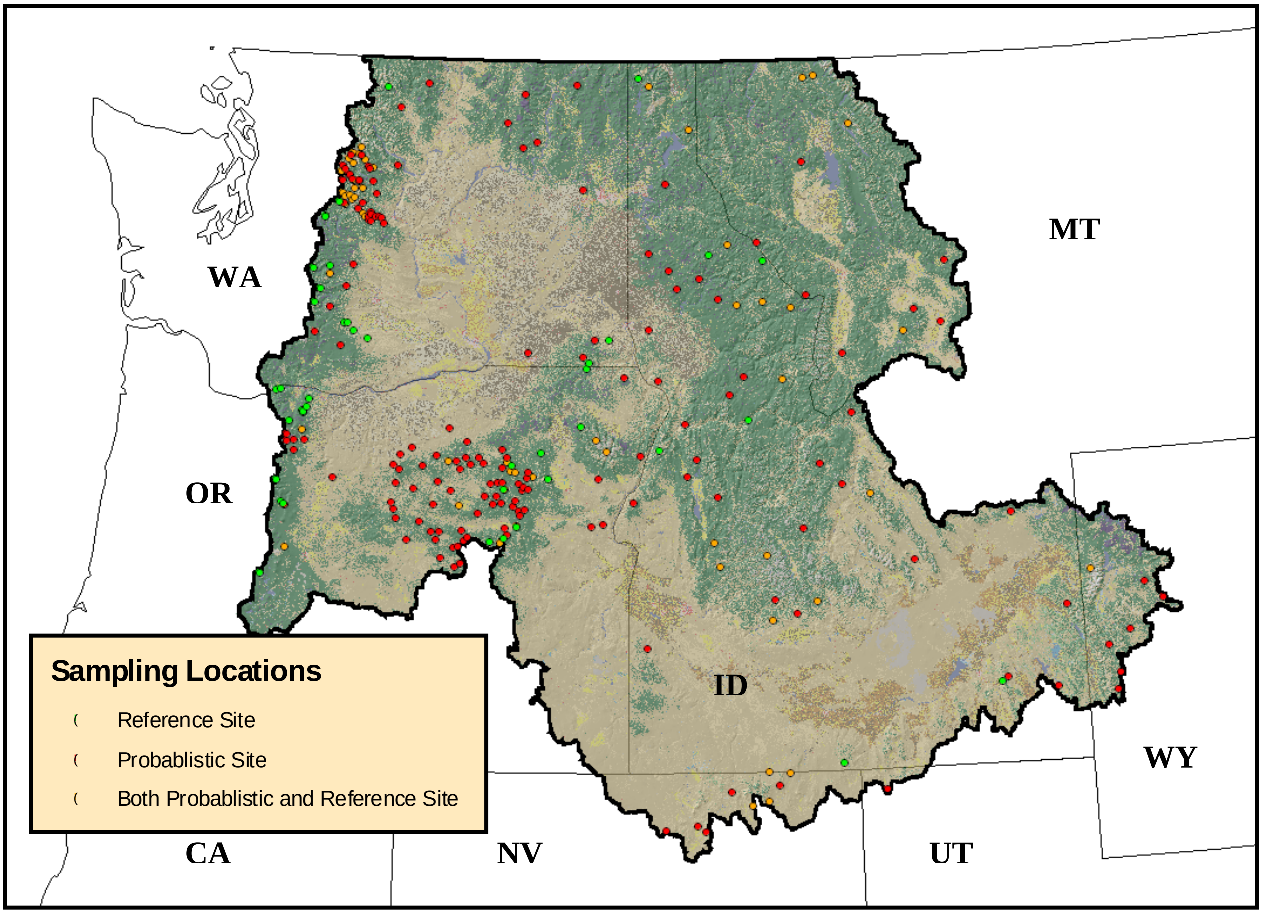
Quality Assurance

The field protocols (Peck et al. 2006) and laboratory procedures used were those developed by EPA for the Western Pilot project. Numerous crews conducted field sampling. Consistency and adherence to the methods was insured by crews participating in training sessions, annual training refreshers, and field audits conducted by EPA personnel. Also, a proportion of the sites were re-sampled to provide estimates of variability to evaluate metrics.

Site Selection

The **sample frame** is the population of all of the streams from which a set of sample reaches can be selected. The sample frame for this study was all perennial wadeable streams channels mapped at 1:100,000 scale within the Interior Columbia River Basin boundary. Sites were selected from wadeable streams (most 1^{st} through 3^{rd} order) using EMAP probability sample design described previously and landscape maps (USGS digital line graphs) overlaid with hydrography (EPA River Reach File 3 and the USGS PNW river reach file data). The stream sample locations were selected in proportion to their occurrence (Overton et al. 1990, Stevens and Olsen 2004).

Sites selected from the sample frame for sampling were subjected to an evaluation process to insure that they were actually part of the target population (both wadeable and perennial) and could be accessed (safe to access, landowner permission). Data were collected from 215 sample sites (Map 2). Sites are listed in Appendix 1.



Map 2. Sample locations of probability and reference sites.

Reference Site Dataset

Reference sites came from three sources: EMAP western pilot probability sites, EMAP western pilot focus area probability sites, and handpicked sites sampled as part of other regional EMAP projects (REMAP sites) in the states of Oregon and Washington. These sites were screened for having minimally disturbed condition yielding 163 reference sites for this analysis (Map 2). The Western Pilot and EMAP focus area sites were screened by personnel at EPA's ORD (Corvallis). The criteria used were that the sites were in a least disturbed condition based on evaluation of water quality and physical habitat parameters (Stoddard et al. 2005b). These sites were also screened by state personnel from Oregon DEQ and Washington Department of Ecology using knowledge from field observations and photo interpretation to give additional verification that these sites were appropriate for use as reference sites (Drake 2004, Merritt 2007). Sites from previously conducted Regional EMAP studies (R-EMAP) within the basin were subjected to the same screening techniques. All data from reference sites were collected with the same (or nearly the same) field protocols as the probability sites (Peck et al. 2006). Sites used from earlier REMAP studies had slight variation in methods – for example, fewer cross sectional measures for substrate (Hayslip et al. 1994). A minimum of 10 reference sites was needed to generate thresholds for each indicator in each ecoregion.

Field and Laboratory Methods

Field data were collected during summer low-flow period from stream reaches whose length is generally 40 times the wetted channel width (150m minimum reach length) following the EMAP wadeable stream field protocols (Peck et al. 2006). These methods are briefly described here.


Photo: S. Hubler, ODEQ

Water Quality

Data for 11 water quality parameters were collected at all sites. Measurements of temperature and conductivity were collected in situ. Water samples were analyzed for acid neutralizing capacity (ANC), chloride, dissolved organic carbon (DOC), ammonium, nitrate, total phosphorous (TP), and sulfate. Dissolved oxygen (DO) was measured with a meter except in Oregon where Winkler titration was used.

Physical Habitat

The following three types of habitat parameters were measured or estimated:

In-channel parameters: Thalweg profile (a longitudinal survey of the deepest part of the channel), and presence/absence of fine sediments were collected at either 100 or 150 equally spaced points along the stream reach. A subjective determination of the habitat unit designations (e.g. riffle, glide, pool) was made at each point. Crews also tallied large woody debris along the reach.

Transect parameters: Measures/observations of channel wetted width, depth, substrate size, canopy closure, and fish cover were taken at eleven evenly spaced transects in each reach. Gradient measurements and compass bearings were collected between each of the 11 transects to calculate reach gradient and channel sinuosity. Also, measures and/or visual estimates of riparian vegetation structure, human disturbance, and bankfull height and width were taken at transects.

Reach parameters: Channel morphology class for the entire reach was determined and instantaneous discharge was measured at one optimally chosen cross-section.

Vertebrates

The objectives of the vertebrate assemblage assessment were to 1) collect all except the rarest species in the assemblage and 2) collect data for estimates of relative abundance of species in the assemblage. Fish were sampled with one-pass electrofishing in all portions of the sample reach. Fish were identified, counted, and measured. Crews also collected fish voucher specimens. Crews captured and identified amphibians but retained no amphibian vouchers. Although these methods were not used to estimate absolute abundance, standardized collection techniques were important for consistent measures of proportionate abundance of species.

Benthic Invertebrates

Macroinvertebrates were collected at the same 11 transects used for collecting habitat data with a D-frame kick net (500 μm mesh). Transect samples were combined into one composite sample per site. Indicator values were based on a subsample of 300 organisms identified to the lowest practical taxonomic level.

Landscape Data

The watershed or 'upstream contributing area' associated with each sample point was delineated using 30-meter digital elevation models and ArcInfo/ArcMap GIS software (ESRI Inc. 2002). An example of a sample site watershed is shown in Figure 1 Within this area, landcover metrics such as % forest or % barren were calculated. Digital coverages from the National Land Cover Database (NLCD) were used as the base data for land cover. The Analytical Tools Interface for Landscape Assessments (ATtILA 3.x), an ArcView Software extension (Ebert et al. 2000), was used to calculate the metrics. Landscape data were also used to calculate sediment delivery.

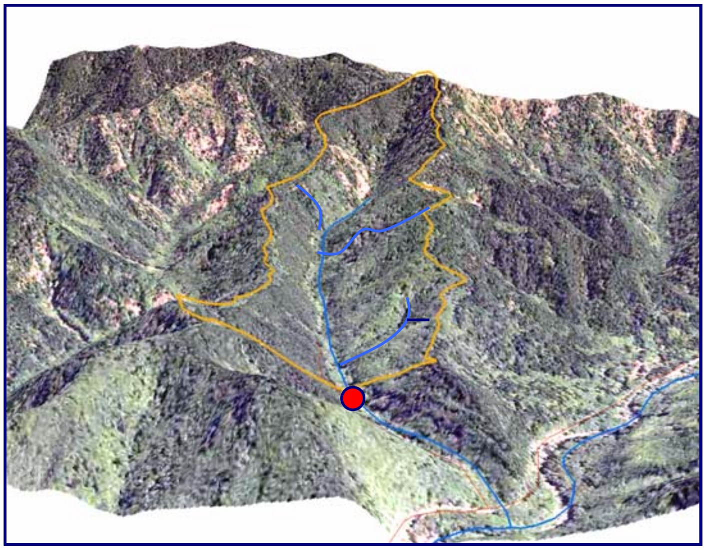


Figure 1. Example of watershed in relation to a typical sample reach.

Analysis Methods

Reference Condition Methods

Data from reference sites were grouped by ecoregion to create relatively homogenous classes to account for the ecological variability across the basin. Thresholds for ‘good’ versus ‘poor’ condition were calculated from a minimum of 10 reference sites in each ecoregion (Appendix 2). When 10 sites were not available, level 3 ecoregions were aggregated with others to which they had the greatest geophysiographic similarity. It was necessary to aggregate ecoregions 15, 16, 17, and 41 (Rockies and Idaho batholith) and ecoregions 10 and 80 (Columbia Plateau and Northern Basin and Range). The remaining ecoregions (4, 9, 11, and 77) had separate reference condition thresholds. There were no samples in Snake River Plain so reference site thresholds were not calculated for that ecoregion.

Threshold values were calculated for metrics that have been shown in previous EMAP evaluations to have meaningful relationships to ecological condition, have relatively high reproducibility (Kaufmann et al. 1999), and have adequate data quantity (little or no missing data) across both the reference site and probability data sets. Reference condition thresholds were calculated for the following 20 metrics (Table 2).

Table 1. The number of reference sites by ecoregion and combined ecoregions.

Aggregated Ecological Regions	Level III Ecoregion (ecoregion number)	Site Count
Northern Rockies (mountainous)	Blue Mountains (11)	21
	Northern Rockies (15)	21
	Idaho Batholith (16)	
	Middle Rockies (17)	
	Canadian Rockies (41)	
Pacific Northwest (mountainous)	Cascades (4)	61
	Eastern Cascades (9)	14
	North Cascades (77)	27
Northern Xeric Basins (xeric)	Columbia Plateau (10)	18
	North Basin Range (80)	

Table 2. Ecological condition metrics calculated with data for both reference and probability sites.

Stressor Category	Metrics Calculated
Water chemistry	sulfate, chloride, phosphorous, nitrogen, pH, and conductivity
Riparian characteristics	riparian disturbance (agricultural types), riparian disturbance (all types), riparian vegetation structure (all 3 layers), canopy density at mid-channel
In-channel complexity	large woody debris volume, in-stream fish cover, relative bed stability, %pool and glide habitat, residual pool area
Fine sediment	% fine-sized sediment, % sand+fine-sized sediment, embeddedness, total suspended solids, turbidity

For each ecoregion, we used all the available reference site data to develop thresholds for “good”, “fair”, and “poor” condition for each condition and stressor indicator. Thresholds were based on the distribution of values in the set of reference sites. For indicators where high values indicated better condition (e.g. quantity of large woody debris), we used the 25th percentile of the distribution of the reference site values to distinguish between “good” (similar to the set of reference sites) and “fair” (somewhat different from the set of reference sites). The 5th percentile was used to distinguish between "fair" and "poor" (very different from the set of reference sites). For indicators where high values indicate disturbance (or poorer condition; e.g. fine sediment), the thresholds were reversed (the 75th percentile of the distribution of the reference site values was used to distinguish between "good" and "fair" condition , and the 95th percentile was used to distinguish between "fair" and "poor" condition.

Scoring was conservative to account for the fact that, although minimally disturbed, reference sites may have some level of human disturbance. By using the 25th percentile as the threshold point for passing or failing (deciding that a site is not in Reference Condition) we are saying that there is a 25% chance that the sites identified as being a reference condition may not indeed be in a least-disturbed condition. Meaning that one quarter of the sites would be mistakenly identified as deviating from reference condition. So we are being environmentally conservative by assuming that the reference sites may have some level of human disturbance. Thresholds for the selected variables are in Appendix 2 and the number of reference sites used for each calculation is in Appendix 3.

Cumulative Distribution Functions

The statistical design of the EMAP dataset allows for the extrapolation of results from sampled sites to the greater target population. Any of the data metrics can be quantitatively described using cumulative distribution functions (CDF's), which show the stream length represented in the target population (or proportion of length) that has values for an indicator at or below some specific value of interest (Figure 2) In this hypothetical example 50% of the stream length has ≤25 biological integrity score and are considered impaired. This is an effective way to show the extent of impairment based on a particular metric for the entire population. Once this distribution is established, thresholds can be drawn at any point in the distribution.

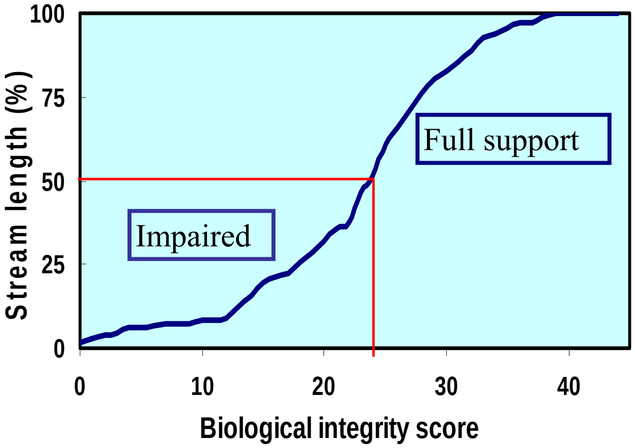


Figure 2. Example of a hypothetical CDF showing a threshold between impaired and full support and the associated proportion of stream length in each category.

Relative Extent Calculation

The relative extent calculation is used to determine which stressor(s) have the greatest extent of impact on the target population. **Relative extent** for each of selected indicators was calculated by comparing the value from each probability site to the reference condition cut-off categories by ecoregion to determine if they were in poor, fair, or good condition. These site 'ratings' were compiled and weighted to determine the kilometers of streams in the Basin within each of the three condition categories

Condition Indicator Calculation- Observed to Expected (O/E) Value

Benthic macroinvertebrate O/E was calculated for each of the probability and reference sites. The observed value was calculated from the site field data. The expected value was developed by modeling the probability of taxa presence based on gradients within a set of environmental variables that are not altered by humans. This model was developed from reference streams located throughout the western United States (Stoddard et al. 2005b) and expected values at each site were calculated by the EPA EMAP team. An O/E value of 1 implies that all of the taxa expected at a reference site are present. A value less than 1 implies a loss of taxa as compared to that expected at reference sites. Sites were rated as ‘poor’ or ‘good’ if they had an O/E score of <0.5 or >0.9 respectively. For example, if a site has less than 50% of the expected taxa then it is in a condition of low biotic diversity for the macroinvertebrate assemblage and represents a ‘poor’ condition. Likewise, if the site has more than 90% of the expected condition then the site has high biotic diversity relative to what would be expected and therefore has a ‘good’ condition. Sites with O/E scores between these two thresholds are considered in ‘fair’ condition. Ecoregions were not used as a factor in the development of the O/E scores.

Relative Risk Determination Methods

The **Relative Risk Ratio** expresses the association between stressors and the biological indicators. Relative risk is a common method for communicating human health information (e.g. risk of heart disease relative to diet or smoking). Relative risk estimates for this report are used to measure the likelihood that the most disturbed or ‘poor’ condition of a biological indicator will occur in streams that are also in a most disturbed or ‘poor’ condition for a particular stressor. We used the O/E metric (macroinvertebrate taxa loss metric) described above as the response variable in comparison to the environmental stressors to estimate the relative risk of the biota to various stressors.

Following methods in Van Sickle et al. (2006), we calculated the relative risk for each environmental stressor as the ratio of stream km where the stressor was ‘poor’ and the O/E score was ‘poor’ to the stream km where the stressor was ‘good’ and the O/E score was ‘poor’. Relative risk (RR) is defined as the ratio of the two probabilities;

$$\textbf{Relative Risk} = \frac{\text{Risk of poor biological condition , given poor stressor condition}}{\text{Risk of poor biological condition, given good stressor condition}}$$

The Relative Risk calculation is made from the estimated stream lengths that have the various combinations of good-poor biological and stressor condition. The stream extent estimates were generated from the comparison of probability site data to reference site thresholds. The following contingency table is an example that shows the approach using turbidity as the stressor.

Stream length estimate		Turbidity disturbance class	
		Good	Poor
O/E index	Good	A: 25891	C: 6564
	Poor	B: 3210	D: 5835
	total	A+B: 29101	C+D: 12399

The risk of finding a most-disturbed condition of macroinvertebrate taxa loss in streams that have most-disturbed condition for turbidity is estimated as:

=D/(C+D)   5835/12399=0.47

Likewise, the risk of finding a most-disturbed condition of macroinvertebrate taxa loss in streams that have a least disturbed condition for turbidity is estimated as:

=B/A+B   3210/29101= 0.11

Combining the two probabilities (0.47 ÷ 0.11) yields a relative risk of 4.3. Therefore, we are 4.3 times more likely to find poor condition for macroinvertebrate taxa loss in streams where the condition for turbidity is poor. We report this relationship only for environmental stressors where there was adequate data to make the calculation. Following Van Sickle et al. (2006) a minimum of five sites were needed in each cell of the O/E to stressor contingency table to estimate relative risk. Relative risk was calculated for the list of stressors that could be rated as poor-fair-good based on the adequacy/completeness of the reference site data and if the convention that all four cells of the relative risk contingency table had a minimum of five sites was met. The 13 metrics analyzed are the same as those listed in Table 2, excluding conductivity, chloride, riparian disturbance – all types, canopy density, fish cover, residual pool area, and slow-water habitat.

Extent of Resource

There is an estimated 109,486 km of wadeable, perennial (target) streams in the Interior Columbia Basin as represented in the sample frame. Of the total sites selected, about 32% were deleted from the final set of sample sites based on site evaluation findings. These sites could not be sampled due to site-specific issues related to physical access and safety and land owner denial of access (Figure 3). A total of 215 probability sites were sampled, which represents approximately 75,000 km (74,976 km actual) of wadeable streams. These sites are considered representative of the target population as they are wadeable, perennial, and are within the Interior Columbia Basin boundary. Also, these sites had adequate macroinvertebrate data needed for the analysis. Therefore, this report is an analysis of about 69% of the total target stream length in the Interior Columbia Basin for most metrics.

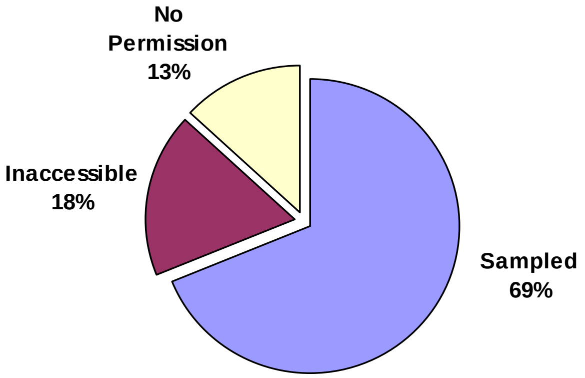


Figure 3. Fate of sites targeted for sampling following site evaluation expressed as percent of total stream length (stream length 109,486).

Stream Order

The wadeable streams in the sample were mostly 1st, 2nd, and 3rd order streams (Figure 4). The number of samples were relatively equally distributed between the three stream orders. Each 1st order sample represents a proportionately large number of stream miles due to the far larger 1st order stream length in the ecoregion.

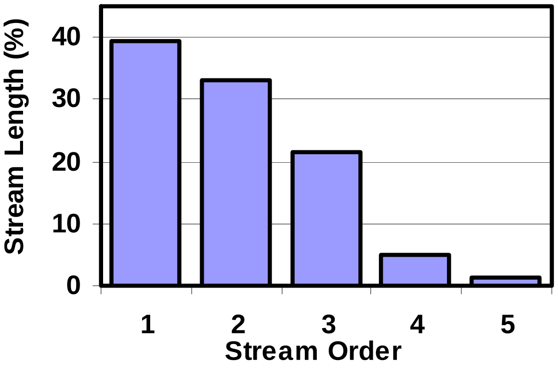


Figure 4. Percent of the total stream length in each Strahler stream order (stream length=74,976km).

Site Distribution by State

The Interior Columbia stream extent includes large portions of Oregon and Washington, portions of Montana, Wyoming, Utah, and Nevada, and almost all of Idaho. Most of the stream length that was represented by this sample was in Idaho with 43% of the total stream length, followed by Montana, Oregon, and Washington (Figure 5). Site count and stream length by State are in Appendix 4.

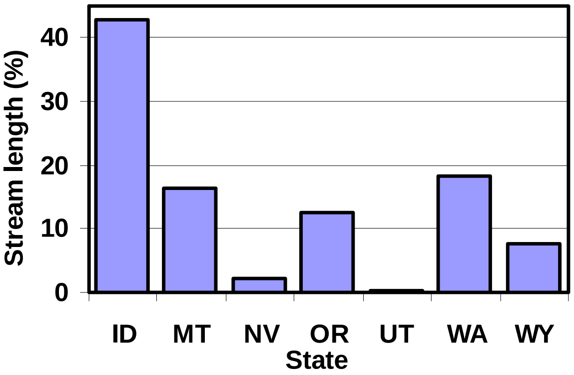


Figure 5. The proportion of target stream length in each State (total length=74,976km).

Site Distribution by Aggregate Level III Ecoregions

The Interior Columbia basin is primarily mountainous with the greatest stream extent being represented in the Rocky Mountain ecoregions (Northern, Middle, and Canadian Rockies) and the Idaho Batholith. The Interior Columbia basin spans portions of 10 Level III Ecoregions (USEPA 2003a, Omernik 1987). These ecoregions were aggregated into three ecological regions to aid in the description of the basin: the Northern Rockies, the Pacific Northwest, and the Northern Xeric Basins. The majority of the streams represented by the sample occur in the mountainous Northern Rockies with the remaining streams relatively equally representing the mountainous Pacific Northwest and the Northern Xeric Basins (Figure 6). The land area categorized as xeric is a substantial portion of the upper Columbia Basin, however perennial wadeable streams are rare in the xeric areas. Only 7.5% of the target stream length occurs in these areas. Stream length and site counts by ecoregion are in Appendix 5.

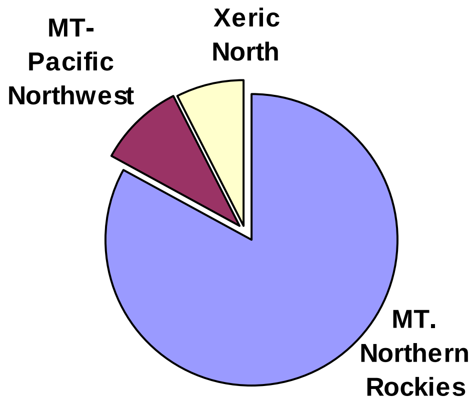


Figure 6. Proportion of target stream length represented in the 3 aggregate ecoregions (stream length=74976 km).

Ecological Condition Assessment

For this assessment, the general condition of the Interior Columbia Basin streams is described using indicators of physical habitat, water chemistry, vertebrate species presence, and macroinvertebrate biological integrity. The purpose of this section is to describe the wadeable streams in the context of their biotic and abiotic characteristics as well as the watershed setting. Statistics presented (means, medians) for the condition metrics are weighted by target stream network to be representative of the region.

Physical Setting--Stream Description

As with the overall Interior Columbia Basin, the landcover associated with the watersheds of wadeable streams is predominately forest land, followed by rangeland and barren land-cover categories (Figure 7). The other cover classes that are relatively rare include wetlands, open-water, alpine areas, agriculture, mining and urban cover types.

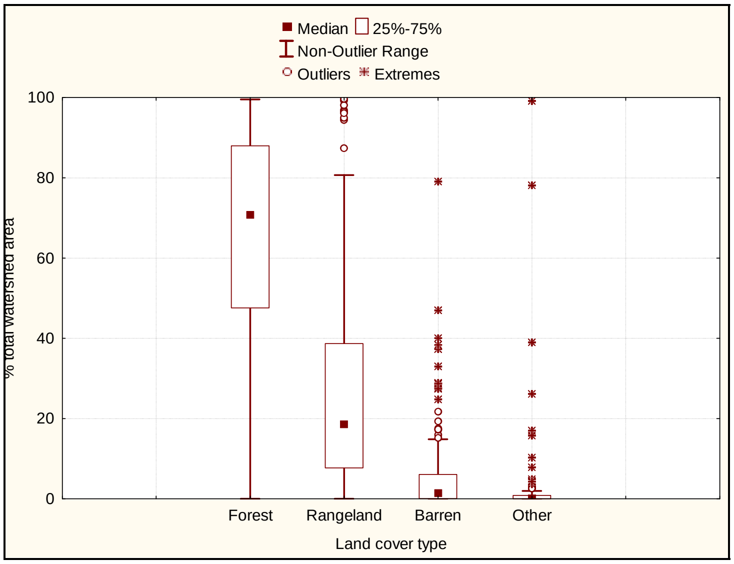


Figure 7. Distribution of land cover types in the watersheds of wadeable streams of the Interior Columbia Basin ("other" includes wetlands, open water, alpine areas, agriculture, mining, and urban).

The wadeable streams in the Interior Columbia Basin are small with mean bankfull width of 4.3 m and depth of 19.4 cm. Channel slopes were moderate (median 4.1 %) and channel habitat type was about equal in terms of fast (riffles, rapids, cascades, and falls) and slow (pools and glides) water. Dominant canopy cover type was typically coniferous, averaging 41% of the reach length (median 27 %). Stream bed substrate was generally coarse. The gravel sized substrate (2-64 mm diameter) was the most common substrate size followed by cobble (64-250 mm) (Figure 8).

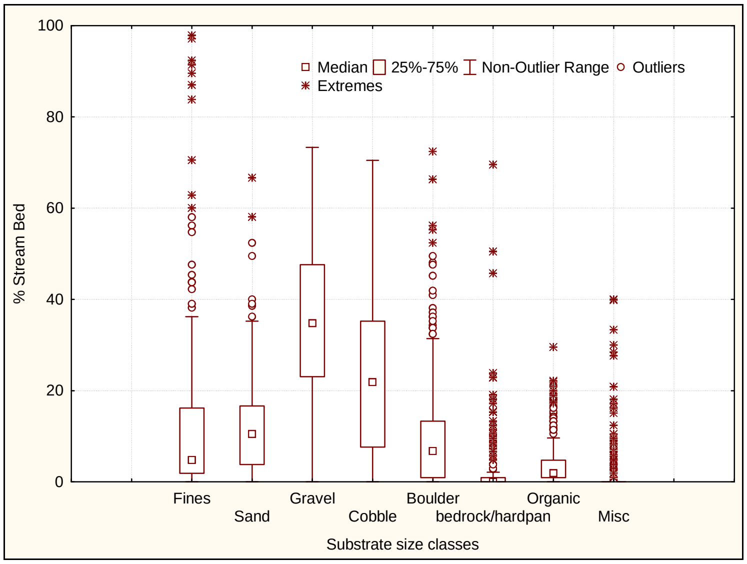


Figure 8. Presence of substrate particle size classes (stream length= 74,976).

Vertebrate Assemblage

Sufficient sampling effort for vertebrates was conducted at 124 of the 215 sites (57%), representing a total target stream length of 45,006 km that could be assessed for condition based on vertebrates. The most common reason for not sampling was permit restrictions due to presence of Threatened and Endangered species (mostly salmon or bull trout). We note that permit restrictions are probably not random, and therefore the assessment results cannot be inferred to that part of the target network where there were permit restrictions. Other obstacles to vertebrate sampling were insufficient time available, extreme terrain/water conditions, or equipment failure. These other problems are probably more random in nature, and even though not sampled, results from the assessed population (in terms of proportion of length) probably apply to this part of the network as well.

Vertebrates were present at most sites, representing 81% of the 45,006 km of stream length (Table 3). Fish were more broadly distributed than amphibians which were only present in 43% of the stream length. Alien fish were somewhat common, present at over 25% of the stream length while alien amphibians were rare (1 site had a bull frog). Vertebrate species richness in wadeable streams ranged from 0 to 7 species and presence of only one fish species was most typical (Figure 9). Fish were not captured from 29% of the stream miles that were sampled.

Table 3. Vertebrate presence in the Basin (n=124 sites, stream length=45,006 km).

Information	% stream length	Comment
Vertebrates present	81	Neither fish/amphibians captured at 19% of the stream length
Amphibians present	43	The tailed frog was the most common amphibian species
Fish present	71	
Salmonids present	70	Rainbow trout were the most common salmonid
Alien fish present	26	Brook trout were the most common alien fish species present

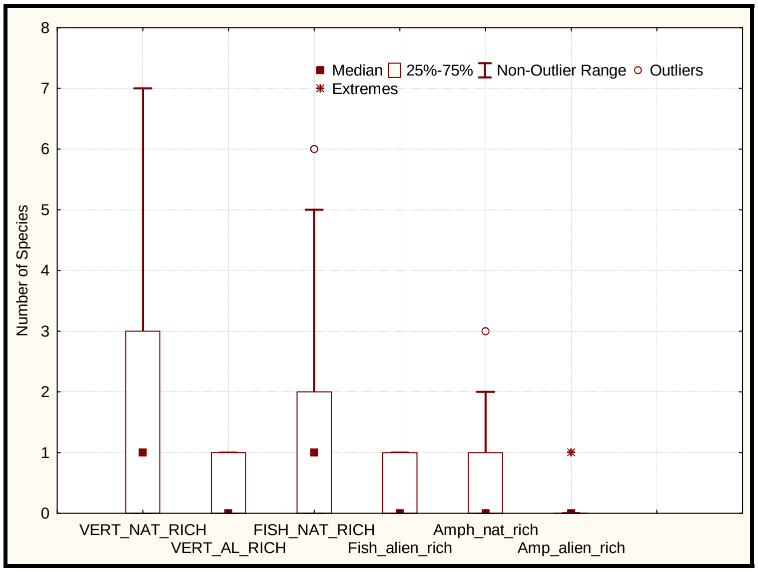


Figure 9. Distribution of native and alien vertebrate richness metrics within the target stream length (stream length= 45,006 km).

Six fish families and five amphibian families (Appendix 6) were present. Salmon/trout species were the most broadly distributed followed by sculpins (Figure 10). Bell toads (tailed frogs) were the most commonly observed amphibian.

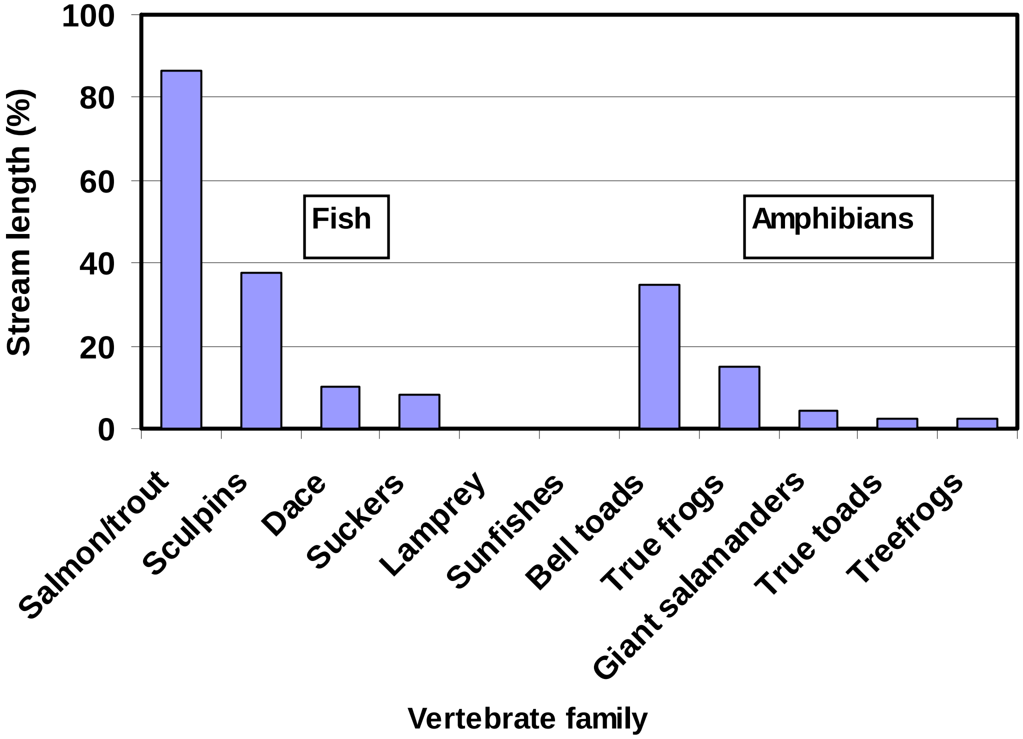


Figure 10. Extent of vertebrate families present in wadeable streams of the Basin (n=102, stream length=30,395km).

Rainbow and cutthroat trout were by far the most common species in the Interior Columbia Basin wadeable streams followed by brook trout, an introduced char species native to the eastern United States (Figure 11). The other alien species that were present, smallmouth bass and brown trout, were rare. The presence of alien species is a concern as these species can alter the balance of the aquatic community. Alien species can compete for space/food resulting in displacement or decline in abundance of native species. Presence of alien species can also disrupt predator/prey relationships with various results such as loss of species diversity. Interbreeding between native and alien species can reduce abundance and fitness of native species. An example is the case of sympatric bull trout and brook trout resulting in hybridization. Twelve species of amphibians were sampled with tailed frog being by far the most common (Figure 12). Sampled fish and amphibian species and their descriptions are in Appendix 6.

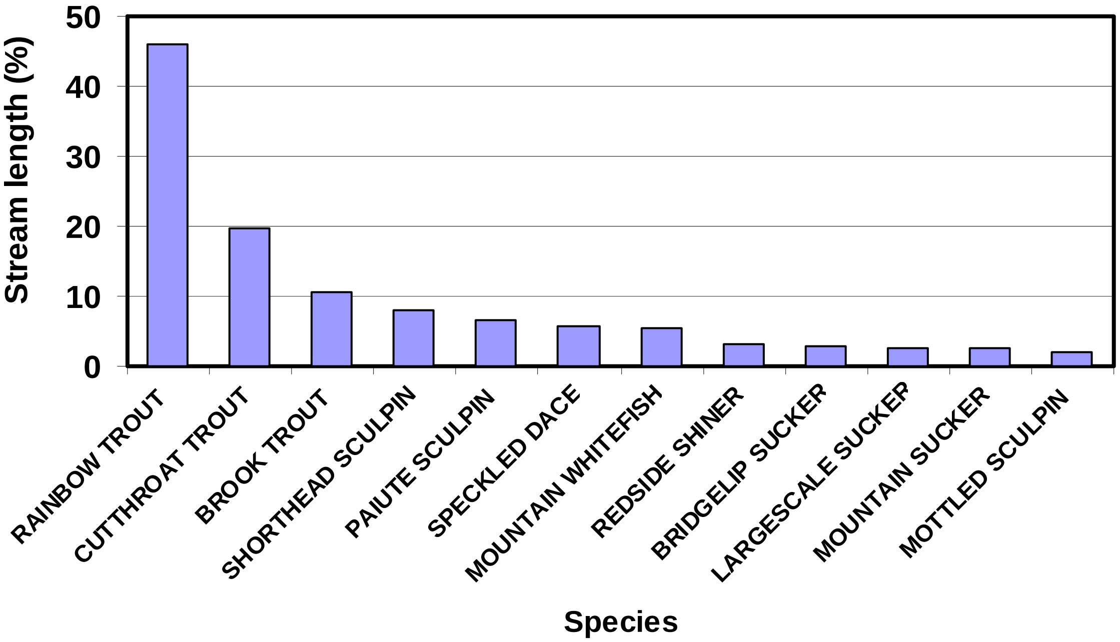


Figure 11. Extent of most common fish species in the Basin (n=124, stream length=45,006 km).

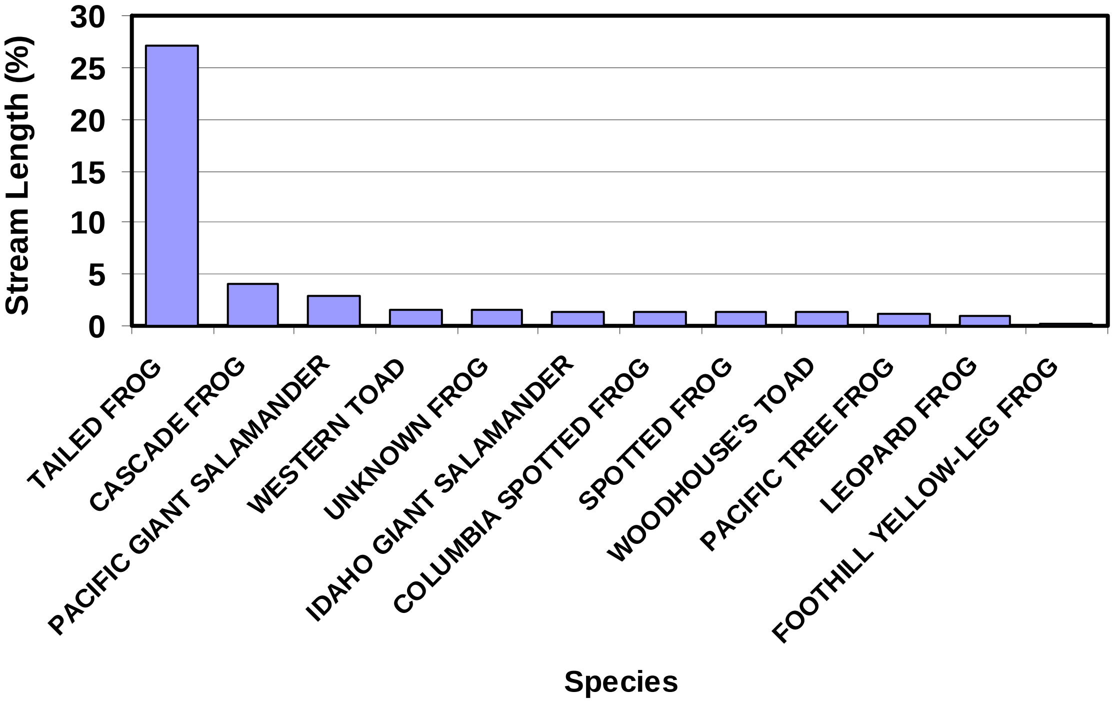


Figure 12. Species presence of amphibians in the Basin (n=124, stream length=45,006 km).

Benthic Macroinvertebrate Assemblage


Photo: S. Hubler, ODEQ

Aquatic benthic macroinvertebrate assemblages are useful for describing overall biological integrity of wadeable streams. These assemblages are responsive to changes in water quality and physical conditions. Much research has been focused on these relationships, thus there is a well developed body of knowledge from which to interpret results. Macroinvertebrates have relatively long life-cycles (typically a year or more) and because they are not very mobile, macroinvertebrate assemblage structure can be used to interpret recent condition. Benthic macroinvertebrate data were available from all sample sites and from all reference sites.

A useful metric for indicating the sensitivity to human disturbance is the proportion of taxa in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddis flies) known as EPT taxa (Plafkin et al. 1989). These orders are known to be relatively sensitive to disturbance or reduced water quality and physical habitat quality. In the Interior Columbia Basin, 50% of the target stream length has at least 24 EPT taxa (Figure 13) which comprised at least 45% of the total taxa enumerated (Figure 14).

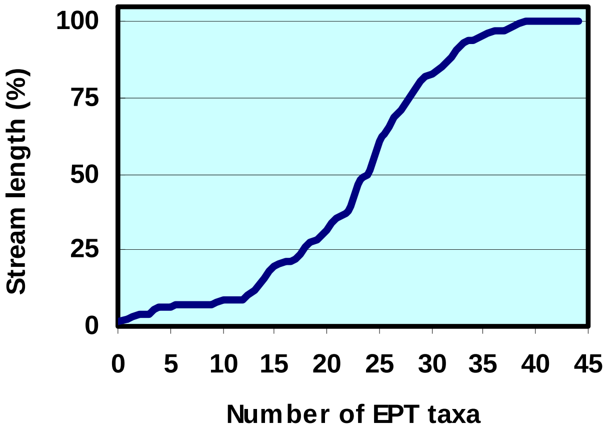


Figure 13. CDF of number of EPT taxa (stream length=74,976 km).

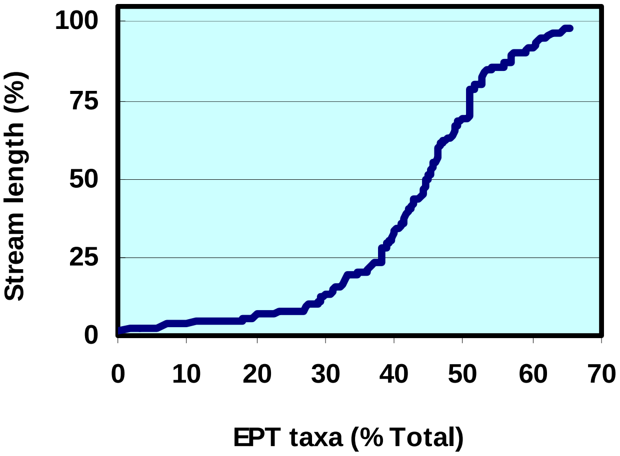


Figure 14. CDF of percent of taxa that are EPT (stream length=74,796 km).

The taxa richness metric O/E is another benthic macroinvertebrate indicator of biotic integrity. Results across the Interior Columbia Basin wadeable streams show that about 50% of the wadeable stream length is in the ‘good’ category based on the O/E ratio exceeding the 0.9 taxa presence threshold (Figure 15). “Poor” condition occurs in about 13% of the wadeable stream length where the O/E ratio is below the 0.5 poor threshold (36% poor and 36% fair).

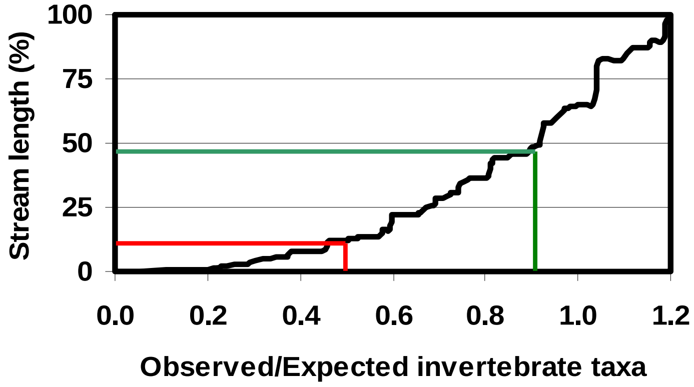


Figure 15. CDF of observed to expected macroinvertebrate taxa presence with thresholds for poor-fair-good condition (stream length=74,976 km).

The poor-fair-good results for benthic invertebrate taxa presence vary across the major combined ecoregions (Figure 16). The mountainous-Northern Rockies ecoregions which contain 82% of the target stream length in the Interior Columbia Basin have about 50% of the length rated as "good' based on the O/E indicator. The Mountainous Pacific Northwest ecoregions (which contain 12% of the target stream length) have over 80% of the length rated in "good" condition based on the O/E indicator. The target stream population in the Xeric North ecoregions have the greatest proportion of length (20%) rated in "poor' condition based on the O/E indicator but the smallest proportion of target stream length (7%).

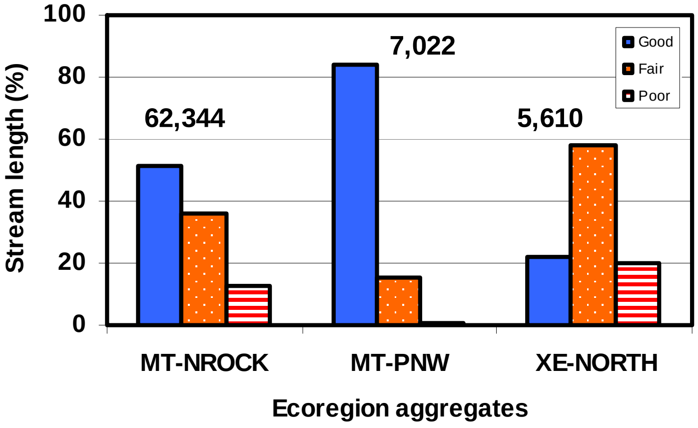


Figure 16. Proportion of stream length in poor-fair-good condition basedon O/E score for three aggregated ecoregions. Stream lengths (km) in each ecoregion are shown.

Stressor Condition Assessment

Stressors indicator descriptions

The chemical and physical condition of streams affects the presence, abundance and distribution of aquatic species. The following is a description of the occurrence of the primary stressor metrics (Table 2) in the Interior Columbia Basin. These metrics are the basis for the description of the condition of the Basin in the following sections on extent and risk to biota. Summary statistics for these metrics are in Appendix 7 for water quality metrics and Appendix 8 for physical habitat and sediment metrics.

Water chemistry indicators

Sulfur is a nutrient that occurs naturally in aquatic systems from rock weathering and volcanism. Arid and semi-arid areas with sulfur containing rocks may have relatively high sulfate (SO_4^{-2}) concentrations as the soils are not as thoroughly leached resulting in high amounts of dissolved solids in surface and ground water. Sources of sulfate from human disturbance are from air pollution including combustion of coal, petroleum, and smelting of sulfide ores resulting in atmospheric deposition. Surface inputs of sulfate are from mining activity and agricultural fertilizers. There is no EPA water quality criterion or suggested value for sulfate in surface waters as levels of sulfate do not generally occur in streams that are considered harmful to biota. However, sulfate is a useful metric as it can be indicative of human disturbance. The mean value for the Basins streams was 10.6 mg/L with 50 % of the wadeable stream length having estimated sulfate concentrations of <1.8mg/L (Figure 17).

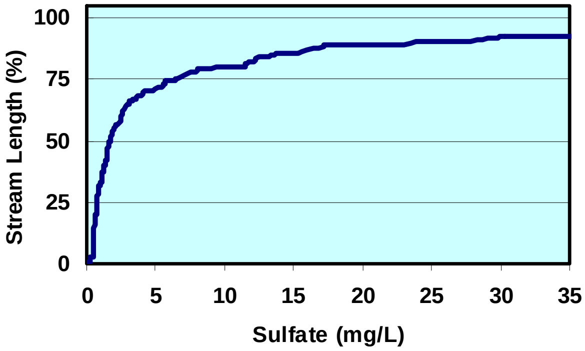


Figure 17. CDF of sulfate (stream length=74,976 km).

Chloride (Cl^-) is present in natural surface waters at low concentrations (Hem 1985) and is generally not considered a problem to biota in natural systems. The EPA does not have a chloride limit for protection of aquatic biota but 250 mg/L is recommended for drinking water. Sources of chloride include industrial discharge, fertilizers, livestock operations, and road de-icing chemicals. Chloride was found to be highly correlated to amounts of human disturbance based on landscape analysis in mid-Atlantic wadeable streams and is considered a good indicator of general human disturbance (Herlihy et al. 1998). The mean Cl^- value for the Basin streams was 1.02 mg/L with 50% of the stream length having estimated concentrations of <0.11 mg/L (Figure 18).

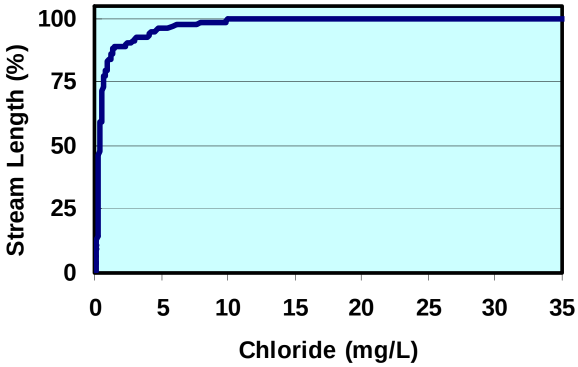


Figure 18. CDF of chloride (stream length=74,976 km).

Excessive nutrient inputs from phosphorous and nitrogen can increase algal growth resulting in decreased water quality associated with eutrophication. Alternatively, loss of nutrient inputs from human disturbance can reduce the productivity of streams that are typically low in nutrients. For example, marine derived nutrients delivered to Pacific Northwest coastal rivers and streams have declined due to large reductions in returns of anadromous fish (Gresh et al. 2000).

Total phosphorous includes dissolved, particulate and dissolved ortho-phosphate forms. The dissolved orthophosphate form is readily assimilated by algae. In natural streams, phosphorous is usually <1 mg/L (Hem 1992). Natural streams draining from volcanic soils in the Northwest can have hundreds of mg/L of total phosphorous however. Sources of excess phosphorous from human causes are domestic and industrial sewage, animal feeding operations, fertilization of agricultural areas, and surface erosion. USEPA (1986) recommends <0.05 mg/L total phosphorous for streams delivering to lakes. The mean total P^- value for the streams of the Basin was 0.03 mg/L with 50% of the wadeable stream length having estimated phosphorous concentrations of <0.01 mg/L (Figure 19).

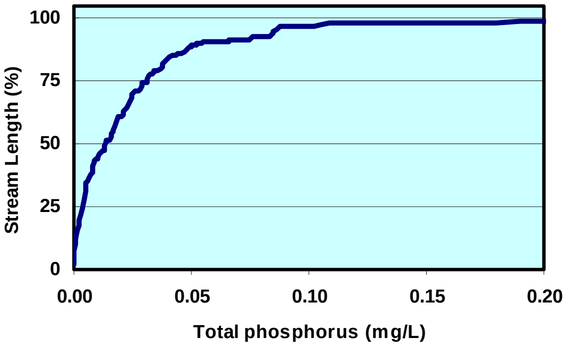


Figure 19. CDF of phosphorous (stream lngth=74976 km).

Nitrogen is frequently the most important nutrient in streams as the inorganic form can often stimulate primary productivity (bacteria and algae). Inorganic nitrogen (nitrate-nitrite and ammonium) is the predominant form of nitrogen in streams. Excess nitrogen can contribute to eutrophication. Human sources of nitrogen include fertilizing, animal feeding operations, sewage/wastewater discharge, and atmospheric deposition. There is not an EPA criterion for nitrogen but a nitrate concentration of <0.3 mg/L is considered preventative of eutrophication (McDonald et al. 1991). The mean total nitrogen value for the streams of the Basin was 0.19 mg/L with 50% of the wadeable stream length having estimated nitrogen concentrations of <0.11 mg/L (Figure 20). Approximately 10% of the stream miles had total nitrogen >0.3 mg/L.

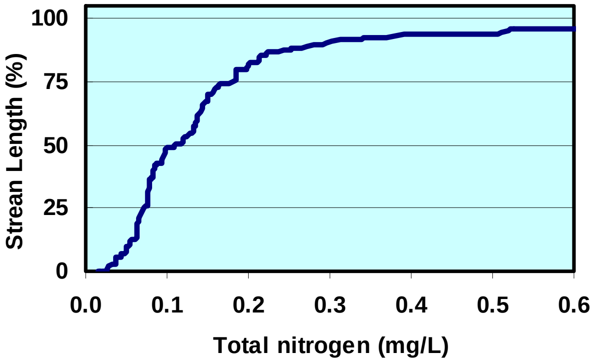


Figure 20. CDF of total nitrogen (stream length = 74976 km).

pH is the concentration of hydrogen ions in moles per liter water expressed as a log scale (log $1/[H^+]$. pH can have direct and indirect effects on stream water chemistry and on biota. Direct effects include fish reproductive and benthic invertebrate emergence success. Acidification in other parts of the country has been implicated with declines in fish populations (Haines and Baker 1986), changes in fish communities (Cusimano et al. 1989) and elevated fish tissue mercury content (Gloss et al.1990). Indirect effects include interactions with the equilibrium of other chemicals in the water. For example the solubility of many metals changes with changed pH. EPA's pH range to protect aquatic life is 6.5 to 9.0. The range in the Basin's streams was 6.2 to 9.2 with median value of 7.7 (Figure 21).

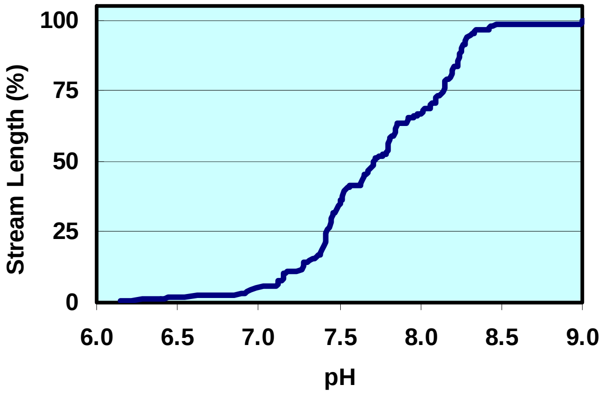


Figure 21. CDF of pH (stream length 74976 km).

Conductivity measures the ion concentration of water. Soluble ions such as nitrates, phosphorous, sulfate, and chloride, can be increased due to human activities as explained previously. Therefore, conductivity can be a useful indicator of water quality impairments from mining and agriculture when it differs from expected natural levels. EPA does not have a suggested conductivity criterion as it varies greatly across streams. Conductivity in the Basin's streams averaged 144.8 µS/cm and the median was 92 µS/cm (Figure 22).

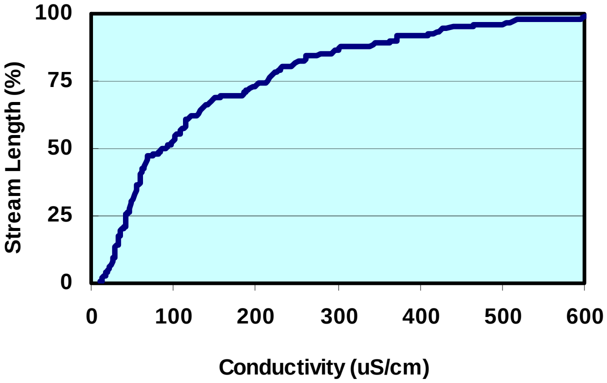


Figure 22. CDF of conductivity (stream length = 74,976 km).

Dissolved oxygen and water temperature are critical for the maintenance of aquatic organisms that use aerobic respiration. Many human activities result in decreasing dissolved oxygen and increasing water temperatures including removal of riparian vegetation, water withdrawals, industrial and municipal point source discharges and agricultural discharges, increased sediment delivery and inputs of organic material. Dissolved oxygen (DO) content is related to turbulence, temperature, and atmospheric pressure. Decreased DO levels are associated with inputs of organic matter, loss of substrate interstitial spaces due to sedimentation, as well as increased temperature and reduced stream flow (MacDonald et al. 1991). In productive streams, dissolved oxygen fluctuates substantially with biological activity (e.g. level of photosynthesis/respiration) so single grab sample measurements may be of limited use. Also, dissolved oxygen was not measured at some sites (see Appendix 7). The EPA's (1986) coldwater criterion for dissolved oxygen is a 7-day mean of 9.5 mg/L (6.5 mg/L interstitial) and a 1-day minimum of 8.0 mg/L (5.0 mg/L interstitial). The mean dissolved oxygen estimated for 44,805 km of stream length (n=167) was 9.1 mg/L and the median was 9.3 mg/L. Conclusions must be drawn with caution, as DO is temporally variable and a single measurement is of questionable value for characterizing stream condition.

Stream temperature is variable depending on air temperature and time of sampling. Many physical parameters affect water temperature in streams including depth, flow, quantity of shade from riparian vegetation and slope-aspect, and groundwater-hyporheic interactions. Human activities can increase water temperatures by increasing the heat load. These include, removal of riparian vegetation, water withdrawals, and alteration of sediment transport that can result in stream widening. Water temperature criteria recommended by EPA in the Pacific Northwest (USEPA 2003b) focus on protecting use by salmonids at their various life history phases. The most stringent recommendation is 9°C to protect bull trout spawning. A criterion of 16°C applies to waters with salmon /trout juvenile rearing areas, while 18°C applies to salmon and trout migration routes. Mean water temperature estimated for 61,130 km of wadeable stream length (n=195) was 10.7°C with a median of 10.0°C.

Riparian Condition Indicators

Intact riparian areas are important for maintaining stream function for many reasons including 1) influencing channel form through root strength; 2) contributing roughness elements (LWD) that force pools and form steps; 3) providing allochthonous inputs of organic matter, and; 4) shading and insulating the channel which influences both summer and winter water temperature, and 5) preventing delivery of sediment and nutrients due to surface erosion. The influence of the riparian zone on streams is variable. For example, the amount of shading provided by the riparian vegetation is related to stream width. Human activities associated with reduced riparian integrity include stream adjacent activities such as logging, animal grazing, agriculture, roads, and urbanization. Metrics used in the assessment related to riparian condition were riparian vegetation structure, human disturbance index and mid-channel canopy density (shade). There are no criteria associated with these metrics, rather they are compared to the reference condition to determine how they relate to the overall condition of the Interior Columbia Basin.

Riparian structure of three vegetation heights (canopy >5m, understory 0.5 to 5m, and ground cover >0.5m) was calculated as the proportion of the reach with the possible range of values from 0 to 1. The proportion of the reach with riparian vegetation presence (combination of all three vegetative layers) averaged 0.78 for the Basin's streams with a median of 0.95 (Figure 23).

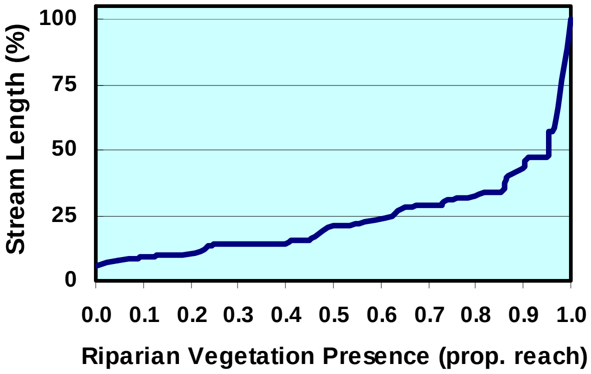


Figure 23. CDF of riparian vegetation presence (stream length=74,976 km).

Human disturbance in the riparian zone is calculated as a proximity-weight disturbance index, which combines the extent of disturbance (based on presence or absence) as well as the proximity of the disturbance to the stream (Kaufmann et al. 1999). Most streams had some level of human-caused riparian disturbance when including all disturbance categories (EMAP metric W1_HALL) recorded in the field (see Peck et al. 2006). Possible values for this metric range from 0 (no disturbance recorded in any of the 22 plots observed at each sample reach) to 1.5 times the number of disturbance types. So a value of 1 is equivalent to having one disturbance type present in every plot, and a value of 1.67 is equivalent to having one type in every plot plus one type adjacent to every plot. Thus, even low values indicate disturbance presence. The average disturbance index was 0.79 and median value of 0.51 (Figure 24). Human disturbance was not observed in an estimated 29% of the estimated stream length. Some level of disturbance from agriculture (pasture and crops) occurred in about 36% of the estimated stream length assessed.

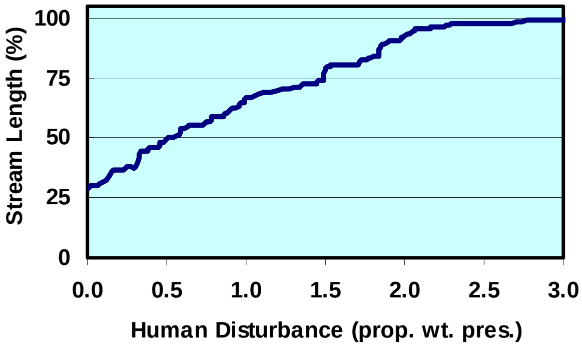


Figure 24. CDF of human disturbance in the riparian zone (stream length 74,976 km).

Changes to the riparian canopy can increase the amount of direct radiation that reaches the stream. Less canopy density can result in greater temperature fluctuations both seasonally and daily. Mean mid-channel canopy density was 63% with median 73% for the assessed stream length (Figure 25).

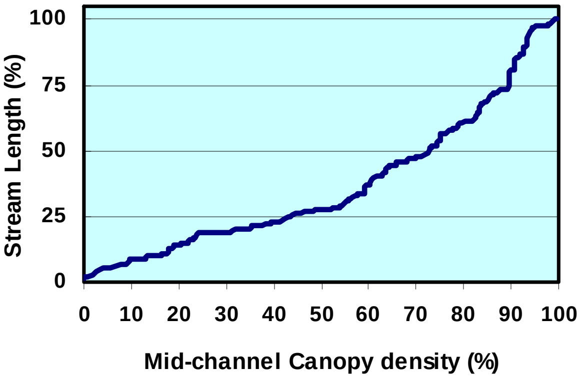


Figure 25. CDF of canopy density measured at mid-channel (stream length=74,390 km).

In-channel habitat complexity indicators

The inputs of water, sediment, and LWD combined with slope, surficial geology, and channel size give streams their characteristic channel complexity. A stream's ability to process inputs of water, sediment and LWD, in the face of natural disturbance regimes, maintains this channel complexity. Human-caused disturbances, which are commonly lower in magnitude but more frequent than natural disturbance events, can alter water, sediment, and LWD inputs. These disturbances can alter the dynamic equilibrium of streams and result in a loss of channel complexity and function. Human alterations to the landscape that can affect inputs include logging, agriculture, urbanization, road construction, water withdrawal, and grazing. The four metrics used to assess channel complexity are relative bed stability (RBS), large woody debris volume, fish cover from large elements (rock, wood, human structures), and area and abundance of pools.

The metric used to evaluate a stream's stability in relation to its sediment load is relative bed stability (RBS). RBS is a comparison of bed substrate size divided by the sediment size that is mobilized during bankfull flow events (Kaufmann et al. 1999). This value is an index of substrate mobility. If this mobility is greater or less than expected, this indicates human-caused sedimentation stress may be present (USEPA 2006a). A large negative value for RBS indicates there are more fine sediments than expected for a stream based on its ability to transport sediment (excess fines). RBS is expressed as a Log10 value so a value of -2 means the median particle size is 100 times smaller that expected. Low RBS values (-4 to -2) would be found in channels that have very mobile substrate and are frequently moved by small flood events (USEPA 2006a). A large positive RBS value (2 to 4) indicates the substrate is coarser than expected. For example, a stream that has been scoured to bedrock by a debris flow or an armored canal would have a high RBS value.

In watersheds where sediment supply is high relative to the streams capacity to transport its bed load, there will typically be excess fine sediment present (Dietrich et al. 1989). This is the typical situation when land use activities increase hill slope erosion and this situation is exacerbated when riparian vegetation is also damaged or removed (Lisle 1982). In the Interior Columbia Basin, mean RBS value was -1.11 and a median of -1.02 (Figure 26). These values are not excessively low indicating that the streams are relatively stable in relation to their sediment load.

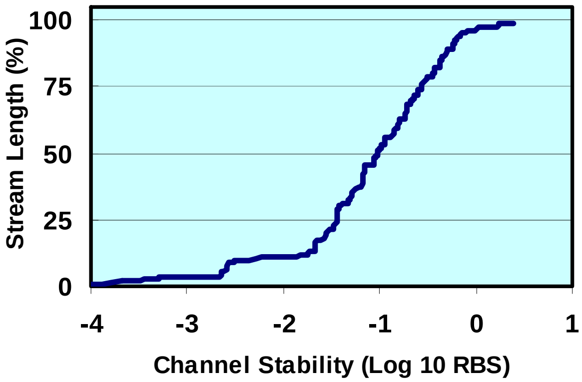


Figure 26. CDF of log10 of the relative bed stability (stream length=64,280 km).

Large woody debris (LWD) recruited to the channel from the riparian zone and hill slopes is important to stream function in channels that are influenced by LWD (typical of streams in the Pacific Northwest). LWD, as single pieces or in accumulations, alters flow and traps sediment, thus influencing channel form and related habitat features (Montgomery and Buffington 1993). Loss of LWD inputs 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.

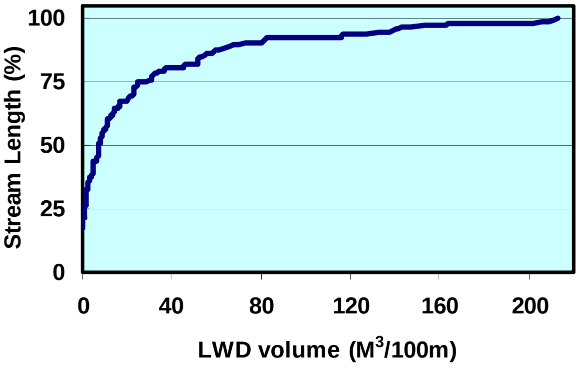


Figure27. CDF of large woody debris volume (stream length=74,976 km).

The volume of LWD including pieces greater than 10 cm diameter ranged from zero to over 213 m^3 per 100 m of stream reach. The mean volume was 26.0 m^3 and the median was 7.2 m^3 (Figure 27). The mean number of pieces of LWD greater than 10 cm diameter in and overhanging the bankfull width of the channel was 22 pieces per 100 m of stream reach with a median of 14 pieces.

Many structural components of streams are used by fish as concealment from predators and as hydraulic refugia. The metric of fish cover (including LWD, boulders, undercut bank and human structures) is indicative of the overall complexity of the channel which is beneficial to other organisms as well. This metric is estimated as the sum of the areal cover from these four fish concealment types and can range from 0 to 3.5 The mean was 0.26 areal cover proportion. This is approximately equivalent to one cover type recorded as a '1' (sparse) and one cover type recorded as a '2' (moderate) at each of the 11 transects in a sample reach. The median value was 0.18 for the estimated stream length assessed (Figure 28).

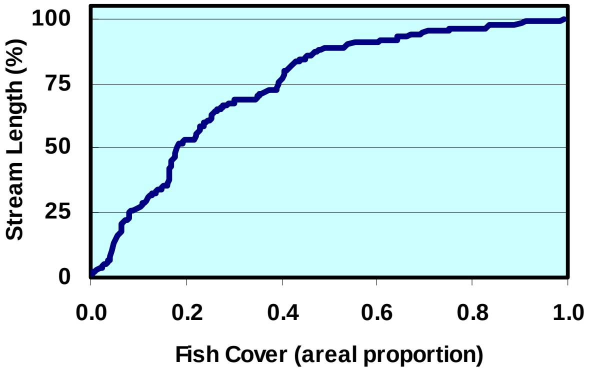


Figure 28. CDF of fish cover (stream length= 74,976 km).

Habitat units are the reach scale classification of habitat based on physical stream features. Fast water areas (i.e. riffles and cascades) are those with higher water velocity, surface turbulence and often shallower water depth in wadeable streams (Bisson et al. 1982). Slow water areas (i.e. glides and pools) have low water velocity, less surface turbulence and are the deeper portion of the streams. The formation of these fast and slow water areas is a function of processes that influence stream bed form including stream size and flow, slope, substrate type, and availability and quantities of large roughness elements that force pools or accumulate sediment that form steps (Montgomery et al. 1995). Having a variety of flow velocities and depths is a characteristic of channel complexity as biotic assemblages use these habitat types differently resulting in increased species richness. Human disturbance that results in the loss of roughness in streams results in habitat simplification which can be indicated by the dominance of riffle habitat (Kershner et al. 2004). Also, habitat complexity can be indicated by pool abundance.

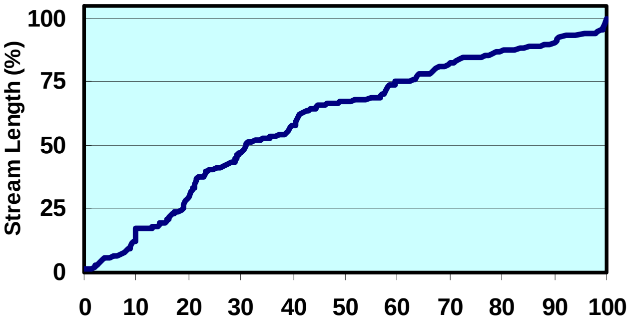


Figure 29. CDF of pool and glide habitat types. (stream length=74,159 km).

Percent slow water is a subjective evaluation of the length of stream that is composed of pools and glides. The mean stream length that was slow water (glides and pools) was 40% and median 31% (Figure 29). The second metric, mean residual pool area (m^2 per100 m stream reach), is calculated from stream depth measurements along the thalweg. Residual pool depth can be visualized as the depth of the water that would remain in a reach if the upstream flow was stopped. Residual pool quantity is an indicator of habitat space. Mean residual pool area ranged from 0-54 m^2/100m with mean of 6 m^2/100m (median 4 m^2/100m).

Sediment quantity indicators

Suspended and deposited sediment occurs at background levels and is important to the ecological function of streams. Sediments transport nutrients, toxicants and organic matter in concentrations that affect stream function. Natural levels of sediment inputs create important habitat features and maintain the dynamic equilibrium of streams. Excessive or decreased sediment inputs can result in impaired function. Also, altered sediment input can have direct and indirect effects to aquatic biota. Human activities that increase fine sediment inputs include erosion from forestry, mining, roads, agriculture, stream channel alterations, and dredging. Decreases in sediment inputs are from sediment being trapped behind dams or the aftermath of extreme stream scour events such as landslides associated with logging. Negative effects from decreases in sediment delivery and transport are a much less frequent and widespread issue compared to excess sediment.

Negative effects to fish habitat from the deposition of fine sediment are well known (reviews by Waters 1995, Chapman 1988). Fine sediment deposition can result in the following impacts to salmonid habitat: 1) reduction of ability of fish to build suitable redds, 2) asphyxiation of developing embryos (hinders water flow decreasing oxygen saturation and removal of metabolic waste), 3) reduction of successful emergence of fry from redds due to burial (blockage of interstices prevents emergence of larvae), 4) reduction of availability of habitat for juveniles and small adult fish (such as family Cottidae) by the filling of cobble interstices used for hiding and cover and filling of pools.

Deposition of excess fine substrate to streams can affect the macro-invertebrate assemblage in several ways including: reducing availability of larger sized particles for attachment, interstitial space for movement between particles, and intra-substrate current velocity and associated dissolved oxygen concentration. Bjornn et al. (1977) reported higher densities of macroinvertebrates in riffles with lower proportions of fine sediment versus those with high proportions. Richards and Bacon (1994) found a significant negative correlation between the abundance of macroinvertebrate taxa and individuals with the presence of fine sediment (<1.5mm diameter) in the hyphoreic zone (subsurface). Macroinvertebrate taxa have varying degrees of tolerance to fine sediment inputs. Some families such as Baetidae, Simuliidae, and the order Plecoptera are shown to have greater degree of population decline with exposure to elevated levels of fine sediment (Culp et al.1986) while most taxa in the family Chironomidae appears to be less affected by exposure to fine sediment.

The metrics used to assess deposited fine sediment are quantity of fine-sized surface substrate and embeddedness. Quantity of fine-sized sediment is the estimate of the substrate particle size that is <2mm diameter (for sand and smaller size fraction) and <0.06mm (for the 'fines' fraction). The mean percent sand plus fines was 24% and the median value was 20% (Figure 30). About 11% of the target streams are dominated by substrate <2 mm (sand and fines ≥50% of the substrate). Embeddedness is the amount that larger substrate particles are surrounded by or ‘embedded into’ smaller particle sizes expressed as a percent. All streams had some level of embeddedness with mean and median value of 52% (Figure 31).

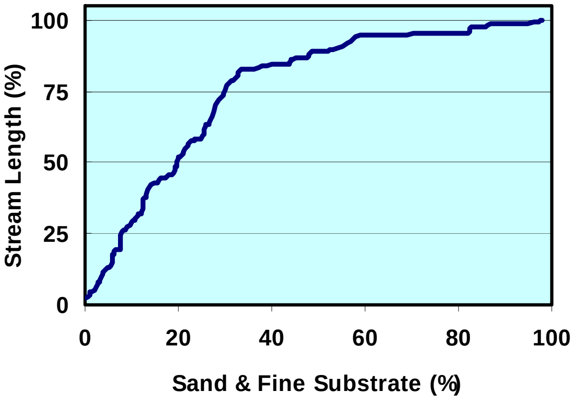


Figure 30. CDF of percent sand and fine ubstrate <2mm diameter (stream length=74,976 km).

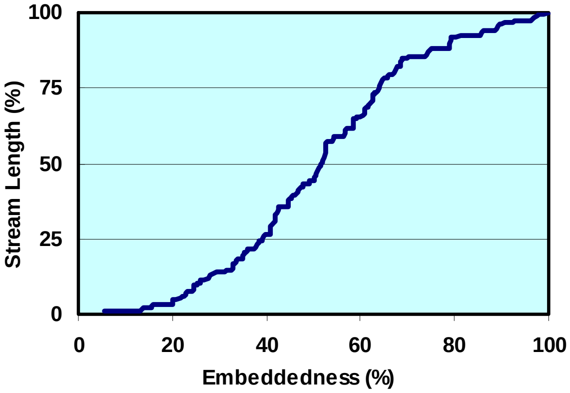


Figure 31. CDF of streambed substrate embeddedness (stream length=74,976 km).

Sediment in suspension also affects stream biota. Fish can be displaced from preferred habitats, reducing their ability to obtain food and avoid predators. Aquatic insects exposed to turbidity can experience increased drift rates and reduced abundance (Culp et al. 1986). Suspended sediment and turbid conditions can have direct effects on primary production due to decreased light penetration, which can inhibit photosynthesis. Decreases in primary production especially to periphyton (aquatic flora growing on submerged substrates) can adversely effect productivity of higher trophic levels which are dependent on primary production as a food source. A reduction in standing crop of primary producers has effects on other strata of the trophic hierarchy (e.g. zooplankton, benthic macroinvertebrates, and fish). A secondary affect of suspended sediment is degradation or loss of habitat due to deposition of this suspended material at diminished flow. Fine sediment deposition is discussed previously. Two metrics were used to assessing suspended sediment: total suspended solids (TSS) and turbidity.

Total suspended solids (TSS) are composed of suspended sediment- typically sand, silt, and clay as well as organic particles and organisms. The size of particles entrained varies with flow characteristics (e.g. velocity, gradient, and turbulence). Also, deposition of suspended sediment is related to particle size and diminished flow. The very fine particle fraction, or wash load (<0.0635mm) tends to stay in suspension for the length of the fluvial system. Turbidity is the optical property of water that describes the amount of light that is refracted or absorbed. Primarily related to the amount silt and clay, turbidity is also influenced by organic particles and compounds and organisms. There is no standardized relationship between turbidity and TSS as the size, weight, and refraction characteristics of the particles contributing to turbidity vary by watershed and in time (USGS 2003).

Suspended sediment and turbidity are highly related to flow conditions with highest amounts occurring during high flow and storm events. Because the EMAP samples are collected during summer low flows water quality criteria are not relevant to these measures. However these data are useful for calculations based on comparisons to reference condition (see next section on Relative Extent and Relative Risk). The mean total suspended solids were 3.2 mg/L with median value of 1.2 mg/L (Figure 32). Mean turbidity was 0.93 NTUs (0.28 median).

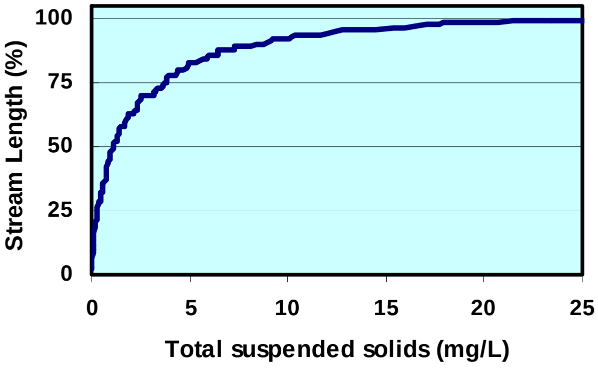


Figure 32. CDF of total suspended solids (stream length=73,758 km).

Relative Extent of Stressors

Important water quality and physical habitat stressors were identified based on the comparison of reference site to probability site data. Abiotic stressors (water quality, riparian, channel complexity, and sediment metrics), were identified and expressed in terms of their relative extent of the stream length assessed in the poor, fair or good category. Values associated with the following stressor extent graphs are in Appendix 9

Photo: G. Merritt, WA Ecology

Results of water chemistry stressor metrics varied from 15% to 37% of the stream extent in the poor condition category. Over 30% of the stream length assessed was in the 'poor' condition category for sulfate, phosphorous, and conductivity (Figure 33). Both pH and nitrogen had <20% of the stream length in the poor condition category.

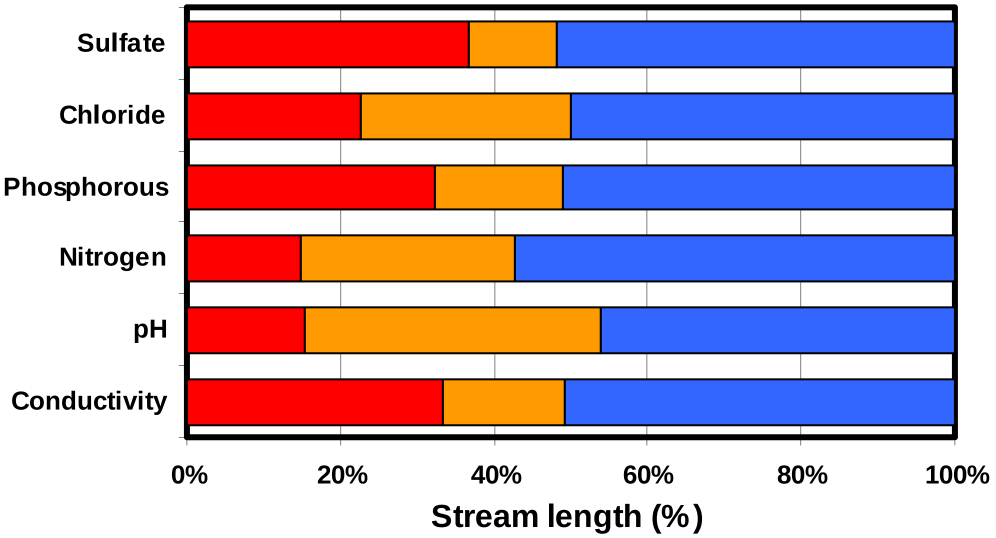


Figure 33. Extent of stream length in poor (red), fair (orange), and good (blue) condition for selected water quality indicators based on comparison of probability site data to thresholds developed from reference site data.

Riparian condition stressor results were variable (Figure 34). Most stream length assessed was in good condition for the quantity of riparian vegetation (69%) and mid-channel canopy density (75%) with <15% of the stream length in the poor condition category for these stressors. Riparian disturbance from all human causes observed was substantial in many streams resulting in 38% of the stream length being in a poor condition category compared to the reference condition. The results for riparian disturbance from agricultural sources only (pasture and crops) were somewhat less (29%).

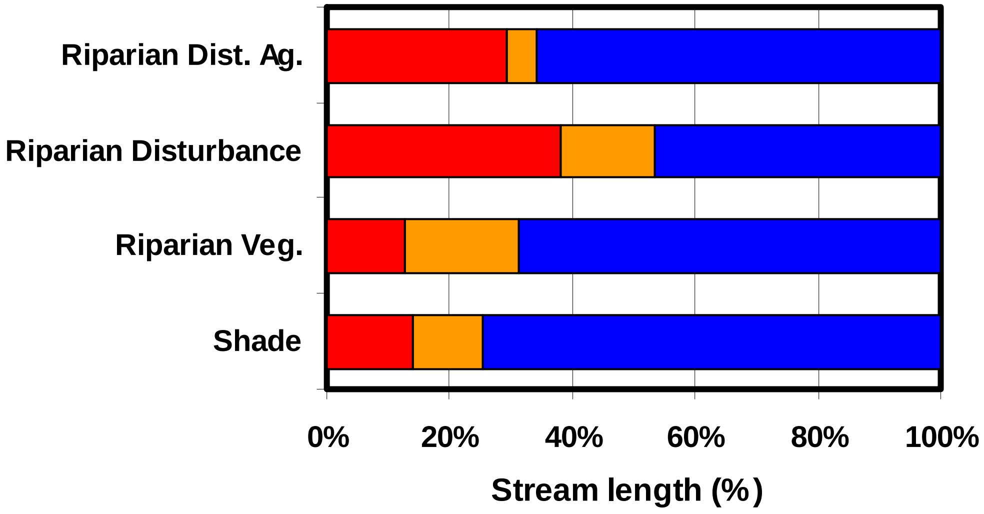


Figure 34. Extent of stream length in poor-fair-good condition for selected physical habitat indicators based on comparison of probability site data to thresholds developed from reference site data.

Channel complexity stressor results were fairly consistent (Figure 35). Most metrics indicated a poor condition for 18% about of the stream length assessed. The metric that varied substantially was slow water habitat (% pools and glides). The large majority of stream length was in the good category (86%) for this stress indicator.

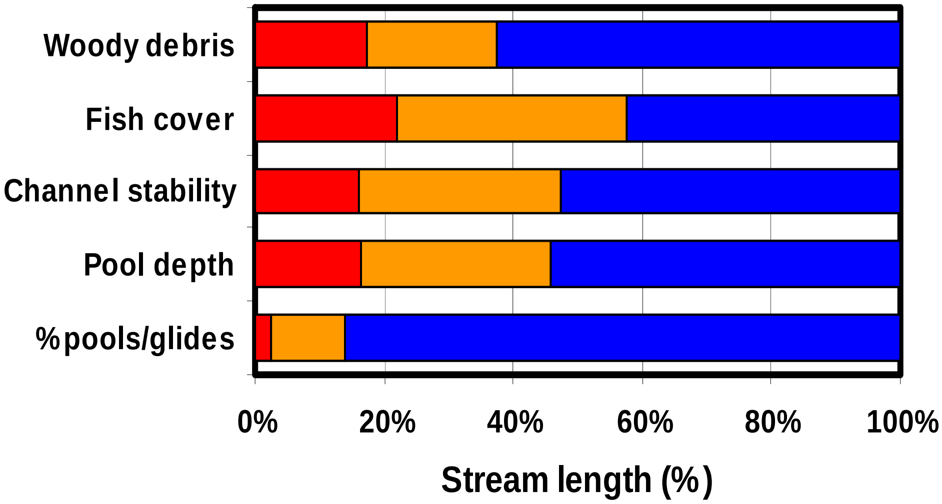


Figure 35. Extent of stream length in poor - fair- good condition for selected physical habitat indicators based on comparison of probability site data to thresholds developed from reference site data.

Generally, the sediment stressor metrics all yielded similar results, with the estimated stream length in poor condition ranging from 18 to 27% (Figure 36). Embeddedness had the greatest extent in poor condition and TSS had the least. Turbidity and TSS would be expected to have similar results and they were almost identical with 60-70 % of stream length classified as good condition. Embeddedness, the most subjective measure, gave results very similar to sand/fines. Inclusion of the sand fraction of the substrate (2mm to 0.06mm particle diameter) rather than fines alone (0.06 and smaller particle diameter) resulted in a slightly greater amount of stream length in the poor category (26% versus 22% for fine-sized alone).

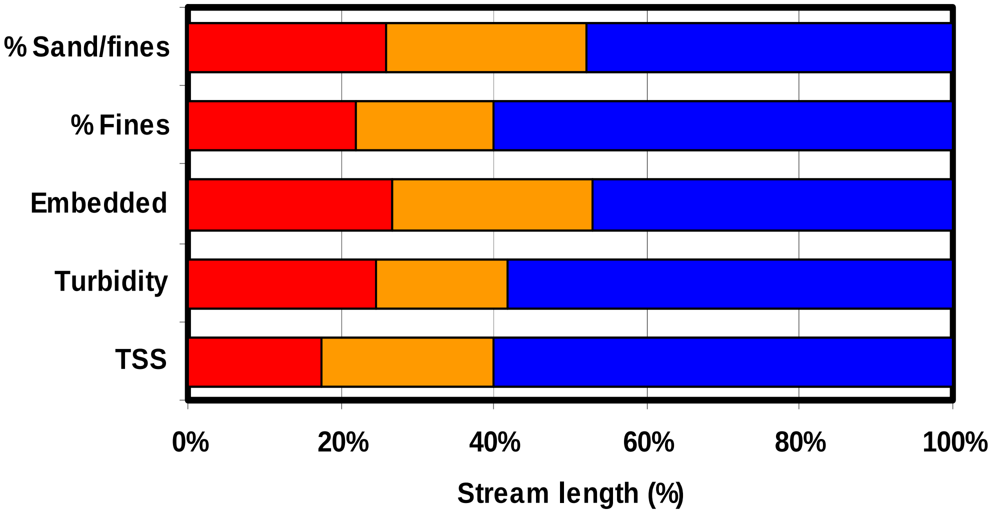


Figure 36. Extent of stream length in poor –fair- good condition for sediment indicators based on comparison of probability site data to thresholds developed from reference site data.

Relative Risk

The relative risk analysis estimates relevance of the effects or associations of the stressors to the stream biota. Benthic macro-invertebrate taxa loss was the biotic indicator for this comparison where site condition is compared to the O/E macro-invertebrate score. Recall from the calculation of relative risk (see methods page 14), that relative risk is the likelihood that the biotic assemblage based on benthic macroinvertebrate taxa loss will be poor when the stress indicator is poor. Values associated with the following relative risk graphs are Appendix 10. Of the 21 stress indicators used in the extent analysis, 13 were useable for the relative risk estimation due to methods restrictions (Appendix 10) Relative risk estimates greater than one are considered to pose a significant effect on the biotic indicator (Van Sickle et al. 2006).

All stress indicators used in the relative risk analysis exceeded the significance threshold of one (Figure 37 and Appendix 10). Each stressor category had at least one stressor that exceeded the relative risk level of four. All indicators of excess sediment, both bed sediments and suspended, had high relative risk scores (exceeding four).

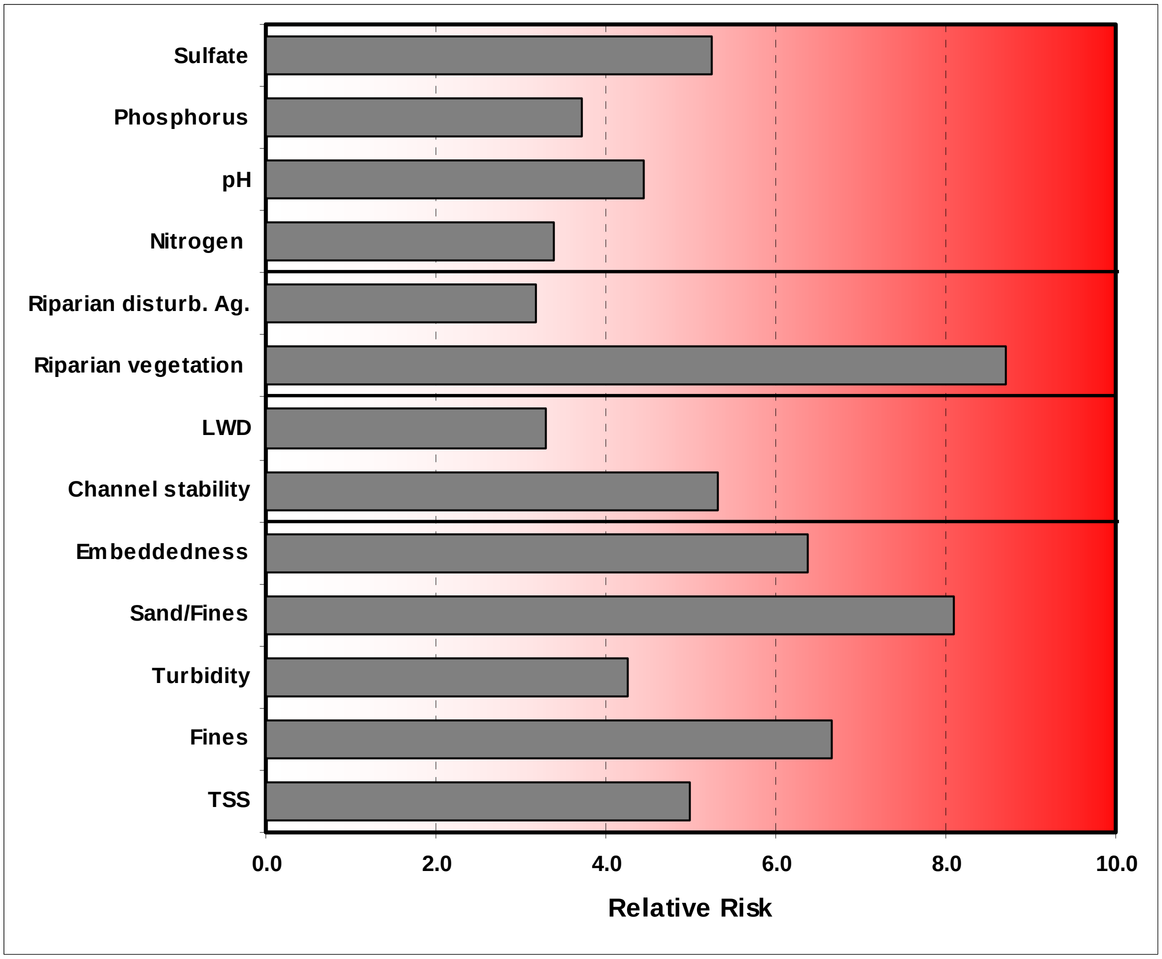


Figure 37. Risk to benthic assemblage (taxa loss) relative to the environmental stressor condition.

Viewing the relative risk in relation to the extent of indicators across the stream length assessed, we see that some indicators with high relative risk were not found to be widely occurring problems (Figure 38). For example, riparian vegetation (all three levels combined) was poor in only an estimated 13% of the stream length, but where this problem does occur the biota are at high risk of being in a poor condition. However, some stressors are both broadly occurring and have high relative risk (Figure 38). For example, the extent of poor condition for most of the sediment indicators is relatively high (≥ 18%) and the relative risk associated with these indicators is also high, ranging from 4.3 for turbidity to 8.1 for sand/fines.

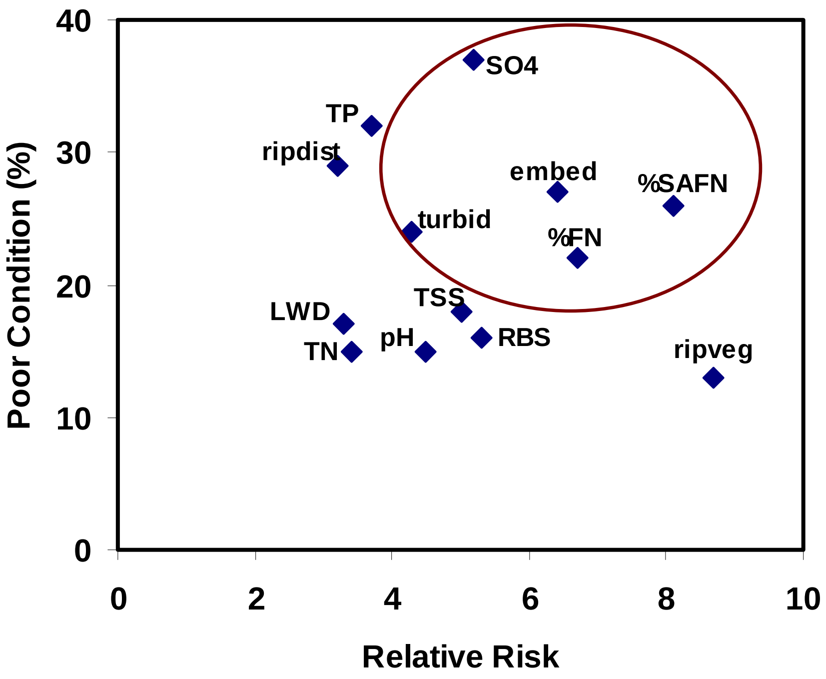


Figure 38. Summary of extent of stressors in poor condition in relation to relative risk. Red circle emphasizes stressor indicators with both high percent of stream length in poor condition and with high relative risk. Refer to Appendix 3 for definition of abbreviated indicator names in this figure.

Conclusions and Recommendations

In general, most streams of the basin are in fair or good condition based on the results of the metrics that could be analyzed. Primary stressors in terms of both extent and risk to biota are excess fine sediment, riparian disturbance from grazing/crops, sulfate, and phosphorous levels.

The results of this analysis support that conditions for aquatic biota would be improved by reducing activities that contribute fine sediment to streams. Erosion and mass wasting controls, protecting and restoring riparian zones, and insuring recruitment of large woody debris at a watershed scale would reduce the stressors influencing aquatic biota.

For this evaluation, we only used one biotic assemblage in which to determine risk to biota. It is preferable to use more assemblages (fish or periphyton) so that the conclusions are more robust. Using multiple assemblages is preferred as a stressor that may be very relevant to one assemblage may have less of a signal for another.

The abundance of reference sites in this Basin allowed condition thresholds for most level III ecoregions to be developed (some Level III ecoregions had to be combined due to insufficient sites). The more refined reference condition thresholds improved the estimates of stream condition.

Additional work that will be pursued using this dataset for the Interior Columbia Basin is to evaluate landscape metrics and models in order to further evaluate the relation of sediment delivery to streams and the associated risk to biota.

Using ecoregions as a way to account for variability and thus ‘scale’ the stressor cut-offs for thresholds of poor-fair-good was reasonable. However, additional work to account for factors (e.g. base lithology, watershed area, and slope) that influence sensitivity to human disturbance (Kauffman and Hughes 2006) would be useful.

Streams in xeric areas are rare so their occurrence in the sample selection frame was also very low. Coupled with access issues and land-owner denials, very large areas had no sample sites. For future EMAP flowing waters projects, it may be necessary to modify the design to ensure that a greater number of streams are sampled in the xeric areas.

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Appendices

Appendix 1. List of probability sites.

SITE_ID	STATE	WGT_COND	STRAHLER	LAT_DD	LON_DD	EcoregionIII
WIDP99-0501	ID	716.2288873	2	46.56095	-114.78078	16
WIDP99-0502	ID	716.2288873	2	44.03402	-115.81346	16
WIDP99-0503	ID	716.2288873	2	46.75859	-116.35642	15
WIDP99-0504	ID	572.9831097	3	47.79687	-116.50889	15
WIDP99-0508	ID	1432.457775	1	43.68952	-115.085	16
WIDP99-0510	ID	716.2288873	2	48.32913	-116.1561	15
WIDP99-0511	ID	572.9831097	3	43.55661	-114.80021	16
WIDP99-0514	ID	716.2288873	2	45.51286	-113.99451	16
WIDP99-0515	ID	716.2288873	2	44.66203	-116.95473	11
WIDP99-0516	ID	716.2288873	2	45.71372	-115.64173	16
WIDP99-0520	ID	716.2288873	2	44.71089	-113.78403	17
WIDP99-0524	ID	572.9831097	3	43.48905	-115.12612	16
WIDP99-0595	ID	716.2288873	2	44.91362	-116.22571	16
WIDP99-0596	ID	358.1144437	3	45.86143	-116.61914	11
WIDP99-0597	ID	477.4859249	2	43.23258	-116.77989	80
WIDP99-0599	ID	1432.457775	1	46.62902	-115.16426	15
WIDP99-0600	ID	572.9831097	3	44.81675	-114.14713	16
WIDP99-0602	ID	572.9831097	3	45.85814	-114.91584	16
WIDP99-0603	ID	358.1144437	3	42.72991	-111.4436	17
WIDP99-0605	ID	1432.457775	1	45.02333	-114.44525	16
WIDP99-0607	ID	572.9831097	3	46.60219	-115.52497	15
WIDP99-0610	ID	859.4746648	5	44.05506	-113.23232	17
WIDP99-0611	ID	572.9831097	3	45.07931	-116.0938	16
WIDP99-0613	ID	1432.457775	1	45.43438	-116.24657	11
WIDP99-0614	ID	716.2288873	2	48.75671	-116.73369	15
WIDP99-0615	ID	572.9831097	3	43.66638	-114.53681	16
WIDP99-0690	ID	716.2288873	2	46.86041	-116.03806	15
WIDP99-0695	ID	572.9831097	3	44.4664	-111.91133	17
WIDP99-0697	ID	716.2288873	2	44.13731	-115.18667	16
WIDP99-0698	ID	859.4746648	4	46.36471	-116.74636	10
WIDP99-0699	ID	716.2288873	2	47.10877	-116.73196	15
WIDP99-0701	ID	1432.457775	1	43.52574	-111.25428	17
WIDP99-0724	ID	572.9831097	3	44.38768	-114.69394	16
WIDP99-0725	ID	1432.457775	1	46.66214	-115.7863	15
WIDP99-0726	ID	1432.457775	1	46.93882	-116.46172	15
WIDP99-0727	ID	358.1144437	3	42.85248	-112.07726	80
WIDP99-0729	ID	716.2288873	2	47.19756	-115.63723	15
WIDP99-0737	ID	1432.457775	1	44.70859	-115.83017	16
WIDP99-0738	ID	572.9831097	3	45.89351	-115.44778	16
WIDP99-0768	ID	358.1144437	3	42.00739	-115.21883	80
WIDP99-0770	ID	716.2288873	2	44.26809	-115.87505	16
WMTP99-0509	MT	1004.895995	2	46.09771	-114.09283	17

Appendix 1 continued. List of probability sites.

SITE_ID	STATE	WGT_COND	STRAHLER	LAT_DD	LON_DD	EcoregionIII
WMTP99-0515	MT	1004.895995	2	48.82479	-114.52056	41
WMTP99-0516	MT	803.916796	3	46.97382	-112.62295	17
WMTP99-0600	MT	803.916796	3	48.83676	-114.36791	41
WMTP99-0607	MT	803.916796	3	48.3536	-113.87986	41
WMTP99-0608	MT	1004.895995	2	47.20769	-115.21949	15
WMTP99-0609	MT	1004.895995	2	46.29743	-113.2271	17
WMTP99-0704	MT	2009.79199	1	47.987	-114.56456	15
WMTP99-0705	MT	1004.895995	2	46.68552	-114.55801	15
WMTP99-0748	MT	803.916796	3	46.37611	-112.70751	17
WMTP99-0801	MT	2009.79199	1	46.51149	-113.08087	17
WNVP99-0514	NV	180.6338246	2	41.71531	-115.22807	80
WNVP99-0615	NV	180.6338246	2	41.99294	-114.94997	80
WNVP99-0622	NV	250.1083726	1	41.476	-116.14632	80
WNVP99-0663	NV	180.6338246	2	41.41776	-116.03335	80
WNVP99-0668	NV	250.1083726	1	41.87257	-115.08706	80
WNVP99-0674	NV	135.4753684	3	41.80692	-115.70369	80
WNVP99-0680	NV	180.6338246	2	41.67083	-115.43303	80
WNVP99-0686	NV	250.1083726	1	41.43368	-116.54478	80
WORP99-0512	OR	36.38058849	2	44.95604	-118.37558	11
WORP99-0518	OR	391.8411011	2	45.88877	-117.08959	11
WORP99-0523	OR	783.6822021	4	44.44759	-117.36697	11
WORP99-0528	OR	36.38058849	2	44.47633	-120.13192	11
WORP99-0529	OR	72.76117698	1	44.84428	-118.49367	11
WORP99-0530	OR	72.76117698	1	44.33353	-118.64122	11
WORP99-0541	OR	36.38058849	2	45.09325	-118.66608	11
WORP99-0542	OR	72.76117698	1	44.5391	-119.03187	11
WORP99-0547	OR	29.1044708	3	44.82201	-120.15535	11
WORP99-0548	OR	36.38058849	2	44.20764	-119.28908	11
WORP99-0551	OR	72.76117698	1	45.18545	-121.64106	4
WORP99-0554	OR	36.38058849	2	44.83757	-118.87883	11
WORP99-0559	OR	36.38058849	2	44.53202	-118.47835	11
WORP99-0560	OR	29.1044708	3	44.58357	-118.41064	11
WORP99-0605	OR	72.76117698	1	45.09683	-121.5505	9
WORP99-0606	OR	18.19029425	3	45.09772	-120.10121	10
WORP99-0607	OR	36.38058849	2	44.43241	-118.51285	11
WORP99-0608	OR	36.38058849	2	44.57589	-118.49073	11
WORP99-0613	OR	24.25372567	2	44.84534	-121.00327	10
WORP99-0622	OR	36.38058849	2	44.04778	-119.25261	11
WORP99-0625	OR	29.1044708	3	45.17222	-118.73584	11
WORP99-0626	OR	36.38058849	2	44.85492	-118.72644	11
WORP99-0630	OR	48.50745133	4	44.75647	-119.41316	11
WORP99-0662	OR	293.8808258	3	45.36827	-119.44512	10
WORP99-0667	OR	1175.523303	1	45.11462	-116.85546	11
WORP99-0677	OR	48.50745133	0	44.1384	-121.59992	9
WORP99-0685	OR	29.1044708	3	45.09665	-119.60892	11

Appendix 1 continued. List of probability sites.

SITE_ID	STATE	WGT_COND	STRAHLER	LAT_DD	LON_DD	EcoregionIII
WORP99-0691	OR	36.38058849	2	45.02468	-119.1499	11
WORP99-0692	OR	72.76117698	1	44.65353	-118.72859	11
WORP99-0698	OR	36.38058849	2	44.30712	-119.17495	11
WORP99-0701	OR	36.38058849	2	45.24921	-121.65964	4
WORP99-0704	OR	36.38058849	2	44.71049	-118.80126	11
WORP99-0710	OR	72.76117698	1	44.37471	-119.25914	11
WORP99-0721	OR	36.38058849	2	44.89811	-118.38238	11
WORP99-0724	OR	48.50745133	4	44.09685	-119.51709	11
WORP99-0728	OR	36.38058849	2	44.39835	-118.67973	11
WORP99-0734	OR	72.76117698	1	44.67177	-118.54373	11
WORP99-0740	OR	587.7616515	2	45.2455	-119.20877	11
WORP99-0745	OR	587.7616515	2	44.89855	-117.42313	11
WORP99-0762	OR	36.38058849	2	44.9714	-119.29882	11
WORP99-0768	OR	48.50745133	4	44.62217	-120.20966	11
WORP99-0769	OR	36.38058849	2	45.05124	-118.66491	11
WORP99-0775	OR	36.38058849	2	44.99865	-119.80257	11
WORP99-0780	OR	48.50745133	4	44.61828	-119.29951	11
WORP99-0787	OR	29.1044708	3	44.90831	-118.31331	11
WORP99-0792	OR	36.38058849	2	44.95446	-120.11004	11
WORP99-0794	OR	48.50745133	4	44.62214	-118.57732	11
WORP99-0800	OR	29.1044708	3	44.20009	-119.3513	11
WORP99-0803	OR	36.38058849	2	45.2055	-121.4153	9
WORP99-0806	OR	72.76117698	1	44.84933	-118.78612	11
WORP99-0815	OR	36.38058849	2	44.26846	-119.97696	11
WORP99-0823	OR	470.2093213	3	44.42964	-117.51413	11
WORP99-0830	OR	587.7616515	2	45.2719	-117.46555	11
WORP99-0841	OR	48.50745133	5	45.03431	-118.97695	11
WORP99-0842	OR	36.38058849	2	44.711	-118.95006	11
WORP99-0851	OR	72.76117698	1	45.19196	-121.54788	9
WORP99-0852	OR	43.65670619	4	45.16741	-119.95186	10
WORP99-0854	OR	29.1044708	3	44.77941	-118.45238	11
WORP99-0856	OR	48.50745133	4	44.0151	-119.33692	11
WORP99-0860	OR	72.76117698	1	44.77885	-118.68596	11
WORP99-0864	OR	36.38058849	2	45.05222	-119.45154	11
WORP99-0866	OR	36.38058849	2	44.27744	-119.59314	11
WORP99-0871	OR	36.38058849	2	44.95509	-118.54965	11
WORP99-0877	OR	72.76117698	1	44.96174	-118.60722	11
WORP99-0883	OR	36.38058849	2	44.56008	-120.17442	11
WORP99-0890	OR	1175.523303	1	45.15893	-117.31785	11
WORP99-0891	OR	36.38058849	2	44.55866	-121.63343	9
WORP99-0917	OR	29.1044708	3	44.44277	-119.81356	11
WORP99-0923	OR	36.38058849	2	44.76812	-119.90937	11
WORP99-0924	OR	36.38058849	2	44.99637	-118.72535	11
WORP99-0928	OR	72.76117698	1	45.30179	-121.44914	9
WORP99-0929	OR	29.1044708	3	44.99278	-120.19689	11

Appendix 1 continued. List of probability sites.

SITE_ID	STATE	WGT_COND	STRAHLER	LAT_DD	LON_DD	EcoregionIII
WORP99-0931	OR	72.76117698	1	44.78677	-118.37703	11
WORP99-0935	OR	29.1044708	3	45.05039	-119.34993	11
WORP99-0937	OR	29.1044708	3	44.34544	-119.65115	11
WORP99-0947	OR	36.38058849	2	44.62332	-119.63725	11
WORP99-0948	OR	36.38058849	2	45.09129	-119.21856	11
WORP99-0972	OR	48.50745133	4	45.08543	-119.0453	11
WORP99-0977	OR	36.38058849	2	44.8447	-119.591	11
WORP99-0985	OR	36.38058849	2	44.35053	-119.54309	11
WORP99-0997	OR	72.76117698	1	44.25692	-118.72987	11
WORP99-1002	OR	48.50745133	4	44.8069	-118.42878	11
WORP99-1003	OR	29.1044708	3	44.63523	-118.84265	11
WORP99-1021	OR	29.1044708	3	44.26681	-119.2195	11
WUTP99-0738	UT	142.3230481	2	41.79791	-113.70932	80
WWAP99-0501	WA	482.0440027	3	46.15187	-120.9786	9
WWAP99-0502	WA	482.0440027	3	46.94703	-120.86765	9
WWAP99-0504	WA	1205.110007	1	48.66948	-118.49916	15
WWAP99-0507	WA	602.5550033	2	46.26366	-121.35376	9
WWAP99-0512	WA	602.5550033	2	46.72988	-120.93914	9
WWAP99-0513	WA	28.0789671	1	47.42888	-120.58642	77
WWAP99-0516	WA	1205.110007	1	48.75608	-119.89609	77
WWAP99-0522	WA	482.0440027	3	48.1391	-118.52751	15
WWAP99-0524	WA	28.0789671	1	47.91787	-120.71826	77
WWAP99-0526	WA	18.7193114	4	47.55338	-120.76985	77
WWAP99-0527	WA	11.23158684	3	47.82841	-120.98266	77
WWAP99-0529	WA	28.0789671	1	47.98425	-120.99859	77
WWAP99-0531	WA	28.0789671	1	47.41879	-120.67906	77
WWAP99-0532	WA	11.23158684	3	47.77337	-120.92748	77
WWAP99-0534	WA	14.03948354	2	47.64945	-121.06659	77
WWAP99-0535	WA	14.03948354	2	48.02028	-120.97756	77
WWAP99-0538	WA	28.0789671	1	47.49884	-120.83942	77
WWAP99-0541	WA	28.0789671	1	47.53807	-121.0253	77
WWAP99-0542	WA	14.03948354	2	47.89761	-120.6963	77
WWAP99-0546	WA	11.23158684	3	47.63122	-120.96894	77
WWAP99-0563	WA	723.066004	4	48.50849	-120.28161	10
WWAP99-0568	WA	602.5550033	2	48.39025	-118.74508	15
WWAP99-0593	WA	1205.110007	1	46.09432	-117.63915	11
WWAP99-0598	WA	602.5550033	2	48.20525	-118.32031	15
WWAP99-0611	WA	28.0789671	1	47.90893	-120.6473	77
WWAP99-0612	WA	14.03948354	2	47.39113	-120.68333	77
WWAP99-0614	WA	11.23158684	3	47.77379	-120.63449	77
WWAP99-0618	WA	14.03948354	2	47.90991	-121.08903	77
WWAP99-0622	WA	14.03948354	2	47.98587	-120.76811	77
WWAP99-0630	WA	14.03948354	2	47.45253	-120.76926	77
WWAP99-0632	WA	14.03948354	2	47.70092	-120.90719	77

Appendix 1 continued. List of probability sites.

SITE_ID	STATE	WGT_COND	STRAHLER	LAT_DD	LON_DD	EcoregionIII
WWAP99-0633	WA	11.23158684	3	47.58554	-120.92391	77
WWAP99-0635	WA	11.23158684	3	47.82426	-120.98872	77
WWAP99-0640	WA	482.0440027	3	46.25956	-117.48154	11
WWAP99-0641	WA	602.5550033	2	46.52663	-121.16615	9
WWAP99-0642	WA	1205.110007	1	46.84485	-121.18622	9
WWAP99-0681	WA	401.7033355	2	46.12959	-118.40646	10
WWAP99-0682	WA	28.0789671	1	47.54551	-121.04039	77
WWAP99-0688	WA	602.5550033	2	47.93462	-120.30551	77
WWAP99-0695	WA	11.23158684	3	47.43262	-120.53316	77
WWAP99-0697	WA	14.03948354	2	47.69859	-120.77602	77
WWAP99-0700	WA	11.23158684	3	47.45026	-120.65278	77
WWAP99-0701	WA	28.0789671	1	47.86274	-121.10128	77
WWAP99-0702	WA	28.0789671	1	47.76982	-120.84474	77
WWAP99-0704	WA	14.03948354	2	48.09626	-120.82736	77
WWAP99-0705	WA	28.0789671	1	48.03268	-120.86401	77
WWAP99-0706	WA	11.23158684	3	47.3599	-120.45611	77
WWAP99-0721	WA	1205.110007	1	48.76751	-117.75771	15
WWAP99-0722	WA	301.2775017	3	47.73425	-117.66951	10
WWAP99-0730	WA	11.23158684	3	47.46304	-120.65988	77
WWAP99-0732	WA	14.03948354	2	47.77466	-120.83299	77
WWAP99-0733	WA	14.03948354	2	47.61033	-120.89884	77
WWAP99-0735	WA	11.23158684	3	48.02649	-120.828	77
WWAP99-0736	WA	11.23158684	3	47.94051	-120.93223	77
WWAP99-0765	WA	14.03948354	2	47.37791	-120.64542	77
WWAP99-0766	WA	28.0789671	1	47.77088	-121.07639	77
WWAP99-0768	WA	11.23158684	3	47.61561	-121.02121	77
WWAP99-0770	WA	18.7193114	4	47.41814	-120.50828	77
WWAP99-0772	WA	14.03948354	2	47.87687	-121.04169	77
WWAP99-0776	WA	28.0789671	1	47.42246	-120.72813	77
WWAP99-0777	WA	14.03948354	2	47.77921	-120.94193	77
WWAP99-0778	WA	11.23158684	3	47.64546	-120.57664	77
WWAP99-0780	WA	18.7193114	0	48.03671	-120.93525	77
WWYP99-0511	WY	1174.305275	1	42.81627	-110.62881	17
WWYP99-0585	WY	1174.305275	1	43.85899	-110.90908	17
WWYP99-0591	WY	469.7221102	3	42.65724	-110.67103	17
WWYP99-0592	WY	469.7221102	3	43.0945	-110.74507	17
WWYP99-0616	WY	782.8701835	4	43.23574	-110.44743	17
WWYP99-0662	WY	1174.305275	1	43.69302	-110.21352	17
WWYP99-0710	WY	469.7221102	3	43.51989	-109.98189	17

Appendix 2. Reference condition cutoff points for thresholds to evaluate extent of good-fair-poor condition, based on comparison to probability site data. Note similar ecoregions were combined for where the number of reference sites was insufficient to use for estimates. Ecoregion 10 and 80 and ecoregions 15,16,17, and 41 were combined.

	Ecoregions											
Metric	**4**	**4**	**9**	**9**	**11**	**11**	**77**	**77**	**10+80**	**10&80**	**15-41**	**15-41**
	Quartile	**Extreme**	**Quartile**	**Extreme**	**Quartile**	**Extreme**	**Quartile**	**Extreme**	**Quartile**	**Extreme**	**Quartile**	**Extreme**
Water Quality												
SO4	2.50	17.20	1.17	3.50	3.10	5.44	3.35	5.54	2.70	4.13	1.80	2.70
PTL	0.03	0.07	0.04	0.10	0.03	0.07	0.00	0.01	0.04	0.07	0.01	0.02
PHSTVL_75	7.70	8.10	7.70	8.00	7.80	8.41	7.75	7.93	7.85	8.88	8.07	8.24
PHSTVL_25	7.32	6.90	7.53	6.91	7.42	6.90	7.29	6.70	7.28	6.49	7.37	6.40
NTL	0.26	0.32	0.26	0.52	0.24	0.28	0.07	0.09	0.29	0.40	0.10	0.21
COND	58.00	102.00	101.00	195.00	75.00	212.00	58.50	85.00	106.00	136.00	106.00	137.00
CL	1.10	3.30	1.00	3.00	0.52	1.49	0.50	0.67	1.53	3.80	0.30	0.50
Riparian Condition												
W1_HAG	0.00	0.00	0.00	0.67	0.00	0.48	0.00	0.00	0.68	1.50	0.00	0.12
W1_HALL	0.13	0.85	0.71	1.08	0.03	1.82	0.33	0.67	1.15	1.50	0.33	0.74
XPCMG	0.95	0.68	0.91	0.77	0.80	0.05	0.75	0.05	0.14	0.00	0.86	0.36
XCDENMID	71.12	47.59	62.70	36.63	22.33	3.21	38.77	21.66	47.33	1.47	55.68	28.28
Inchannel Habitat Complexity												
V1TM100	18.04	4.74	8.43	0.00	3.02	0.00	7.67	2.98	0.49	0.00	5.02	0.00
XFC_BIG	0.35	0.20	0.25	0.12	0.22	0.04	0.17	0.12	0.16	0.00	0.25	0.09
LRBS_BW5	-0.92	-1.73	-1.20	-1.85	-1.32	-1.52	-0.65	-1.19	-1.24	-2.93	-0.95	-1.74
RP100	4.50	1.09	4.09	2.99	4.86	0.77	2.57	1.41	4.61	0.58	3.88	2.76
PCT_SLOW	19.33	7.88	19.33	4.00	16.00	1.33	13.00	11.00	8.00	1.67	9.90	0.00
PCT_FAST	80.00	92.12	79.33	96.00	84.00	98.67	87.00	89.00	92.00	98.33	90.10	100.00
Sediment Quality												
TSS	1.15	66.00	2.60	9.00	2.00	4.56	1.36	2.46	6.50	22.90	1.50	6.00
PCT_FN	5.00	16.67	13.33	18.95	11.43	21.90	1.90	8.57	16.67	62.86	4.76	11.43
TURB	1.00	2.00	1.21	2.00	1.00	2.00	0.12	0.15	3.13	12.80	0.23	0.45
PCT_SAFN	12.73	45.45	27.50	43.81	21.90	31.43	9.52	29.09	29.52	71.43	16.19	28.57
XEMBED	38.83	65.00	62.73	81.18	46.92	69.64	32.73	50.00	63.75	86.67	50.62	60.83

Appendix 3. Number of reference sites used to calculate condition thresholds by ecoregion.

Metric	Description	4	9	11	77	10&80	15,16,17&41
Water Quality							
SO4	sulfate	60	14	19	27	19	21
PTL	total phosphorous	51	14	15	27	19	21
PHSTVL	pH	57	14	18	27	19	21
NTL	nitrogen	61	14	19	27	19	21
COND	conductivity	61	14	19	27	19	21
CL	chloride	51	13	14	27	19	21
Riparian Condition							
W1_HAG	riparian disturbance from agriculture	61	14	17	27	18	21
W1_HALL	riparian disturbance all types	61	14	17	27	18	21
XPCMG	riparian vegetation structure	55	12	17	25	18	21
XCDENMID	Mid-channel canopy density	61	14	17	27	18	20
Inchannel Habitat Complexity							
V1TM100	largewoody debris volume	55	12	17	25	16	21
XFC_BIG	fish cover	55	12	17	25	18	21
LRBS_BW5	channel stability	55	11	14	26	13	21
rp100	residual pool area	55	11	14	26	18	18
PCT_SLOW	%pools+glides	61	14	17	27	18	21
PCT_FAST	% riffle+rapids+cascades+falls	61	14	17	27	18	21
Sediment Quality							
TSS	total suspended solids	60	14	19	27	19	21
PCT_FN	% fines <0.06mm diameter)	61	14	21	27	18	21
TURB	turbidity	55	12	19	25	16	21
PCT_SAFN	% sand+fines <2mm diameter)	61	14	21	27	18	21
XEMBED	embeddedness	55	12	17	25	16	21

Appendix 4. Proportion of stream length assessed by state (n=215, total stream length=74,976km).

State	Stream length (km)	% total stream length	Site count
ID	32,135	42.9	41
MT	12,260	16.4	11
NV	1,608	2.1	8
OR	9,332	12.4	84
UT	142	0.2	1
WA	13,784	18.4	63
WY	5,715	7.6	7

Appendix 5. Estimated wadeable stream length and sample site counts by ecoregion (total stream length=74,976 km).

Aggregated Ecological Regions	Level III Name	Stream length (km)	Site Count	Reference site count
Northern Rockies (mountains)	Blue Mountains (11)	12,697	77	21
	Northern Rockies (15)	17,858	19	21
	Idaho Batholith (16)	13,895	18	
	Middle Rockies(17)	15,282	17	
	Canadian Rockies (41)	2,613	3	
Pacific Northwest (mountains)	Cascades (4)	109	2	61
	Eastern Cascades (9)	4,316	12	14
	North Cascades (77)	2,597	47	27
Northern Xeric Basins (xeric)	Columbia Plateau (10)	2,666	8	18
	North Basin Range (80)	2,944	12	

Appendix 6. Species characteristics classification for aquatic vertebrate species. Fish classification based on Zaroban et al. (1999) and amphibian classification based on EPA tolerance descriptions (Unpublished data available in S.W.I.M. database).

Family/Species	**Common name**	**Tolerance**	**Habitat**	**Thermal**	**Trophic**
		Fish Species			
Family: Catostomidae					
Catostomus columbianus	bridgelip sucker	tolerant	benthic	cool	herbivore
Catostomus macrocheilus	largescale sucker	tolerant	benthic	cool	omnivore
Catostomus platyrhynchus	mountain sucker	intolerant	benthic	cool	herbivore
Family: Centrarchidae					
Micropterus dolomieu	smallmouth bass	intolerant	water column	cool	piscivore
Family: Cottidae					
Cottus bairdii	mottled sculpin	intolerant	benthic	cool	invertivore
Cottus beldingii	Paiute sculpin	intolerant	benthic	cold	invertivore
Cottus cognatus	slimy sculpin	intolerant	benthic	cold	invertivore
Cottus confusus	shorthead sculpin	sensitive	benthic	cold	invertivore
Cottus leiopomus	Wood River sculpin	sensitive	benthic	cold	invertivore
Cottus rhotheus	torrent sculpin	intolerant	benthic	cold	invert/piscivore
Family: Cyprinidae					
Rhinichthys cataractae	longnose dace	intolerant	benthic	cool	invertivore
Rhinichthys osculus	speckled dace	intolerant	benthic	cool	invertivore
Richardsonius balteatus	redside shiner	intolerant	water column	cool	invertivore
Family: Petromyzontidae					
Lampetra richardsoni	lamprey	intolerant	hider	cool	filter feeder
Family: Salmonidae					
Oncorhynchus clarki	cutthroat trout	sensitive	water column	cold	invert/piscivore
Oncorhynchus mykiss	rainbow trout/steelhead	sensitive	hider	cold	invert/piscivore
Oncorhynchus tshawytscha	Chinook salmon	sensitive	water column	cold	invertivore
Prosopium williamsoni	mountain whitefish	intolerant	benthic	cold	invertivore
Salmo trutta	brown trout	intolerant	hider	cold	invert/piscivore
Salvelinus confluentus	bull trout	sensitive	hider	cold	invert/piscivore
Salvelinus fontinalis	brook trout	intolerant	hider	cold	invert/piscivore

Appendix 6 continued. Species characteristics classification for aquatic vertebrate species. Fish classification based on Zaroban et al. (1999) and amphibian classification based on EPA tolerance descriptions (Unpublished data available in S.W.I.M. database).

Family/Species	**Common name**	**Tolerance**	**Habitat**	**Thermal**	**Trophic**
		Amphibian Species			
Family: Bufonidae					
Bufo boreas	western toad	intolerant	edge/hider	cool	invertivore
Bufo woodhousii	Woodhouse's toad	intolerant	edge/hider	cool	invertivore
Family: Dicamptodontidae					
Dicamptodon aterrimus	Idaho giant salamander	very sensitive	benthic/hider	cold	invert/piscivore
Dicamptodon tenebrosus	Pacific giant salamander	very sensitive	benthic/hider	cold	invert/piscivore
Family: Hylidae					
Pseudacris regilla	Pacific tree frog	intolerant	edge/hider	cool	invertivore
Family: Leiopelmatidae					
Ascaphus truei	tailed frog	very sensitive	edge/hider	cold	invertivore
Family: Ranidae					
Rana boylii	foothill yellow-legged frog	very sensitive	edge/hider	cold	invertivore
Rana cascadae	Cascade frog	very sensitive	edge/hider	cold	invertivore
Rana luteiventris	Columbia spotted frog	sensitive	edge/hider	cold	invertivore
Rana pipiens	leopard frog	tolerant	edge/hider	warm	invertivore
Rana pretiosa	spotted frog	very sensitive	edge/hider	warm	invertivore

Appendix 7. Summary statistics for water chemistry metrics for 215 probability sites sampled in the Interior Columbia Basin. Note the grand total of target stream length in the basin is 109,486 km. Data for most metrics were available at all of the sample sites representing 74,976 stream km, approximately 69% of the target stream length.

Indicator	**Units**	**n**	**Weighted stream km**	**Mean**	**-95% confid.**	**+95% confid.**	**Median**	**Minimum**	**Maximum**	**Range**	**Variance**	**Std.Dev.**	**Std. Error**
Sulfate (SO_4^{2-})	mg/L	215	74976	10.59	10.41	10.78	1.78	0.16	307.05	306.89	680.80	26.09	0.095
Chloride (Cl^-)	mg/L	215	74976	1.02	1.01	1.04	0.37	0.11	39.95	39.84	5.66	2.38	0.009
total phosphorous	mg/L	215	74976	0.03	0.03	0.03	0.01	0.00	0.42	0.42	0.00	0.05	0.000
total nitrogen	mg/L	215	74976	0.19	0.19	0.19	0.11	0.02	5.54	5.53	0.19	0.44	0.002
pH	-log[H]	215	74976	7.74	7.73	7.74	7.72	6.15	9.21	3.06	0.21	0.46	0.002
Conductivity	uS/cm	215	74976	144.77	143.76	145.78	92.00	12.00	663.00	651.00	19808.18	140.74	0.514
Dissolved oxygen (DO)	mg/L	167	44805	9.09	9.08	9.11	9.30	2.60	19.70	17.10	3.29	1.81	0.009
Temperature	Celsius	195	61130	10.75	10.72	10.79	10.00	1.90	45.50	43.60	21.48	4.63	0.019
Turbidity	NTU	215	74976	0.93	0.91	0.94	0.28	0.08	26.50	26.42	4.07	2.02	0.007
TSS	mg/L	214	73758	3.15	3.10	3.19	1.20	0.00	177.36	177.36	37.78	6.15	0.023

Appendix 8. Summary statistics for physical habitat and sediment metrics for 215 probability sites sampled in the Interior Columbia Basin. All statistics are weighted bases on the targeted stream networked represented by the sample sites. Note the grand total of target stream length in the basin is 109,486 km. Data for most metrics were available at all of the sample sites representing 74,976 stream km, approximately 69% of the target stream length.

code	Indicator	Units	n	stream km	Mean	-95% confid.	+95% confid.	Median	Min.	Max.	Range	Var	Std. Dev.	Std. Error
XSLOPE	slope	%	215	74976	5.22	5.19	5.25	4.14	0.15	34.92	4.32	19.95	4.47	0.02
XWIDTH	mean wetted width	m	215	74976	4.06	4.03	4.08	2.79	0.19	25.71	3.64	16.24	4.03	0.01
W1_HAG	Agricultural disturbance	prox. Wtd. Sum	215	74976	0.37	0.37	0.38	0.00	0.00	1.50	0.69	0.33	0.57	0.00
W1_HALL	all human disturbance	prox. Wtd. Sum	215	74976	0.79	0.78	0.79	0.51	0.00	5.89	1.50	0.66	0.81	0.00
XPCMG	presence 3 layers canopy structure	proportion reach	215	74976	0.78	0.77	0.78	0.95	0.00	1.00	0.36	0.10	0.32	0.00
XCDENMID	mid-channel canopy density	%	214	74390	63.23	63.02	63.44	72.79	0.00	99.47	45.72	849.15	29.14	0.11
PCAN_C	coniferous dominated canopy	proportion reach	215	74976	0.41	0.40	0.41	0.27	0.00	1.00	0.86	0.16	0.41	0.00
V1TM100	volume LWD in/above active channel (class1 >)	m^3/100m	215	74976	26.00	25.68	26.31	7.17	0.00	213.18	24.43	1934.46	43.98	0.16
C1W_100	LWD active channel (class1 >)	Pieces/ 100m	215	74976	21.56	21.36	21.75	14.09	0.00	157.50	157.5	768.05	27.71	0.10
XFC_BIG	Structural fish cover	Areal prop.	215	74976	0.26	0.26	0.26	0.18	0.00	0.99	0.31	0.05	0.22	0.00
RP100	mean residual pool area	m2/100m reach	203	64996	5.93	5.89	5.97	4.18	0.01	53.89	53.88	24.54	4.95	0.019
LRBS_BW5	log10[relative bed stability]	N/A	202	64280	-1.11	-1.11	-1.10	-1.02	-4.29	0.76	0.88	0.64	0.80	0.00
PCT_SLOW	%pools+glides	% reach	214	74159	40.39	40.19	40.60	31.00	0.00	100.00	41.00	825.94	28.74	0.11
PCT_FAST	%Fast water	% reach	214	74159	58.29	58.08	58.50	69.00	0.00	100.00	45.00	872.51	29.54	0.11
PCT_SAFN	%Sand+fines<2mm	% reach	215	74976	24.01	23.86	24.15	20.00	0.00	97.89	22.65	425.68	20.63	0.08
PCT_FN	%fines (<0.06mm)	% reach	215	74976	11.43	11.30	11.56	4.76	0.00	97.89	12.38	334.32	18.28	0.07
XEMBED	embeddedness	%	215	74976	52.10	51.96	52.24	52.07	5.40	100.00	24.78	385.32	19.63	0.07

Appendix 9. Extent of poor-fair-good condition for indicators expressed as percent of stream length assessed (75,000 km total). Results based on comparison of probability site data to thresholds values generated from reference sites.

Metric	Description	Poor	Fair	Good	Relative Risk Calculated?
Water Quality					
SO4_MG	sulfate	37	11	52	yes
PTL_MG	total phosphorous	32	17	51	yes
PHSVL	pH	15	39	46	yes
NTL_MG	nitrogen	15	28	57	yes
COND	conductivity	33	16	51	inadequate #sites by o-e category
CL_MG	chloride	23	27	50	inadequate #sites by o-e category
Riparian Condition					
W1_HAG	riparian disturbance from agriculture	29	5	66	yes
W1_HALL	riparian disturbance all types	38	15	47	inadequate #sites by o-e category
XPCMG	riparian vegetation structure	13	19	69	yes
XCDENMID	Mid-channel canopy density	14	11	75	inadequate #sites by o-e category
In-channel Habitat Complexity					
V1TM100	large woody debris volume	17	20	63	yes
XFC_BIG	fish cover	22	36	42	inadequate #sites by o-e category
LRBS_BW5	channel stability	16	32	52	yes
RP100	residual pool area	16	29	54	inadequate #sites by o-e category
PCT_SLOW	%pools+glides	2	12	86	inadequate #sites by o-e category
PCT_FAST	% riffle+cascade+rapids+falls	2	11	85	inadequate #sites by o-e category
Sediment Quantity					
TSS	total suspended solids	18	22	60	yes
PCT_FN	% fines	22	18	60	yes
TURB	turbidity	24	17	58	yes
PCT_SAFN	% sand+fines	26	26	48	yes
XEMBED	embeddedness	27	26	47	yes

Appendix 10. Estimating relative risk estimate for stressors. Data used for calculation of relative risk where A=good O/E index and Good stressor metric value, B= poor O/E index and Good stressor metric value, C= Good O/E index and Poor stressor metric value, and D= Poor O/E index and Poor stressor metric value. Relative risk calculated as =(D/C+D)/(B/A+B). Note: minimum of five sites in each A, B, C, D categories required to calculated relative risk (Chloride, Temperature, and riparian Dist., and shade All were not useable).

Metric	**Description**	**A (site#)**	**C (site#)**	**B (site#)**	**D (site#)**	**A (km)**	**C (km)**	**B (km)**	**D (km)**	**Relative Risk**
Water Quality										
SO4_MG	sulfate	71	20	10	15	24622	7311	2446	6570	5.2
PTL_MG	total phosphorous	68	17	10	8	23676	9158	2214	4287	3.7
PHSVL	pH	50	14	5	5	24093	3536	2005	1841	4.5
NTL_MG	nitrogen	81	10	10	9	25314	6128	1884	1883	3.4
COND	conductivity	54	26	**4**	19	24542	7385	2214	5054	
CL_MG	chloride	67	12	**3**	17	29813	3662	106	5506	
Riparian Condition										
W1_HAG_R	riparian disturbance from agriculture	76	28	6	19	28461	9371	3551	5092	3.2
W1_HALL_R	riparian disturbance all types	47	35	**4**	18	22167	11015	3495	5429	
XPCMG_R	riparian vegetation structure	78	9	7	8	29362	4729	1623	3969	8.7
XCDENMID_R	Mid-channel canopy density	87	8	16	**4**	32569	3305	2714	3566	
In-channel Habitat Complexity										
V1TM100_R	large woody debris volume	77	9	10	5	27514	4713	3750	3085	3.3
XFC_BIG_R	fish cover	67	12	**4**	13	22960	4437	1805	5866	
LRBS_BW5_R	channel stability	68	11	8	13	21887	2530	2356	2711	5.3
RP100_R	residual pool area	65	6	14	**1**	20504	4171	5122	573	
PCT_SLOW_R	%pools+glides	88	6	25	**0**	30969	1667	8241	0	
PCT_FAST_R	% riffle+cascade+rapids+falls	87	6	25	**0**	30933	1667	8241	0	
Sediment Quality										
TSS	total suspended solids	73	15	7	12	27021	4530	2677	3715	5.0
PCT_FN-R	% fines	73	14	8	16	30122	4423	2766	5633	6.7
TURB	turbidity	72	20	14	12	25891	6564	3210	5835	4.3
PCT_SAFN_R	% sand+fines	63	18	7	17	24789	4645	1783	5514	8.1
XEMBED_R	embeddedness	57	15	6	14	22580	4874	2034	5412	6.4