A Department of Ecology Report

Multi-Metric Index Development for Biological Monitoring in Washington State Streams

Abstract

The Freshwater Monitoring Unit (FMU) at the Washington State Department of Ecology (Ecology) assesses the water and biological quality of surface waters in Washington State. This document describes classification and multi-metric index calibration approaches for biological criteria development in Washington State using benthic macroinvertebrates. This document also presents biological classification results for western Washington and proposed multi-metric indices for the Puget Lowland and Cascades regions. In the context of an *a priori* classification scheme, level III ecoregion was the single most important variable accounting for biological variability. Other landscape and reach-scale variables could clearly account for more variability. However, further stratification is not practical at this time, due to the paucity of regional reference sites surveyed. Calibrated multi-metric indices of the Puget Lowland and Cascades (combined) ecoregions yielded discrimination efficiencies of 80.0% and 87.5%, respectively.

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Introduction

Background

The Federal Clean Water Act (Section 101) mandates the development of water management programs that evaluate, restore, and maintain the chemical, physical, and biological integrity of the nation's waters (U.S. EPA 1990). Traditional measurements of chemical and physical components for rivers and streams do not provide sufficient information to detect or resolve all surface water problems. Biological evaluation of surface waters provides a broader approach. Biological assessments supplement chemical evaluation by:

- Directly measuring the most sensitive resources at risk.
- Measuring a stream component that integrates and reflects human influence over time.
- Providing a diagnostic tool that synthesizes chemical, physical, and biological perturbations (Hayslip 1993).

The Washington Department of Ecology (Ecology) collects biological information from rivers and streams throughout the state. A long-term monitoring program was established in 1993 to explore spatial patterns and identify temporal trends in benthic macroinvertebrate assemblages. Gradually, the program has developed a large base of information that describes biological characteristics of reference and degraded conditions. Reference conditions are found in streams with little or no human impact.

One of our primary goals is to develop biological criteria. Biological criteria are typically univariate (i.e. single variable) endpoints. These endpoints are determined by comparing the biological condition of reference sites with non-reference sites. Confidence in these assessments is defined by the natural variability about the reference condition.

Biological criteria for stream health are generally based on either a multi-metric or multivariate approach. One commonly used multi-metric approach uses an aggregation of individual community metrics that comprise the Benthic Index of Biological Integrity (B-IBI). One multivariate approach is the River Invertebrate Prediction and Classification System (RIVPACS). Detailed methods for the multi-metric B-IBI approach are outlined in Kerans and Karr (1994), Barbour et al. (1999) and Karr and Chu (1999). Detailed methods for the RIVPACS approach are outlined in Wright et al. (1993), Norris and Georges (1993), Reynoldson et al. (1995), and Wright (1995).

Washington State currently uses results from a RIVPACS multivariate model as its primary biological criterion (Hawkins and Ostermiller, In Prep). Multi-metric indices, however, are also being developed across Washington State for confirmation of multivariate modeling results, for use in the stressor identification process, and for educational purposes. A B-IBI has been calibrated for the Puget Lowland region of Washington State (Kleindl 1995; Fore et al. 1996; Karr 1998), but it was developed with field protocols that are different from Ecology's. We need to calibrate multimetric indices using data from Ecology field protocols. In addition, this analytical framework can be applied to different regions of Washington State, where calibrated biometrics do not currently exist.

Objectives

This document outlines the analytical process Ecology's Freshwater Monitoring Unit (FMU) has selected for 1) determining the strength of *a priori* classification schemes, 2) selecting candidate biometrics for a multi-metric index, 3) calibrating biometrics, 4) integrating biometrics into a multi-metric index, and 5) testing multi-metric index performance. Since this program constantly accrues new data, biometric development is meant to be an iterative process. Future iterations of this process are meant to test stability of the current classification scheme, component biometric performance, and calibration. We expect these elements of biocriteria development to stabilize as a critical mass of representative reference and degraded conditions are accrued. This document also presents the current calibrated multi-metric indices for the Puget Lowland and Cascades Ecoregions.

Methods

Establish a Data Collection Protocol

Biological data were collected following Plotnikoff and Wiseman (2001) throughout the state at a range of reference and test sites. This protocol samples benthic macroinvertebrates in representative riffle-habitat (Figure 1).

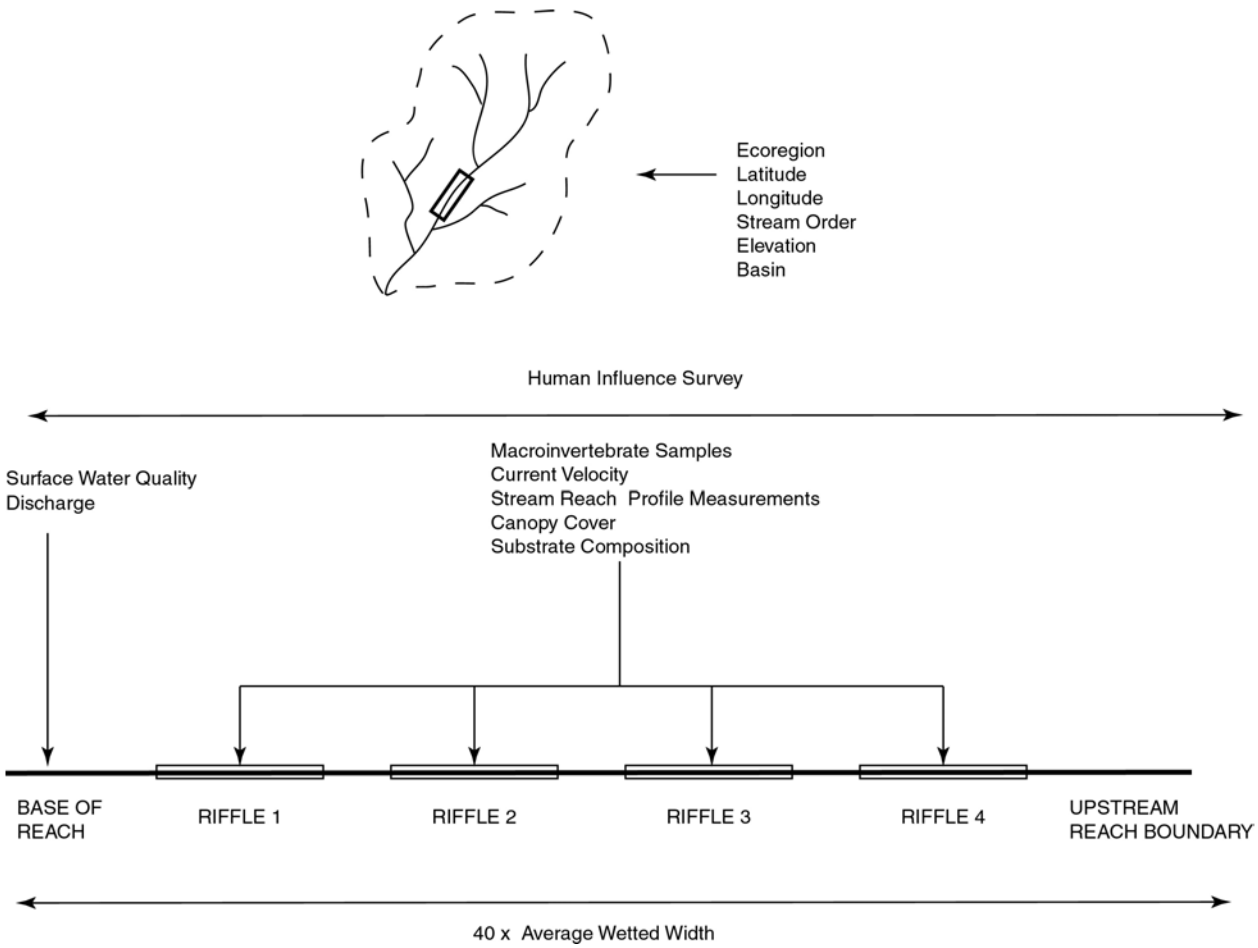

Figure 1. Spatial distribution of field operations.

Establish Criteria for Reference Conditions

Reference sites are intended to represent relatively unimpacted or least impacted conditions. Minimally disturbed conditions reflect sites that have experienced very little historical human activity that alters stream integrity. Least disturbed sites have been degraded by humans historically, but exhibit some level of recovery. We use these reference sites to describe natural biological variability in time and space.

Reference site information is used as a measure of biological potential for particular stream settings. Identifying a response in the biological community to environmental degradation is determined by comparison to reference sites. For consistency, identification of reference sites followed these guidelines:

- Map potential areas where reference sites are expected.

- Evaluate whether candidate reference areas are concentrated in one part of a watershed or are in a variety of locations (candidate sites may not be physically comparable to degraded sites if they are unique to a small portion of a watershed).
- Eliminate areas with relatively high human modifications (past and present).
- Field visits; verify current condition of each site.
- Choose reference sites that approximate stream type and setting as those that will be surveyed for suspected degradation.

Evaluation of regional patterns and variability is most effective in the absence of any human degradation. Degraded sites may introduce error into observed regional patterns, unless there are intrinsic biological attributes within a stream class that persist over a degradation gradient. If all streams in the region have been disturbed to a certain degree, however, a least disturbed condition must be identified and used for that region. We suspect this situation to occur in the Columbia Plateau, Coastal Lowlands, and Puget lowlands.

Establish a Classification Scheme

Defining the spatial distribution of aquatic invertebrate species is an important step in knowing how to use biological information as a guide for resource management. The search for spatial pattern in biological communities serves to describe minimum expectations in stream types across the state; especially when only a subset of streams can be surveyed. In Washington State streams, distinct regional patterns exist among the benthic macroinvertebrate communities. Variables at different spatial scales are often required to explain regional patterns in benthic macroinvertebrate communities (Hawkins et al. 2000).

Plotnikoff (1992) found that communities differ as a function of region and season among similar-sized streams in three ecoregions (Puget Lowland, Cascade Mountains, and Columbia Basin). Surveys in the Yakima River Basin, Washington identified segment-level variables (valley type and watershed characteristics) as the best correlates with biological community expressions over basins and regions of the landscape (Carter et al. 1996). Plotnikoff and Ehinger (1997) stressed the importance of reach-level variables (temperature, pH, conductivity, wetted width/ bankfull width ratio, elevation) in shaping the macroinvertebrate communities. The large-scale expressions such as ecoregions (Omernik and Gallant 1986; Pater et al. 1998) or components of ecoregion descriptions like topography, elevation, or climate can be helpful in parsing streams into groups, because they incorporate many landscape-scale variables into relatively homogenous groups.

FMU's Ambient Biological Monitoring Program currently uses ecoregions as the initial partitioning variable (Figure 2). Level III ecoregion (Pater et al. 1998) was chosen as an initial stratification variable, because the ecoregions integrate physiographic conditions that likely influence macroinvertebrate distribution, and their large regional scale allows for other segment and reach-scale variables to nest within them, if necessary, to account for additional natural variability. The Cascade Mountains contain 3 level III ecoregions. These ecoregions were pooled in order to increase the number of reference sites in the class. Once the appropriate strata were selected and classes defined, indices were developed in each stream class, respectively.

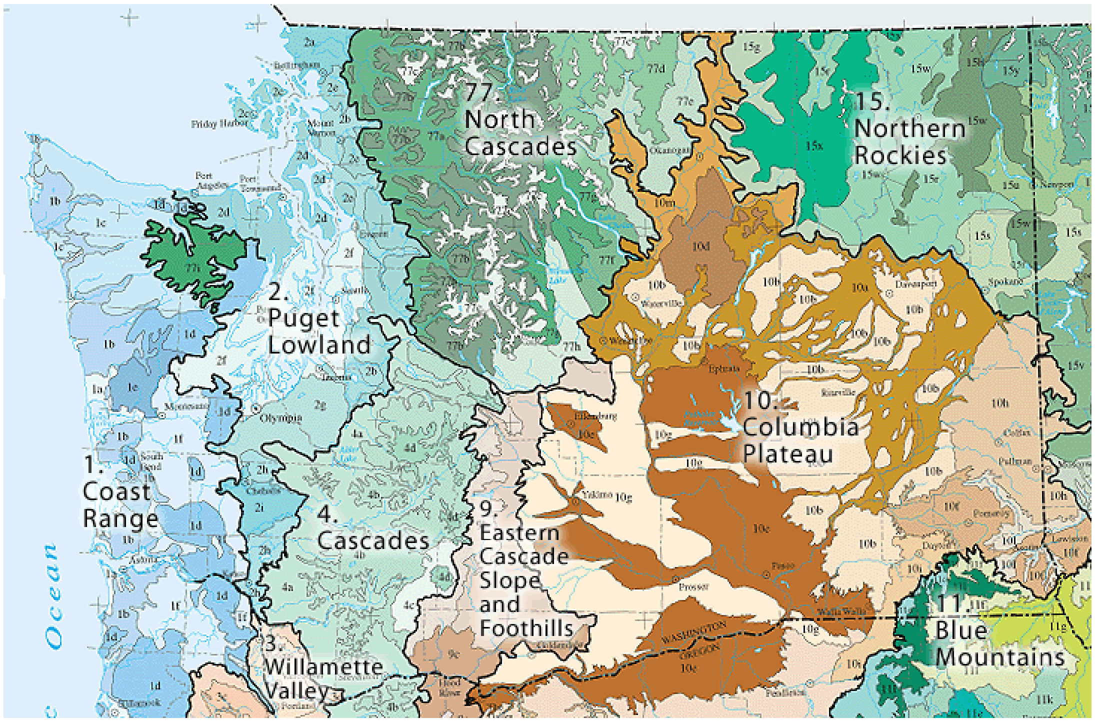

Figure 2. Ecoregions of Washington State (Pater et al. 1998)

Assessment of Classification Strength

Mean Similarity

A strong classification scheme reduces spatial "noise" or variability. Each class with similar "natural" species composition then form the foundation for effective index development, respectively. Classification strength is defined by the degree to which classifications maximize within-class biotic similarity relative to between-class similarity of reference sites (VanSickle 1997; VanSickle and Hughes 2000). Likewise, classification strength expressions are calculated by examining the overall, or mean, within-class and between-class similarities.

In a similarity matrix, a within-class mean similarity can be derived from within each cluster class. Likewise, between-class mean similarities can be derived from the same matrix (Figure 3). This summary similarity matrix is further reduced by taking the mean of the within-class similarities (W) and between-class similarities (B), respectively (Figure 3). These two means (W and B) can be compared to evaluate classification strength. The comparison can be expressed as a ratio (B/W) or difference (W-B) (Figure 4). As classification strength increases, the ratio expression decreases and the difference of the similarities increases (Figure 4).

The expression of similarity differences (i.e. of between and within similarities) can be expressed graphically as a dendrogram. The mean similarity dendrogram is an effective graphic that displays similarity values between classification schemes (VanSickle 1997; VanSickle and Hughes 2000).

FMU compares the strength of a given classification to the optimal partitioning strategy of biological cluster results based on a Bray-Curtis similarity measure and an average grouping metric. The cluster classes are partitioned into a similar number of classes that would be produced from the *a priori* scheme being evaluated. In an *a priori* scheme, reference classes are determined by a stratification variable "up front". An *a posteriori* scheme uses an optimal partitioning strategy of biological cluster classes, and then models probability of membership based on predictor variables.

Although a number of *a priori* different classification schemes can be tested, in this current evaluation, I tested two *a priori* schemes against an optimal partitioning strategy of biological cluster classes (BIO). One scheme was based on a combination of Level III ecoregions (ECO) (Pater et al. 1998). Another scheme was based on geographic proximity (GP). The GP *a priori* reference classes were constructed by clustering latitude and longitude coordinates. In order to test whether or not each *a priori* scheme partitioned biological variability beyond random, permutation tests were run testing a "no class structure" hypothesis. The permutation tests consisted of randomizing reference sites into classes 10,000 times, calculating classification strengths from each randomization, producing a distribution from that population, and comparing the two *a priori* classification strengths against that distribution.

In order to further investigate the similarity of references sites, we produced a non-metric multidimensional scaling (NMDS) plot from the same references site similarity matrix. The same plot was presented three times labeled by BIO, ECO, and GP class membership, respectfully. Since the *a posteriori* cluster classes were produced from the same similarity matrix as the NMDS plot, we expected each cluster class to cluster on the plot. Clustering of the ECO and GP classes would indicate a successful *a priori* scheme.

In order to investigate classification variables other than ecoregion and geographic proximity, I ran the BIO-ENV procedure in the Primer statistical package (Clarke and Ainsworth 1993). This procedure requires a physicochemical data set, corresponding to the same reference sites that produced the biological similarity matrix. I chose to include level III ecoregion, other regional variables, and reach-scale variables in the data set, because we suspected that natural biological variability could be further parsed at the geographic and reach scales. In the BIO-ENV procedure, Principal Components Analysis (PCA) plots are run on the reference sites, based on their physicochemical properties. In order to determine which variables were the most influential, different combinations of variables (total of 1 and 3 variables) were run in every possible combination in to produce PCA plots in an iterative fashion. In each iteration, the PCA plot was compared to the NMDS plot. In comparing the two plots, if the configuration of the references sites matched up closely, the single variable, or 3 variables that were chosen to produce the PCA plot were considered useful in explaining the biological variability that manifested in the NMDS plot. The overlap in site configurations was quantified by a harmonic correlation (Clarke and Ainsworth 1993).

Class	Site						Mean Similarity					
1	Smith Cr.	1					1	*0.8*				W = 0.58
	Forks Cr.	*0.8*	1				2	**0.2**	*0.5*			B = 0.20
	Elkhorn Cr.	*0.9*	*0.7*	1			3	**0.21**	**0.2**	*0.4*		
2	Jim Cr.	**0.25**	**0.24**	**0.16**	1			1	2	3		
	Canyon Cr.	**0.31**	**0.21**	**0.14**	*0.6*	1						
	Squire Cr.	**0.15**	**0.18**	**0.12**	*0.5*	*0.6*	1					
3	Quartz Cr.	**0.19**	**0.14**	**0.21**	**0.26**	**0.24**	**0.17**	1				
	Bear Cr.	**0.17**	**0.23**	**0.25**	**0.19**	**0.18**	**0.23**	*0.4*	1			
	Bumping R.	**0.21**	**0.26**	**0.19**	**0.14**	**0.16**	**0.24**	*0.5*	*0.4*	1		
		Smith Cr.	Forks Cr.	Elkhorn Cr.	Jim Cr.	Canyon Cr.	Squire Cr.	Quartz Cr.	Bear Cr.	Bumping R.		
			1			2			3			

Figure 3. An example of how to derive mean within (W) and mean between (B) similarity values from a similarity matrix. Bold values are similarities between classes, and italicized values are similarities within classes.

			Mean Similarity			
a posteriori clusters	*a priori* ecoregions	*a priori* geog. Proximity clusters	1	#		
			2	#	#	
			3	#	#	#
		W = #				
		B = #				

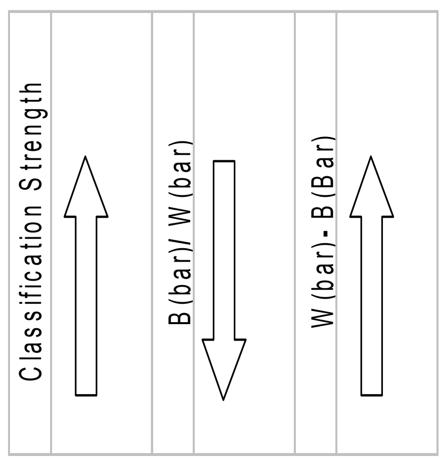

Figure 4. The relationship between mean similarity expressions and classification strength.

Assigning Test Sites to its Reference Class

In an *a priori* classification scheme, the pertinent landscape and/or reach scale attributes of each test site can be readily obtained. The attributes are compared to the classification scheme and assigned to its appropriate reference class. For example, in a classification scheme using Level III ecoregions, a test site in the Level III Puget Lowlands would be evaluated based on the criteria developed for that Puget Lowland reference class.

Metrics Defined

A multi-metric index (B-IBI) is composed of several component biological metrics. A biological metric is an expression of a biological community attribute that responds to human disturbance in a predictable fashion. Each metric describes a different aspect or function of the community. For example, metrics describe the richness, composition, prevalent feeding strategies, life histories, and habits of the benthic community (Table 1). We included candidate metrics that have already been successful in the Pacific Northwest (Kleindl 1995; Fore et al. 1996; Karr 1998), and metrics recommended for widespread use in the United States (Barbour et al. 1999). We also created two tolerance metrics (% Tolerant (TV7) and Intolerant Richness (TV3)). We used taxa attributes from Wisseman (1998). Clinger designations are from Merritt and Cummins (1996). Karr (1998) and Karr and Chu (1999) discuss the use of clingers designations in component metrics. The general response of metric values to increasing levels of stress is termed the "Trend with Increasing Stress" (TwI; Stribling et al. 2000). When a metric decreases with increasing stress, the TwI is negative. TwI is positive when a metric increases with stress (Table 1).

Table 1. Candidate metrics for biometric index development.

Metric	Functional Category	Trend with Increasing Stress	Explanation
% Chironomidae	Composition	+	Percent of the family Chironomidae of the total sample count
% Ephemeroptera	Composition	-	Percent of the order Ephemeroptera of the total sample count
% EPT	Composition	-	Percent of the orders Ephemeroptera, Plecoptera, and Trichoptera of the total sample count
Total Richness	richness	-	Number of taxa
EPT Richness	richness	-	Number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera.
Ephemeroptera Richness	richness	-	Number of taxa in the order Ephemeroptera
Plecoptera Richness	richness	-	Number of taxa in the order Plecoptera
Trichoptera Richness	richness	-	Number of taxa in the order Trichoptera
Hilsenhoff Biotic Index (HBI)	tolerance	+	The HBI is calculated by multiplying the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals.
Intolerant Richness (bi)	tolerance	-	Number of highly intolerant taxa, as defined by Wisseman (1998).
% Tolerant (bi)	tolerance	+	Percent of the highly tolerant taxa of the total sample count, as defined by Wisseman (1998).
Intolerant Richness (TV3)	tolerance	-	Number of intolerant taxa (tolerance value less than 3)
% Tolerant (TV7)	tolerance	+	Percent of the tolerant taxa (tolerance value greater than 7) of the total sample count
% Top 3 Abundant	tolerance	+	Percent of the top 3 abundant taxa of the total sample count
Clinger Richness	Trophic/Habit	-	Number of clinger taxa
% Clingers	Trophic/Habit	-	Percent of clinger taxa of the total sample count
% Filterers	Trophic/Habit	variable	Percent of the filterer taxa of the total sample count
% Predators	Trophic/Habit	-	Percent of the predator taxa of the total sample count
% Scrapers	Trophic/Habit	variable	Percent of the scraper of the total sample count
Long-Lived Richness	voltinism	-	Number of long-lived taxa

Selection of Metrics

In each given reference class, different community attributes may change along a human disturbance gradient. Metric sensitivity may be a function of prevalent land use gradients (e.g. urbanization and agriculture in the Puget Lowlands vs. logging and mining in the Cascade Mountains) and/or the intrinsic vulnerability of different community attributes in different settings. Overall metric sensitivity can be measured by comparing the values between reference and test sites. This comparison is typically done with Box and Whisker plots, and can be expressed numerically by its Discrimination Efficiency (DE; Stribling et al. 2000). The DE is the percentage of test sites that score below the 25th percentile of the companion reference class distribution in TwI (-) metrics, and above the 75th percentile in TwI (+) metrics. Metrics are only useful when they respond to pollution in a predictable way. A useful metric responds to either a specific stressor or to cumulative impacts.

> *The DE is a numerical description of the degree of separation between metric value distributions of "reference" and "degraded" sites and is calculated as:*
>
> $$DE = 100*(a/b)$$
>
> *Where a = the number of degraded samples scoring below the 25th or 75th percentile of the reference distribution and b = the total number of degraded samples (Stribling et al. 2000).*

We ranked the 20 candidate metric DE's, and selected metrics associated with the highest ten values for inclusion in the multimetric index. Other attributes of metric performance, however, excluded selection of candidate metrics, even if they have high DE's. Metrics are excluded when they have an insufficient range, or when they are correlated with other metrics with a higher DE. To avoid signal redundancy (i.e. Type I error), metrics with a rank correlation coefficient >0.9 were not used together in a multi-metric index for a given stream class. Metrics with correlation coefficients >0.8 were only used if absolutely necessary. It is also important to include metrics describing different aspects of community function in the overall index (Karr and Chu 1999). The diversity of component metrics increases the chance that community health is comprehensively evaluated. Furthermore, diverse component metrics improve diagnostic capacity.

Calibration of Metrics

When the ten component metrics are selected, the values were transformed into dimensionless units. This is done by trisecting the overall distribution (reference and test), excluding reference outliers. Reference outliers are defined by the 95th percentile for TwI (-) metrics and the 5th percentile for TwI (+) metrics (Stribling et al. 2000). Scores of 1, 3, and 5 are assigned to each trisection range.

Each visit in the calibration data set was then scored based on the ten metrics chosen, and their associated criteria. The ten scores for each visit were then summed to yield the multi-metric index score. The index scores are also interpreted with percentiles. Scores above the 25th percentile of reference index scores are interpreted as "good" (Stribling et al. 2000). The difference between the 25th reference percentile score and the minimum score is then bisected, with the upper half interpreted as "fair", and the lower half as "poor".

Assessment of the Multi-metric Index

A good DE of the calibration dataset indicates that the mechanics of the index are functioning properly. A low DE for a calibration dataset indicates that the index is not going to be sensitive. An assessment of the index DE with an independent dataset is also required to test performance while avoiding circularity. A DE higher than that calculated from the calibration dataset is a positive indicator of metric performance (Jessup and Stribling 2000). Confidence about each good-fair-poor cutpoint can be evaluated by evaluating visit replicates. Inter-annual and within-index period visit replicates are necessary to determine the sampling variability about these cutpoints.

Results

Classification

Classification schemes were evaluated for western Washington with 45 references sites distributed throughout the region (Figure 5). Presence/absence (P/A) clustering results indicate that many sites shared over 60% of their taxa, while a number of other sites shared less taxa (Figure 6). Classification strengths calculated from mean similarities show that the optimal partitioning strategy (cluster classes; BIO) partitioned much more variability than by grouping the reference sites by ecoregion (ECO) or geographic proximity (GP; Table 2). However, ECO and GP did produce classification strengths significantly better than random (Table 2).

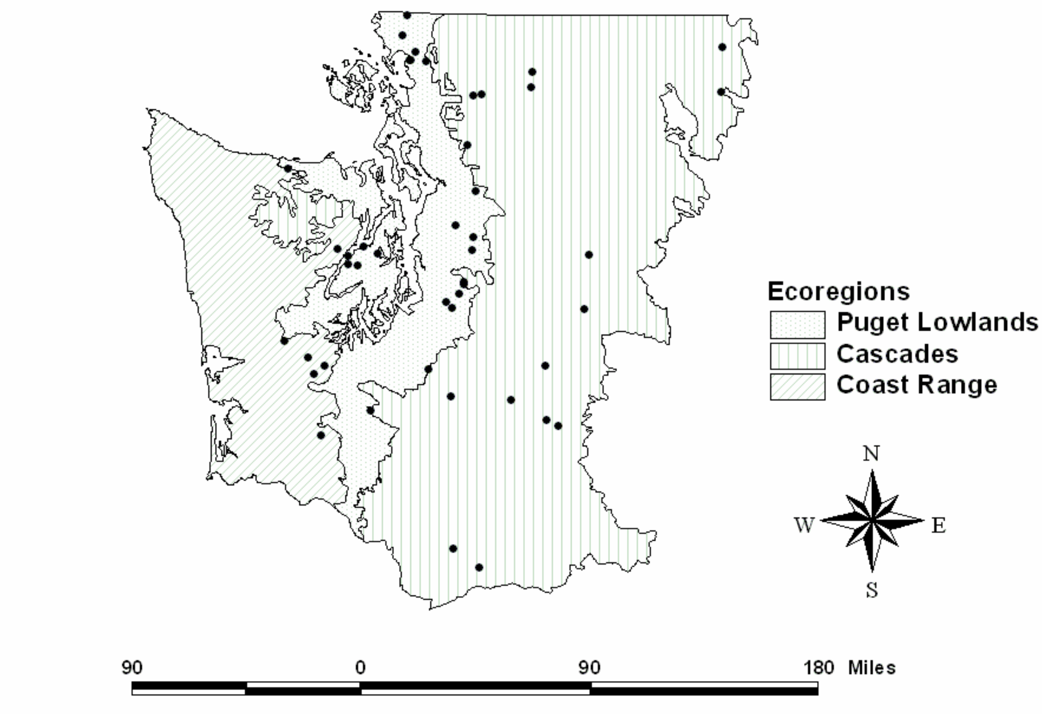

Figure 5. Reference sites used to evaluate alternative classification schemes in the Coast Range, Puget Lowlands, and combined Cascades Level III Omernik ecoregions (North Cascades, Cascades, and Eastern Slopes and Foothills).

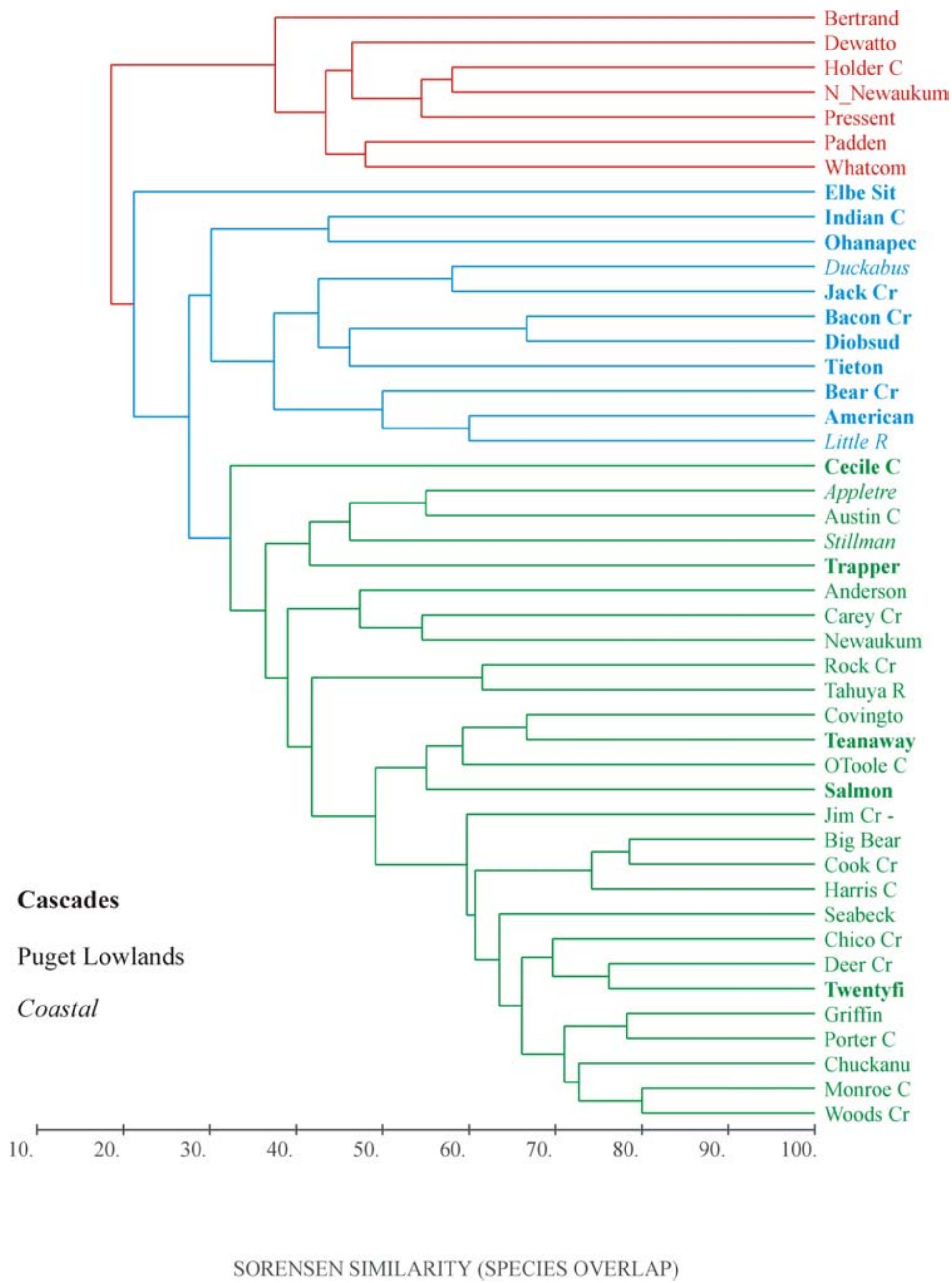

Figure 6. Cluster dendrogram of reference sites using a Sorensen similarity measure and an average linkage metric. Distinct clusters used for optimal variance partitioning are defined by the different colors.

Table 2. Classification strength of each classification scheme and associated results of "No Class Structure (NCS)" permutation tests.

Classification	No. of Classes	NCS Test?	Species Abundance W(bar)-B(Bar), p	Species Abundance B(bar)/W(bar), (p)
BIO	3	No	0.20	0.544
ECO	3	Yes	0.07, (<=0.0001)	0.800, (<=0.0001)
GP	3	Yes	0.04, (<=0.0009)	0.872, (<=0.0010)

The biologically based clusters had the lowest between-group similarity, and around 20% more species overlap within cluster classes, except for class 2, which had around 10% more species overlap (Figure 7). Class 2 was composed mostly of sites in the cascades. In the ecoregions scheme, the cascades class also had lowest within-group similarity (Figure 7). Finally, the geographical proximity scheme had worst overall scheme, with the within-group similarity sharing less than 8 percent more taxa than between groups (Figure 7).

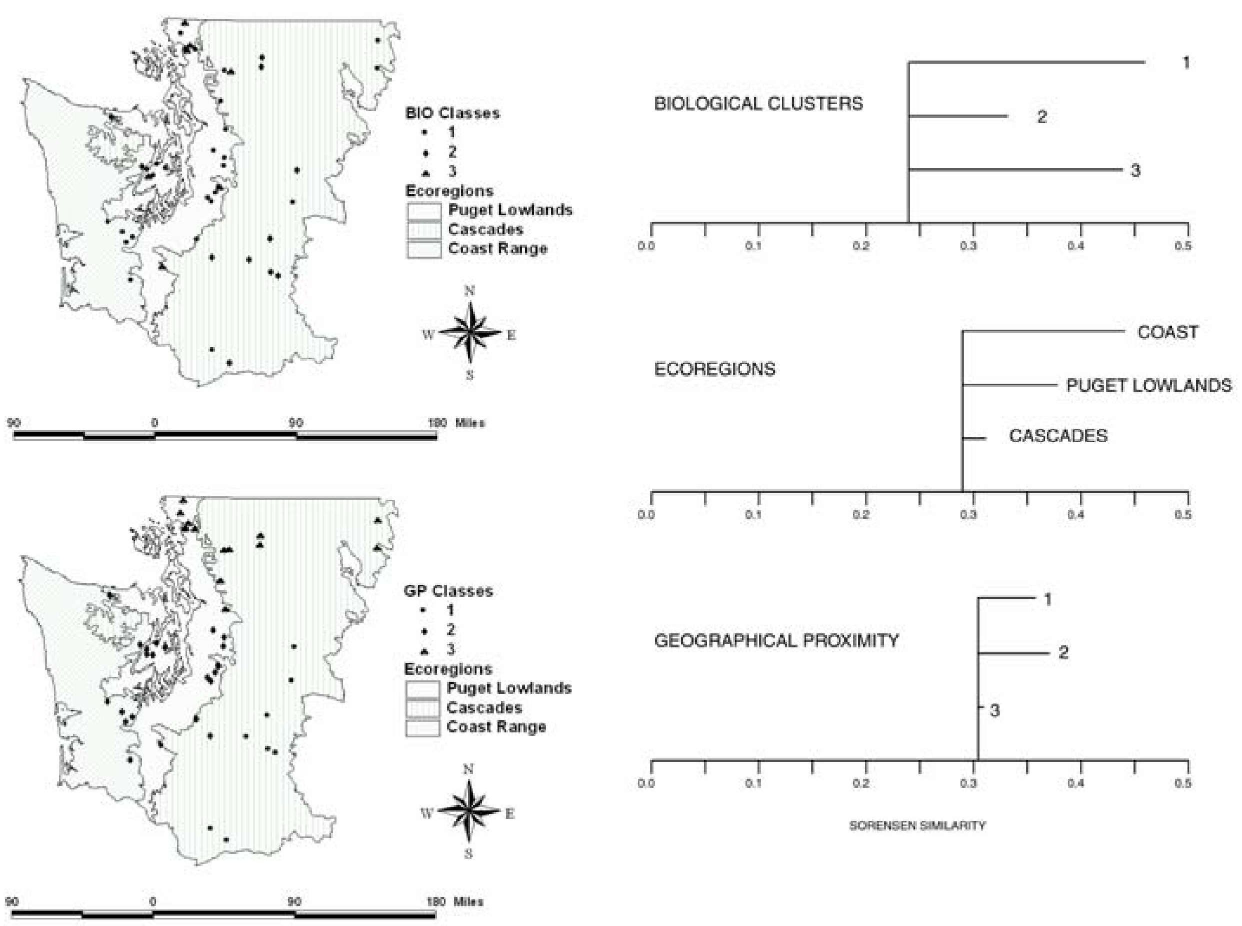

Figure 7. Mean Similarity dendrograms expressing the components of overall scheme classification strength. The vertical limb marks the between-class mean similarity, and the end of each horizontal node marks the within-group similarity of each reference class in a given scheme.

A similar pattern is shown by producing NMDS plots from the same similarity matrix. The first plot shows the high level of agreement with the cluster class results (Figure 8). The same plot labeled by ecoregion shows that ecoregions do account for biological structure (Figure 9). However, sites belonging to each ecoregion varied linearly, suggesting that an additional gradient(s) are present. The NMDS plot labeled by Geographic Proximity classes showed weak site grouping, suggesting that this scheme was not effective (Figure 10).

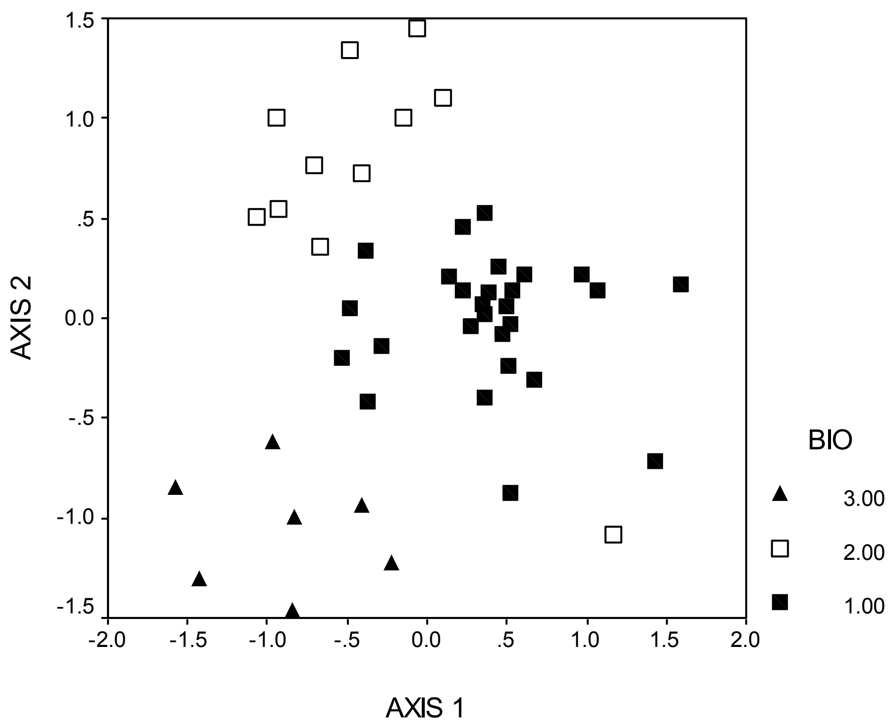

Figure 8. NMDS plot of reference sites labeled by biological cluster class membership.

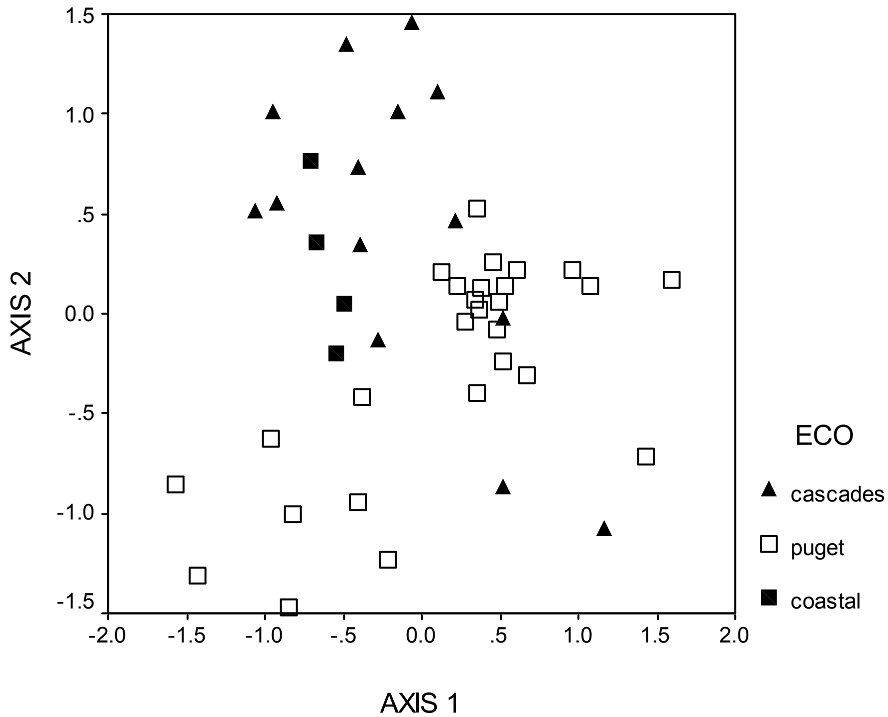

Figure 9. NMDS plot of reference sites labeled by ecoregion class membership.

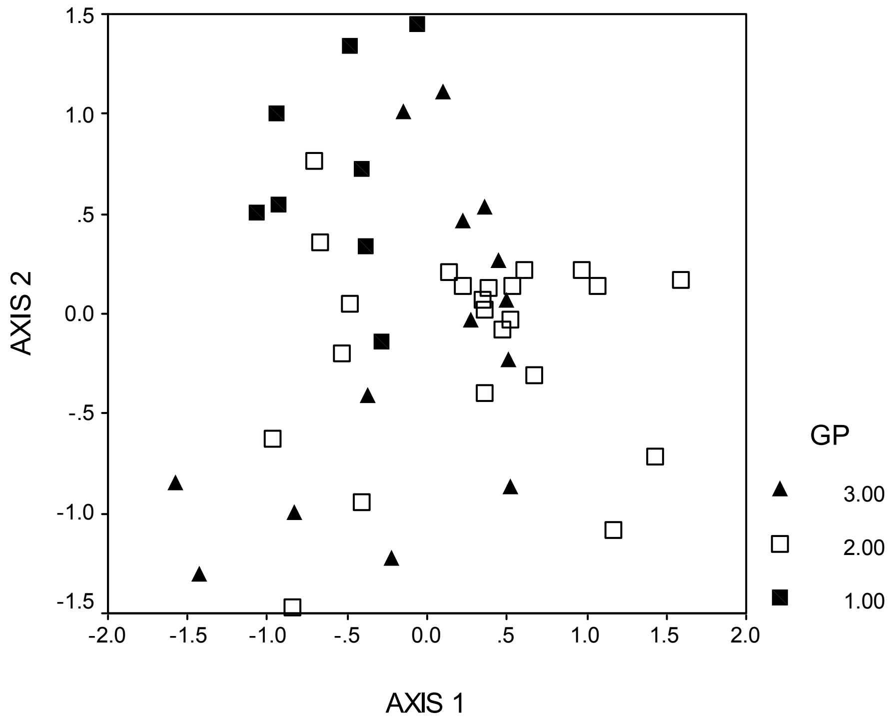

Figure 10. NMDS plot of reference sites labeled by Geographic Proximity class membership.

The BIO-ENV procedure was run four different times. The first time, the entire reference data set was used across all ecoregions, and the PCA plots were constrained to one variable. Possible variables included ecoregion, latitude, longitude, stream order, elevation, gradient, % boulder/cobble, % course gravel, % fine sediment (<16 mm), and bankfull width. Ecoregion was the single variable that had the best correspondence with the NMDS plot (Table 3). In order to investigate which variables were important within each ecoregion, the procedure was run again, with each ecoregion dataset, respectively. The PCA plots were run with all 3- variable combinations. Combinations of latitude, longitude, stream order, gradient, and bankfull width appeared to produce PCA plots that corresponded the best with the NMDS plots (Table 3). These variables could be candidates for further reference class partitioning, when more data become available.

Table 3. Harmonic correlations of site configuration overlap between the NMDS plot and PCA plots using the noted variables.

Site Group	Combinations	Variables	r
All Sites	1	Ecoregions	0.227
Coastal	3	Latitude Longitude, Stream Order	0.88
Puget Lowlands	3	Latitude Gradient Bankfull Width	0.135
Cascades	3	Stream Order Gradient Bankfull Width	0.441

Index Development

In the Puget Lowland and Cascades Ecoregions, metrics from each category (Appendix A) with the highest DE's were selected for the multi-metric index (Tables 4,5). In the Puget Lowlands, Clinger Richness, EPT richness, and Intolerant Richness (TV3) were excluded in order to reduce inter-correlated variables (Table 6). The HBI metric was not selected because three other metrics in the tolerance category were already selected. In the Cascades, EPT richness, and Intolerant Richness (TV3) were excluded in order to reduce inter-correlated variables (Table 7).

Table 4. Candidate metric Discrimination Efficiencies for the Puget Lowlands.

Metric	Category	DE	Used in Index
Ephemeroptera Richness	richness	61.5	Yes
% Tolerant (TV7)	tolerance	53.8	Yes
Clinger Richness	Trophic/Habit	53.8	No
EPT Richness	richness	50.0	No
Long-Lived Richness	voltinism	50.0	Yes
% top 3 abundant	tolerance	46.2	Yes
% Clingers	Trophic/Habit	42.3	Yes
Intolerant rRchness (bi)	tolerance	42.3	Yes
Intolerant Richness (TV3)	tolerance	42.3	No
Total Richness	richness	42.3	Yes
Trichoptera Richness	richness	42.3	Yes
% Predators	Trophic/Habit	38.5	Yes
HBI	tolerance	38.5	No
Plecoptera Richness	richness	34.6	Yes
% Ephemeroptera	Composition	34.6	No
% Tolerant (bi)	tolerance	30.8	No
% EPT	Composition	23.1	No
% Filterers	Trophic/Habit	19.2	No
% Chironomidae	Composition	15.4	No
% Scrapers	Trophic/Habit	15.4	No

Table 5. Candidate metric Discrimination Efficiencies for the Cascades.

Metric	Category	DE	Used in Index
% Filterers	Trophic/Habit	61.3	Yes
Intolerant Richness (TV3)	Tolerance	58.1	No
intolerant richness (bi)	Tolerance	51.6	Yes
HBI	Tolerance	48.4	Yes
% Clingers	Trophic/Habit	45.2	Yes
EPT Richness	Richness	45.2	No
Total Richness	Richness	38.7	Yes
% Tolerant (bi)	Tolerance	35.5	Yes
Plecoptera Richness	Richness	35.5	Yes
Trichoptera Richness	Richness	35.5	Yes
% Ephemeroptera	Composition	29.0	Yes
Clinger Richness	Trophic/Habit	29.0	Yes
% EPT	Composition	29.0	No
% Top 3 Abundant	Tolerance	22.6	No
Ephemeroptera Richness	Richness	22.6	No
% Chironomidae	Composition	19.4	No
% Predators	Trophic/Habit	12.9	No
% Tolerant (TV7)	Tolerance	12.9	No
Long-Lived Richness	Voltinism	12.9	No
% Scrapers	Trophic/Habit	0.0	No

Table 6. Kendall's Tau Rank Correlations between Puget Lowland metrics greater than 0.80.

Metrics		Tau
Clinger Richness	Ephemeroptera Richness	0.88
Clinger Richness	EPT Richness	0.87
Clinger Richness	Total Richness	0.82
Clinger Richness	Trichoptera Richness	0.81
Ephemeroptera Richness	EPT Richness	0.93
Ephemeroptera Richness	Intolerant Richness (TV3)	0.88
EPT Richness	Total Richness	0.92
EPT Richness	Trichoptera Richness	0.88
EPT Richness	Intolerant Richness (TV3)	0.95
Total Richness	Trichoptera Richness	0.84
Total Richness	Intolerant Richness (TV3)	0.90
Intolerant Richness (TV3)	Trichoptera Richness	0.81

Table 7. Kendall's Tau Rank Correlations between Cascades metrics greater than 0.80.

Metrics		Tau
Intolerant Richness (bi)	Intolerant Richness (TV3)	0.81
EPT Richness	Plecoptera Richness	0.85
EPT Richness	Total Richness	0.92
Plecoptera Richness	Intolerant Richness (TV3)	0.87
Total Richness	Intolerant Richness (TV3)	0.87

Scoring criteria for the selected metrics were determined by a trisection of the 5th and 95th percentiles of the entire dataset (reference and test) for each ecoregion, respectively (Table 8-9). The calibration dataset was then scored based on these criteria. These scores were then summed for each site visit to yield multi-metric index scores (Appendix B). The index impairment thresholds were determined (Table 10) and tested with the calibration dataset and independent datasets for each ecoregion, respectively (Table 11).

Table 8. Scoring criteria for Puget Lowland metrics selected for the multi-metric index.

		Percentiles		Scoring Criteria		
Category	Metric	5%	95%	1	3	5
Richness	total richness	12	45	<24	24-33	>33
Richness	Ephemeroptera Richness	1	9	<4	4-6	>6
Richness	Plecoptera Richness	0	9	<3	3-5	>5
Richness	Trichoptera Richness	0	10	<4	4-6	>6
Tolerance	intolerant richness (bi)	0	4	<2	2	>2
Tolerance	% Tolerant (TV7)	0	30	>19	11-19	<11
Tolerance	% top 3 abundant	36	89	>70	54-70	<54
Trophic/Habit	% Predators	1	30	<11	11-19	>19
Trophic/Habit	% Clingers	3	70	<26	26-47	>47
Voltinism	Long-Lived Richness	0	8	<3	3-5	>5

Table 9. Scoring criteria for Cascade metrics selected for the multi-metric index.

		Percentiles		Scoring Criteria		
Category	Metric	5%	95%	1	3	5
Composition	% Ephemeroptera	12	80	<35	35-57	>57
Richness	Total richness	21	68	<37	37-52	>52
Richness	Plecoptera Richness	0	14	<5	5-9	>9
Richness	Trichoptera Richness	5	16	<9	9-12	>12
Richness	Clinger Richness	7	21	<12	12-16	>16
Tolerance	Intolerant richness (bi)	1	14	<6	6-9	>9
Tolerance	% Tolerant (bi)	0	34	>23	12-23	<12
Tolerance	HBI	1.74	4.87	>3.8	2.8-3.8	<2.8
Trophic/Habit	% Clingers	0.16	72	<36	36-54	>54
Trophic/Habit	% Filterers	0	42	>28	15-28	<15

Table 10. Definitions of narrative assessments by ecoregion using index values.

Narrative Assessment	Percentile of reference index values	Puget Lowland s	Cascades
Good	≥25th	>30	>28
Fair	<25th	20- 30	23- 28
Poor	--	<20	<23

Table 11. Discrimination efficiencies of each index with the calibration dataset and an independent verification dataset.

	Puget Lowlands	Cascades
Calibration DE	61.53%	51.61%
Verification DE	80.00%	87.50%

Discussion

Classification

Level III ecoregions clearly partitioned a significant amount of biological variability. Ecoregions have been useful in different geographical areas (Rabeni and Doisy 2000, Feminella 2000, Gerritsen et al. 2000), at least as a primary stratification variable (Sandin and Johnson 2000). As more data are accrued, other landscape (latitude, stream order) and reach-scale (bankfull width, gradient) variables could be applied, and will likely partition more variability. This may be particularly true of the Cascades combined reference class. The more extreme topography and glacial influence of the North Cascades may prove to result in different biological assemblages, although this was not detected in the current classification data set. As more data are accrued, the robustness of the current classification scheme will be re-evaluated. The utility of an *a posteriori* classification scheme currently in use for Washington State (Hawkins and Ostermiller, In Prep) will also be evaluated for use with a mutimetric index.

Index Development

The two multi-metric indices described in this document reasonably represent macroinvertebrate community function. The functional representation in these indices should yield sensitivity to different types of disturbance. The Puget Lowland Index is similar to a current index used in the Pacific Northwest (Kleindl 1995; Fore et al. 1996; Karr 1998). The two major differences are 1) the Clingers are expressed as a percentage of the sample, rather than as richness metric, and 2) the % Tolerant metric was defined by the % taxa with tolerance values greater than 7, rather than the "highly" tolerant taxa.

The indices did a marginal job of correctly scoring the calibration sites as reference (good) or non-reference (fair or poor), with DE's of 64.5% (Puget Lowlands) and 51.6% (Cascades) (Table 11). In Wyoming, their index scores from their calibration data set agreed with an *a priori* reference status 81.3% of the time (Jessup and Stribling 2000). Our verification datasets had DE's of 80.0% (Puget Lowlands) and 87.5% (Cascades) (Table 11), which is comparable to Wyoming's verification DE of 87.9% (Jessup and Stribling 2000). The lower calibration DE's were probably caused by sites in the calibration data set that were termed non-reference due to slight human modification, that had little or no biological degradation. A "sub-reference" category may help solve this problem. The indices and their components can be tested over time, as they are applied to new reference and test sites. Development of independent disturbance variables at the reach and landscape scales would be an effective means of testing index sensitivity. The diagnostic capacity of the index and component metrics needs to be tested against specific stressors. The statistical attributes of the indices need to be investigated further. Within-season and inter-annual variability need to be estimated for each index. These estimates of variability will allow us to estimate confidence in scores that are near the narrative assessment thresholds.

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Appendix A

Class	site name	date	type	reference	HBI
Puget Lowlands	Austin Cr	07/11/2002	calibration	reference	3.94
Puget Lowlands	Bertrand Cr @ Bertheusen Park	09/10/1998	calibration	reference	4.26
Puget Lowlands	Big Bear Creek	09/14/1999	calibration	reference	4.85
Puget Lowlands	Carey Creek	08/17/1999	calibration	reference	4.87
Puget Lowlands	Chico Creek	08/19/1999	calibration	reference	5.32
Puget Lowlands	Chuckanut Cr @ Aroyo Park	07/11/2002	calibration	reference	4.88
Puget Lowlands	Covington Cr	08/18/1999	calibration	reference	3.43
Puget Lowlands	Deer Cr @ Deer Creek Drive	09/15/1999	calibration	reference	3.81
Puget Lowlands	Dewatto River	08/19/1998	calibration	reference	3.86
Puget Lowlands	Griffin Cr @ Trestle (Waterway 2000)	09/13/1999	calibration	reference	4.82
Puget Lowlands	Harris Creek	09/13/1999	calibration	reference	3.50
Puget Lowlands	Holder Cr nr Hobart	08/20/1998	calibration	reference	4.58
Puget Lowlands	Jim Cr nr Mouth	08/20/2001	calibration	reference	4.58
Puget Lowlands	N. Fork Newaukum R @ Watershed Bndry	08/17/1998	calibration	reference	3.90
Puget Lowlands	Newaukum Creek	08/18/1999	calibration	reference	3.66
Puget Lowlands	Rock Cr abv Summit-Landsberg Rd	09/09/1999	calibration	reference	5.95
Puget Lowlands	Seabeck Cr nr mouth	08/05/2002	calibration	reference	5.05
Puget Lowlands	Tahuya R	08/19/1998	calibration	reference	4.52
Puget Lowlands	Upper Tahuya R	09/10/1999	calibration	reference	5.05
Puget Lowlands	Whatcom Cr blw Whatcom Falls	09/11/1998	calibration	reference	4.55
Puget Lowlands	Woods Cr abv Woods Cr Rd.	09/13/1999	calibration	reference	4.49
Puget Lowlands	Catherine Cr nr mouth	09/16/1997	calibration	Test	4.71
Puget Lowlands	Chambers Cr at Steilacoom Lake	09/18/1997	calibration	Test	4.43
Puget Lowlands	Dungeness R	09/19/1994	calibration	Test	3.28
Puget Lowlands	Hylebos Creek	08/16/1999	calibration	Test	6.19
Puget Lowlands	Little Anderson Cr	08/19/1999	calibration	Test	6.57
Puget Lowlands	Little Pilchuck Cr	09/16/1997	calibration	Test	3.23
Puget Lowlands	McSorley Creek @ Saltwater St. Park	08/17/1999	calibration	Test	5.89
Puget Lowlands	Newaukum Cr at 212th St	09/03/1997	calibration	Test	3.93
Puget Lowlands	North Fork Dakota Cr at Stein Rd	09/17/1996	calibration	Test	4.88
Puget Lowlands	Padden Cr at Fairhaven Park	09/12/1996	calibration	Test	5.05
Puget Lowlands	Padden Cr at Lake Padden Park	09/09/1996	calibration	Test	2.69
Puget Lowlands	Pilchuck Cr @ Hi-Way 9	09/06/2001	calibration	Test	4.24
Puget Lowlands	Pilchuck Cr @ I-5	09/06/2001	calibration	Test	4.07
Puget Lowlands	Portage Cr 1	09/18/1995	calibration	Test	4.59
Puget Lowlands	Portage Cr 2	09/05/2001	calibration	Test	5.24
Puget Lowlands	Portage Cr 3	09/05/2001	calibration	Test	4.26
Puget Lowlands	Samish R	09/15/1995	calibration	Test	3.35
Puget Lowlands	Siebert Cr blw SR101	09/21/1994	calibration	Test	3.91
Puget Lowlands	Smith Cr at Cedarville Br	09/10/1996	calibration	Test	5.44
Puget Lowlands	South Prairie Cr at Burnett	03/09/1997	calibration	Test	4.76
Puget Lowlands	Squalicum Cr at Cornwall Park	09/11/1996	calibration	Test	5.60
Puget Lowlands	Sumas River blw Swift Cr	09/12/1996	calibration	Test	5.54
Puget Lowlands	Swamp Creek @ Bothel Way	08/12/1999	calibration	Test	5.65
Puget Lowlands	Upper Padden Cr	09/10/1998	calibration	Test	4.42
Puget Lowlands	Wapato Creek @ Freeman Rd	08/16/1999	calibration	Test	6.16
Puget Lowlands	Woods Cr at Calhoun Rd	09/17/1997	calibration	Test	4.46
Puget Lowlands	Quilceda Creek, Station 44N	09/23/1996	verification	reference	4.24
Puget Lowlands	68i	09/18/1996	verification	Test	4.87
Puget Lowlands	Edgecomb Creek, Station 60D	09/19/1996	verification	Test	2.86
Puget Lowlands	Munson Creek, Station 73C	09/23/1996	verification	Test	5.58
Puget Lowlands	Munson Creek, Station 73B	09/25/1996	verification	Test	7.48
Puget Lowlands	Munson Creek, Station 73D	09/18/1996	verification	Test	4.80
Puget Lowlands	Quilceda Creek, Station 44H	09/20/1996	verification	Test	5.20
Puget Lowlands	Quilceda Creek, Station 49B	09/20/1996	verification	Test	5.62

Class	site name	date	type	reference	HBI
Puget Lowlands	Mid. Fk. Quilceda Creek, Station 58B	09/19/1996	verification	Test	5.47
Puget Lowlands	Mid. Fk. Quilceda Creek, Station 58F	09/19/1996	verification	Test	4.18
Puget Lowlands	Armstrong Cr	09/04/2001	verification	Test	5.45
Puget Lowlands	Bear Creek-Little	08/12/1999	verification	Test	6.03
Puget Lowlands	Big Soos Cr at 208th St	09/04/1997	verification	Test	5.70
Puget Lowlands	California Cr at Bruce Rd	09/17/1996	verification	Test	6.82
Puget Lowlands	Canyon Cr	09/04/2001	verification	Test	4.13
Cascades	American R @ Bumping R Rd.	07/24/2002	calibration	reference	2.20
Cascades	American R. @ Hells Crossing	09/29/2000	calibration	reference	2.21
Cascades	Bacon Creek	09/13/2000	calibration	reference	3.32
Cascades	Bear Cr	09/29/2000	calibration	reference	1.68
Cascades	Bear Cr nr Carson	09/11/2001	calibration	reference	3.03
Cascades	Boulder Cr @ Highway 530	07/31/2001	calibration	reference	4.57
Cascades	Cecile Cr	08/28/1997	calibration	reference	2.95
Cascades	Diobsud Cr	10/11/2002	calibration	reference	2.82
Cascades	Elbe Site (unnamed)	10/12/1995	calibration	reference	2.50
Cascades	Indian Cr at SR12	09/23/1993	calibration	reference	3.25
Cascades	Jack Cr nr Rock Is. Campground	09/22/2000	calibration	reference	1.77
Cascades	Jim Cr	09/14/1999	calibration	reference	5.00
Cascades	Jim Cr @ Naval Station	08/20/2001	calibration	reference	3.09
Cascades	Middle Fork Teanaway R	08/14/2002	calibration	reference	2.68
Cascades	Ohanapecosh R	08/27/1993	calibration	reference	4.57
Cascades	OToole Cr @ Skagit Valley Highway	09/15/1999	calibration	reference	3.70
Cascades	Pressentin Cr nr mouth	09/09/1998	calibration	reference	3.47
Cascades	S. Fork Tieton R.	09/28/2000	calibration	reference	1.83
Cascades	South Fork Manastash Cr	09/21/2000	calibration	reference	1.77
Cascades	South Fork Salmon Cr	09/09/1997	calibration	reference	4.00
Cascades	Squire Cr nr Mouth	07/31/2001	calibration	reference	3.10
Cascades	Trapper Cr at Trapper Cr Wilderness	08/07/2002	calibration	reference	4.60
Cascades	Little Beaver Creek	08/21/2001	calibration	reference	1.21
Cascades	Diobsud Creek Upper	08/19/2002	calibration	reference	1.74
Cascades	Goodell Creek Upper	09/12/2000	calibration	reference	2.32
Cascades	McAlester Creek- Stehekin	09/13/2001	calibration	reference	3.12
Cascades	Bridge Creek South Fork	09/12/2001	calibration	reference	2.50
Cascades	Deer Cr @ RM 1.0	07/31/2001	calibration	Test	3.77
Cascades	Finney Cr	09/12/1995	calibration	Test	2.88
Cascades	Gold Cr	10/10/1993	calibration	Test	4.66
Cascades	Grant Cr	09/20/1995	calibration	Test	4.70
Cascades	Green R at Kanasket	09/29/1994	calibration	Test	3.19
Cascades	Huckleberry Cr (WRIA 10)	09/05/1997	calibration	Test	4.60
Cascades	Hutchinson Cr at DNR campground	09/10/1996	calibration	Test	3.84
Cascades	Illabot Cr	09/12/1995	calibration	Test	5.05
Cascades	Jackman Cr	09/13/1995	calibration	Test	4.86
Cascades	Little Deer Cr nr Mouth	08/02/2001	calibration	Test	3.33
Cascades	Little Naches R	09/20/1993	calibration	Test	3.13
Cascades	Long Cr	09/19/1995	calibration	Test	3.22
Cascades	Loup Loup Cr	09/10/1997	calibration	Test	3.75
Cascades	Methow R at Mazama	09/11/1997	calibration	Test	2.99
Cascades	Middle Fork Toats Coulee Cr	09/06/1996	calibration	Test	2.82
Cascades	N. Fork Stillaguamish R @ Hazel	08/01/2001	calibration	Test	4.12
Cascades	N. Fork Stillaguamish R @ RM39	07/30/2001	calibration	Test	3.92
Cascades	N.F. Teanaway	08/14/2002	calibration	Test	2.69
Cascades	North Fork Toats Coulee Cr	08/29/1997	calibration	Test	2.98
Cascades	Racehorse Cr	09/10/1996	calibration	Test	3.60
Cascades	Rattlesnake Cr	08/10/1993	calibration	Test	3.30

Class	site name	date	type	reference	HBI
Cascades	Sarsapkin Cr	09/11/1996	calibration	Test	3.06
Cascades	Simmons Cr	10/11/1995	calibration	Test	2.70
Cascades	South Fork Toats Coulee Cr	08/28/1997	calibration	Test	3.02
Cascades	Swauk Cr at Mineral Springs	08/13/1993	calibration	Test	4.06
Cascades	Taylor Cr	10/13/1994	calibration	Test	3.78
Cascades	Thompson Cr nr mouth	09/16/1996	calibration	Test	3.26
Cascades	Twentyfivemile Cr	09/18/1997	calibration	Test	4.82
Cascades	Twisp R at W. Buttermilk Cr Rd	09/10/1997	calibration	Test	3.62
Cascades	W.F. Teanaway	08/14/2002	calibration	Test	3.32
Cascades	Yakima River, Upper Hansen	09/25/2002	calibration	Test	3.07
Cascades	Newhalem Creek	09/11/2000	verification	reference	2.55
Cascades	McAllister Creek- Thunder	09/26/2001	verification	reference	1.15
Cascades	Park Creek	09/19/2001	verification	reference	1.06
Cascades	Chilliwack Reach 1	09/16/1999	verification	reference	2.47
Cascades	Chilliwack Indian Camp (Reach 4)	09/16/1999	verification	reference	2.18
Cascades	Chilliwack Above US Cabin (Reach 5)	09/15/1999	verification	reference	1.54
Cascades	Chilliwack River above Easy Creek (Reach 6)	09/15/1999	verification	reference	1.03
Cascades	Lightning Creek	09/09/1999	verification	reference	2.49
Cascades	Happy Creek	09/09/2001	verification	reference	2.00
Cascades	Marble Creek	09/26/2000	verification	reference	3.26
Cascades	Breckenridge Cr blw South Pass Rd	09/12/1996	verification	Test	4.58
Cascades	Butter Creek at FR5290	08/27/1993	verification	Test	4.32
Cascades	Chewack R	09/11/1997	verification	Test	2.89
Cascades	Clearwater R	09/05/1997	verification	Test	4.72
Cascades	Deer Cr @ RM 0.5	09/20/1995	verification	Test	4.71

% Tolerant (bi)	% Chironomidae	% Clingers	% Ephemeroptera	% EPT	% Filterers	% Predators	% Scrapers	% Top 3 Abundant	% Tolerant (TV7)
0.34	0.12	0.30	0.55	0.74	0.00	0.12	0.20	0.48	0.02
0.02	0.19	0.35	0.14	0.49	0.01	0.19	0.28	0.55	0.22
0.14	0.32	0.39	0.09	0.32	0.13	0.01	0.25	0.54	0.14
0.24	0.21	0.42	0.38	0.50	0.15	0.06	0.16	0.59	0.05
0.05	0.17	0.72	0.12	0.19	0.63	0.04	0.06	0.84	0.00
0.05	0.48	0.26	0.22	0.29	0.01	0.05	0.15	0.63	0.08
0.08	0.13	0.55	0.20	0.69	0.12	0.05	0.34	0.49	0.10
0.09	0.12	0.31	0.34	0.66	0.22	0.08	0.08	0.54	0.00
0.02	0.31	0.23	0.16	0.60	0.13	0.18	0.05	0.53	0.01
0.35	0.06	0.47	0.39	0.67	0.35	0.05	0.07	0.67	0.02
0.11	0.15	0.42	0.29	0.66	0.12	0.09	0.17	0.40	0.07
0.00	0.24	0.40	0.35	0.50	0.23	0.07	0.11	0.61	0.01
0.35	0.11	0.56	0.30	0.38	0.22	0.07	0.09	0.55	0.04
0.02	0.12	0.62	0.32	0.63	0.29	0.10	0.27	0.43	0.01
0.16	0.15	0.42	0.38	0.55	0.01	0.03	0.32	0.42	0.07
0.09	0.41	0.08	0.03	0.15	0.01	0.03	0.00	0.77	0.30
0.42	0.27	0.17	0.48	0.58	0.11	0.07	0.04	0.71	0.02
0.02	0.53	0.21	0.13	0.37	0.03	0.15	0.06	0.58	0.02
0.01	0.71	0.11	0.19	0.25	0.01	0.04	0.07	0.88	0.01
0.18	0.08	0.58	0.20	0.38	0.40	0.10	0.10	0.58	0.00
0.14	0.27	0.47	0.21	0.49	0.28	0.05	0.14	0.60	0.00
0.32	0.19	0.35	0.15	0.39	0.12	0.11	0.18	0.35	0.07
0.06	0.05	0.84	0.06	0.80	0.83	0.01	0.00	0.89	0.01
0.22	0.09	0.25	0.54	0.77	0.14	0.14	0.15	0.48	0.05
0.07	0.55	0.03	0.01	0.01	0.00	0.01	0.04	0.88	0.21
0.00	0.48	0.03	0.00	0.04	0.01	0.05	0.00	0.89	0.41
0.08	0.07	0.68	0.27	0.72	0.37	0.04	0.28	0.57	0.02
0.19	0.15	0.22	0.19	0.35	0.21	0.02	0.00	0.67	0.28
0.21	0.23	0.30	0.38	0.61	0.08	0.02	0.22	0.55	0.03
0.20	0.24	0.00	0.31	0.47	0.24	0.10	0.01	0.68	0.03
0.32	0.18	0.20	0.28	0.50	0.09	0.14	0.08	0.50	0.13
0.05	0.04	0.04	0.05	0.69	0.04	0.60	0.05	0.68	0.14
0.19	0.23	0.44	0.24	0.41	0.10	0.03	0.16	0.46	0.13
0.17	0.14	0.49	0.32	0.47	0.20	0.03	0.23	0.48	0.10
0.00	0.00	0.11	0.59	0.70	0.09	0.23	0.01	0.90	0.05
0.19	0.12	0.29	0.25	0.38	0.06	0.08	0.04	0.54	0.24
0.04	0.21	0.29	0.21	0.50	0.03	0.12	0.25	0.35	0.21
0.01	0.00	0.49	0.45	0.49	0.04	0.34	0.43	0.81	0.10
0.08	0.01	0.38	0.33	0.62	0.23	0.25	0.22	0.38	0.04
0.12	0.21	0.21	0.06	0.21	0.00	0.15	0.00	0.56	0.29
0.22	0.07	0.63	0.31	0.45	0.44	0.03	0.15	0.66	0.03
0.39	0.30	0.06	0.02	0.10	0.03	0.08	0.02	0.71	0.09
0.67	0.09	0.04	0.57	0.58	0.04	0.18	0.00	0.76	0.00
0.29	0.33	0.25	0.12	0.24	0.01	0.05	0.07	0.56	0.12
0.00	0.25	0.28	0.13	0.41	0.30	0.12	0.04	0.52	0.03
0.01	0.75	0.03	0.01	0.01	0.02	0.04	0.00	0.88	0.14
0.23	0.06	0.55	0.25	0.72	0.41	0.02	0.05	0.62	0.05
0.09	0.04	0.44	0.19	0.64	0.19	0.18	0.21	0.40	0.22
0.41	0.07	0.19	0.46	0.67	0.08	0.11	0.02	0.56	0.12
0.03	0.15	0.27	0.18	0.65	0.01	0.25	0.16	0.35	0.04
0.50	0.05	0.28	0.41	0.61	0.25	0.01	0.07	0.67	0.13
0.16	0.03	0.07	0.02	0.02	0.06	0.02	0.06	0.82	0.74
0.30	0.08	0.38	0.30	0.59	0.33	0.07	0.09	0.52	0.07
0.43	0.10	0.15	0.37	0.48	0.00	0.03	0.18	0.46	0.19
0.51	0.17	0.20	0.45	0.52	0.16	0.05	0.00	0.69	0.07

% Tolerant (bi)	% Chironomidae	% Clingers	% Ephemeroptera	% EPT	% Filterers	% Predators	% Scrapers	% Top 3 Abundant	% Tolerant (TV7)
0.36	0.41	0.03	0.09	0.11	0.03	0.11	0.03	0.57	0.13
0.30	0.10	0.35	0.47	0.71	0.08	0.19	0.15	0.53	0.01
0.15	0.14	0.34	0.15	0.23	0.13	0.02	0.08	0.57	0.31
0.36	0.35	0.13	0.35	0.39	0.08	0.01	0.02	0.82	0.13
0.20	0.48	0.15	0.06	0.11	0.05	0.02	0.12	0.63	0.11
0.11	0.37	0.00	0.01	0.01	0.00	0.00	0.01	0.82	0.46
0.40	0.03	0.36	0.66	0.78	0.13	0.07	0.14	0.64	0.01
0.13	0.08	0.62	0.73	0.85	0.00	0.10	0.48	0.49	0.03
0.00	0.02	0.32	0.25	0.96	0.00	0.07	0.82	0.80	0.01
0.46	0.02	0.40	0.84	0.95	0.00	0.06	0.28	0.76	0.02
0.00	0.05	0.75	0.29	0.88	0.03	0.10	0.61	0.61	0.05
0.14	0.05	0.55	0.33	0.78	0.07	0.13	0.34	0.42	0.12
0.00	0.35	0.24	0.40	0.49	0.13	0.08	0.09	0.70	0.02
0.10	0.02	0.34	0.31	0.72	0.06	0.21	0.14	0.08	0.06
0.14	0.04	0.34	0.42	0.79	0.02	0.33	0.26	0.64	0.15
0.01	0.10	0.22	0.05	0.32	0.01	0.16	0.07	0.48	0.08
0.01	0.00	0.34	0.23	0.64	0.06	0.32	0.22	0.46	0.04
0.02	0.01	0.59	0.51	0.86	0.00	0.07	0.65	0.58	0.11
0.34	0.16	0.31	0.40	0.57	0.16	0.06	0.08	0.58	0.06
0.17	0.15	0.34	0.28	0.65	0.12	0.07	0.11	0.46	0.02
0.20	0.03	0.54	0.58	0.76	0.07	0.09	0.17	0.48	0.03
0.02	0.00	0.75	0.21	0.28	0.69	0.07	0.13	0.75	0.01
0.01	0.20	0.33	0.20	0.65	0.06	0.14	0.33	0.41	0.11
0.08	0.11	0.41	0.27	0.67	0.03	0.19	0.29	0.30	0.05
0.01	0.05	0.69	0.54	0.78	0.15	0.13	0.43	0.61	0.01
0.02	0.02	0.57	0.32	0.93	0.02	0.10	0.56	0.49	0.02
0.24	0.18	0.56	0.26	0.50	0.07	0.07	0.23	0.50	0.00
0.00	0.42	0.11	0.47	0.56	0.01	0.05	0.08	0.76	0.01
0.34	0.17	0.28	0.42	0.53	0.13	0.08	0.04	0.56	0.03
0.00	0.05	0.58	0.76	0.92	0.01	0.09	0.47	0.60	0.00
0.08	0.03	0.45	0.80	0.93	0.00	0.11	0.41	0.51	0.02
0.00	0.01	0.37	0.91	0.94	0.00	0.02	0.37	0.77	0.04
0.03	0.19	0.38	0.35	0.61	0.00	0.16	0.27	0.59	0.18
0.05	0.05	0.30	0.32	0.74	0.02	0.12	0.41	0.44	0.16
0.05	0.47	0.21	0.22	0.30	0.04	0.07	0.06	0.57	0.11
0.10	0.00	0.28	0.60	0.77	0.11	0.15	0.24	0.40	0.01
0.02	0.09	0.72	0.20	0.35	0.55	0.02	0.14	0.70	0.00
0.10	0.00	0.27	0.36	0.38	0.23	0.37	0.03	0.71	0.02
0.04	0.15	0.37	0.15	0.52	0.11	0.06	0.02	0.40	0.07
0.36	0.20	0.24	0.50	0.65	0.08	0.09	0.11	0.64	0.04
0.21	0.04	0.51	0.42	0.60	0.13	0.14	0.20	0.50	0.04
0.00	0.00	0.30	0.12	0.26	0.02	0.67	0.11	0.79	0.04
0.00	0.00	0.56	0.18	0.28	0.41	0.34	0.16	0.78	0.04
0.34	0.05	0.33	0.62	0.83	0.13	0.08	0.20	0.49	0.01
0.18	0.00	0.57	0.33	0.63	0.15	0.29	0.25	0.44	0.01
0.13	0.00	0.10	0.61	0.86	0.03	0.11	0.17	0.45	0.01
0.16	0.06	0.58	0.22	0.68	0.32	0.12	0.14	0.41	0.01
0.12	0.26	0.38	0.50	0.72	0.00	0.17	0.23	0.50	0.01
0.10	0.02	0.37	0.29	0.73	0.05	0.26	0.12	0.10	0.04
0.29	0.14	0.41	0.62	0.70	0.13	0.07	0.14	0.54	0.01
0.23	0.16	0.40	0.46	0.58	0.04	0.08	0.18	0.38	0.10
0.07	0.10	0.55	0.48	0.72	0.07	0.16	0.22	0.34	0.03
0.05	0.02	0.31	0.30	0.65	0.04	0.24	0.16	0.08	0.05
0.12	0.05	0.17	0.43	0.67	0.07	0.18	0.08	0.23	0.12
0.24	0.00	0.44	0.27	0.58	0.07	0.26	0.14	0.34	0.01

% Tolerant (bi)	% Chironomidae	% Clingers	% Ephemeroptera	% EPT	% Filterers	% Predators	% Scrapers	% Top 3 Abundant	% Tolerant (TV7)
0.09	0.00	0.28	0.25	0.73	0.03	0.20	0.16	0.08	0.08
0.13	0.09	0.19	0.31	0.66	0.04	0.15	0.19	0.34	0.01
0.04	0.02	0.30	0.34	0.71	0.06	0.20	0.19	0.09	0.05
0.27	0.00	0.46	0.24	0.42	0.05	0.33	0.21	0.56	0.02
0.07	0.00	0.34	0.32	0.50	0.24	0.26	0.20	0.37	0.04
0.02	0.09	0.30	0.46	0.70	0.10	0.10	0.26	0.28	0.07
0.27	0.05	0.48	0.36	0.57	0.40	0.04	0.10	0.71	0.01
0.19	0.29	0.29	0.36	0.64	0.00	0.23	0.10	0.61	0.01
0.09	0.07	0.55	0.33	0.76	0.30	0.10	0.12	0.43	0.01
0.04	0.59	0.24	0.09	0.25	0.09	0.02	0.07	0.64	0.03
0.17	0.04	0.37	0.76	0.82	0.00	0.05	0.30	0.60	0.02
0.01	0.03	0.56	0.70	0.95	0.00	0.05	0.41	0.64	0.01
0.02	0.03	0.61	0.58	0.91	0.03	0.14	0.60	0.60	0.00
0.14	0.02	0.29	0.71	0.96	0.01	0.03	0.34	0.51	0.01
0.04	0.07	0.43	0.70	0.89	0.02	0.16	0.44	0.47	0.00
0.05	0.03	0.51	0.78	0.93	0.00	0.07	0.20	0.68	0.01
0.04	0.03	0.73	0.82	0.93	0.00	0.07	0.54	0.72	0.02
0.04	0.02	0.49	0.68	0.77	0.00	0.03	0.45	0.66	0.20
0.01	0.11	0.28	0.31	0.76	0.02	0.15	0.21	0.31	0.02
0.04	0.00	0.33	0.70	0.80	0.01	0.04	0.33	0.78	0.19
0.02	0.09	0.16	0.27	0.42	0.43	0.05	0.11	0.64	0.02
0.02	0.00	0.56	0.15	0.39	0.37	0.27	0.05	0.55	0.03
0.22	0.05	0.63	0.49	0.77	0.11	0.11	0.31	0.36	0.00
0.12	0.32	0.35	0.24	0.38	0.21	0.06	0.06	0.63	0.00
0.15	0.00	0.18	0.35	0.42	0.15	0.47	0.16	0.75	0.02

Intolerant Richness (bi)	Clinger Richness	Ephemeroptera Richness	EPT Richness	Plecoptera Richness	Long-Lived Richness	Total Richness	Trichoptera Richness	Intolerant Richness (TV3)
11	21	14	36	12	11	52	10	33
2	13	6	18	5	4	33	7	15
1	9	5	13	1	1	24	7	8
4	13	8	19	3	2	30	8	14
1	9	4	12	6	4	19	2	8
3	15	7	20	7	5	36	6	16
2	16	8	22	5	6	32	9	15
1	7	5	15	6	2	23	4	13
0	10	5	15	6	5	28	4	8
2	15	8	18	5	7	30	5	12
2	15	9	20	3	5	32	8	15
1	11	5	20	6	4	31	9	13
1	16	8	21	5	4	33	8	16
2	13	6	15	5	6	29	4	12
3	13	4	15	4	5	31	7	12
2	9	4	12	3	4	24	5	10
2	12	6	18	8	5	30	4	16
0	9	5	13	6	5	24	2	9
0	7	4	9	3	4	17	2	7
2	9	4	11	3	2	20	4	8
0	14	8	18	4	6	29	6	12
2	16	9	28	9	8	49	10	17
0	3	1	2	0	0	9	1	0
4	7	6	15	6	1	21	3	12
0	1	1	1	0	2	11	0	0
0	5	1	7	4	2	18	2	5
1	12	8	23	5	5	36	10	15
0	6	3	7	2	2	17	2	4
2	15	7	18	2	4	30	9	14
3	2	4	15	8	4	27	3	11
1	12	7	20	5	4	38	8	16
1	2	4	11	3	1	29	4	10
1	17	7	20	5	6	33	8	15
1	10	4	11	5	5	28	2	10
2	5	1	6	0	1	16	5	4
0	11	4	15	5	4	31	6	12
2	12	6	19	6	6	36	7	15
0	6	4	7	0	0	14	3	4
1	9	6	17	6	2	31	5	11
1	4	2	7	3	4	16	2	5
1	16	8	22	4	6	30	10	16
0	6	3	12	3	1	27	6	7
0	1	2	3	1	1	15	0	2
0	10	4	9	1	4	23	4	4
0	5	4	13	5	2	25	4	10
0	2	1	2	0	1	17	1	1
1	13	7	19	5	6	34	7	13
3	11	5	20	6	3	38	9	18
2	6	3	11	4	2	25	4	10
8	10	6	25	9	6	47	10	21
1	4	3	6	0	4	21	3	4
0	2	1	1	0	2	15	0	1
2	7	5	16	5	3	30	6	14
1	6	5	10	3	3	22	2	9
1	5	2	7	2	3	24	3	6

Intolerant Richness (bi)	Clinger Richness	Ephemeroptera Richness	EPT Richness	Plecoptera Richness	Long-Lived Richness	Total Richness	Trichoptera Richness	Intolerant Richness (TV3)
1	5	5	9	3	5	35	1	5
5	16	8	28	10	6	44	10	25
0	9	7	15	4	5	30	4	10
1	9	5	11	1	3	21	5	6
0	5	4	10	3	1	24	3	5
0	1	1	1	0	0	15	0	0
2	10	7	15	5	3	25	3	13
5	20	13	27	5	7	41	9	25
4	13	8	24	5	4	30	11	21
8	14	10	25	6	2	37	9	25
12	24	12	36	12	6	51	12	33
6	18	8	25	6	6	38	11	21
1	13	11	20	3	2	31	6	12
14	19	17	43	12	9	62	14	31
4	13	10	24	5	4	34	9	21
12	10	7	24	10	5	40	7	21
7	11	9	24	5	2	34	10	18
10	14	7	25	9	4	34	9	23
1	15	7	19	5	6	29	7	13
4	17	10	25	7	5	37	8	21
4	20	11	25	5	7	38	9	21
7	13	11	27	11	4	39	5	22
1	13	8	22	4	4	34	10	15
4	18	7	26	8	5	42	11	21
7	13	12	28	7	2	34	9	24
5	20	8	28	7	9	42	13	25
8	20	10	29	5	7	40	14	24
1	12	7	19	7	2	29	5	14
5	20	14	32	5	5	47	13	24
10	10	10	27	11	1	37	6	23
6	14	12	29	9	3	36	8	26
4	8	8	16	3	1	21	5	14
13	14	11	32	12	4	39	9	28
16	13	11	39	12	3	49	16	32
2	11	12	20	2	1	32	6	15
3	12	11	21	4	5	31	6	12
2	7	7	16	4	0	21	5	11
1	7	8	12	0	1	21	4	7
5	17	6	23	7	9	34	10	18
6	16	12	27	9	3	35	6	25
7	16	13	30	9	6	42	8	22
1	12	5	13	0	2	23	8	10
0	6	5	9	0	0	14	4	6
4	13	12	25	5	3	35	8	19
10	21	11	32	12	10	43	9	26
5	13	14	28	5	5	41	9	18
7	14	7	24	6	7	38	11	20
3	13	11	29	11	4	36	7	26
7	19	18	42	11	9	58	13	29
2	10	10	19	4	3	26	5	15
3	14	8	19	4	5	34	7	16
1	20	9	27	6	7	44	12	24
13	20	20	46	12	8	68	14	34
2	7	9	17	3	3	28	5	9
4	14	11	25	7	9	43	7	19

Intolerant Richness (bi)	Clinger Richness	Ephemeroptera Richness	EPT Richness	Plecoptera Richness	Long-Lived Richness	Total Richness	Trichoptera Richness	Intolerant Richness (TV3)
18	21	18	53	17	13	77	18	37
14	16	10	34	16	7	51	8	30
13	20	22	50	12	8	68	16	34
3	16	9	19	5	7	33	5	15
3	12	5	13	2	7	25	6	8
12	14	21	50	14	2	62	15	37
1	13	9	22	6	6	32	7	17
8	17	13	32	10	5	46	9	29
1	18	9	26	7	6	40	10	22
1	15	6	15	3	6	28	6	11
6	7	10	25	9	2	33	6	19
11	9	11	30	9	1	37	10	25
14	12	9	33	10	2	41	14	28
7	5	11	20	7	1	27	2	16
7	4	8	18	9	1	25	1	15
9	7	8	23	8	0	31	7	21
9	7	10	24	9	0	30	5	21
6	9	10	22	8	2	27	4	17
15	11	10	31	8	2	38	13	26
8	12	12	27	8	2	33	7	24
6	22	16	37	6	14	60	15	25
4	14	7	22	6	5	31	9	18
3	16	11	27	7	7	38	9	23
3	12	9	20	3	2	27	8	15
1	5	5	7	0	0	12	2	3

Appendix B

Class	site_name	date	type	reference	% Tolerant (bi)
Puget Lowlands	Austin Cr	07/11/2002	calibration	reference	1
Puget Lowlands	Chuckanut Cr @ Aroyo Park	07/11/2002	calibration	reference	5
Puget Lowlands	Covington Cr	08/18/1999	calibration	reference	5
Puget Lowlands	Carey Creek	08/17/1999	calibration	reference	5
Puget Lowlands	Griffin Cr @ Trestle (Waterway 2000)	09/13/1999	calibration	reference	1
Puget Lowlands	Harris Creek	09/13/1999	calibration	reference	5
Puget Lowlands	Jim Cr nr Mouth	08/20/2001	calibration	reference	1
Puget Lowlands	N. Fork Newaukum R @ Watershed Bndry	08/17/1998	calibration	reference	5
Puget Lowlands	Newaukum Creek	08/18/1999	calibration	reference	5
Puget Lowlands	Holder Cr nr Hobart	08/20/1998	calibration	reference	5
Puget Lowlands	Woods Cr abv Woods Cr Rd.	09/13/1999	calibration	reference	5
Puget Lowlands	Bertrand Cr @ Bertheusen Park	09/10/1998	calibration	reference	5
Puget Lowlands	Dewatto River	08/19/1998	calibration	reference	5
Puget Lowlands	Deer Cr @ Deer Creek Drive	09/15/1999	calibration	reference	5
Puget Lowlands	Tahuya R	08/19/1998	calibration	reference	5
Puget Lowlands	Whatcom Cr blw Whatcom Falls	09/11/1998	calibration	reference	5
Puget Lowlands	Big Bear Creek	09/14/1999	calibration	reference	5
Puget Lowlands	Seabeck Cr nr mouth	08/05/2002	calibration	reference	1
Puget Lowlands	Chico Creek	08/19/1999	calibration	reference	5
Puget Lowlands	Rock Cr abv Summit-Landsberg Rd	09/09/1999	calibration	reference	5
Puget Lowlands	Upper Tahuya R	09/10/1999	calibration	reference	5
Puget Lowlands	South Prairie Cr at Burnett	03/09/1997	calibration	Test	5
Puget Lowlands	Catherine Cr nr mouth	09/16/1997	calibration	Test	1
Puget Lowlands	Little Pilchuck Cr	09/16/1997	calibration	Test	5
Puget Lowlands	Newaukum Cr at 212th St	09/03/1997	calibration	Test	5
Puget Lowlands	Padden Cr at Fairhaven Park	09/12/1996	calibration	Test	1
Puget Lowlands	Pilchuck Cr @ Hi-Way 9	09/06/2001	calibration	Test	5
Puget Lowlands	Portage Cr 3	09/05/2001	calibration	Test	5
Puget Lowlands	Siebert Cr blw SR101	09/21/1994	calibration	Test	5
Puget Lowlands	Woods Cr at Calhoun Rd	09/17/1997	calibration	Test	5
Puget Lowlands	North Fork Dakota Cr at Stein Rd	09/17/1996	calibration	Test	5
Puget Lowlands	Dungeness R	09/19/1994	calibration	Test	5
Puget Lowlands	Padden Cr at Lake Padden Park	09/09/1996	calibration	Test	5
Puget Lowlands	Pilchuck Cr @ I-5	09/06/2001	calibration	Test	5
Puget Lowlands	Upper Padden Cr	09/10/1998	calibration	Test	5
Puget Lowlands	Swamp Creek @ Bothel Way	08/12/1999	calibration	Test	1
Puget Lowlands	Portage Cr 2	09/05/2001	calibration	Test	5
Puget Lowlands	Samish R	09/15/1995	calibration	Test	5
Puget Lowlands	Portage Cr 1	09/18/1995	calibration	Test	5
Puget Lowlands	Smith Cr at Cedarville Br	09/10/1996	calibration	Test	5
Puget Lowlands	Squalicum Cr at Cornwall Park	09/11/1996	calibration	Test	1
Puget Lowlands	Chambers Cr at Steilacoom Lake	09/18/1997	calibration	Test	5
Puget Lowlands	Sumas River blw Swift Cr	09/12/1996	calibration	Test	1
Puget Lowlands	McSorley Creek @ Saltwater St. Park	08/17/1999	calibration	Test	5
Puget Lowlands	Wapato Creek @ Freeman Rd	08/16/1999	calibration	Test	5
Puget Lowlands	Little Anderson Cr	08/19/1999	calibration	Test	5
Puget Lowlands	Hylebos Creek	08/16/1999	calibration	Test	5
Puget Lowlands	Quilceda Creek, Station 44N	09/23/1996	verification	reference	5
Puget Lowlands	Edgecomb Creek, Station 60D	09/19/1996	verification	Test	5
Puget Lowlands	Mid. Fk. Quilceda Creek, Station 58F	09/19/1996	verification	Test	1
Puget Lowlands	Canyon Cr	09/04/2001	verification	Test	1
Puget Lowlands	Munson Creek, Station 73D	09/18/1996	verification	Test	1
Puget Lowlands	Station 68i	09/18/1996	verification	Test	1
Puget Lowlands	Armstrong Cr	09/04/2001	verification	Test	5
Puget Lowlands	Mid. Fk. Quilceda Creek, Station 58B	09/19/1996	verification	Test	1

Class	site_name	date	type	reference	% Tolerant (bi)
Puget Lowlands	Quilceda Creek, Station 44H	09/20/1996	verification	Test	1
Puget Lowlands	Big Soos Cr at 208th St	09/04/1997	verification	Test	5
Puget Lowlands	Munson Creek, Station 73C	09/23/1996	verification	Test	1
Puget Lowlands	Quilceda Creek, Station 49B	09/20/1996	verification	Test	1
Puget Lowlands	Bear Creek-Little	08/12/1999	verification	Test	1
Puget Lowlands	California Cr at Bruce Rd	09/17/1996	verification	Test	5
Puget Lowlands	Munson Creek, Station 73B	09/25/1996	verification	Test	5
Cascades	Bear Cr	09/29/2000	calibration	reference	5
Cascades	Cecile Cr	08/28/1997	calibration	reference	5
Cascades	American R @ Bumping R Rd.	07/24/2002	calibration	reference	5
Cascades	McAlester Creek- Stehekin	09/13/2001	calibration	reference	5
Cascades	South Fork Salmon Cr	09/09/1997	calibration	reference	5
Cascades	Bear Cr nr Carson	09/11/2001	calibration	reference	5
Cascades	Jack Cr nr Rock Is. Campground	09/22/2000	calibration	reference	5
Cascades	South Fork Manastash Cr	09/21/2000	calibration	reference	5
Cascades	Little Beaver Creek	08/21/2001	calibration	reference	5
Cascades	Middle Fork Teanaway R	08/14/2002	calibration	reference	5
Cascades	S. Fork Tieton R.	09/28/2000	calibration	reference	5
Cascades	Bacon Creek	09/13/2000	calibration	reference	1
Cascades	Pressentin Cr nr mouth	09/09/1998	calibration	reference	5
Cascades	Diobsud Creek Upper	08/19/2002	calibration	reference	5
Cascades	Elbe Site (unnamed)	10/12/1995	calibration	reference	5
Cascades	Diobsud Cr	10/11/2002	calibration	reference	5
Cascades	Jim Cr @ Naval Station	08/20/2001	calibration	reference	5
Cascades	American R. @ Hells Crossing	09/29/2000	calibration	reference	5
Cascades	Goodell Creek Upper	09/12/2000	calibration	reference	5
Cascades	Indian Cr at SR12	09/23/1993	calibration	reference	5
Cascades	Ohanapecosh R	08/27/1993	calibration	reference	5
Cascades	Squire Cr nr Mouth	07/31/2001	calibration	reference	5
Cascades	Trapper Cr at Trapper Cr Wilderness	08/07/2002	calibration	reference	1
Cascades	OToole Cr @ Skagit Valley Highway	09/15/1999	calibration	reference	5
Cascades	Boulder Cr @ Highway 530	07/31/2001	calibration	reference	5
Cascades	Jim Cr	09/14/1999	calibration	reference	1
Cascades	Little Naches R	09/20/1993	calibration	Test	5
Cascades	Middle Fork Toats Coulee Cr	09/06/1996	calibration	Test	5
Cascades	North Fork Toats Coulee Cr	08/29/1997	calibration	Test	5
Cascades	Sarsapkin Cr	09/11/1996	calibration	Test	5
Cascades	South Fork Toats Coulee Cr	08/28/1997	calibration	Test	5
Cascades	Thompson Cr nr mouth	09/16/1996	calibration	Test	5
Cascades	Twisp R at W. Buttermilk Cr Rd	09/10/1997	calibration	Test	5
Cascades	N.F. Teanaway	08/14/2002	calibration	Test	5
Cascades	Hutchinson Cr at DNR campground	09/10/1996	calibration	Test	5
Cascades	Simmons Cr	10/11/1995	calibration	Test	5
Cascades	Loup Loup Cr	09/10/1997	calibration	Test	5
Cascades	Methow R at Mazama	09/11/1997	calibration	Test	5
Cascades	Green R at Kanasket	09/29/1994	calibration	Test	5
Cascades	W.F. Teanaway	08/14/2002	calibration	Test	5
Cascades	Long Cr	09/19/1995	calibration	Test	5
Cascades	Finney Cr	09/12/1995	calibration	Test	5
Cascades	Little Deer Cr nr Mouth	08/02/2001	calibration	Test	1
Cascades	Rattlesnake Cr	08/10/1993	calibration	Test	1
Cascades	Taylor Cr	10/13/1994	calibration	Test	5
Cascades	Yakima River, Upper Hansen	09/25/2002	calibration	Test	5
Cascades	Deer Cr @ RM 1.0	07/31/2001	calibration	Test	5
Cascades	Huckleberry Cr (WRIA 10)	09/05/1997	calibration	Test	1

Class	site_name	date	type	reference	% Tolerant (bi)
Cascades	Grant Cr	09/20/1995	calibration	Test	5
Cascades	Illabot Cr	09/12/1995	calibration	Test	5
Cascades	N. Fork Stillaguamish R @ Hazel	08/01/2001	calibration	Test	1
Cascades	N. Fork Stillaguamish R @ RM39	07/30/2001	calibration	Test	1
Cascades	Racehorse Cr	09/10/1996	calibration	Test	5
Cascades	Swauk Cr at Mineral Springs	08/13/1993	calibration	Test	1
Cascades	Twentyfivemile Cr	09/18/1997	calibration	Test	1
Cascades	Gold Cr	10/10/1993	calibration	Test	5
Cascades	Jackman Cr	09/13/1995	calibration	Test	5
Cascades	Park Creek	09/19/2001	verification	reference	5
Cascades	Bridge Creek South Fork	09/12/2001	verification	reference	5
Cascades	Happy Creek	09/09/2001	verification	reference	5
Cascades	McAllister Creek- Thunder	09/26/2001	verification	reference	5
Cascades	Chilliwack Indian Camp (Reach 4)	09/16/1999	verification	reference	5
Cascades	Chilliwack River above Easy Creek (Reach 6)	09/15/1999	verification	reference	5
Cascades	Chilliwack Above US Cabin (Reach 5)	09/15/1999	verification	reference	5
Cascades	Lightning Creek	09/09/1999	verification	reference	5
Cascades	Newhalem Creek	09/11/2000	verification	reference	5
Cascades	Chilliwack Reach 1	09/16/1999	verification	reference	5
Cascades	Marble Creek	09/26/2000	verification	reference	5
Cascades	Chewack R	09/11/1997	verification	Test	1
Cascades	Breckenridge Cr blw South Pass Rd	09/12/1996	verification	Test	5
Cascades	Butter Creek at FR5290	08/27/1993	verification	Test	5
Cascades	Clearwater R	09/05/1997	verification	Test	5
Cascades	Deer Cr @ RM 0.5	09/20/1995	verification	Test	5

% Chironomidae	% Clingers	% Ephemeroptera	% EPT	% Filterers	% Predators	% Scrapers	% Top 3 Abundant	% Tolerant (TV7)	Intolerant Richness (bi)
5	3	5	5	5	3	5	5	5	5
1	3	3	3	5	1	5	5	5	5
5	5	3	5	5	1	1	5	5	3
5	3	5	3	5	1	5	5	5	5
5	3	5	5	5	1	5	5	5	3
5	3	3	5	5	1	5	5	5	3
5	5	3	3	5	1	5	5	5	1
5	5	3	5	5	1	1	5	5	3
5	3	3	5	5	1	1	5	5	5
5	3	3	3	5	1	5	5	5	1
5	3	3	3	5	1	5	5	5	1
5	3	1	3	5	3	1	5	1	3
5	1	1	5	5	3	5	5	5	1
5	3	3	5	5	1	5	5	5	1
1	1	1	3	5	3	5	5	5	1
5	5	3	3	1	1	5	5	5	3
5	3	1	3	5	1	1	5	5	1
5	1	5	5	5	1	5	1	5	3
5	5	1	1	1	1	5	1	5	1
5	1	1	1	5	1	5	1	1	3
1	1	1	1	5	1	5	1	5	1
5	5	3	3	1	1	5	5	5	5
5	3	1	3	5	3	5	5	5	3
5	5	3	5	1	1	1	5	5	1
5	3	3	5	5	1	5	5	5	1
5	1	3	3	5	3	5	5	5	1
5	3	3	3	5	1	5	5	5	1
5	3	3	3	5	1	1	5	1	5
5	3	3	5	5	5	1	5	5	1
5	5	3	5	1	1	5	5	5	1
5	1	3	3	5	1	5	5	5	5
5	1	5	5	5	3	5	5	5	5
5	1	1	5	5	5	5	5	5	1
5	5	3	3	5	1	1	5	5	1
5	3	1	3	5	3	5	5	5	1
5	3	1	1	5	1	5	5	5	1
5	1	3	3	5	1	5	5	1	1
5	5	5	3	5	5	1	1	5	1
5	1	5	5	5	5	5	1	5	3
5	1	1	1	5	3	5	5	1	1
5	1	1	1	5	1	5	1	5	1
5	5	1	5	1	1	5	1	5	1
5	1	5	5	5	3	5	1	5	1
5	1	1	3	5	1	5	5	1	1
1	1	1	1	5	1	5	1	5	1
1	1	1	1	5	1	5	1	1	1
1	1	1	1	5	1	5	1	1	1
5	3	1	5	5	3	5	5	1	5
5	3	1	5	5	5	5	5	5	5
5	3	5	5	5	3	5	5	5	5
5	3	5	5	5	1	5	5	5	3
5	3	3	5	5	1	5	5	5	3
5	1	5	5	5	3	5	5	5	3
5	3	1	1	5	1	5	5	1	1
5	1	1	1	5	1	5	5	5	1

% Chironomidae	% Clingers	% Ephemeroptera	% EPT	% Filterers	% Predators	% Scrapers	% Top 3 Abundant	% Tolerant (TV7)	Intolerant Richness (bi)
5	1	3	3	5	1	5	5	5	1
1	1	1	1	5	1	5	5	5	1
5	3	5	5	5	1	5	5	5	1
5	1	5	5	5	1	5	5	5	1
5	1	3	3	5	1	5	1	5	1
5	1	1	1	5	1	5	1	1	1
5	1	1	1	5	1	5	1	1	1
5	5	1	5	5	1	1	1	5	5
5	1	1	3	5	3	5	5	5	5
5	5	5	5	5	1	1	5	5	1
5	3	1	3	5	3	5	1	1	5
5	5	1	3	5	1	5	5	5	3
5	5	1	5	5	3	5	5	1	3
5	5	3	5	5	1	1	1	1	5
5	5	1	5	5	1	1	5	5	1
5	5	5	5	5	1	1	1	5	3
5	3	3	5	5	1	5	5	5	1
5	5	3	5	5	1	1	1	5	3
5	3	5	5	5	1	5	1	5	3
5	3	1	3	5	3	5	5	5	1
5	3	5	5	5	1	1	5	5	1
5	1	1	1	5	3	5	5	5	5
5	1	3	5	5	5	5	1	1	1
5	1	1	3	5	1	5	5	5	1
5	1	1	5	5	1	1	1	5	1
5	3	5	5	5	1	5	1	5	1
5	1	1	3	5	5	5	5	5	3
5	5	1	1	1	1	5	1	5	3
1	1	3	3	5	1	5	1	5	1
5	1	3	3	5	1	5	1	5	1
5	1	1	3	5	3	5	5	1	1
1	1	3	1	5	1	5	1	5	1
5	1	3	3	5	1	5	1	5	1
5	5	1	3	5	5	5	5	5	5
5	3	1	5	5	5	5	5	5	3
5	1	1	3	5	5	5	5	5	5
5	1	1	3	5	5	5	5	5	5
5	1	1	5	5	3	5	5	5	5
5	1	3	3	5	1	5	5	5	5
5	3	3	3	5	5	5	1	5	3
5	5	3	3	5	3	5	5	5	1
5	3	3	3	5	3	5	5	5	1
5	1	1	3	5	3	5	5	5	5
5	5	1	3	1	1	5	5	5	3
5	3	3	5	5	1	5	5	5	1
5	3	1	3	5	1	5	5	5	1
5	5	1	5	1	1	5	5	5	1
5	1	3	5	5	1	5	5	5	1
5	1	5	5	5	1	5	5	5	1
5	1	5	5	5	1	5	5	5	1
5	3	1	3	5	5	5	5	5	1
5	1	1	1	5	5	5	5	5	1
1	1	1	1	5	1	5	1	5	1
1	1	1	1	5	1	5	1	1	1
5	1	3	3	5	1	5	1	5	3

% Chironomidae	% Clingers	% Ephemeroptera	% EPT	% Filterers	% Predators	% Scrapers	% Top 3 Abundant	% Tolerant (TV7)	Intolerant Richness (bi)
5	1	3	1	5	5	5	1	5	1
5	1	1	1	5	5	5	1	5	1
5	3	5	3	5	1	5	5	5	1
5	3	3	3	5	1	5	5	1	1
5	1	3	3	5	3	5	5	1	1
5	3	1	1	5	5	5	1	5	1
5	3	3	3	1	1	5	1	5	1
5	5	1	1	1	1	5	1	5	1
5	5	1	1	1	5	5	1	5	1
5	5	3	5	5	3	1	1	5	5
5	1	1	5	5	3	5	5	1	5
5	1	3	5	5	3	5	5	5	5
5	5	5	5	5	1	5	1	5	5
5	3	5	5	5	3	1	5	5	3
5	5	5	5	5	1	1	1	5	3
5	3	5	5	5	1	5	1	5	3
5	3	5	5	5	1	1	1	1	3
5	3	5	5	5	1	5	1	5	3
5	1	5	5	5	1	5	5	5	3
5	1	5	5	5	1	5	1	1	1
5	5	3	5	5	1	5	5	5	1
5	1	1	1	1	1	5	1	5	1
5	5	1	1	1	5	5	1	5	1
1	1	1	1	5	1	5	1	5	1
5	1	1	1	5	5	5	1	5	1

Clinger Richness	Ephemeroptera Richness	EPT Richness	HBI	Plecoptera Richness	Long-Lived Richness	Total Richness	Trichoptera Richness	Intolerant Richness (TV3)	Index
5	5	5	5	5	5	5	5	5	46
5	5	5	5	5	3	5	3	5	40
5	5	5	5	3	5	3	5	5	40
5	5	5	5	3	1	3	5	5	36
5	5	3	5	3	5	3	3	5	36
5	5	5	5	3	3	3	5	5	36
5	5	5	5	3	3	3	5	5	36
5	3	3	5	3	5	3	3	5	36
5	3	3	5	3	3	3	5	5	36
3	3	5	5	5	3	3	5	5	34
5	5	3	5	3	5	3	3	5	34
5	3	3	5	3	3	3	5	5	32
3	3	3	5	5	3	3	3	3	32
3	3	3	5	5	1	3	3	5	30
3	3	3	5	5	3	3	1	3	30
3	3	3	5	3	1	1	3	3	30
3	3	3	5	1	1	3	5	3	28
5	3	3	5	5	3	3	3	5	28
3	3	3	1	5	3	1	1	3	26
3	3	3	1	3	3	3	3	3	22
3	3	1	5	3	3	1	1	3	20
5	5	5	5	5	5	5	5	5	46
5	5	5	5	5	5	5	5	5	44
5	3	5	5	5	3	5	5	5	38
5	5	5	5	3	3	5	5	5	36
5	5	5	5	3	3	5	5	5	36
5	5	5	5	3	5	3	5	5	36
5	3	5	5	5	3	5	5	5	36
3	3	3	5	5	1	3	3	3	34
5	3	3	5	3	3	3	5	3	34
1	3	3	5	5	3	3	1	3	32
3	3	3	5	5	1	1	1	5	30
1	3	3	5	3	1	3	3	3	30
3	3	3	5	3	3	3	1	3	30
1	3	3	5	3	1	3	3	3	30
3	3	1	1	1	3	3	3	1	28
3	3	3	1	3	3	3	3	3	24
1	3	1	5	1	1	1	1	1	24
1	1	1	5	1	1	1	3	1	22
1	1	1	1	3	3	1	1	1	20
1	1	3	1	3	1	3	3	3	20
1	1	1	5	1	1	1	1	1	18
1	1	1	1	1	1	1	1	1	16
1	1	1	1	1	1	1	1	1	14
1	1	1	1	1	1	1	1	1	14
1	1	1	1	3	1	1	1	1	12
1	1	1	1	1	1	1	1	1	10
3	3	5	5	5	3	5	5	5	38
3	3	5	5	5	5	5	5	5	46
5	5	5	5	5	5	5	5	5	46
3	5	3	5	3	3	3	1	5	32
3	3	3	5	3	3	3	3	5	32
1	1	3	5	3	1	3	3	3	28
3	5	3	1	3	3	3	3	3	28
1	3	1	1	3	3	5	1	1	28

Clinger Richness	Ephemeroptera Richness	EPT Richness	HBI	Plecoptera Richness	Long-Lived Richness	Total Richness	Trichoptera Richness	Intolerant Richness (TV3)	Index
1	3	3	1	3	3	1	1	3	24
1	3	1	1	1	1	3	1	1	22
1	1	1	1	1	3	1	1	1	22
1	1	1	1	1	3	3	1	3	22
3	3	3	1	1	3	1	3	3	20
1	1	1	1	1	1	1	1	1	10
1	1	1	1	1	1	1	1	1	10
5	3	3	5	5	3	3	3	5	42
5	5	5	5	5	5	5	5	5	42
5	3	3	5	3	5	3	3	3	40
3	3	3	5	5	3	3	5	5	40
5	1	3	5	3	5	3	5	3	40
5	1	1	5	3	3	3	3	3	38
3	1	1	5	3	3	1	3	3	38
5	1	3	5	3	5	3	5	3	38
1	1	3	5	5	1	1	1	3	36
5	3	1	5	3	5	3	3	3	36
3	3	3	5	3	1	1	3	3	36
3	1	1	5	3	1	3	3	3	34
5	1	3	5	3	3	3	3	3	34
3	3	3	5	3	1	1	1	3	32
1	1	1	5	5	3	3	1	3	32
3	1	1	5	3	3	1	3	3	30
5	1	1	5	3	3	3	1	3	30
3	1	1	5	3	3	1	3	3	28
1	1	1	5	1	1	1	1	1	28
1	1	1	5	3	1	1	3	3	28
3	3	3	1	5	3	3	1	3	28
3	1	1	5	3	1	1	1	1	28
5	3	3	1	3	3	3	5	3	28
3	1	1	5	1	3	1	3	1	26
3	3	1	1	1	1	1	1	1	22
3	1	1	1	3	3	1	1	1	20
5	3	3	5	5	5	3	3	5	42
5	5	5	5	5	5	5	5	5	42
5	5	5	5	5	5	5	5	5	42
5	5	5	5	5	5	5	5	5	42
5	5	5	5	5	5	5	5	5	42
3	5	5	5	5	1	5	5	5	42
5	1	3	5	5	3	3	3	5	40
5	1	3	5	3	5	3	3	3	38
5	5	3	5	3	1	3	3	3	36
3	3	3	5	5	5	3	3	5	36
5	1	3	5	3	5	3	3	3	34
3	3	3	5	5	3	3	1	3	34
5	1	1	5	3	5	1	3	3	32
5	1	3	5	3	3	3	3	3	32
1	3	3	5	3	1	3	3	3	30
1	3	1	5	1	3	1	1	1	26
3	3	1	5	3	1	1	1	3	26
3	3	1	5	3	5	3	1	3	26
3	1	1	5	1	5	1	1	1	24
3	1	1	5	1	3	1	1	1	24
1	3	1	5	1	1	1	1	1	22
3	3	3	1	3	1	1	1	3	22

Clinger Richness	Ephemeroptera Richness	EPT Richness	HBI	Plecoptera Richness	Long-Lived Richness	Total Richness	Trichoptera Richness	Intolerant Richness (TV3)	Index
1	1	1	1	1	1	1	1	1	20
3	1	1	1	1	1	1	1	1	20
1	1	1	1	1	1	1	1	1	20
3	1	1	1	1	3	1	1	1	20
1	1	1	1	1	1	1	1	1	20
3	1	1	1	3	5	1	1	1	20
3	1	1	1	3	3	1	3	1	20
1	1	1	1	1	1	1	1	1	18
1	1	1	1	1	1	1	1	1	18
1	1	3	5	3	1	3	5	3	40
3	3	5	5	5	1	3	5	5	38
1	1	3	5	3	1	3	5	5	36
1	3	3	5	3	1	1	1	3	36
1	1	1	5	5	1	1	1	3	34
1	1	1	5	3	1	1	1	3	34
1	1	1	5	3	1	1	1	3	32
1	1	1	5	3	1	1	1	3	32
1	3	1	5	3	3	1	1	3	32
1	3	1	5	3	1	1	1	1	30
1	3	1	5	3	1	1	1	3	28
5	3	3	5	3	5	3	3	3	34
5	3	3	1	3	5	5	5	3	28
3	1	1	1	3	3	1	3	3	24
1	1	1	1	1	1	1	1	1	18
1	1	1	1	1	1	1	1	1	18