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Using Invertebrates to Assess the Quality of Washington Streams and to Describe Biological Expectations

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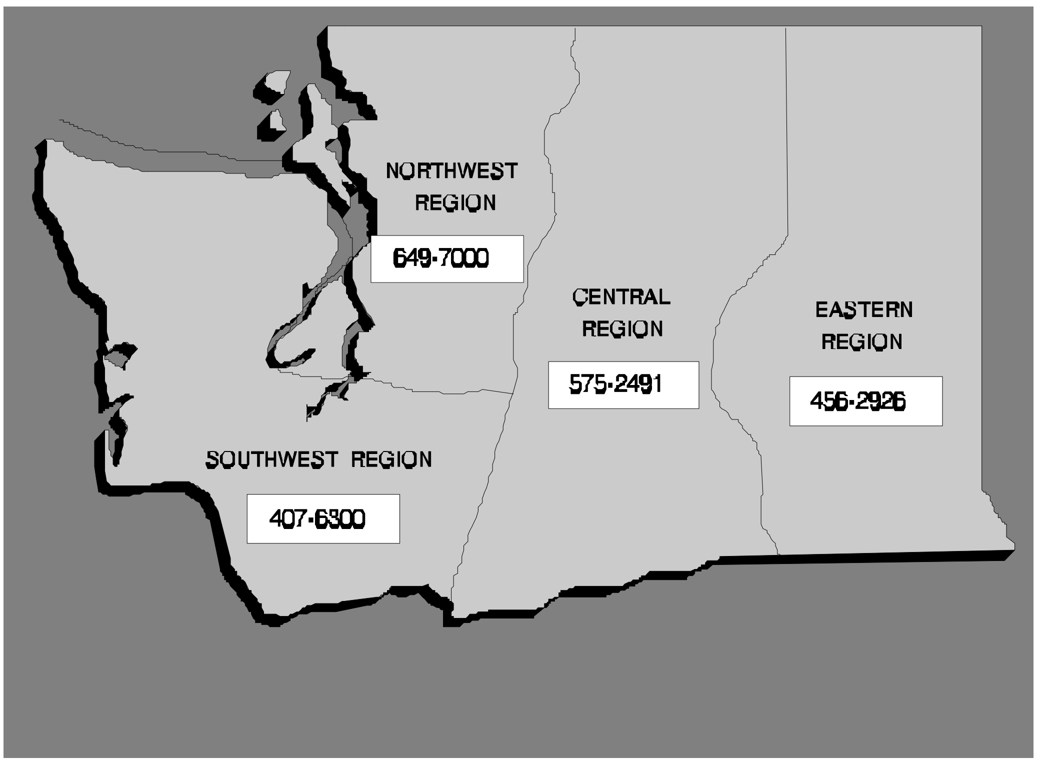

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Using Invertebrates to Assess the Quality of Washington Streams and to Describe Biological Expectations

by
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Olympia, Washington 98504-7710

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Abstract

An ongoing survey of streams in Washington State has been based on collection and analysis of the macroinvertebrate assemblage. A hypothesis-testing approach was used to define a hierarchical framework that would identify: biological regions, important environmental variables and indicator assemblages. Classification analysis was used to define geographic regions that were biologically similar across the Washington landscape and physicochemical variables associated with regions. Eight hypotheses were proposed in order to determine distinctions among landscape, reach and site-specific biological conditions. Data collected from most areas of the state indicated three emergent biological regions: western Cascades and lowlands (Puget Sound and Coast Range), interior plateau and eastern Cascades (Columbia Plateau and east Cascades), and northeastern interior mountains (Northern Rockies). Two of the biological regions were further divided into distinct groups and appeared to be distinguished by local geology, topography, climate and anthropogenic impacts. Five environmental variables were characteristic of site conditions within clusters: water temperature, pH, conductivity, gradient, and elevation. Biological regions and environmental variables are the basis for categorizing streams across the Washington landscape. Taxa assemblages were found to be strongly associated with some of the stream conditions in the regions. Verification of the proposed expected biological conditions for each region/stream type combination will be based on future surveys.

Introduction

Ambient Biological Monitoring Program Objectives

The Ambient Biological Monitoring Program has several objectives for stream quality assessments in Washington:

- to define and document statewide baseline conditions of instream invertebrate biology,
- to measure spatial and temporal variability of population and community attributes,
- to identify a regional framework based on invertebrate community similarity,
- to identify indicator taxa, and
- to relate stream quality with the Department of Ecology's Water Quality Management Areas (WQMA's) using stream invertebrates.

Stream assessment using aquatic invertebrates is intended to expand the Ambient Monitoring Program by generating additional environmental information.

Hypotheses (*a priori* expectations of biological condition & response)

Stream invertebrate response to changing physical stream condition is well documented in existing literature (Plafkin *et al*. 1989; Karr 1991; Resh and Jackson 1993). Analysis of data was intended to identify regional similarity of invertebrate communities and physical variables that explained the similarity.

Sampling design of the Ambient Biological Monitoring Program evaluated:

- biology of different stream habitats
- physical characteristics of a stream responded to by biology in a consistent pattern
- effectiveness of the stream reach sampling strategy in characterizing biology

The following hypotheses were tested:

1. Riffle habitat assemblages contain distinct taxa from those found in pool habitat.
2. Riffle and pool assemblages respond in different ways to stream degradation.
3. Highly mobile taxa are found in both riffle and pool habitats.
4. Site differences (*i.e*, in terms of macroinvertebrate assemblages) may partly be explained by regional attributes (*i.e.*, montane topography and arid plateau).
5. Biologically important physical variables invoke measurable biological responses.
6. Multiple physical variables that characterize a stream channel and influence the type of biological assemblage present can be measured and used to partition streams into "sets."
7. Replicate samples with highly variable assemblages collected from within a stream reach indicate a severe channel disturbance.

Ecology's Ambient Biological Monitoring Program

For the past three years (1993-1995), the Ambient Monitoring Program in the Department of Ecology has been collecting biological information in wadeable rivers and streams throughout the state. A consistent strategy for collection of aquatic invertebrates (benthic macroinvertebrates) was developed for this program following preliminary biological surveys (Plotnikoff, 1994; Plotnikoff, 1995). The monitoring program design focused on invertebrate community similarity at a regional scale (Plotnikoff, 1992).

Stream invertebrate information is often helpful when chemical and physical water quality measures fail to protect stream health. Evaluating a greater part of the stream environment (*i.e.*, chemical, physical, and biological components) has produced accurate and less costly (Yoder and Rankin, 1995) identification of stream degradation (Karr, 1995; Rankin *et al*., 1995). Biological monitoring provides useful information that can also serve as an early warning system (Rosenberg and Resh, 1993).

Stream dwelling invertebrates respond to changes in the physical, chemical and biological environment. Benthic macroinvertebrates generally inhabit a localized area of a stream throughout their life cycle. Therefore, the individual organisms are continually exposed to any changes that occur in the chemical and physical environment (Rosenberg and Resh, 1996). Continuous exposure to the localized condition presents an historical view of a stream's quality.

Regional Frameworks: Application to Invertebrate Monitoring

Washington State can be divided into distinct geographic areas based on topography, climate, land uses, soils, geology, and naturally occurring vegetation. The geographic areas have common names such as the Columbia Plateau, Cascade Range, Coastal Range, Northern Rockies, Puget Lowland, Blue Mountains, or the small portion of Willamette Valley (Figure 1). Each of the regions has been described using landscape characteristics overlain on each other to locate boundaries (Omernik and Gallant, 1986). The resulting boundaries form geographic areas called 'ecoregions.'

Ecoregion frameworks can include many or fewer geographic variables to describe the regional boundaries. Fewer geographic variables result in identification of fewer ecoregions (Bailey, 1995). Many geographic variables used to identify landscape regions enable definition of sub-ecoregions (Bryce and Omernik, 1997; Pater *et al*., 1997) (Figure 2). Regardless of the analytical strategy used to identify ecoregions, their primary utility in this program is to identify naturally occurring geographic access within which stream biological expectations are described.

The Department of Ecology addresses many water quality issues by Water Quality Management Area (WQMA) (Figure 3). The WQMAs will sometimes contain portions of two or more regions with different biological expectations. The WQMA is an interface where technical information is merged with policy and regulation.

Figure 1.

Washington State Ecoregions

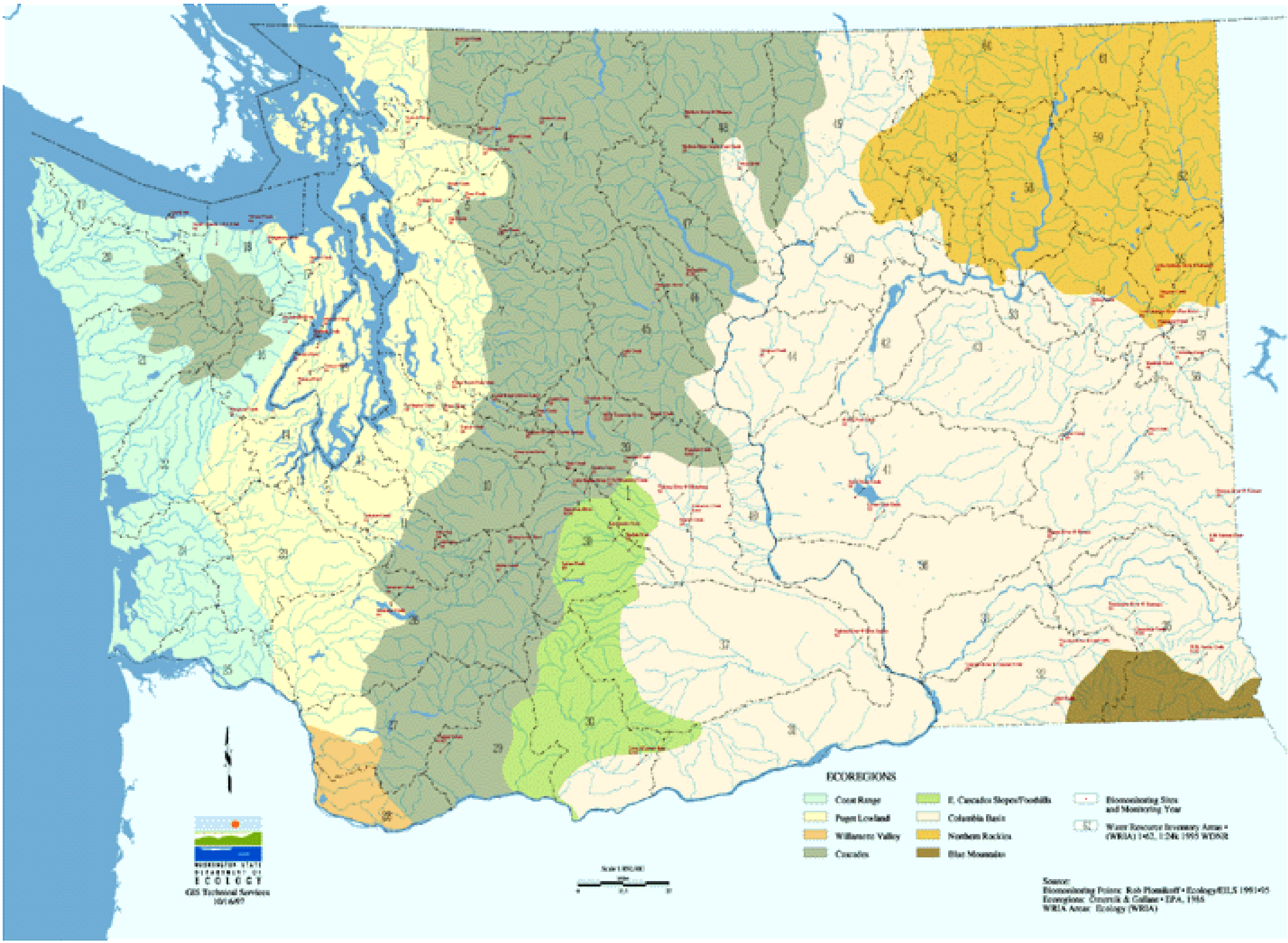
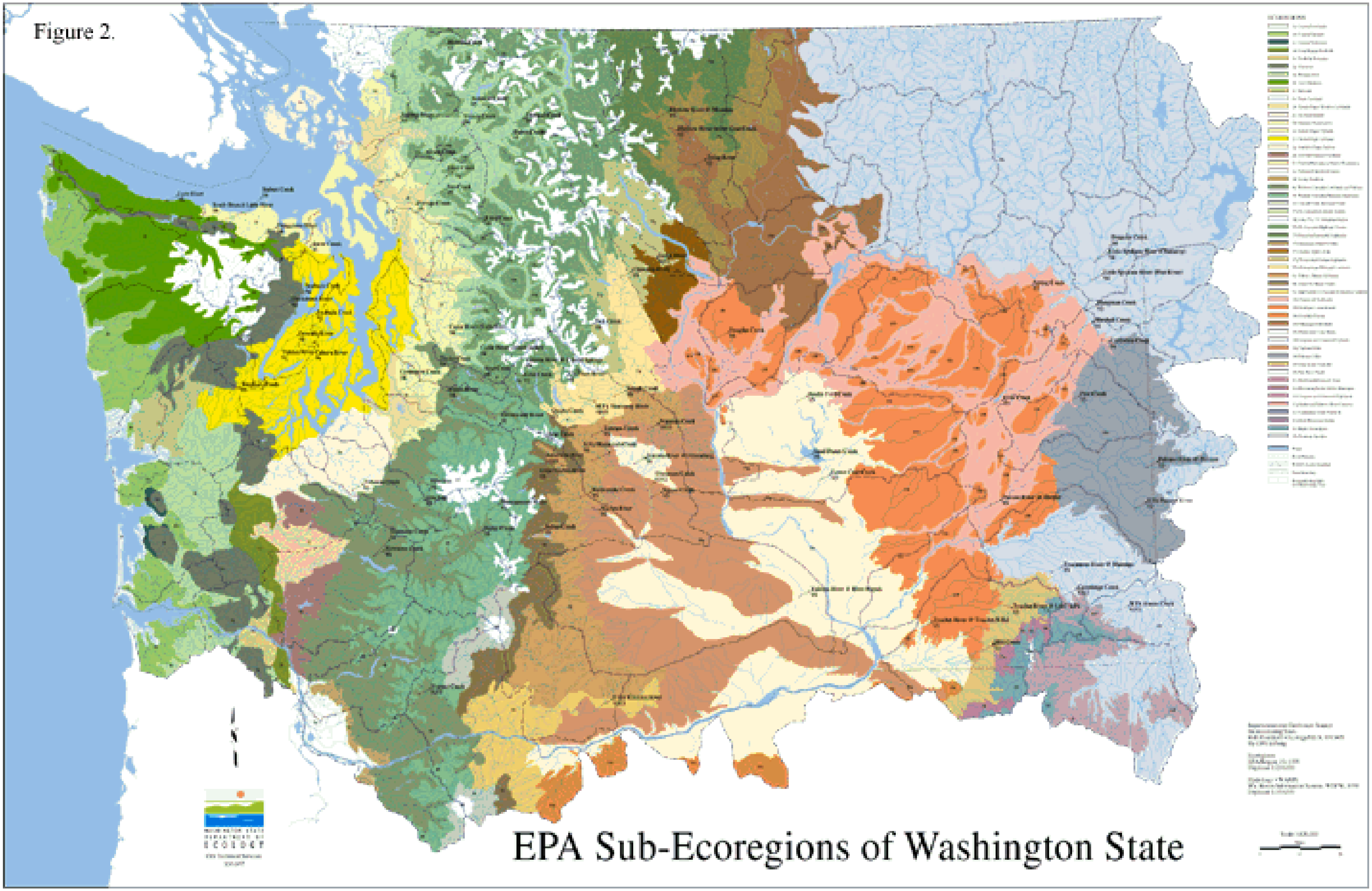


Figure 2.



EPA Sub-Ecoregions of Washington State

Figure 3.

Water Quality Management Areas

Methods

Description of Study Area

Twenty sites were monitored in each year (1993 and 1994) except during summer 1995 (ten sites), yielding data from fifty locations throughout the state of Washington.

Streams are located by water quality management area (WQMA) in Figures 4-15. Each of the WQMA's have been reproduced separately in the figures and accompanied by a state locator map. The detail of stream networks within each WQMA was preserved so that many of the smaller streams surveyed would appear.

Site Selection Strategy

Streams within WQMA's of the state were selected on a predetermined schedule as part of the Department of Ecology's Watershed Planning Process (McBride, 1996). Four WQMA's per year are considered for placement of biological monitoring sites. Each WQMA represents a region of the state (*i.e.*, southwest, northwest, central, and eastern). Specific location of a monitoring site is based on local knowledge of type and severity of degradation to be evaluated (e.g., sedimentation, enrichment, temperature).

Wadeable streams were selected based on two criteria: (1) sites that had visual signs of degradation, and (2) least disturbed sites. The least disturbed sites approximated instream physical characteristics and setting as the degraded site.

Environmental Variables

A standard set of variables was measured at each stream for the years 1993, 1994, and 1995. Table 1 lists variables measured and the scale of measurement (landscape, reach, and site-specific). Organization of the variables at each scale was similar to those of Carter *et al*. (1996). The field forms used to record measurements at each stream are in Appendix I.

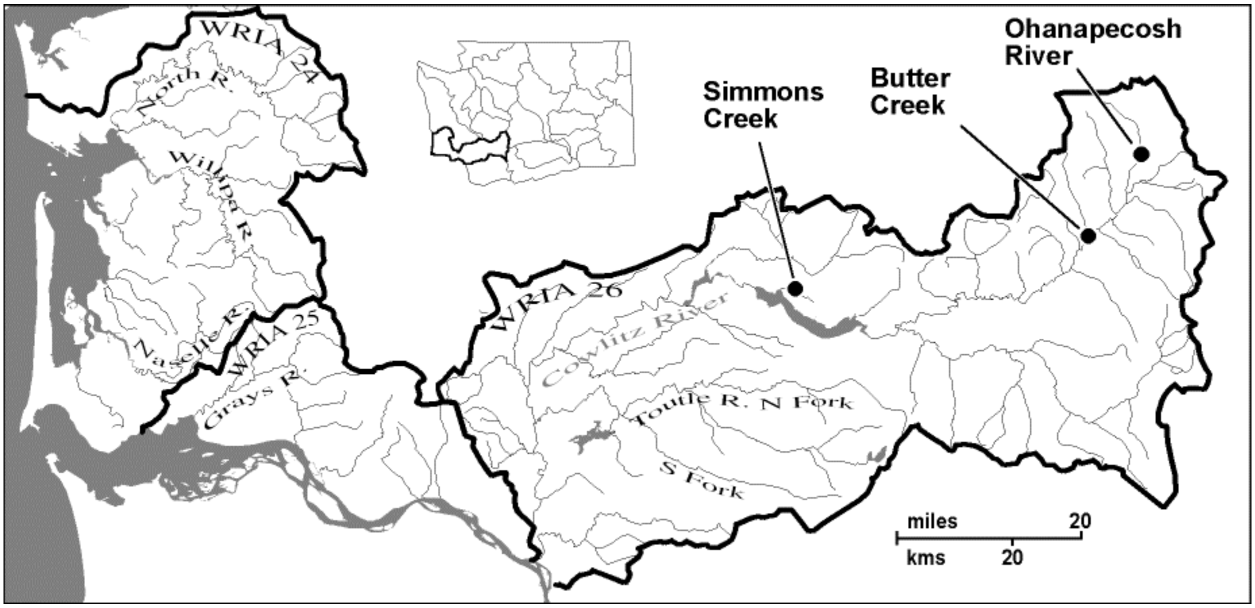


Figure 4. Lower Columbia Water Quality Management Area. Summer 1993 biological monitoring sites.

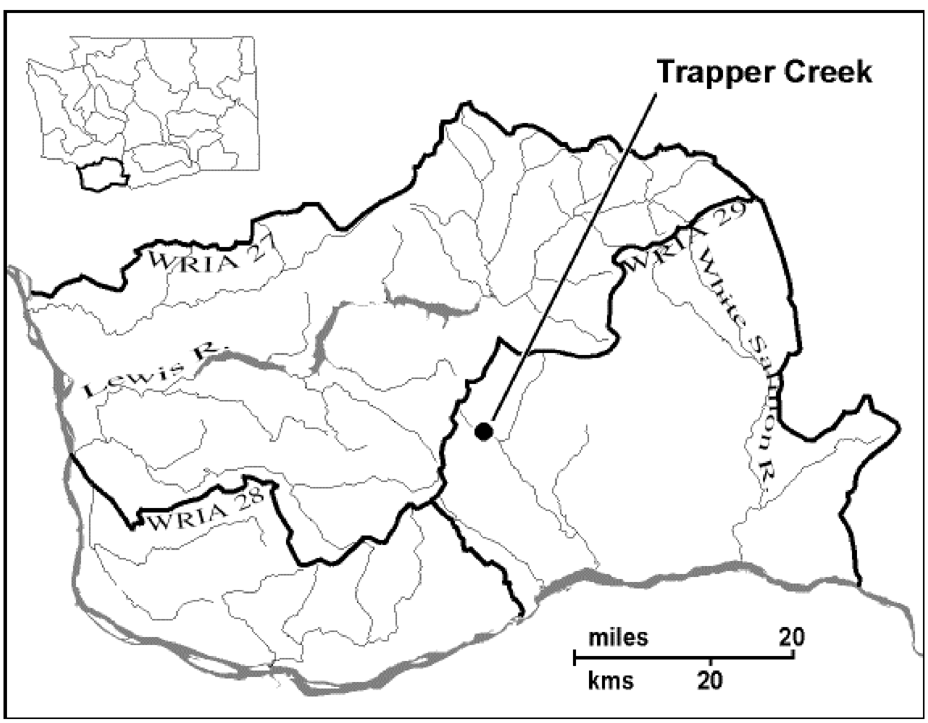


Figure 5. Columbia Gorge Water Quality Management Area. Summer 1993 biological monitoring sites.

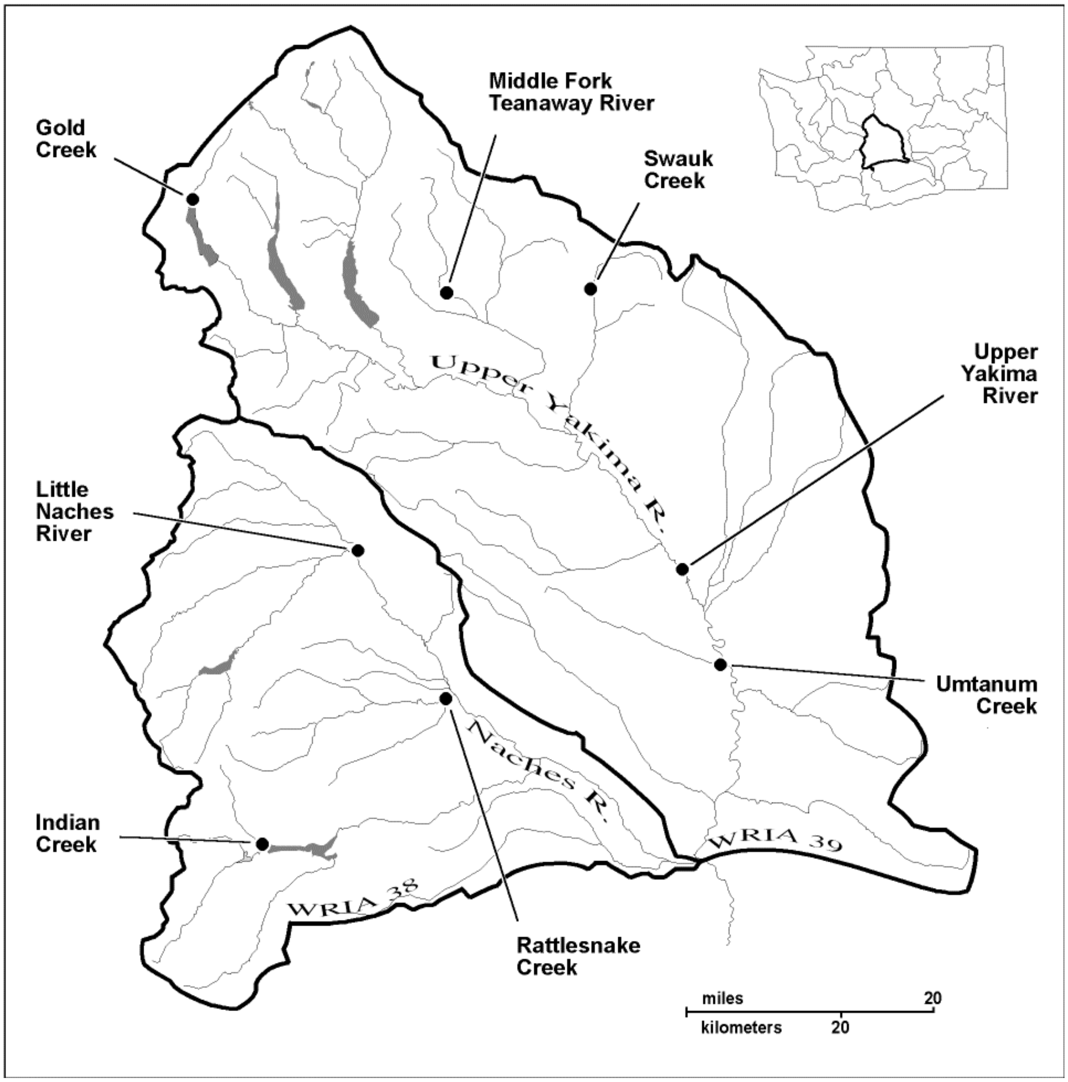


Figure 6. Upper Yakima Water Quality Management Area. Summer 1993 biological monitoring sites.

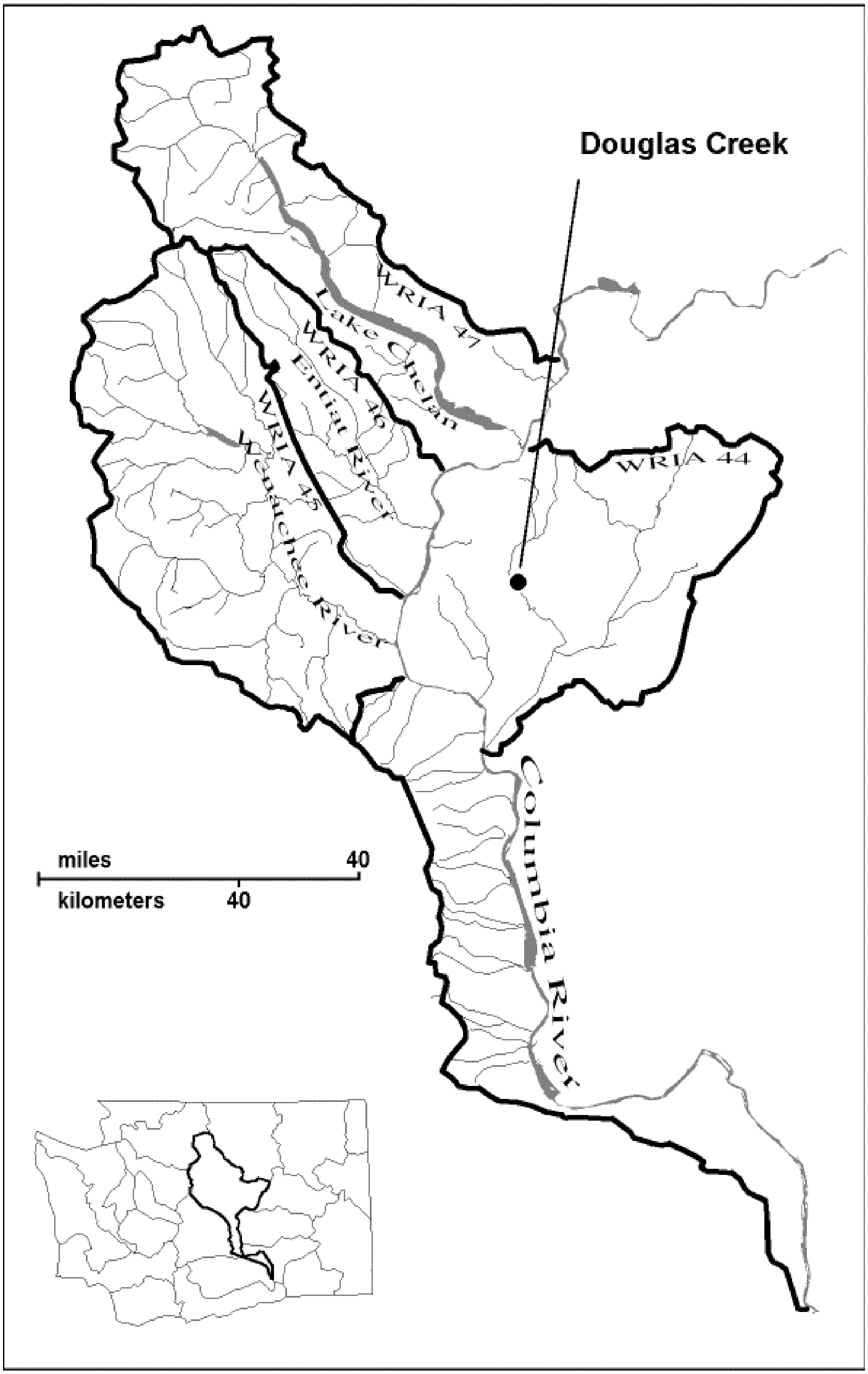


Figure 7. Wenatchee Water Quality Management Area. Summer 1993 biological monitoring sites.

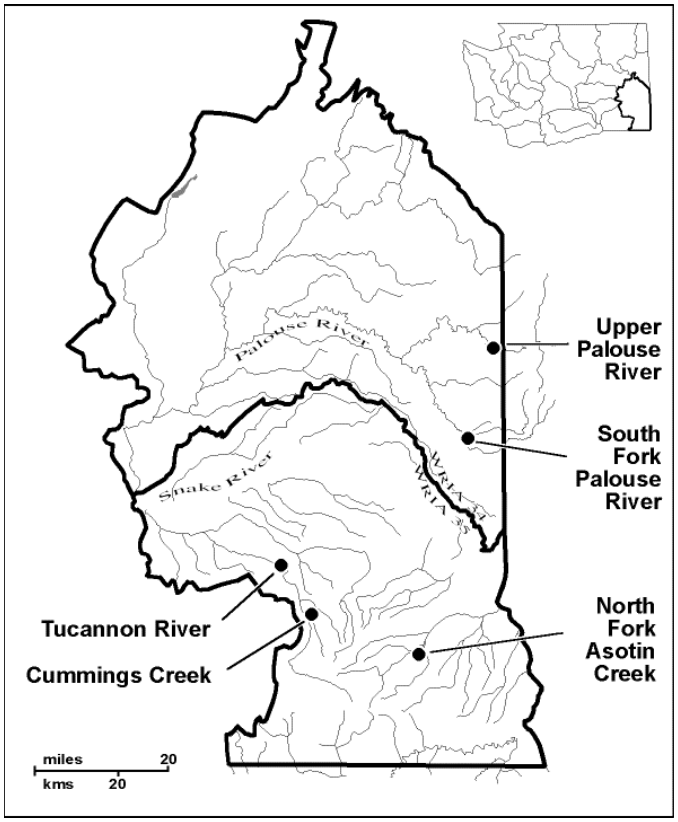


Figure 8. Upper Snake Water Quality Management Area. Summer 1993 biological monitoring sites.

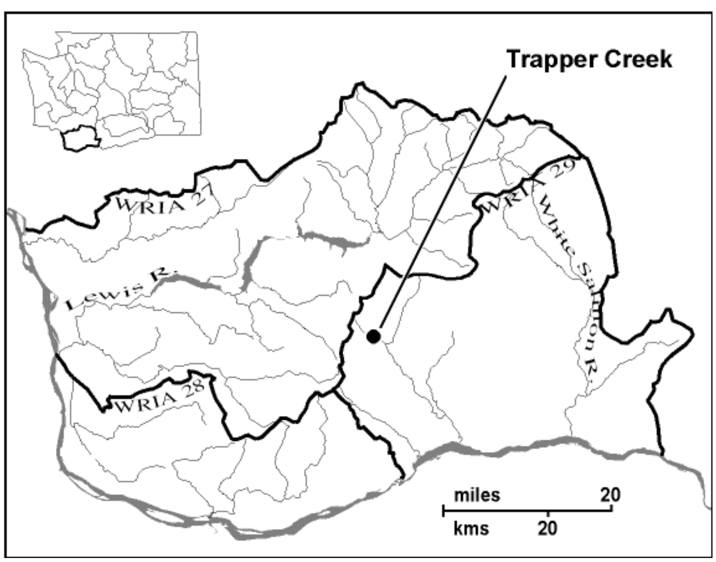


Figure 9. Middle Columbia Water Quality Management Area. Summer 1993 biological monitoring sites.

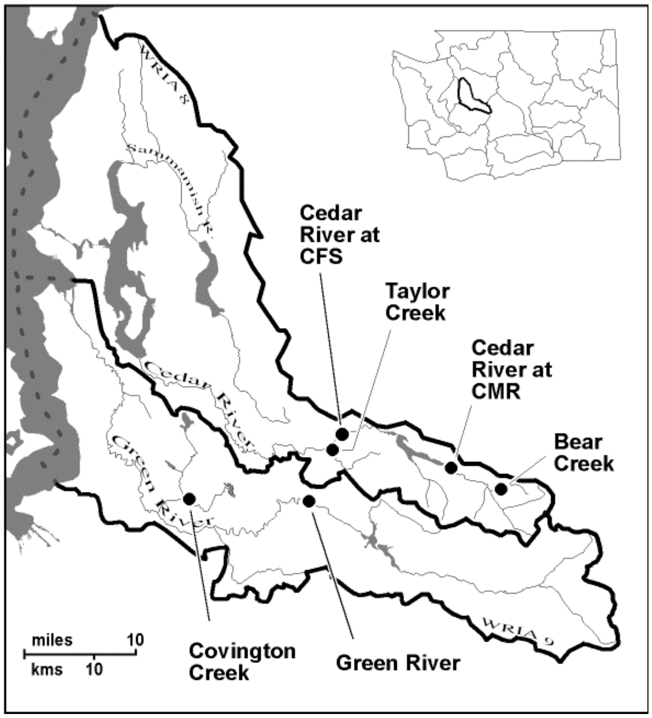


Figure 10. Cedar/Green Water Quality Management Area. Summer 1994 biological monitoring sites.

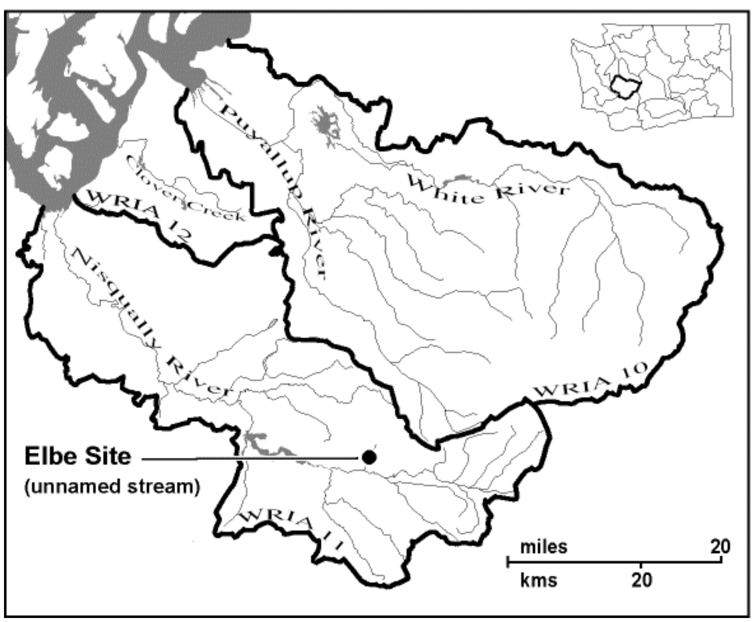


Figure 11. South Puget Sound Water Quality Management Area. Summer 1994 biological monitoring sites.

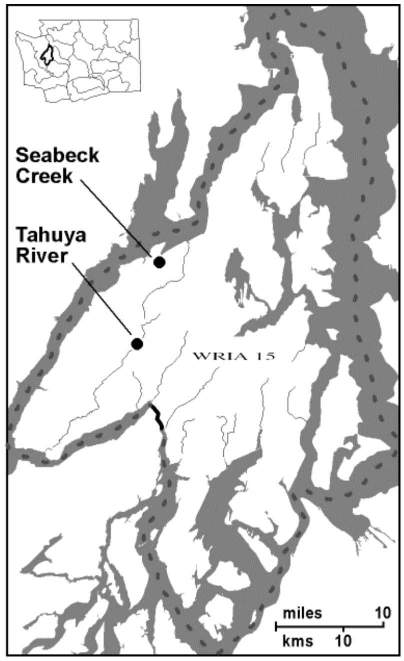


Figure 12. Kitsap Water Quality Management Area. Summer 1994 biological monitoring sites.

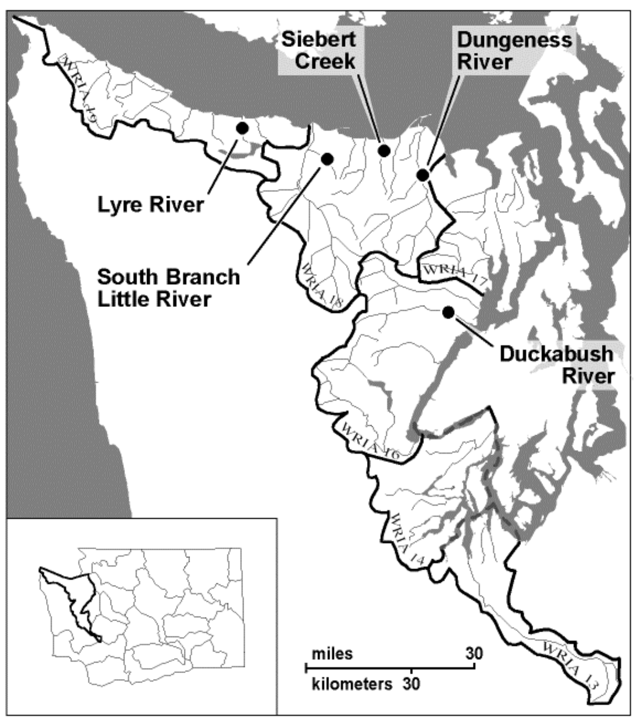


Figure 13. Eastern Olympic Water Quality Management Area. Summer 1994 biological monitoring sites.

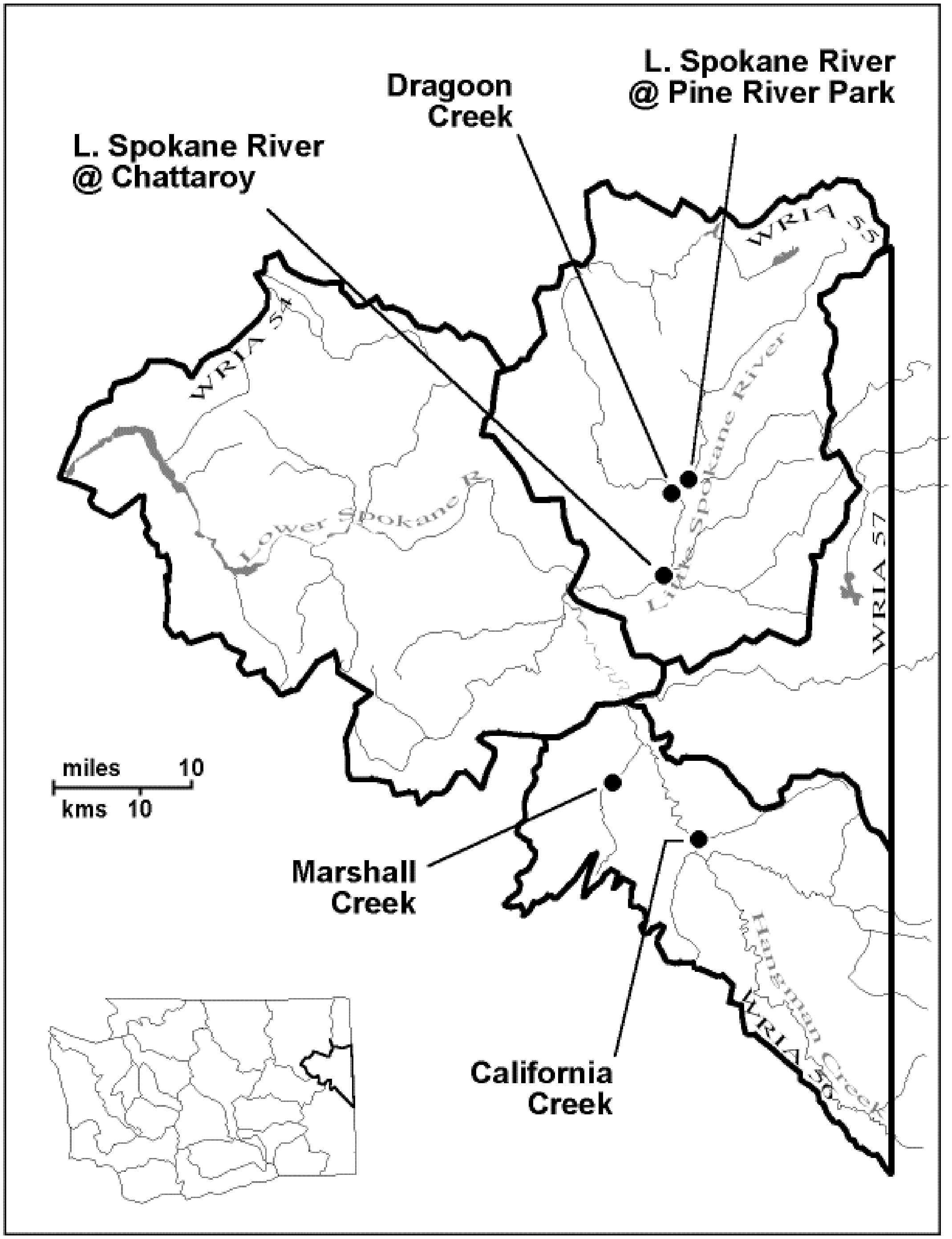


Figure 14. Spokane Water Quality Management Area. Summer 1994 biological monitoring sites.

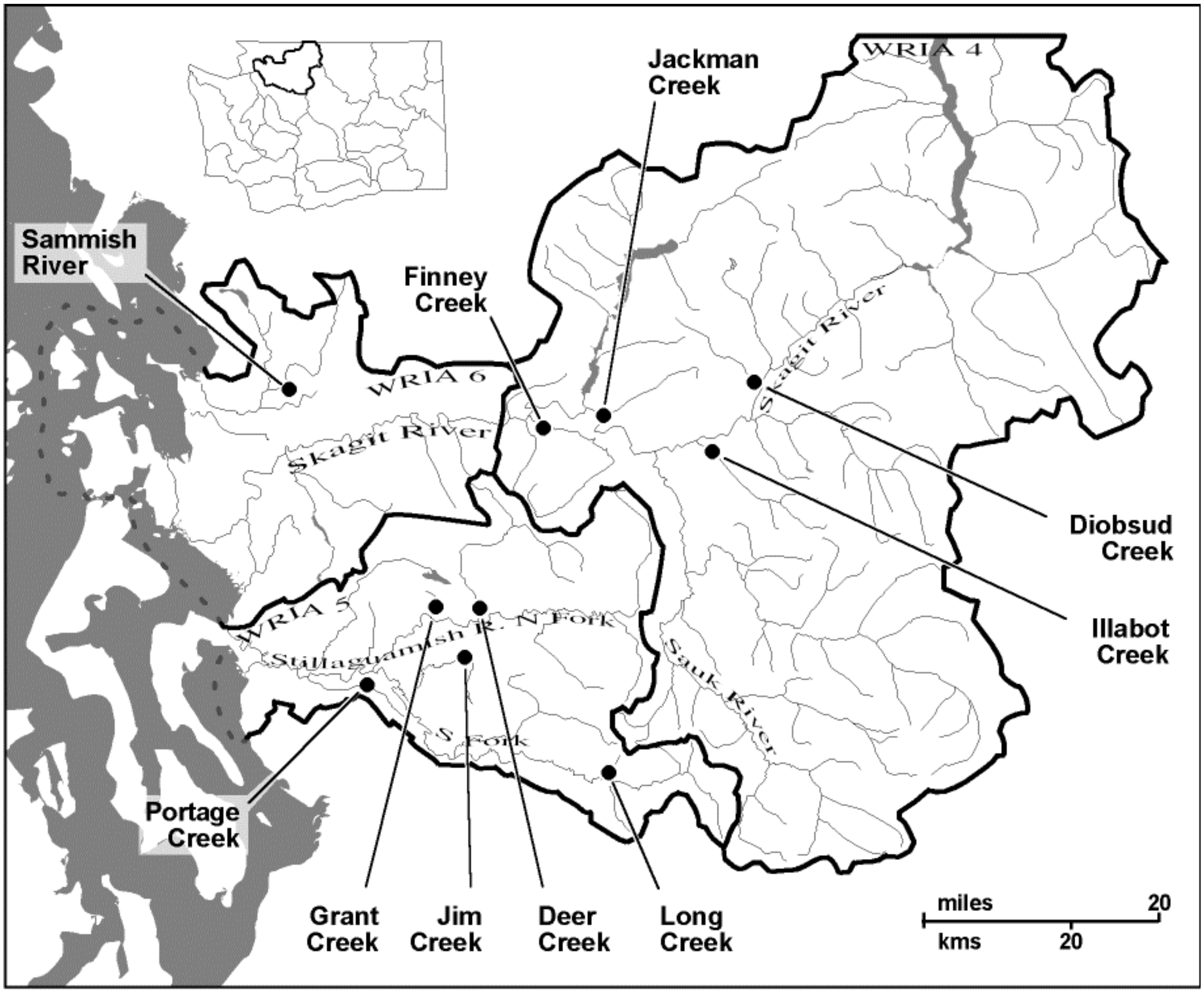


Figure 15. Skagit/Stillaguamish Water Quality Management Area. Summer 1995 biological monitoring sites.

Table 1. Physical and chemical variables measured at each stream and their scale of measurement (landscape, reach, and site-specific).

Scale of Measurement		
Landscape	**Reach**	**Site-specific**
Ecoregion	Stream Order	Depth
Subregion	Gradient	% Cobble
	Elevation	% Coarse Gravel
	Riparian Condition*	Velocity
	Flow	% Canopy Cover
	Wetted Width	
	Bankfull Width	
	Water Temperature	
	Dissolved Oxygen	
	Conductivity	
	pH	

* Numerically expressed through a categorical ranking process of the streams surveyed (1993-1995). Lowest score was 0.2 (Finney Cr.) and the highest score 10.0 (Trapper Cr.). All fifty sites received a score that was a multiple of 0.2 and based on the following criteria:
- ◊ vegetation closer to the wetted channel was more desirable
- ◊ higher density of understory/ground cover was better
- ◊ greater diversity in age of overhead canopy was desirable
- ◊ high density of trees was more desirable
- ◊ high density of trees/shrubs/bushes was more desirable

Stream Habitat

Stream reaches typically contain two easily identified and contrasting areas of stream habitat: riffles (broken surface water) and pools (slow-moving or eddying water). The primary reason for surveying these two habitats was to incorporate multiple invertebrate assemblage types.

Multiple samples were collected at each stream site. Four biological samples were collected in riffle habitat and four samples were collected in pool habitat. First, collection locations in riffle habitat were selected based on the following criteria:

- depth of riffle,
- substrate size, and
- location within a riffle area of the stream (forward, middle, back).

Sampling among several riffles in a stream increased representation of physical differences in this habitat. Also, the sampling design was expected to generate a larger number of benthic macroinvertebrate taxa from a reach. Variations in physical condition of the riffle habitat provided an opportunity to collect both common and rare taxa.

Benthic macroinvertebrates were collected at four locations in pool habitat. The locations within a reach were determined by finding representative combinations of the following variables:

- depth of pool, and
- location within the channel (side, middle, behind a boulder/woody debris).

Absence of flowing water in pool habitat resulted in low sampler efficiency. Most stream bottom samplers rely on flowing water to direct macroinvertebrates into a collection net. In the absence of flowing water, loss of individual organisms increased. Benthic organisms collected from pools provided reliable synoptic lists of taxa, but not community characterizations dependent on density estimates.

Habitat-Specific Degradation

Separate riffle and pool samples were collected at all sites. Invertebrate assemblages collected in 1993 were analyzed for similarity between habitats. Riffle and pool invertebrate assemblages were compared in order to identify: (1) differences based on habitat type, (2) stream conditions under which differences occur, and (3) whether identification of a difference between habitats is useful information.

Representativeness of Sampling

We evaluated the efficiency and representativeness of the reach survey design by collecting replicate riffle samples from some reaches and analyzing them in the laboratory. Some replicate sampling was conducted during the 1993-1994 years, but the greater effort was placed in the 1995 biological surveys. Evaluation of replicate samples addressed appropriateness of sample design in describing the invertebrate communities from streams in the North- and South Cascade Range.

Sampling Stream Macroinvertebrates

Stream benthic macroinvertebrates were sampled from reach lengths forty times the average width. Macroinvertebrate samples were collected from riffle and pool habitats with a D-Frame kicknet (sampling area=2.0 ft^2). A device fastened to the base of the D-Frame kicknet enclosed a one-foot by two-foot area in front of the sampler. The substrate in the enclosed area was removed and scrubbed with a brush to dislodge invertebrates into the collection net. Samples from each habitat type were stored in ethanol-filled containers.

Macroinvertebrate samples from most sites were composited into a single riffle sample and a single pool sample. As part of the data quality objectives, approximately 10 percent of total sites monitored in a year were included as part of an evaluation of community variability within a stream reach. Replicate samples were stored in separate containers at each of these streams. A detailed description of the stream survey protocols can be found in Plotnikoff (1994).

Cluster Analysis: Similarity of Invertebrate Communities

Invertebrate community similarity was determined using a statistical technique called cluster analysis. Two attributes of the invertebrate data were important: (1) the presence of species, and (2) the density estimate for each species. The analytical results were used as a template to test hypotheses.

A hierarchical agglomerative clustering technique was used to determine biological similarity among survey sites (COMPAH; Clarke and Warwick, 1994). The Bray-Curtis similarity coefficient and group average was used to classify sites. Normal (site clustering) and inverse (species clustering) analyses were performed on the transformed data matrix.

Correlation of Invertebrate Communities with Environmental Variables

Identifying the relationship between environmental variables and invertebrate communities was eventually used to interpret results from invertebrate community similarity. A statistical method for determining environmental variable correlation with invertebrate communities simplified the task of eliminating extraneous information.

Analytical results from the classification of sites were associated with environmental variables (Clarke and Ainsworth, 1993), allowing determination of those that had the highest correlations with the invertebrate matrix. The distribution for each environmental variable was examined with a 'density' graphics function (Wilkinson, 1990), using a $\log_{10}(x+1)$ transformation for those variables that did not approximate a normal distribution. Combinations of variables that showed strong colinearity were eliminated.

The need for transforming each physical and chemical variable was identified by graphing individual distributions. Distribution graphs for the variables were produced by individual year and for the combination of three years (1993-1995). Following data transformation, density plots for all two-variable combinations were used to determine conditions of colinearity. Two-variable comparisons that indicated relationships were eliminated from further analyses.

Colinearity between variables was determined using 'draftsman plots' described by Clarke and Ainsworth (1993) and analyzed using SYSTAT (Wilkinson, 1990). Remaining environmental variables were correlated with the results of cluster analysis using a procedure in PRIMER

(Clarke and Warwick, 1994). The harmonic (weighted Spearman) rank correlation (r) was used to express the proportion of the variance explained for relationships between the biotic similarity matrix and the abiotic similarity matrix. Harmonic rank correlation (r) values derived from the environmental data matrix are not equivalent to the Spearman correlation coefficient. The numeric values reported indicated the strength of the relationship between the biotic similarity matrix and a select group of environmental variables.

PRIMER is able to analyze six environmental variables at one time. In order to analyze eighteen variables, a moving subset procedure was developed to identify environmental variables with greatest correlation to the biotic similarity matrix. Exploratory analysis of the environmental variables proceeded in consecutive groups: 1-6, 4-9, 7-12, 10-15, and 13-18. Six highly correlated variables were chosen following two iterations through the 'moving subset procedure.' Variables were rearranged into groups according to similar correlation values in the second iteration of the similarity analysis.

Indicator Groups and Species

Characteristic species of site clusters were described by examining the constancy and fidelity of species groups. The constancy of a species group is the proportion of sites in a cluster at which taxa from a distinct group appears. Fidelity of a species group is a measure of it's 'uniqueness' to a site cluster from among all sites surveyed.

Species were listed in indicator groups when a species cluster had a constancy of ≥70%. Species were listed as indicator taxa when fidelity of a species cluster was high.

Preparation of Data for Analysis

a. Species data

A standard list of taxa was constructed for all collections and two rules were developed to condense site species lists. The merge rule was used to combine related specimens to their most abundant taxonomic level. Unidentifiable specimens that were damaged or immature were assumed to be representatives of the next highest taxonomic level.

The drop rule was applied when the abundance of family level identifications was greater than the abundance of related genera. The generic categories were dropped and combined into the family taxonomic level in all subsequent samples of that dataset. For example, identification to the generic level was difficult and sometimes unreliable for the Simuliidae and the Chironomidae, therefore, taxonomic identifications below family level were "dropped" for these groups and density estimates for each group were combined.

b. Data reduction

Reduction of the species matrix accommodated: (1) limited computational capacity of the software, and (2) redundancy or validity in taxonomic information. The taxa list was first reduced by eliminating all taxa that were less than one percent of the total abundance in a sample. Number of taxa retained for analysis is listed for each year in Table 2. Interpretation of clustering results are unclear with too many rare taxa. Rare taxa should be examined further if they are specialists.

Table 2. Number of taxa used in data analysis following reduction of rare taxa in the biological data matrix.

Year	Number of taxa retained for analysis of riffle and pool habitat	Number of taxa retained for analysis of riffle habitat	Rare taxa cut levels
1993	181	181	total number of taxa
	110	81	cut level 1%
1994	161	91	cut level 1%
1995	150	85	cut level 1%

c. Standardization and transformation of abundance data

The reduced taxa abundance data were initially standardized with a percent transformation. An additional $\log_{10}(x+1)$ transformation of the percent standardized data was used to eliminate zero abundance estimates. Effectiveness of different transformations in cluster analysis was evaluated by comparing the log transformed data with results from square root-, double square root-, and presence-absence transformations. Clarke (1993) outlines the use of transformations and standardizations in community structure analyses.

Coefficients of variation (CV) were calculated for each taxon from among the replicates collected at eight sites. The CV's calculated for each taxon were based on two expressions of the data: (1) abundance of a taxon per unit area of stream bottom, and (2) percent transformed abundance data. An arithmetic mean coefficient of variation (MCV) was determined for taxon abundance (MCVA) and for percent transformed abundance (MCVP). The MCVA and MCVP were calculated for all eight sites from which replicate samples were collected. The MCV was higher for abundance data than for percent transformed abundance for nearly all streams except Long Creek and Simmons Creek collections during 1995 (Table 3).

Table 3. Mean Coefficients of Variation (MCV) calculated first by determining the coefficient of variation (CV) for each taxon among the replicates at a site and then summing the CV's.

Year	River	# of Taxa	# of Replicates	MCVA (%)	MCVP (%)
1993	Ohanapecosh River	42	4	145	133
1994	Elbe Site	68	4	150	138
	Simmons Creek	69	3	140	132
1995	Diobsud Creek	37	4	130	128
	Elbe Site	48	4	108	101
	Finney Creek	36	4	151	149
	Long Creek	43	4	148	149
	Simmons Creek	52	4	125	126

MCVA: Mean Coefficient of Variation of abundance data.
MCVP: Mean Coefficient of Variation of percent transformed data.

A sign test (Wilkinson, 1990) was used to determine significant differences, if any, between coefficients of variation (CV's) calculated from abundances versus percent transformations. The number of cases where CV abundances (CVA) differed from CV percentages (CVP) is listed in Table 4. Overall, CVA's were significantly larger (p=0.08) than CVP's which indicated that the percent transformed data was less variable among replicates than when using the abundance data (Table 4). The percent transformed data of taxa collected from a site was used in further analyses.

Table 4. Results of a sign test to determine if coefficients of variation (CV's) calculated from abundances or percent transformed data were less variable.

Year	River	# of CVA > CVP	# of CVP > CVA	Probability
1993	Ohanapecosh River	16	14	0.86
1994	Elbe Site	31	14	0.02
	Simmons Creek	31	26	0.59
1995	Diobsud Creek	15	9	0.3
	Elbe Site	24	17	0.35
	Finney Creek	11	10	1
	Long Creek	11	15	0.55
	Simmons Creek	20	23	0.76
Overall		159	128	0.08

Probability: probability that the lesser of the two differences is significantly lower

d. *Missing environmental data*

Several values for physical and chemical variables were estimated by regression or arithmetic mean, where applicable. The dissolved oxygen concentration for the Gold Creek survey was estimated with linear regression. A value for average velocity at the Upper Yakima site surveyed in 1993 was not available and consequently was estimated from two similar-sized streams.

Results

Regional Similarity of Sites (1993-1995 Surveys)

Invertebrate monitoring information was analyzed for collections made from 1993-1995. Collecting occurred in streams from most of the major watersheds throughout the state (Figure 3). A statewide dataset analysis was initiated to identify distinct site-groupings. Further analysis of the site groups was used to describe invertebrate communities under narrower ranges of physical conditions.

Several groups of sites were identified using invertebrate data (Figure 16). Three major groups of sites representing regions were identified from the cluster analysis: interior montane, coastal lowlands and mountains, and interior plateau and foothills (Figure 16). Secondary sub-groups demarcating regional invertebrate similarity were also identified. Results of regional analysis with invertebrate communities were compared with corresponding ecoregions (Table 5).

Table 5. Geographic areas identified by analyzing the similarity among invertebrate communities collected from fifty sites across the state.

Major Group	Sub-Group	Ecoregion*
Interior Mountains	a. West slope N. Rockies	1 Northern Rockies 2. Columbia Basin
Coastal Lowlands and Mountains	a. North Cascade Range b. Olympic Range	1. Cascades 2. Coast Range
Interior Plateau and Foothills	a. Semi-arid plateau b. Montane (east slope Cascade Range)	1. Columbia Basin 2. Cascades 3. (South) Eastern Cascades Slopes & Foothills

* ecoregion delineation following Omernik & Gallant (1986)

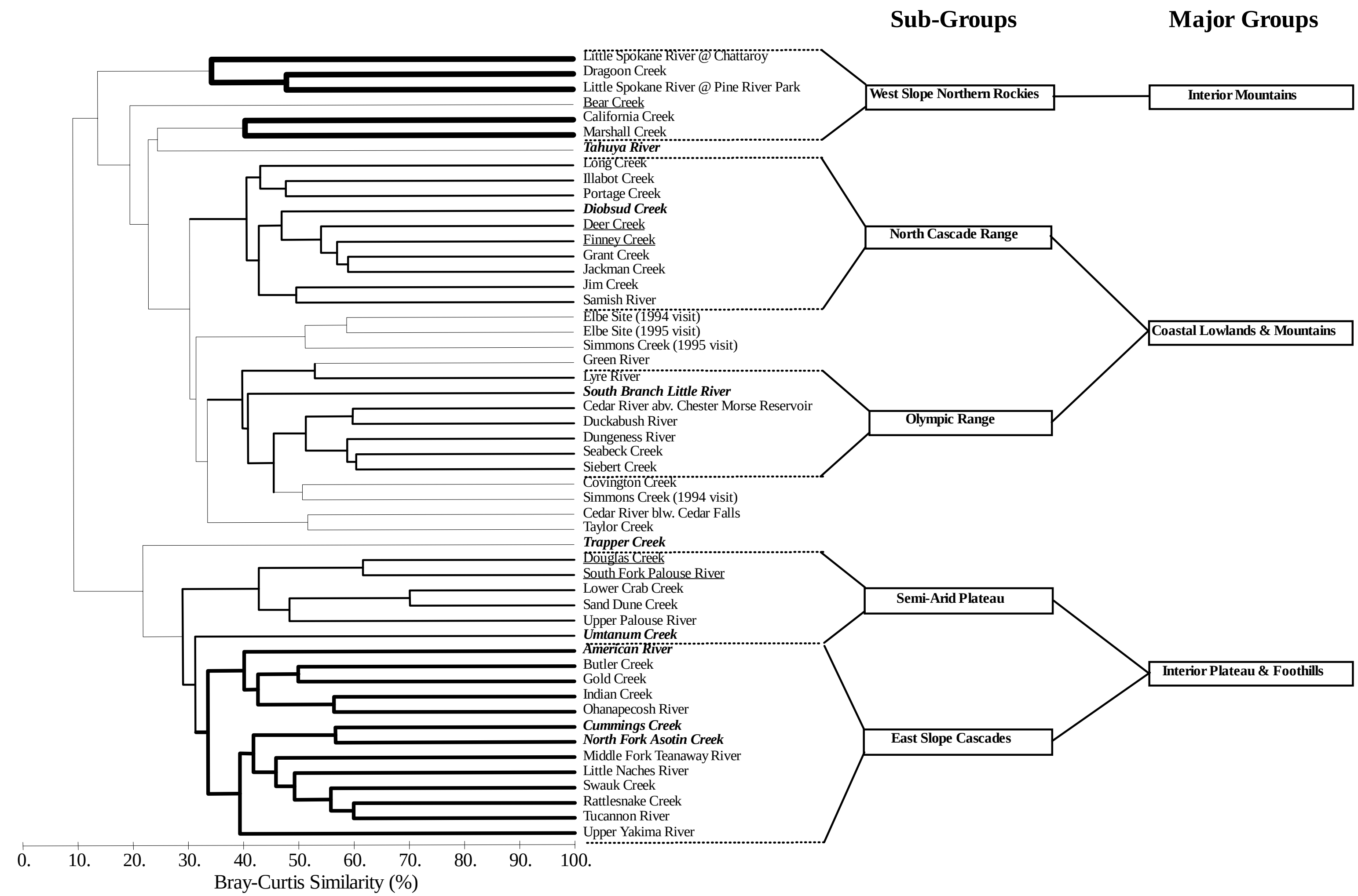


Figure 16. Site groupings based on invertebrate assemblage similarity. Major site groupings and Sub-Groups are identified from analysis of summer 1993-1995 surveys. Least disturbed sites are indicated with italics and severely degraded sites are underlined.

Watershed Condition

a. 1993 Survey

Six site clusters were identified from macroinvertebrate data collected in 1993 (Figure 17; Appendix IIa). Each cluster of sites was associated with a Water Quality Management Area (WQMA). A description of stream condition was provided for WQMA's. Least disturbed sites (*e.g.*, Trapper Creek, North Fork Asotin Creek, Cummings Creek, and Umtanum Creek) and a large river site (*e.g.*, Upper Yakima River) had distinct invertebrate communities.

b. 1994 Survey

Seven site clusters were identified from 1994 macroinvertebrate surveys (Figure 18; Appendix IIb). All of the streams surveyed during this year were situated in mountainous regions. Least disturbed conditions were contrasted with canopy loss (*i.e.*, grazing or logging), water regulation, or sediment transport. Invertebrates were collected from a group of streams with greater distances between them in 1994 compared to the previous year's work.

c. 1995 Survey

Five site clusters were identified from analysis of 1995 invertebrate data (Figure 19; Appendix IIc). Most streams visited in 1995 were considered to have been influenced by recent or historic logging activity. Two streams surveyed in the lower drainage of agricultural areas were distinct from upper drainage, mountain regions.

Least Disturbed Site Identification

Sites chosen for invertebrate monitoring in 1993, 1994, and 1995 included least disturbed streams. A least disturbed stream was considered to have limited access and no visual signs of impact. The stream setting (*e.g.*, National Park, Wilderness) was used to choose candidate streams.

Least disturbed streams were confirmed by analysis of invertebrate monitoring in each year (1993-1995). Biological conditions in 1993 at Trapper Creek and Umtanum Creek were unrelated (*i.e.,* opposite ends of the clustering diagram) (Figure 17). Least disturbed sites from 1994 invertebrate monitoring were located in Puget Sound and the Northern Olympic Peninsula (Figure 18). A single least disturbed site (Diobsud Creek) in the Skagit watershed was confirmed by macroinvertebrates.

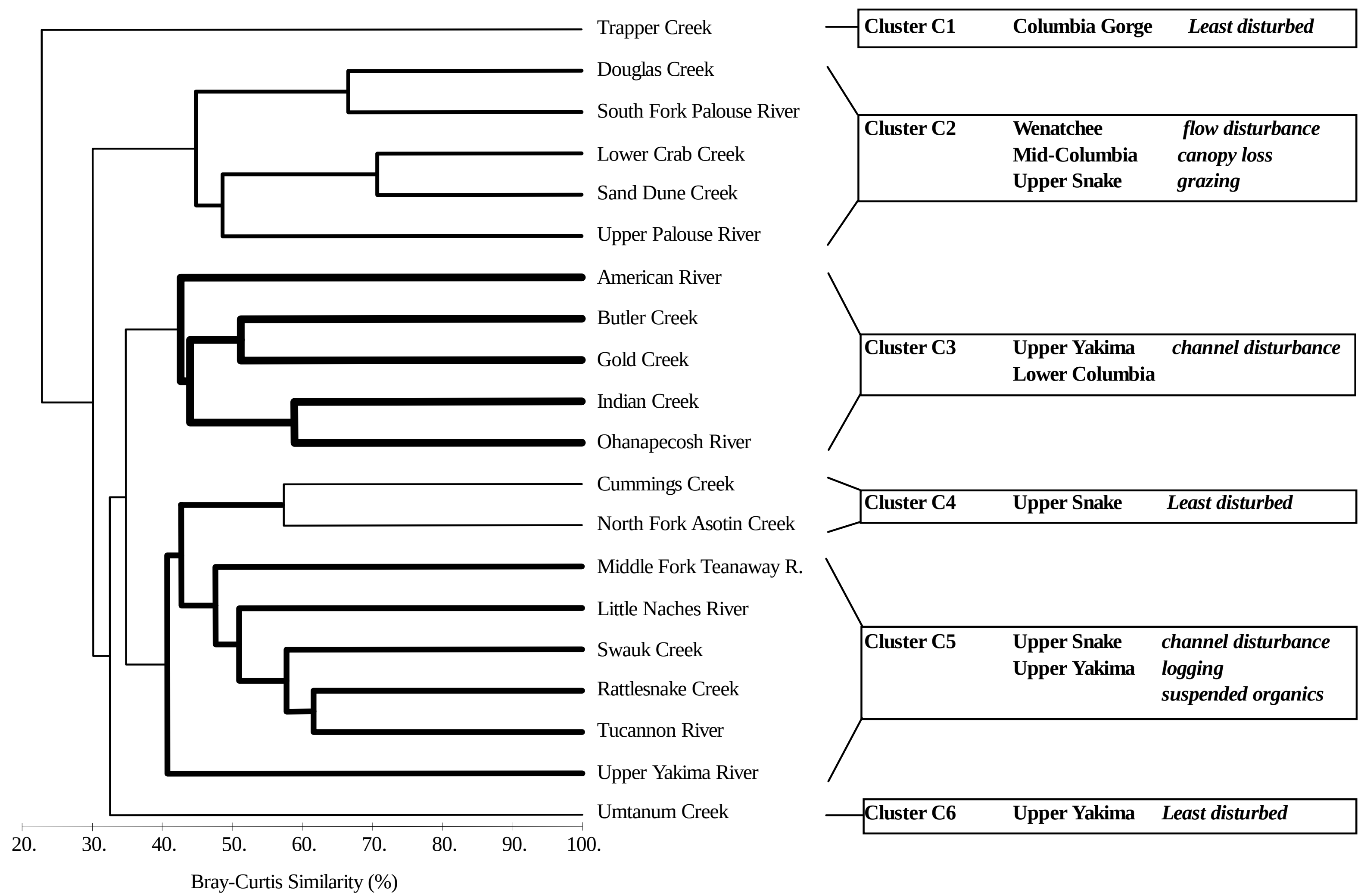


Figure 17. Site groupings based on invertebrate assemblage similarity. Water Quality Management Areas (WQMA's) are related with factors that cause stream disturbance. All sites were surveyed during summer 1993.

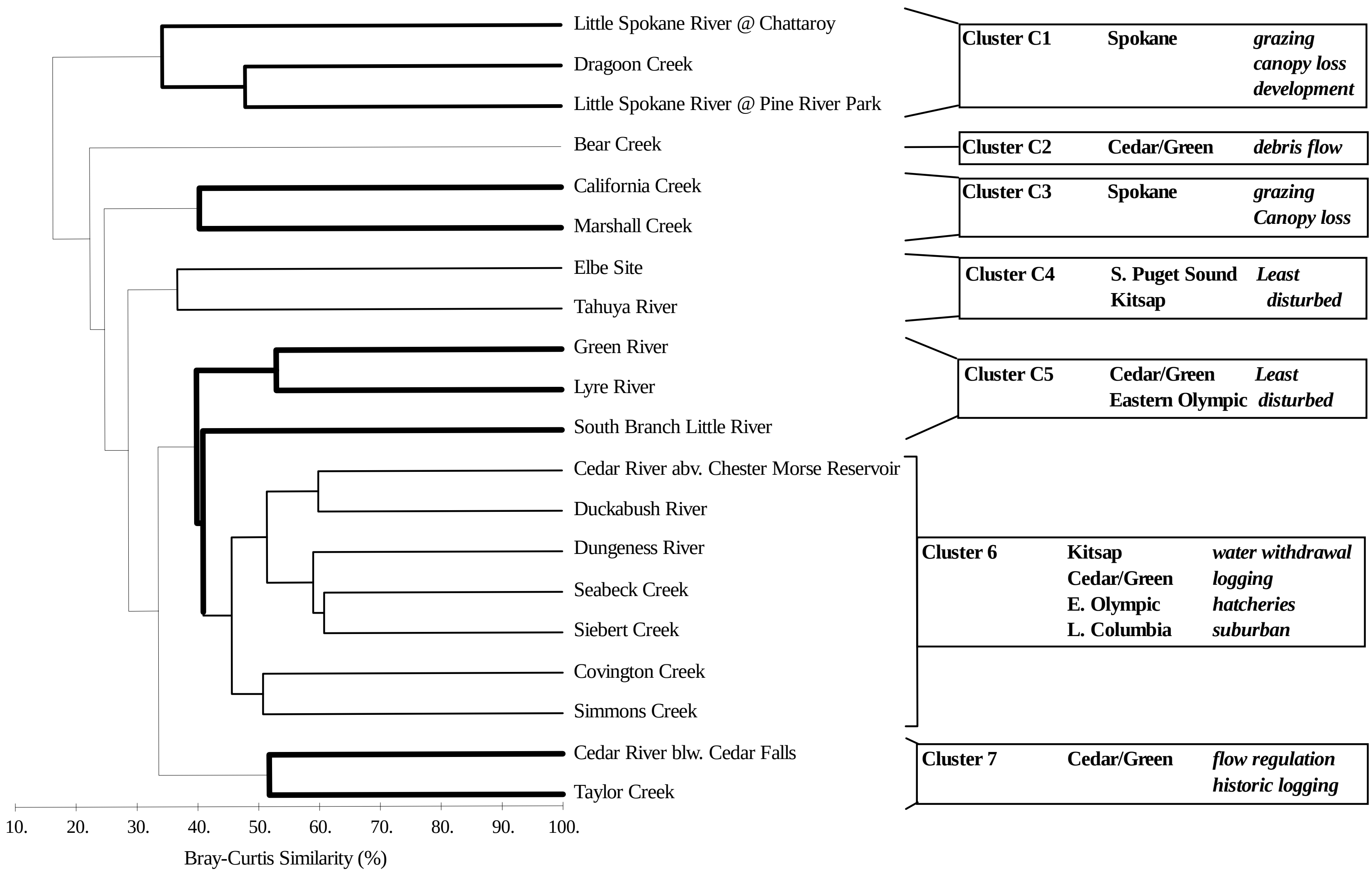


Figure 18. Site groupings based on invertebrate assemblage similarity. Water Quality Management Areas (WQMA's) are related with factors that cause stream disturbance. All sites were surveyed during summer 1994.

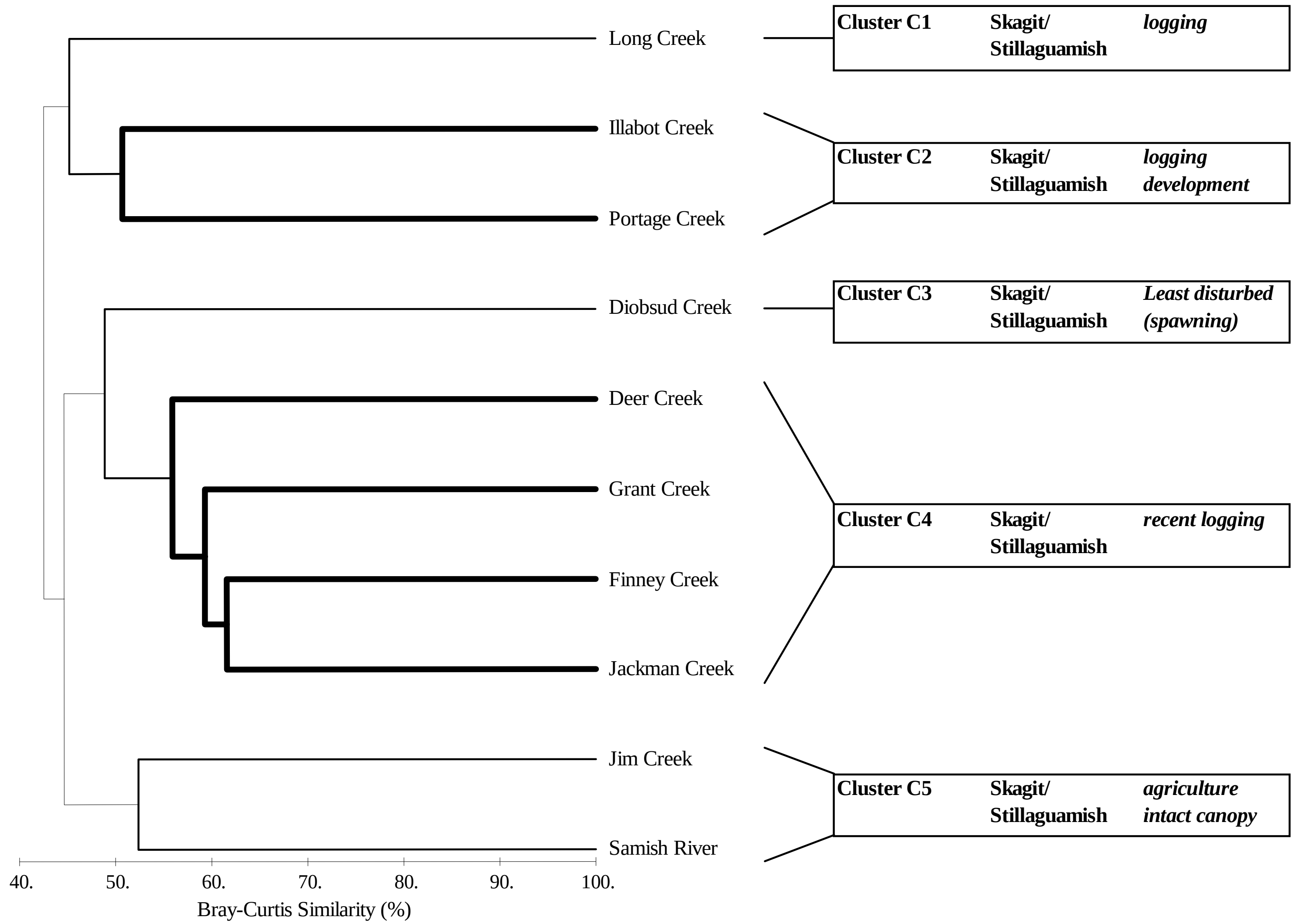


Figure 19. Site groupings based on invertebrate assemblage similarity. Water Quality Management Areas (WQMA's) are related with factors that cause stream disturbance. All sites were surveyed during summer 1995.

Identifying Habitat-Specific Degradation (riffle/pool sampling)

Thirty-nine stream observations representing riffle and pool invertebrate communities formed nine clusters (assemblage similarity >40%) following classification analysis. Cluster groups for the riffle/pool classification analysis are described in Table 6.

Macroinvertebrate assemblages from riffle habitat and pool habitat clustered together at twelve streams. Sites in which invertebrate communities were similar in both habitats included: Douglas Creek, South Fork Palouse River (@ Pullman), Lower Crab Creek, Sand Dune Creek, Upper Palouse River (@ Palouse), American River, Middle Fork Teanaway River, Rattlesnake Creek, Cummings Creek, North Fork Asotin Creek, Swauk Creek, and Ohanapecosh River.

Invertebrate communities were distinctly different in riffle and pool habitats of seven streams (Table 6). Pool habitat communities were distinct in clusters G and B. Two of the remaining riffle communities (Umtanum Creek and Trapper Creek) were distinct from each other and all other clusters. The remaining streams formed the Cascade range cluster (F). These streams had highly eroded channels.

Stream sites located in regional transition zones, between high elevation ranges and the interior arid plateau, clustered together (Clusters C and D, Table 6). Montane streams that were degraded by sediment transport had similar invertebrate communities. Intermediate-sized streams located in deeply divided topography (North Fork Asotin Creek and Cummings Creek) and a large low gradient stream (Upper Yakima River) had distinct communities.

Alternative Analyses for Identifying Regional Similarity of Communities

Non-metric Multidimensional Scaling (MDS) is an ordination algorithm that displays associations of variables in two-dimensions (Clarke and Warwick, 1994). The extent of similarity between two sites (based on their biology) is spatially related and de-emphasizes numeric quantification. The numerical similarity between sites is not provided with MDS, rather, site associations are inferred by their location in two-dimensional space.

Non-metric Multidimensional Scaling was not used beyond an initial analysis using invertebrate data. The ability to interpret site associations using MDS is a measure known as ‘stress.’ A high estimate for ‘stress’ (>0.20) indicates a high level of difficulty in interpreting similarity between sites. The high stress level (0.21) calculated from the invertebrate matrix indicated that relationships among some sites were difficult to identify.

Table 6. Classification analysis of site observations combining riffle (1) and pool (0) habitat information. The biotic matrix was percent standardized and transformed with the $\log_{10}$ (x+1) function.

Cluster	Sites	Characteristics
A	Douglas Creek 0,1 South Fork Palouse River 0,1	Low flow, Columbia Basin streams, draining agricultural wheatland, extremely high flows from late February to early April, low taxon occurrence.
K1, K2	Lower Crab Creek 0,1 Sand Dune Creek 0,1 Upper Palouse River 0,1	Irrigation return flow, heavy soil erosion, Columbia Plateau, basalt rock, fairly constant flow throughout the year, no riparian zone, low gradient, thus no strong difference between riffle and pool, low taxon occurrence, clusters out with square root, double square root and $\log_{10}$(x+1)-transformation.
G	Gold Creek 0 Little Naches River 0 Butter Creek 0 Indian Creek 0 Trapper Creek 0	Pool Cluster, clusters out regardless of transformation ('pseudo-pools'- see text for definition).
W	American River 0, 1	Pristine stream in wilderness area.
F	Butter Creek 1 Gold Creek1 Indian Creek 1 Ohanapecosh River 0,1	Cascade mountain streams; Indian Creek and Ohanapecosh River in National Park; 42% similarity to American River biota; natural aggradation.
B	Tucannon River 0 Umtanum Creek 0	Real Pools, in arid land streams, coarse gravel substrate, complex communities, show close similarities with all transformations.
C	Cummings Creek 0,1 North Fork Asotin Creek 0,1 Upper Yakima River 1	Cummings Creek and NFAsotin are tributaries to the Snake river. Sampling sites at transition from mountainous region to arid plateau.
D	Swauk Creek 0,1 Middle Fork Teanaway R. 0,1 Little Naches River 1 Rattlesnake Creek 0,1 Tucannon River 1	Sediment impacted streams, from natural and anthropogenic sources.
X	Trapper Creek 1	Single site→riffle.
X	Umtanum Creek 1	Single site→riffle.

Replicate Samples from Streams

Similarity of invertebrate communities including sites with replicate samples was presented in Figure 20. Analytical results showed that in almost all cases replicate macroinvertebrate collections were more similar to within site collections than they were to other stream sites. One exception, the Finney Creek replicate samples did not cluster together (Figure 20).

Site Condition and Stream Habitat

Combinations of environmental variables that were strongly correlated with invertebrate assemblages are reported in Table 7. A set of variables was identified for each monitoring year (*e.g.*, 1993, 1994, and 1995). A final set of variables relates stream characteristics to invertebrate assemblages statewide for this sample of streams.

Table 7. Environmental variable sets that demonstrated the best relationship with aquatic invertebrate assemblages.

Year	Variables	Correlation (r)
1993	Temperature pH Conductivity Riparian Condition	0.428
1994	pH Dissolved Oxygen Conductivity Gradient	0.515
1995	Bankfull Width Wetted Width Gradient Elevation	0.677
1993,1994,1995	Temperature pH Conductivity Gradient Elevation	0.421

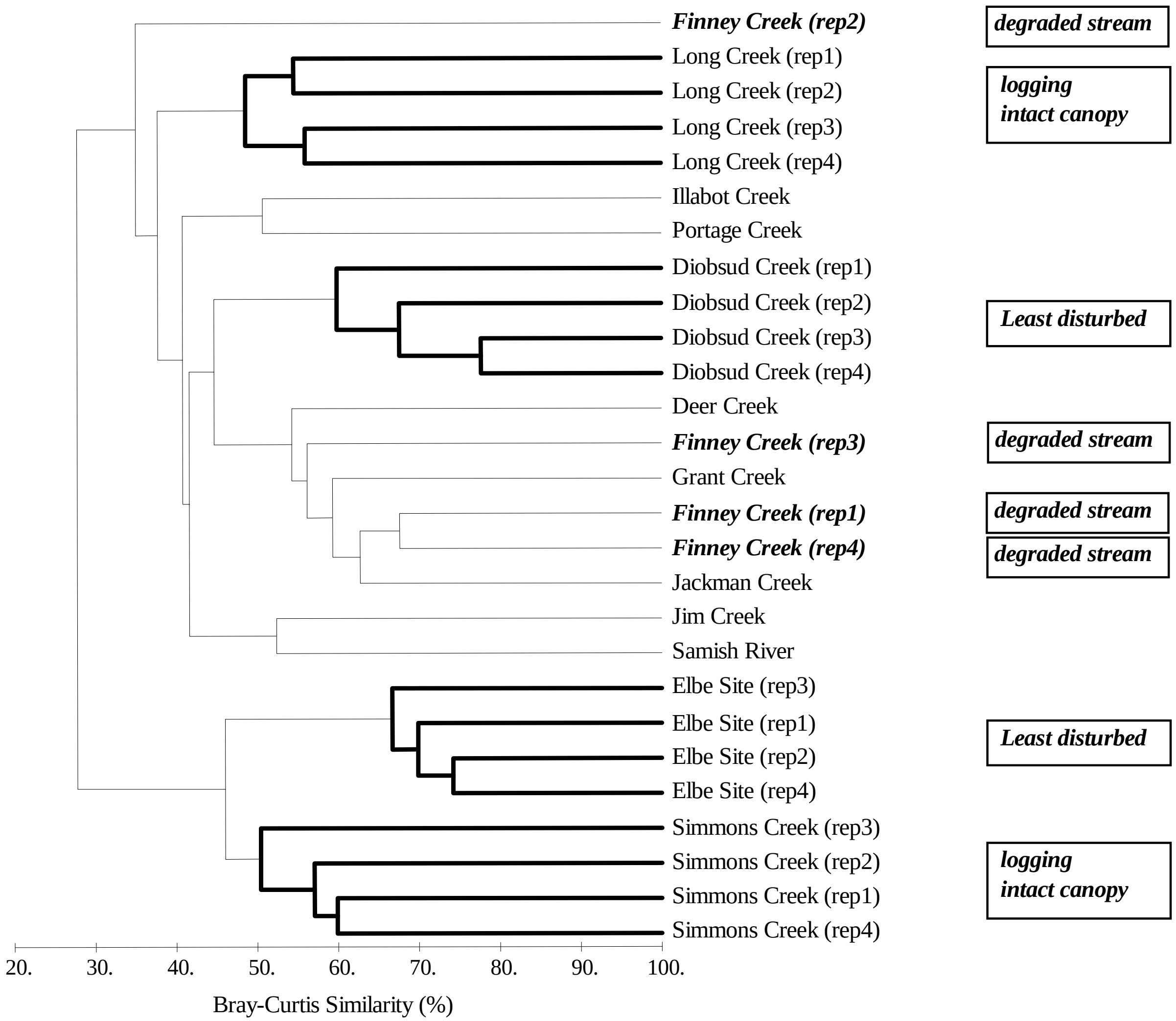


Figure 20. Site groupings based on invertebrate assemblage similarity. Analysis of replicate sample similarity from select streams. Sites were surveyed during summer 1995.

Environmental Variables that Describe Site Conditions

A combination of four variables provided the strongest correlation with invertebrate assemblages from the 1993 sites (Table 8). Mountain streams were contrasted with semi-arid plateau streams using the variables temperature, pH, conductivity, and riparian condition. Contrasts among these streams were: (1) coldwater versus warmwater streams, (2) open canopy, coldwater streams, and (3) open canopy, warmwater streams. Surface water had neutral to slightly alkaline pH at 1993 survey sites.

Surveys conducted in 1994 were at coldwater streams. Environmental variables strongly correlated with invertebrate assemblages were: pH, dissolved oxygen, conductivity and stream gradient (Table 9). Three stream conditions were contrasted: (1) streams with neutral pH and those that were alkaline, (2) high gradient with low gradient streams, and (3) streams that had high conductivity in specific regions of the state.

Stream characteristics strongly correlated with invertebrate assemblages collected during the 1995 survey were bankful width, wetted width, gradient, and elevation (Table 10). The stream sites contrasted high gradient, high elevation streams with low gradient, low elevation streams. Bankful width estimates were approximately twice the distance of wetted widths for sites visited in 1995.

Stream Conditions and Indicator Species

Two invertebrate assemblages were identified from the 1993 survey that were indicative of stream conditions (Figure 21). A least disturbed site in the Southern Cascade Range contained coldwater indicator taxa (Table 11). The second group of taxa was collected from streams with riparian and channel changes. An indicator group of taxa from these East Cascade and Blue Mountain Range streams suggested that deposited and suspended organic particles were abundant. Several of the taxa from the indicator group consume attached algae from large rocks in streams.

Invertebrate assemblages collected during the 1994 survey contrasted least disturbed conditions, recent- and historic damage to streams (Table 12). The indicator species defined site similarities from two regions of the state: Puget Lowland and mid-Cascade Range (Figure 22). Three indicator groups were from coldwater streams. Stream gradient was high at the debris damaged site, moderate at the least disturbed sites, and low at sites where stand age of the surrounding forest was less than forty years.

Invertebrate monitoring in North Cascade streams during 1995 identified two distinct assemblages. A low gradient, least disturbed site contrasted with a high elevation stream that had recently been logged (Table 13). The number of taxa collected from North Cascade streams was low and is reflected by lists of indicator taxa. Two species clusters correspond with site cluster diagrams (Figure 23).

Table 8. Environmental variables that were correlated with stream invertebrate assemblages collected in summer 1993. The number of Water Quality Management Area (WQMA) groups correspond with site groupings determined by classification analysis.

WQMA's & Groups	Variable	Range	x±sd	Land Use
Columbia Gorge	Temperature-**cold**	11.7 oC		Least disturbed
(N=1)	pH-**neutral**	7.4		(Forested)
Cluster C1	Conductivity-**low**	107 umhos/cm		
	Riparian Condition-**intact**	95% closed		
Mid-Columbia	Temperature-**warm**	19.0-24.0	(21.0±2.2)	Irrigation return flow
Upper Snake	pH-**alkaline**	8.0-9.2	(8.6±0.5)	Canopy disturbance
Upper Yakima	Conductivity-**high**	100-490	(331±149.8)	Grazing
(N=5)	Riparian Condition-**open**	43%-68%	(60±9.9)	
Cluster C2				
Upper Yakima	Temperature-**cold**	5.1-12.7	(9.3±3.4)	Channel disturbance
Lower Columbia	pH-**neutral**	7.4-8.5	(7.9±0.4)	(natural &
(N=5)	Conductivity-**low**	38-89	(66±20)	anthropogenic)
Cluster C3	Riparian Condition-**open**	36%-68%	(60±13.6)	
Upper Snake	Temperature-**cold**	13.5-14.0	(13.8±0.35)	Least disturbed
Upper Yakima	pH-**alkaline**	8.4	(8.4±0)	(Forested)
(N=2)	Conductivity-**moderate**	107-380	(243.5±193.0)	
Cluster C4	Riparian Condition-**intact**	68%-94%	(81.0±18.4)	
Upper Snake	Temperature-**cold**	9.3-19.8	(15.1±4.0)	Channel disturbance
Upper Yakima	pH-**alkaline**	7.7-8.4	(8.2±0.3)	(anthropogenic)
(N=6)	Conductivity-**low**	83-225	(123.3±51.9)	Logging activity
Cluster C5	Riparian Condition-**open**	31%-68%	(60.1±14.8)	
Upper Yakima	Temperature-**warm**	16.2		Least disturbed
(N=1)	pH-**alkaline**	9.4		(Semi-arid plateau)
Cluster C6	Conductivity-**high**	239		
	Riparian Condition-**open**	61%		

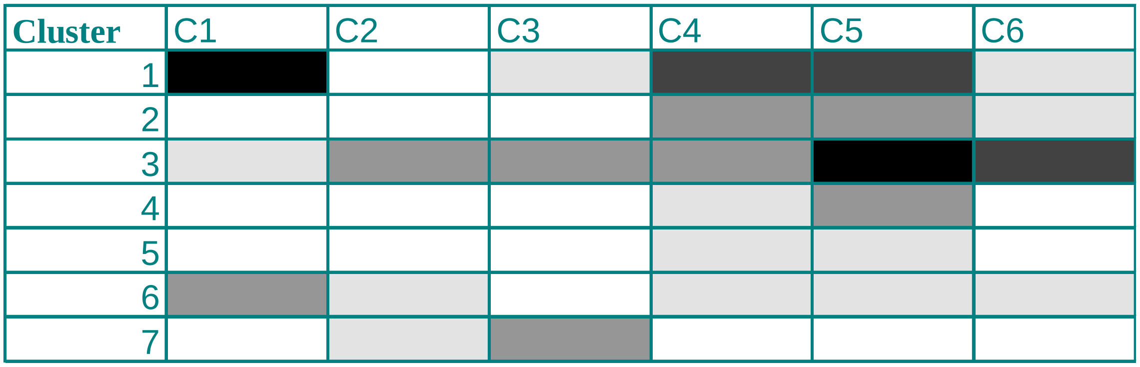
Table 9. Environmental variables that were correlated with stream invertebrate assemblages collected in summer 1994. The number of Water Quality Management Area (WQMA) groups correspond with site groupings determined by classification analysis.

WQMA's & Groups	Variable	Range	x±sd	Land Use
Spokane	pH-**alkaline**	8.5-8.7	(8.6±0.1)	Grazing
(N=3)	Dissolved Oxygen-**high**	11.1-11.9 mg/L	(11.6±0.4)	Canopy Loss
Cluster C1	Conductivity-**high**	222-315 umhos/cm	(273±47)	Development
	Gradient-**low**	0.5%-2.75%	(1.6±1.1)	
Cedar/Green	pH-**neutral**	7.8		Debris torrent
(N=1)	Dissolved Oxygen-**moderate**	10.6		
Cluster C2	Conductivity-**low**	37		
	Gradient-**high**	8.75%		
Spokane	pH-**alkaline**	8.0-8.1	(8.0±0.7)	Grazing
(N=2)	Dissolved Oxygen-**moderate**	9.6-10.3	(10.0±0.5)	Canopy Loss
Cluster C3	Conductivity-**high**	253-278	(266±18)	
	Gradient-**low**	2.0%	(2.0±0)	
South Puget	pH-**neutral**	7.3-8.1	(7.7±0.6)	Least disturbed
Sound/Kitsap	Dissolved Oxygen-**moderate**	9.1-10.9	(10.0±1.3)	(forested)
(N=2)	Conductivity-**low**	56-74	(65±12.7)	
Cluster C4	Gradient-**moderate**	0.25%-8.0%	(4.12%±5.5%)	
Cedar/Green	pH-**neutral**	7.8-8.2	(8.0±0.2)	Least disturbed
Eastern Olympic	Dissolved Oxygen-**moderate**	9.7-11.0	(10.3±0.7)	(forested)
(N=3)	Conductivity-**low**	62-140	(99±39)	
Cluster C5	Gradient-**low**	1.5%-4.5%	(2.6%±1.6%)	
Kitsap	pH-**neutral**	7.3-8.1	(7.9±0.3)	Water withdrawal
Cedar/Green	Dissolved Oxygen-**moderate**	9.7-11.4	(10.6±0.6)	Moderate logging
Eastern Olympic	Conductivity-**low**	43-225	(112.8±61.8)	Hatcheries
Lower Columbia	Gradient-**moderate**	1.25%-7.5%	(2.9±2.1)	Suburban growth
(N=7)				
Cluster C6				
Cedar/Green	pH-**neutral**	7.7-7.8	(7.7±0.1)	Flow regulation
(N=2)	Dissolved Oxygen-**high**	10.4-11.4	(10.9±0.7)	Historic logging
Cluster C7	Conductivity-**low**	33-61	(47±19.8)	
	Gradient-**low**	1.0%-2.25%	(1.6±0.9)	

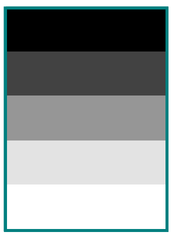
Table 10. Environmental variables that were correlated with stream invertebrate assemblages collected in summer 1995. The number of Water Quality Management Area (WQMA) groups correspond with site groupings determined by classification analysis.

WQMA's & Groups	Variable	Range	x±sd	Land Use
Skagit/	Bankful width	20.8 m		Logging
Stillaguamish	Wetted width	5.8 m		
(N=1)	Gradient	4.25%		
Cluster C1	Elevation	1292.1 ft		
Skagit/	Bankful width	4.8-45	24.9±28.4	Logging
Stillaguamish	Wetted width	2.6-17.8	10.2±10.7	Suburban growth
(N=2)	Gradient	2.25%-3.0%	2.6%±0.5	
Cluster C2	Elevation	98-315.7	206.8±153.9	
Skagit/	Bankful width	24.0		Least disturbed
Stillaguamish	Wetted width	11.9		(forested)
(N=1)	Gradient	3.0%		
Cluster C3	Elevation	344.6		
Skagit/	Bankful width	13.5-60.5	30.75±21.5	Recent logging
Stillaguamish	Wetted width	5.3-35.45	16.6±13.1	
(N=4)	Gradient	1.0%-1.75%	1.4%±0.3%	
Cluster C4	Elevation	125.1-203.6	176.2±35.0	
Skagit/	Bankful width	7.0-17.1	12.1±7.2	Agriculture
Stillaguamish	Wetted width	4.5-10.6	7.5±4.3	Intact canopy
(N=2)	Gradient	1.25%-3.75%	2.5%±1.8%	
Cluster C5	Elevation	82.0-421.1	251.6±239.8	

Constancy (Site Clusters)

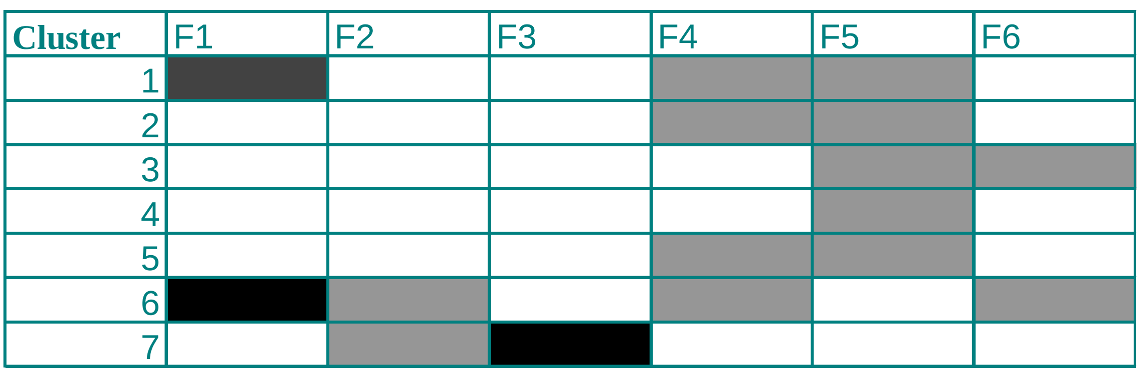


Constancy Intervals

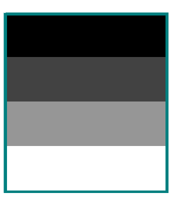


>= 70% Very High
>= 50% High
>= 30% Medium
>= 10% Low
< 10% Very Low

Fidelity (Species Clusters)



Fidelity Intervals



>= 3 High
>= 2 Medium
>= 1 Low
< 1 Negative

Figure 21. Constancy and fidelity taxa groups for clusters identified in the summer 1993 biological monitoring effort.

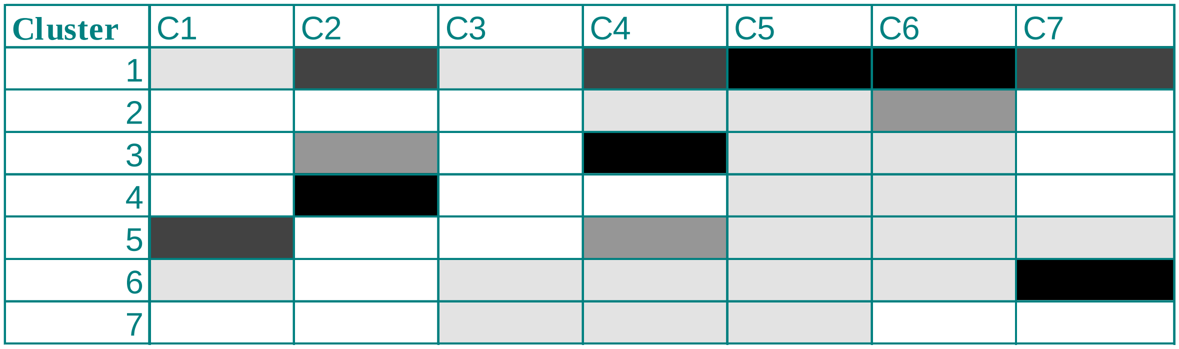
Table 11. Indicator groups and indicator species from streams surveyed in Washington during summer 1993. Indicator groups contain species that occur at >70% of the streams that have similar invertebrate communities. Indicator species always occur at streams that have similar invertebrate communities.

Indicator Groups (Constancy >70%)	**Indicator Species (Fidelity - High)**
Southern Cascade Mountains	
(Least disturbed) **Site Cluster C1**	**Species Cluster F1**
Acentrella sp.	*Epeorus longimanus*
Serratella tibialis	*Perlomyia sp.*
Skwala curvata	*Podmosta obscura*
Sweltsa Group	*Megarcys signata*
Arctopsyche grandis	
Zapada sp.	
Drunella doddsi	
Rithrogena hageni	
Cinygmula sp.	
Calineuria californica	
Doroneuria baumanni	
Hydracarina	
Hesperoperla pacifica	
Rhyacophila angelita	
Paraleptophlebia sp.	
Rhyacophila acropedes	
East Cascade Range & Blue Mountains	
(Riparian and channel degradation)	
Site Cluster C5	
Antocha sp.	no species identified
Heterlimnius sp.	
Zaitzevia sp.	
Paraleptophlebia bicornuta	
Baetis bicaudatus	
Chironomidae	
Simuliidae	
Baetis tricaudatus	
Hydropsyche sp.	
Optioservus sp.	
Brachycentrus americanus	
Glossosoma sp.	
Pteronarcys sp.	

Table 12. Indicator groups and indicator species from streams surveyed in Washington during summer 1994. Indicator groups contain species that occur at >70% of the streams that have similar invertebrate communities. Indicator species always occur at streams that have similar invertebrate communities.

Indicator Groups (Constancy >70%)	**Indicator Species (Fidelity - High)**
Mid-Cascade Range (Debris torrent damage)	
Site Cluster C2	**Species Cluster F2**
Brachycentrus occidentalis	*Brachycentrus occidentalis*
Ephemerella grandis	*Ephemerella grandis*
Caudatella hystrix	*Caudatella hystrix*
Parapsyche almota	*Parapsyche almota*
Dolophilodes sp.	*Dolophilodes sp.*
Megarcys signata	*Megarcys signata*
Prostoia sp.	*Prostoia sp.*
Taenionema sp.	*Taenionema sp.*
Rhyacophila acropedes	*Rhyacophila acropedes*
Zapada Oregonensis group	*Zapada Oregonensis* group
Puget Lowland & S. Cascade Range (Least disturbed)	
Site Cluster C4	**Species Cluster F4**
Ceratopsyche sp.	*Ceratopsyche sp.*
Hexatoma sp.	*Hexatoma sp.*
Chelifera sp.	*Chelifera sp.*
Dicranota sp.	*Dicranota sp.*
Sphaeriidae	Sphaeriidae
Doroneuria baumanni	*Doroneuria baumanni*
Yoraperla mariana	*Yorraperla mariana*
Lepidostoma sp.	*Lepidostoma sp.*
Rhyacophila brunnea	*Rhyacophila brunnea*
Rhyacophila narvae	*Rhyacophila narvae*
Rhyacophila varula	*Rhyacophila varula*
Mid-Cascade Range (Historic logging)	
Site Cluster C7	**Species Cluster F7**
Alloperla sp	*Alloperla sp..*
Arctopsyche sp.	*Arctopsyche sp.*
Claassenia sabulosa	*Claassenia sabulosa*
Polycentropus sp.	*Polycentropus sp.*
Ameletus sp.	*Ameletus sp.*
Parapsyche almota	*Parapsyche almota*
Nematoda	Nematoda
Epeorus sp.	*Epeorus sp.*
Ampumixis discolor	*Ampumixis discolor*
Atherix variegata	*Atherix variegata*
Ceratopsyche sp.	*Ceratopsyche sp.*
Zaitzevia sp.	*Zaitzevia sp.*
Cleptelmis sp.	*Cleptelmis sp.*
Optioservus sp.	*Optioservus sp.*

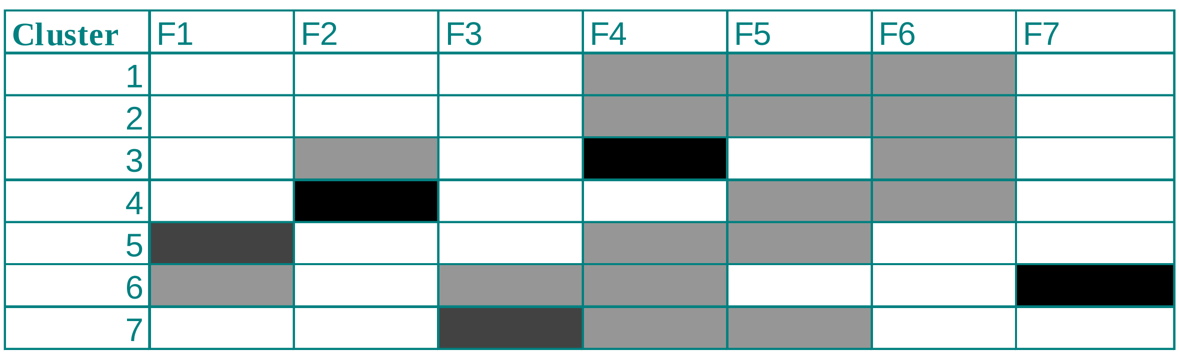
Constancy (Site Clusters)



Constancy Intervals

- >= 70% Very High
- >= 50% High
- >= 30% Medium
- >= 10% Low
- < 10% Very Low

Fidelity (Species Clusters)



Fidelity Intervals

- >= 3 High
- >= 2 Medium
- >= 1 Low
- < 1 Negative

Figure 22. Constancy and fidelity of taxa groups for clusters identified in the summer 1994 biological monitoring effort.

Table 13. Indicator groups and indicator species from streams surveyed in Washington during summer 1995. Indicator groups contain species that occur at >70% of the streams that have similar invertebrate communities. Indicator species always occur at streams that have similar invertebrate communities.

Indicator Groups (Constancy >70%)	**Indicator Species (Fidelity - High)**
North Cascades (Upper drainage; logging)	
Site Cluster C1	**Species Cluster F1**
Amiocentrus sp.	*Amiocentrus sp.*
Rithrogena robusta	*Rithrogena robusta*
Apatania sp.	*Apatania sp.*
Utaperla sp.	*Utaperla sp.*
Limnephilidae (immature)	Limnephilidae (immature)
Rhyacophila sibirica	*Rhyacophila sibirica*
Baetis sp.	*Baetis sp.*
Skwala sp.	*Skwala sp.*
Pericoma sp.	*Pericoma sp.*
North Cascades (Low gradient; least disturbed)	
Site Cluster C3	**Species Cluster F3**
Anagapetus sp.	*Anagapetus sp.*
Lara avara	*Lara avara*
Leuctridae	Leuctridae

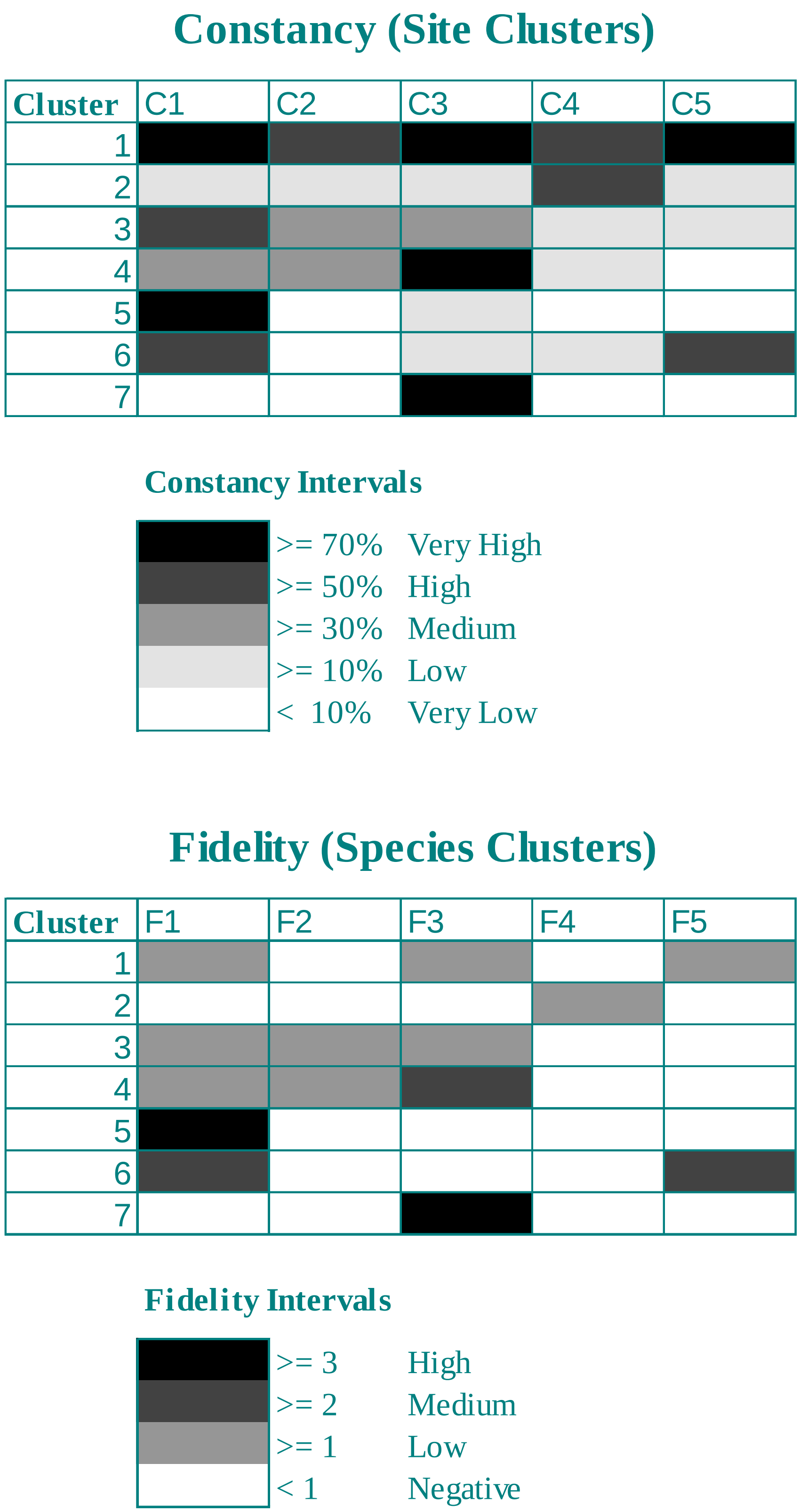


Figure 23. Constancy and fidelity of taxa groups for clusters identified in summer 1995 biological monitoring effort.

Four ‘potential’ indicator assemblages were identified from site cluster and species cluster diagrams (Table 14). Several taxa assemblages potentially satisfied the definition used for an indicator group (≥70% constancy) or indicator species (‘high’ fidelity). ‘Potential’ indicators were groups of taxa that did not appear to satisfy the constancy and fidelity definitions within the same site cluster column (e.g., Figure 21; species cluster F3). The potential indicator taxa were located at streams in the mid- and North Cascade Range and from the Puget Sound.

Discussion

Regional Biological Conditions

Analysis of invertebrates from streams throughout the state identified assemblage similarities within three major groups: interior montane, coastal lowlands and mountains, and the interior plateau and foothills. Sites containing similar macroinvertebrate communities were classified correctly into one of these major geographic regions. One site was misclassified (Bear Creek) into the interior montane group. Bear Creek is located in the coastal mountains. Some refinement of these regions may be required over time as further data are collected.

The major regions in which invertebrate assemblages were similar contained distinct ‘sub-groups’ (Figure 16). Streams with similar invertebrate taxa were found in specific geographic areas of these regions. Sub-groups were comprised of sites from similar geographic regions and similar human influence. Macroinvertebrate communities were characterized for each sub-group and reflected the influence of geographic setting and site conditions.

Identification of distinct geographic areas using invertebrate assemblages showed some similarity to other landscape partitioning strategies. Ecoregions (Omernik and Gallant, 1986) based on terrestrial variables were compared to regions identified by stream invertebrates (Table 5). The distribution of invertebrate species was found to transcend ecoregion boundaries. Fewer stream invertebrate regions were identified.

Watershed Condition

a. 1993 Survey

The interior region of the state (East of the Cascade Range) was surveyed in 1993 and had invertebrate communities that distinguished least disturbed from degraded stream conditions. Invertebrate communities in mountainous portions of the interior (East Cascades and Blue Mountains) were influenced by channel disturbance. Sites that were channelized (*e.g.,* Butler Creek) or had broad floodplains (*e.g.*, Gold Creek) had minimal shading from riparian canopy. Surface water temperatures were low and appeared unaffected by the absence of a significant riparian canopy (Table 8).

Table 14. Species that have potential for indicator status. Taxa lists compiled from 1993, 1994 and 1995 surveys. Each group had some relationship to streams in a region of Washington State.

Region		
Mid-Cascade Range (upper drainage of rivers and streams)	Puget Sound (mid- & low elevation)	North Cascades (mid- & low elevation)
(Species Cluster F3)	**(Site Clusters C5 & C6)**	**(Site Clusters C1 & C5)**
Wet & Dry Zones	**Wet Zone**	**Wet Zone**
Amiocentrus sp.	*Acentrella sp.*	*Acentrella insignificans*
Blepharicera sp.	*Hydropsyche morosa*	*Hydropsyche sp.*
Ceratopsyche sp.	*Baetis tricaudatus*	*Baetis tricaudatus*
Gastropoda	Chironomidae	Chironomidae
Cheumatopsyche sp.	*Simulium sp.*	*Simulium sp.*
Nectopsyche sp.	*Cinygmula sp.*	*Cinygmula sp.*
Protoptila sp.	Oligochaeta	Oligochaeta
Stenelmis sp.	*Zapada cinctipes*	*Zapada cinctipes*
Hemerodromia sp.	*Rithrogena hageni*	*Rithrogena sp.*
Tricorythodes sp.	*Sweltsa* Group	*Sweltsa* Group
Unionidae	*Drunella doddsi*	*Attenella margarita*
Dubiraphia sp.	*Glossosoma sp.*	*Glossosoma sp.*
Hyalella azteca	*Heterlimnius corpulentus*	*Heterlimnius corpulentus*
	Hydracarina	Hydracarina
	Paraleptophlebia sp.	*Paraleptophlebia heteronea*
	Pericoma sp.	*Baetis bicaudatus*
	Planariidae	*Micrasema sp.*
		Ironodes nitidus
		Dicranota sp.
		Optioservus sp.
		Least Disturbed
		(Site Cluster C3)
		Arctopsyche grandis
		Ostracoda
		Rhyacophila brunnea
		Rhyacophila verrula
		Cultus sp.
		Epeorus albertae
		Rhyacophila betteni
		Nematoda
		Cinygma sp.
		Cheumatopsyche sp.
		Haploperla sp.
		Epeorus (Ironodes)

Montane stream conditions in the Cascade range and Blue Mountains had either an effective riparian canopy that shaded the stream surface or lacked an effective riparian canopy altogether. Some of the Cascade mountain streams (e.g., Butler Creek, Gold Creek, Indian Creek) had broad stream channels with receded flows. Most of these channels were dry during the time of sampling which resulted in minimal shading of the stream surface. Streams sampled in the Blue Mountains (e.g., Cummings Creek, North Fork Asotin Creek) had intact riparian canopies, but probably contained moderate nutrient-enrichment as indicated by the invertebrate community. Cattle grazing occurred every other year near these streams. All of the surveyed reaches were located along the transition between montane and semi-arid plateau.

The Columbia Plateau had distinct invertebrate assemblages in streams with irrigation return flow. Surface water temperature and conductivities were high in these streams.

Sites potentially least disturbed from the interior mountain regions and the Columbia Plateau were confirmed with biological data (Figure 17). The interior mountains and foothills references (*i.e.*, Trapper Creek, North Fork Asotin Creek, and Cummings Creek) were coldwater streams with closed riparian canopies. The single Columbia Plateau site (*i.e.*, Umtanum Creek) had cooler surface water than other streams in the region. Limited human access and signs of activity were characteristic of all east side reference streams.

b. 1994 Survey

Sites surveyed in 1994 were located in the wetter west side of the Cascade Range and the drier Northern Rockies foothills. Foothills streams of the Northern Rockies had in common high pH and conductivities. Much of the riparian vegetation was missing and banks were eroded at these streams. Grazing and riparian canopy loss were the identifiable impacts at each of these sites.

Some unimpacted stream conditions were recognized in the west slope Cascade and Puget Lowland regions (e.g., Elbe Site, Tahuya River) (Figure 18). Streams in the same drainage that were either regulated by reservoir dams or had historic logging impacts (e.g., Cedar River below Cedar Falls, Taylor Creek) contained invertebrate assemblages indicative of streams rich in suspended organics. A small high gradient stream (Bear Creek) had a degraded channel condition resulting from a massive debris flow. The upper portion of this small drainage had been clearcut. Analysis of the macroinvertebrate community and their preferred food source suggested that elevated levels of suspended organics were present.

c. 1995 Survey

The North Cascades and Puget Lowlands contained macroinvertebrate communities that distinguished between low elevation streams and those located in mountainous terrain. The high elevation stream (e.g., Long Creek) had a high gradient and a broad active channel compared to the wetted width (Table 10). A contrast between invertebrate assemblages at high elevation sites was found with those at lower elevations. Lower elevation sites were mountain least disturbed (e.g., Diobsud Creek) and lowland valley (e.g., Jim Creek and Samish River) (Figure 19). A land use in mountainous areas such as logging has been associated with an increase in transport of detritus to the stream channel (Bormann *et al*., 1974). The invertebrates collected reflect the availability of this food source.

A Framework for Biocriteria

Earlier analysis of stream biological information indicated that macroinvertebrate assemblages are limited in distribution to geographic regions in Washington. The distribution of aquatic invertebrate species is limited by the ability of an animal to migrate and through geographic isolating mechanisms. Human activity may have altered the natural patterns of macroinvertebrate colonization by changing the physical instream conditions, thus limiting the extent of distribution.

The focus for biocriteria development should be on how human intervention changes stream biota. Does biology respond to human activity in a consistent way or are these geographic differences? A common method for describing geographic areas are by 'ecoregions' for which there are several delineation strategies (Bailey, 1995; Omernik and Gallant, 1986). A regional framework should accommodate the focus of the analysis, in this case, the aquatic macroinvertebrates and their response to degradation.

Least Disturbed Sites

Least disturbed conditions were identified in each sampling year (1993-1995). In some cases, there were no known least disturbed conditions for each watershed in a region, but were otherwise found in a similar landscape setting (*e.g.*, Columbia Plateau or Cascade range). Least disturbed sites were confirmed by invertebrate communities.

Least disturbed sites from different regions did not have the same macroinvertebrate compositions (e.g., Trapper Creek versus Umtanum Creek) (Figure 17). Invertebrate assemblages in least disturbed streams resembled conditions from other sites within the same geographic area
(e.g., Green River, Lyre River, South Branch Little River). Dendrograms describing the relationship among sites are contrasted with the least disturbed condition (e.g., Diobsud Creek) (Figure 19). Diobsud Creek is a good reference for: Deer Creek, Grant Creek, Finney Creek, and Jackman Creek.

Identifying least disturbed conditions is important for determining invertebrate assemblage changes. Least disturbed conditions surveyed contained distinct invertebrate assemblage. These invertebrates were uniquely related to the least disturbed condition and biological characteristics at sites in contiguous drainages.

Annual monitoring of least disturbed sites would provide a measure of temporal variability in the invertebrate community. A measure of natural variability would indicate how small a change in the macroinvertebrate community would be detectable in response to a stressor.

Identifying Habitat-Specific Degradation (riffle/pool sampling)

Invertebrate assemblages in pools are different from riffle assemblages in some streams. Streams that contained 'pseudo' pools (*e.g.*, pools in mountain streams that were better defined as depositional zones) were distinct from 'true' pools found in lowland streams. A depositional zone in a mountain stream was located near sides of channels, behind large boulders or woody debris. A true pool was found in a mid-stream location.

Riffle and pool invertebrate assemblages were similar in some Columbia Basin streams (Table 6; Clusters A, K1, K2). Streams in these clusters were related based on severity of flooding or a change in flood timing. Flash flooding occurs naturally in Douglas Creek and South Fork Palouse River. Flood timing was changed by raising water levels during summer months through irrigation return flow (*e.g.*, Lower Crab Creek, Sand Dune Creek). In both cases, sediment transport in streams was assumed to be high and may have reduced riffle and pool habitat to a more common type. This may explain the high level of invertebrate assemblage similarity in these habitats.

Cascade Range streams that had not been disturbed by human activity had distinct riffle and pool invertebrate assemblages (Table 6; Clusters F and G). All of these streams were surveyed at lower drainage locations on Cascade Range streams. These streams have distinct habitat types that are visually identifiable as riffles and pools.

The value of biological information from pool habitat can be summarized by the following:

1. Degradation may selectively occur in pool habitat and not the riffles. Even so, this survey data did not show consistent biological differences between riffles and pools.

2. Comparison of pool invertebrate assemblages to riffle invertebrate assemblages may reveal the effect of natural hydrologic disturbance, as well, the biological response resulting from physical disturbance (Minshall and Minshall, 1977; Brown and Brussock, 1991). The collection of pool samples should be used if this habitat is: 1) used as a refuge during a portion of the year, or 2) if pools are the dominant habitat. Based on the current data, it would be more cost-effective to place monitoring effort in sampling riffles.

Alternative Analyses for Identifying Regional Similarity of Communities

A numerical value was used to indicate an ability to visually interpret site associations in two-dimensions. The high ‘stress’ value indicated that some of the information displayed in two-dimensions could not be interpreted. The ordination analysis used had difficulty in distinguishing anthropogenically disturbed sites from naturally disturbed sites.

Collecting Replicate Samples

Information about the number and kinds of invertebrate species in each replicate was used to determine the likelihood of accurately describing a stream reach community with less than four samples. The results indicated that a ‘core’ group of taxa were found in all replicates at a site, with one exception (Finney Creek).

Within stream reach replicate collections resembled one another in four of five streams (Figure 20). Two of the streams were least disturbed sites (*i.e.,* Diobsud Creek and Elbe Site) and the remaining two streams were in an area where recent logging activity was visible (*i.e.,* Long Creek and Simmons Creek). Finney Creek replicates showed partial similarity among four samples. Dissimilarity of replicates from within a single stream reach could be a result of severe stream channel degradation. Finney Creek in the Skagit River watershed had visual evidence of braiding channels, extensive bank erosion, and a broad unwetted channel.

The Relationship between Habitat Variables and Invertebrate Communities

The distribution of invertebrate species in streams, in part, depends on their tolerance to site-specific conditions. Associations between distinct invertebrate communities and the physical, chemical and biological stream conditions in which they are found is key for identifying stream degradation.

Habitat variables related to a single site or groups of sites were described as a range of conditions in which invertebrate species were found. A single variable or group of variables that were different between site groups were used to describe environmental conditions in which particular biota of a region occur.

Indicator groups of species are reflective of the tolerance to one or more unique environmental variables. The indicator species identified are preliminary and the lists should be validated. The lists for each cluster of similar sites may be conservative if the collecting in this program was not comprehensive.

Conclusions

a. Hypotheses

Several *a priori* hypotheses were presented earlier. Each hypothesis is addressed in order of original presentation.

1. Riffle and pool habitats contained distinct biological assemblages in some low- to mid-elevation mountain streams. Pool habitat in all other streams surveyed showed no difference in biotic composition.

2. Monitoring of riffle habitat is adequate to determine response of stream biota to human influences.

3. Analysis of the 1993 biological survey information demonstrated that several taxa were found in riffle and pool habitats. Taxa found in multiple habitats may be the result of temporal changes.

4. Several major regional areas within Washington and sub-groups were identified with distinct stream assemblages. The regional distinctions are 'building blocks' for further detailed analysis.

5. Environmental variables were correlated with site clusters. The contrast of sites within different WQMA's for each year (1993-1995) was an effective approach for identifying correlations between/among biological assemblages and influential environmental variables.

6. Multiple physical features in the stream setting appear to directly influence stream macroinvertebrate condition. Use of single variables as predictors of biological condition is not reliable.

7. Environmental variables with the strongest relationship to biological conditions were used to create a chart that partitioned streams into 'sets' (Figure 24). Several key variables arranged in a decision-matrix are necessary when: (a) site comparisons are made using the statewide dataset as a reference, and (b) to correctly compare a candidate site to a least disturbed condition with similar chemical and physical characteristics. A key initially used variables common to all or most of the distinct site clusters (Table 15). Indicator taxa lists were associated with regions, where possible.

8. Severe channel disturbance can result in unusually high patchy distribution of populations. Patchiness of assemblages in Finney Creek appeared to result from extreme physical changes in the stream channel. Recolonization of disturbed stream habitat can occur rapidly if temporary refugia are available to macroinvertebrates (*e.g.*, behind boulders, near banks, side channels) (Townsend, 1989).

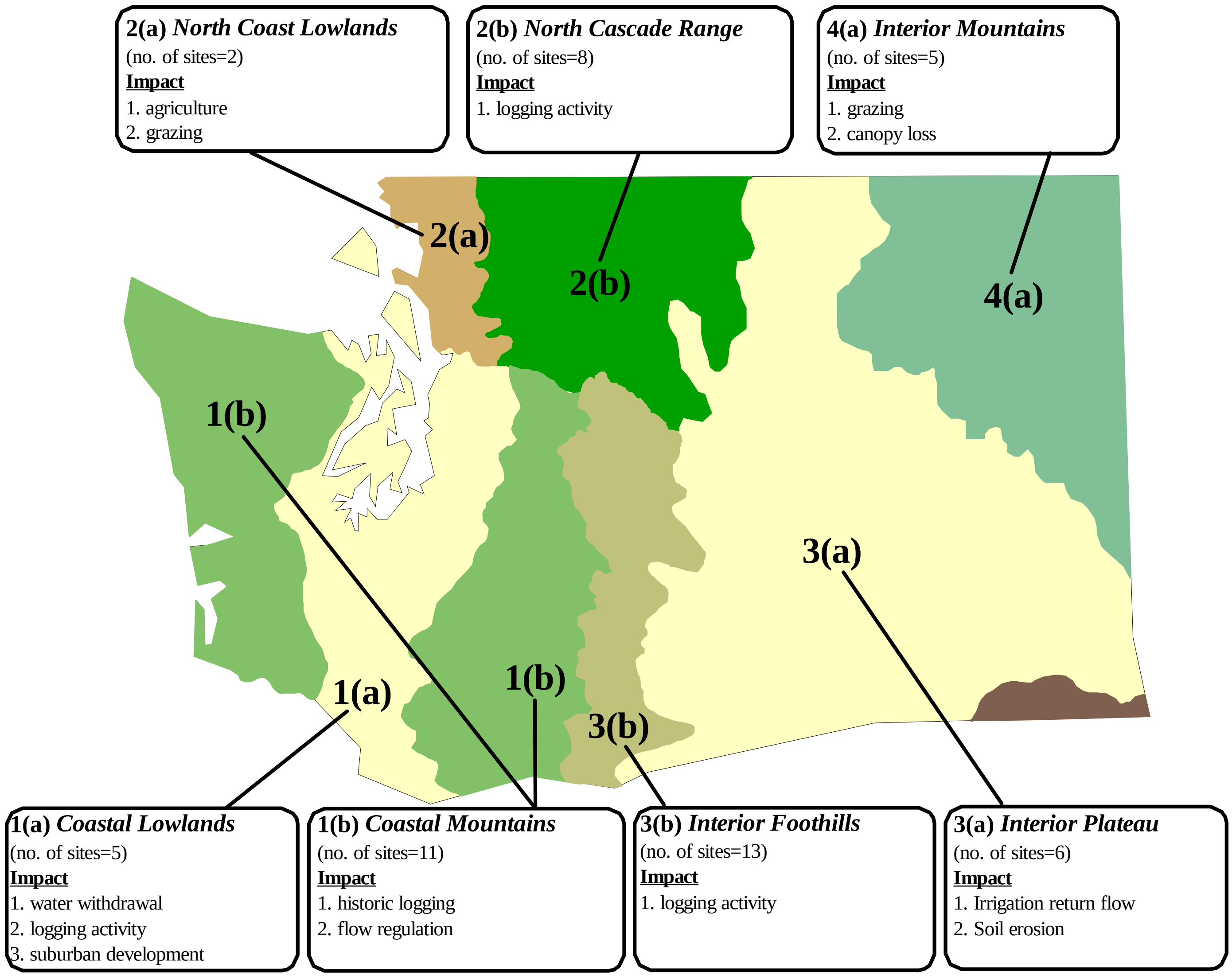


Figure 24. Geographic regions of Washington in which macroinvertebrate assemblages were similar. Related regions (*e.g.*, 1a and 1b) formed four major regions that contained biologically distinct assemblages. This regionalization strategy is a conceptual model based on fifty sites surveyed between 1993-1995.

Table 15. A conceptual key for identifying indicator species in some regions of Washington under least disturbed stream conditions. Regions listed without indicator species failed to show strong biological continuity among sites surveyed. The candidate stream is degraded if misclassification to a region occurs using the environmental variables. Observations for this key were collected from wadable streams between late-August and early-October.

Environmental Variable	**Condition**	**Region & Indicator List** (Cluster no. and Table no.)
1. Temperature (^{o}C)	warm (> 18.8)	Interior Plateau
	cold (< 18.8)	2
2. Conductivity (µmhos/cm)	high (> 180)	Interior Mountains
	low (< 180)	3
3. pH (standard units)	alkaline (> 8.0)	Interior Foothills (Cluster C5; Table 11)
	neutral (< 8.0)	3(a)
3(a) wetted width/ bankful width ratio	high (> 40%)	4 (widths approach the same size)
	low (< 40%)	5 (broad bankful width at low flow)
4. Elevation	low (Puget Lowland)	Coastal Lowlands (Cluster C4; Table 12)
	high (Cascades)	Coastal Mountains (Clusters C1&C7; Tables 11&12)
5. Elevation	low (Puget Lowland)	North Coast Lowlands (Cluster C3; Table 13)
	high (Cascades)	North Cascade Range (Cluster C1; Table 13)

note: physical, chemical and biological measurements used to construct this conceptual key were collected from fifty survey sites beginning 1993 through 1995.

Finney Creek biological data were analyzed along with several sites from which replicate samples were collected (Figure 20). The replicate observations from Finney Creek contained dissimilar biological assemblages from other stream sites. The assemblage difference among replicates indicated that reach-level recovery did not occur. Frequency and severity of the hydrologic disturbance was an apparent factor (Allan, 1995).

b. Stream Temperature and Invertebrates

Many of the variables determined to be integral in explaining why sites clustered in specific patterns were related to surface water temperature. Water temperature is one environmental variable that has a major influence on aquatic invertebrate development, metabolism and physical activity (Hynes, 1970). Characterization of surface water temperature patterns in a variety of stream conditions is an important consideration.

Broad diel temperature fluctuations usually occur in streams that have a poor riparian canopy condition and are located in lowland areas (Ward, 1984). A high tolerance to large temperature fluctuations is characteristic of invertebrate assemblages in these stream reaches (*e.g*., Douglas Creek and South Fork Palouse River).

c. Using Invertebrates to Characterize Watershed Condition

Stream macroinvertebrates are found in all waterways of Washington State. Therefore, their utility as an environmental indicator has great potential. We conclude from our past monitoring effort (Plotnikoff, 1992, 1994, 1995) and the ubiquitous nature of macroinvertebrates that they can provide useful environmental information on which to base planning and decision-making.

Reasonable comparisons are made between streams in similar geographic settings to determine their condition. Further work in identification of the state’s biological regions will be based on current knowledge of stream biota. Maintaining the biological integrity of Washington’s streams is a crucial step in protecting this important natural resource.

Literature Cited

Allan, J.D., 1995. Stream Ecology: Structure and Function of Running Waters. Chapman & Hall, NY, pp. 249-256.

Bailey, R.G., 1995. Description of the ecoregions of the United States, 2nd ed. Miscellaneous Publications No. 1391. USDA Forest Service, Washington, D.C., 108 p.

Bormann, F.H., G.E. Likens, T.G. Siccama, R.S. Pierce and J.S. Easton, 1974. "The export of nutrients and recovery of stable conditions following deforestation at Hubbard Brook." Ecological Monographs 44:255-277.

Brown, A.V. and P.P. Brussock, 1991. "Comparisons of benthic invertebrates between riffles and pools." Hydrobiologia 220:99-108.

Bryce, S. and J.M. Omernik, 1997 (in prep.). Subregions of the Columbia Plateau Ecoregion. United States Environmental Protection Agency, Research Laboratory, Corvallis, OR.

Carter, J.L., S.V. Fend and S.S. Kennelly, 1996. "The relationships among three habitat scales and stream benthic macroinvertebrate community structure." Freshwater Biology 35:109-124.

Clarke, K.R., 1993. "Non-parametric multivariate analyses of changes in community structure." Australian Journal of Ecology 18:117-143.

Clarke, K.R. and M. Ainsworth, 1993. "A method of linking multivariate community structure to environmental variables." Marine Ecology Progress Series 92:205-219.

Clarke, K.R. and R.M. Warwick, 1994. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. National Environmental Research Council, U.K. 144 p. (Companion User Guide to PRIMER v3.1b)

COMPAH, updated by Gallagher E.D. Gallagher@umbsky.cc.umb.edu

Hynes, H.B.N., 1970. The Ecology of Running Waters. Liverpool University Press, Liverpool, Great Britain, 555 p.

Karr, J.R., 1991. "Biological Integrity: a long-neglected aspect of water resource management. Ecological Applications 1(1):66-84.

Karr, J.R., 1995. "Protecting aquatic ecosystems: clean water is not enough." *In* Biological Assessment and Criteria: Tools for Water Resource Planning and decision making. W.S. Davis and T.P. Simon, eds., Lewis Publishers, London, pp. 7-14.

McBride, R., 1996. "An Overview of Washington State's Watershed Approach to Water Quality Management." *In* Watershed '96 Conference Proceedings. Washington State Department of Ecology, Olympia, WA, pp. 343-345.

Minshall, G.W. and J.N. Minshall, 1977. "Microdistribution of benthic invertebrates in a Rocky Mountain (U.S.A.) stream." Hydrobiologia 55(3):231-249.

Omernik, J.M. and A.L. Gallant, 1986. Ecoregions of the Pacific Northwest. EPA/600/3-86/033. U.S. Environmental Protection Agency, Corvallis, OR, 39 p.

Pater, D.E., S. Bryce, T.D. Thorson, J. Kagan, C. Chappell, J.M. Omernik, S. Azevedo and A.J. Woods, 1997 (in prep.). Ecoregions of Western Washington and Oregon. United States Environmental Protection Agency, Research Laboratory, Corvallis, OR.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross and R.M. Hughes, 1989. Rapid Assessment Protocols for Use in Streams and Rivers. Benthic Macroinvertebrates and Fish. EPA 440-4-89-001. Office of Water, Regulations, and Standards, U.S. Environmental Protection Agency, Washington, D.C.

Plotnikoff, R.W., 1992. Timber, Fish, & Wildlife Ecoregion Bioassessment Pilot Project. Washington State Department of Ecology, Olympia, WA. Ecology Publication No. 92-63, 57 p.

------, 1994. Instream Biological Assessment Monitoring Protocols: Benthic Macroinvertebrates. Washington State Department of Ecology, Olympia, WA. Ecology Publication No. 94-113, 27 p.

------, 1995. Ambient Monitoring Instream Biological Assessment: Progress Report of 1993 Pilot Survey. Washington State Department of Ecology, Olympia, WA. Ecology Publication No. 95-333, 31 p.

Rankin, E.T., C.O. Yoder and D.S. Mishne, 1995. 1994 Ohio Water Resource Inventory: summary, conclusions and recommendations. State of Ohio Environmental Protection Agency, Columbus, OH. Ohio EPA Technical Bulletin MAS/1995-7-2, 70 p.

Resh, V.H. and J.K. Jackson, 1993. Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. *In* D.M. Rosenberg and V.H. Resh, eds. Freshwater Biomonitoring and Benthic Macroinvertebrates, Chapman & Hall, New York, NY, pp. 195-233.

Rosenberg, D.M. and V.H. Resh, 1993. "Introduction to freshwater biomonitoring and benthic macroinvertebrates." *In* D.M. Rosenberg and V.H. Resh, eds. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman & Hall, New York, NY, pp. 1-9.

Rosenberg, D.M. and V.H. Resh, 1996. "Use of aquatic insects in biomonitoring." *In* R.W. Merritt and K.W. Cummins, eds. An Introduction to the Aquatic Insects of North America, third edition. Kendall/Hunt Publishing Company, Dubuque, IA, pp. 87-97.

Tate, C.M. and J.S. Heiny, 1995. "The ordination of benthic invertebrate communities in the South Platte River Basin in relation to environmental factors." Freshwater Biology 33:439-454.

Townsend, C.R., 1989. "The patch dynamics concept of stream community ecology." Journal of the North American Benthological Society 8(1):36-50.

Wilkinson, L., 1990. SYSTAT: The System for Statistics. SYSTAT, Inc., Evanston, IL.

Yoder, C.O. and E.T. Rankin, 1995. "Biological criteria program development and implementation in Ohio." *In* W.S. Davis and T.P. Simon, eds. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, London, pp. 109-144.

Zar, J.H., 1984. Biostatistical Analysis, 2nd ed. Prentice-Hall, Inc. Englewood Cliffs, NJ, 718 p.

Appendix I

Waterbody Name: ____________________

Location/Station #: ____________________

Major Basin: ____________________

Dominant Land Use: ____________________

Date/Time: ____________________

Weather: ____________________

Latitude/Longitude: ____________________

Investigators: ____________________

SURFACE WATER INFORMATION			
Parameters	**Measurement (Qualifiers)**		
Temperature			
pH		Calibration or Calibration Check:	
Conductivity			
Dissolved Oxygen Sample Time:	Bottle no.	mL of titrant	Correction factor
Qualitative Observations			
Water Clarity			
Water Odors			
Sediment Odors			
Surface Films			

Field Notes:	
Photograph:	
Photograph:	

STREAM REACH PROFILE							
Transect	Wetted Width (riffles)	Bankfull Width (riffles)	Maximum Depth (riffles)	Residual Pool Depth (Dp-Dc=RPD)			Stream Gradient (Clinometer)
				Dp	Dc	RPD	
Riffle 1							
Riffle 2							
Riffle 3							
Riffle 4							

STREAM DISCHARGE					
Observation (Circle units)	Width (m or ft)	Depth (m or ft)	Velocity (m/s or ft /s)	Flag	Comments
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Residual Pool Depth: Dp=maximum depth of pool, Dc=depth at pool crest (or tailout), RPD=residual pool depth

SUBSTRATE MEASUREMENTS		
Substrate Parameter	**Riffle 1**	**Riffle 2**
Depth (m)		
Size Class (# intersections)		
Bedrock (smooth)		
Bedrock (rough)		
Boulder (250 to 4000 mm)		
Cobble (64 to 250 mm)		
Coarse Gravel (16 to 64 mm)		
Fine Gravel (2 to 16 mm)		
Sand (0.06 to 2 mm)		
Silt/Clay/Muck (not gritty)		
Wood (any size)		
Other (comment)		

SUBSTRATE MEASUREMENTS		
Substrate Parameter	**Riffle 3**	**Riffle 4**
Depth (m)		
Size Class (# intersections)		
Bedrock (smooth)		
Bedrock (rough)		
Boulder (250 to 4000 mm)		
Cobble (64 to 250 mm)		
Coarse Gravel (16 to 64 mm)		
Fine Gravel (2 to 16 mm)		
Sand (0.06 to 2 mm)		
Silt/Clay/Muck (not gritty)		
Wood (any size)		
Other (comment)		

CANOPY COVER MEASUREMENTS				
DENSIOMETER (count open intersections)				
Direction	Riffle 1	Riffle 2	Riffle 3	Riffle 4
Center (up)				
Center (down)				
Center (left)				
Center (right)				
Left Bank				
Right Bank				

HUMAN INFLUENCE		
O = not present B = on bank C = within 10m P = > 10m		
Disturbance	**Left Bank**	**Right Bank**
Dike/Riprap		
Buildings		
Pavement		
Road/Railroad		
Pipes (inlet/outlet)		
Landfill/Trash		
Park/Lawn		
Row Crops		
Pasture/Range		
Logging Operations		

Substrate measurements are made with a 60 cm diameter hoop and at least 50 observations within the sample area.

Stream Cross-Section Profile					
Observation No.	Width (m or ft)	Riffle 1	Riffle 2	Riffle 3	Riffle 4
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					

(vertical, equidistant measurements from bankful horizontal line to stream bottom)

Current Velocity (m/sec or ft/sec)	
Transect	Velocity
Riffle 1	
Riffle 2	
Riffle 3	
Riffle 4	

0.6x Depth from Surface

Current Velocity (m/sec or ft/sec)	
Transect	Velocity
Riffle 1	
Riffle 2	
Riffle 3	
Riffle 4	

Bottom of Stream

Qualitative Habitat Assessment Survey - Visual
Riffle/Run Prevalence

Site Name: Site No: Date: Evaluator Initial:

Habitat Parameter	Optimal	Sub-Optimal	Marginal	Poor
1. Substrate-Percent Fines (fraction < 6.35mm)	< 10% (16-20)	10 - 20% (11-15)	20 - 50% (6-10)	> 50% (0-5)
2. Instream Cover (cobble gravel, large woody debris, undercut banks, macrophytes)	> 50% (16-20)	30 - 50% (11-15)	10 - 30% (6-10)	< 10% (0-5)
3. Embeddedness (Riffle) (gravel, cobble, boulder particles)	0 - 25% (16-20)	25 - 50% (11-15)	50 - 75% (6-10)	> 75% (0-5)
4. Velocity/Depth	all habitats i)slow/deep ii)slow/shallow iii)fast/deep iv)fast/shallow (16-20)	3 of 4 (11-15)	2 of 4 (6-10)	1 of 4 (0-5)
5. Channel Shape	trapezoidal (11-15)	rectangular (6-10)		inverse trapezoidal (0-5)
6. Pool/Riffle Ratio (distance between riffles/stream width)	5 - 7 (frequent sequence) (12-15)	7 - 15 (less frequent) (8-11)	15 - 25 (Infrequent riffle) (4-7)	> 25 (homogeneous) (0-3)
7. Width to Depth Ratio (wetted width/depth)	< 7 (12- 15)	8 - 15 (8-11)	15 - 25 (4-7)	> 25 (0-3)
8. Bank Vegetation (streambank coverage)	> 90% (9-10)	70 - 89% (6-8)	50 - 79% (3-5)	< 50% (0-2)
9. Lower Bank Stability (evidence of erosion)	Stable (9-10)	Little Erosion (6-8)	Mod. Erosion (3-5)	Unstable (0-2)
10. Disruptive Pressures (evidence of vegetation disruption on streambanks)	Minimal (all remains) (9-10)	Evident (60-90%) (6-8)	Obvious (30-60%) (3-5)	High (< 30%) (0-2)
11. Zone of Influence (width of riparian zone)	≥4 x BFW (BFW=Bankfull Width) (9-10)	≥2 & <4 (6-8)	≥1 & <2 (3-5)	little or none (0-2)
12. Successional Stage (forested sites only)	old-growth (9-10)	young (6-8)	pole sapplings (3-5)	seedlings/ clearcut (0-2)

Appendix II

		C1	C2					C3			
Group	**Taxa**	**TRAPPER**	**DOUGLAS**	**SFPALOU**	**LCRABCR**	**SANDDUN**	**UPALOUS**	**AMERICA**	**BUTLER**	**GOLDCRK**	**INDIAN**
1	*Acentrella sp.*	382.5	0	0	30	15	0	60	0	0	50
1	*Serratella tibialis*	75	0	0	0	0	0	0	120	0	0
1	*Skwala curvata*	105	0	0	0	0	20	10	180	0	10
1	*Sweltsa Group*	150	0	0	0	0	0	10	240	22.5	20
1	*Arctopsyche grandis*	15	0	0	0	0	0	200	315	0	140
1	*Zapada sp.*	15	0	0	0	0	0	200	210	157.5	130
1	*Drunella doddsi*	75	0	0	0	0	0	70	75	30	50
1	*Rithrogena hageni*	45	0	0	0	0	0	160	0	105	160
1	*Cinygmula sp.*	45	0	0	0	0	40	0	30	172.5	200
1	*Calineuria californica*	7.5	0	0	0	0	0	40	45	0	0
1	*Doroneuria baumanni*	7.5	0	0	0	0	0	30	0	0	0
1	Hydracarina sp.	15	0	0	0	5	0	30	15	0	50
1	*Hesperoperla pacifica*	45	0	0	0	0	0	50	30	0	0
1	*Rhyacophila angelita*	45	0	0	0	0	0	100	30	15	10
1	*Paraleptophlebia sp.*	22.5	0	0	0	0	0	50	30	30	0
1	*Rhyacophila acropedes*	15	0	0	0	0	0	50	15	45	20
2	*Epeorus grandis*	0	0	0	0	0	30	120	0	22.5	0
2	*Osobenus sp.*	0	0	0	0	0	0	60	0	0	0
2	*Epeorus (Ironodes)*	0	0	0	0	0	0	0	0	0	110
2	*Neophylax sp.*	0	0	0	0	0	0	60	0	0	110
2	*Hexatoma sp.*	0	0	0	0	0	0	20	30	0	60
2	*Rhyacophila vaccua*	0	0	0	0	0	0	20	0	0	80
2	*Tipula sp.*	0	0	0	0	0	0	0	0	0	30
3	*Antocha sp.*	0	0	0	0	0	0	0	45	0	0
3	*Heterlimnius sp.*	0	135	0	0	0	130	10	0	0	0
3	*Zaitzevia sp.*	0	0	0	0	0	40	0	0	0	0
3	*Paraleptophlebia bicornuta*	0	0	0	0	0	0	0	0	0	0
3	*Baetis bicaudatus*	0	0	120	0	30	90	60	630	0	120
3	Chironomidae	30	1365	2430	430	125	320	330	1590	165	370
3	Simuliidae	0	420	1005	270	0	110	60	4695	1252.5	190
3	*Baetis tricaudatus*	0	360	150	430	265	240	0	285	45	20

3	*Hydropsyche sp.*	7.5	975	0	1300	545	2000	40	45	0	0
3	*Optioservus sp.*	0	1125	225	50	0	460	0	0	0	0
3	*Brachycentrus americanus*	0	0	0	0	0	0	70	0	0	0
3	*Glossosoma sp.*	0	0	0	0	0	0	20	45	0	110
3	*Pteronarcys sp.*	0	0	0	0	0	0	0	30	0	0
4	*Agapetus sp.*	0	0	0	0	0	0	0	0	0	0
4	*Suwallia sp.*	0	0	0	0	0	0	100	0	0	0
4	*Prosimulium sp.*	0	0	0	0	0	20	0	0	7.5	0
4	*Ameletus sp.*	0	0	0	0	0	0	0	0	0	0
4	*Perlinodes aureus*	0	0	0	0	0	0	20	0	0	0
4	*Siphlonura sp.*	0	0	0	0	0	0	0	0	0	0
4	*Chimarra sp.*	157.5	0	0	0	0	0	0	0	0	0
4	*Claassenia sabulosa*	0	0	0	0	0	0	0	0	0	0
4	*Rhynchelmis sp.*	0	0	0	0	0	0	0	0	0	0
4	*Glutops sp.*	0	0	0	0	0	0	10	0	0	10
4	*Narpus sp.*	0	0	0	0	0	0	0	0	0	0
5	*Atherix variegata*	0	0	0	0	0	0	20	0	0	0
5	*Attenella margarita*	0	0	0	0	0	0	10	0	37.5	0
5	*Cultus pilatus*	0	0	0	0	0	0	0	0	0	0
5	*Drunella spinifera*	0	0	0	0	0	0	0	0	0	0
5	*Micrasema sp.*	0	0	0	0	0	0	0	0	7.5	0
5	*Doddsia occidentalis*	0	0	0	0	0	0	0	0	0	650
5	Lumbriculidae	0	0	0	0	0	0	0	15	0	130
5	*Drunella coloradensis*	0	0	0	0	0	0	0	30	0	0
5	*Paraperla frontalis*	0	0	0	0	0	0	0	0	0	0
5	Planariidae	0	0	0	0	0	0	0	0	0	0
5	*Epeorus deceptivus*	0	0	0	0	0	0	0	0	0	10
5	*Isoperla sp.*	0	0	0	0	0	0	0	0	0	0
6	*Epeorus longimanus*	15	0	0	0	0	0	0	0	0	0
6	*Perlomyia sp.*	30	0	0	0	0	0	0	0	0	0
6	*Podmosta obscura*	37.5	0	0	0	0	0	0	0	0	0
6	*Megarcys signata*	22.5	0	0	0	0	0	0	0	7.5	0
6	*Dicranota sp.*	0	120	0	0	0	0	0	0	7.5	20

6	Perlodidae	0	0	0	0	0	0	0	0	0	0
6	*Brachycentrus occidentalis*	0	0	0	0	0	0	0	15	0	0
6	*Lepidostoma sp.*	0	120	15	0	0	0	0	30	7.5	0
6	Brachycentridae	0	0	0	0	0	0	0	0	0	0
7	*Amiocentrus sp.*	0	0	0	0	0	0	0	0	37.5	0
7	*Blephariceras sp.*	0	0	0	0	0	0	0	0	0	0
7	*Ceratopsyche sp.*	0	0	0	0	0	410	0	0	0	0
7	Gastropoda	0	0	0	0	0	70	0	0	0	0
7	*Cheumatopsyche sp.*	0	180	120	740	100	0	0	0	0	0
7	*Nectopsyche sp.*	0	0	0	20	65	0	0	0	0	0
7	*Protoptila sp.*	0	0	0	20	160	0	0	0	0	0
7	*Stenelmis sp.*	0	0	0	80	120	0	0	0	0	0
7	*Hemerodromia sp.*	0	0	0	40	5	20	0	0	0	0
7	*Tricorythodes sp.*	0	0	0	40	15	0	0	0	0	0
7	Unionidae	0	0	0	10	30	50	0	0	0	0
7	*Dubiraphia sp.*	0	0	90	0	0	0	0	0	0	0
7	*Hyalella azteca*	0	2040	600	0	0	0	0	0	0	0

Group	Taxa	C3	C4		C5						C6
		OHANAPE	CUMMING	NFASOTI	MFTEANA	LNACHES	SWAUKCR	RATTLES	TUCANNO	UYAKIMA	UMTANUM
1	*Acentrella sp.*	0	0	20	330	945	0	209.94	390	0	0
1	*Serratella tibialis*	0	15	30	100	135	70	75.81	135	115	0
1	*Skwala curvata*	0	0	20	340	90	30	83.31	45	0	0
1	*Sweltsa Group*	4	0	0	0	0	0	158.28	0	0	0
1	*Arctopsyche grandis*	2	25	0	40	45	0	0	0	0	0
1	*Zapada sp.*	11	30	30	0	270	10	0	0	0	0
1	*Drunella doddsi*	0	0	0	380	270	30	0	0	0	0
1	*Rithrogena hageni*	62	0	0	290	570	0	0	0	0	0
1	*Cinygmula sp.*	21	10	130	40	480	80	70.83	315	0	0
1	*Calineuria californica*	0	0	0	0	135	80	3.33	0	0	0
1	*Doroneuria baumanni*	7	0	0	0	75	20	0	0	0	0
1	Hydracarina sp.	0	0	10	0	45	10	15	45	0	0
1	*Hesperoperla pacifica*	0	25	10	0	60	20	3.33	0	0	0
1	*Rhyacophila angelita*	0	5	0	50	15	0	0	0	2.5	0
1	*Paraleptophlebia sp.*	0	5	0	0	30	60	3.33	45	0	270
1	*Rhyacophila acropedes*	3	0	30	0	0	60	0	0	0	15
2	*Epeorus grandis*	0	5	10	0	0	10	29.16	15	0	15
2	*Osobenus sp.*	0	0	0	0	0	0	0	0	0	0
2	*Epeorus (Ironodes)*	0	0	30	0	0	0	0	0	0	0
2	*Neophylax sp.*	0	0	30	10	0	0	9.99	0	0	0
2	*Hexatoma sp.*	5	0	0	20	15	10	0	0	0	0
2	*Rhyacophila vaccua*	0	0	0	30	0	50	7.5	0	0	0
2	*Tipula sp.*	1	0	0	0	0	0	3.33	15	7.5	0
3	*Antocha sp.*	0	0	160	20	105	130	14.16	75	140	0
3	*Heterlimnius sp.*	0	0	200	60	45	150	80.79	180	2.5	15
3	*Zaitzevia sp.*	0	0	0	230	0	360	232.41	900	0	165
3	*Paraleptophlebia bicornuta*	0	0	0	40	0	70	0	210	0	0
3	*Baetis bicaudatus*	35	285	890	120	60	780	173.28	405	350	1485
3	Chironomidae	11	60	310	170	1620	980	410.73	1380	220	240
3	Simuliidae	13	170	1060	100	120	100	97.41	60	7.5	585
3	*Baetis tricaudatus*	3	15	210	240	210	90	171.6	720	165	0
3	*Hydropsyche sp.*	0	0	30	60	1260	140	109.98	210	190	90
3	*Optioservus sp.*	0	225	660	0	1245	750	383.31	885	62.5	15
3	*Brachycentrus americanus*	0	0	370	0	225	0	0	690	0	0
3	*Glossosoma sp.*	8	125	400	0	0	0	15	270	637.5	15
3	*Pteronarcys sp.*	0	35	1400	0	0	0	10.83	135	0	0
4	*Agapetus sp.*	0	0	0	280	0	130	3.33	0	0	0
4	*Suwallia sp.*	0	20	0	190	0	160	0	0	0	0

4	*Prosimulium sp.*	0	0	0	190	0	0	0	0	0	60
4	*Ameletus sp.*	0	0	0	80	0	20	18.33	0	0	0
4	*Perlinodes aureus*	0	0	0	130	15	0	48.33	0	0	0
4	*Siphlonura sp.*	0	0	0	50	0	0	0	0	0	0
4	*Chimarra sp.*	3	20	10	0	0	0	0	150	0	0
4	*Claassenia sabulosa*	0	15	0	0	90	0	3.33	240	2.5	0
4	*Rhynchelmis sp.*	0	20	0	0	0	0	0	105	0	0
4	*Glutops sp.*	0	30	0	0	0	0	3.33	0	0	0
4	*Narpus sp.*	0	50	40	0	15	30	0	0	7.5	0
5	*Atherix variegata*	0	0	20	0	240	0	32.49	0	0	0
5	*Attenella margarita*	0	0	20	0	270	10	30	0	22.5	0
5	*Cultus pilatus*	0	0	0	0	135	0	0	0	0	0
5	*Drunella spinifera*	0	0	0	10	105	0	0	0	7.5	0
5	*Micrasema sp.*	0	0	0	0	270	10	0	0	0	0
5	*Doddsia occidentalis*	9	0	0	0	0	0	0	0	0	0
5	Lumbriculidae	24	0	0	0	45	0	18.33	0	15	0
5	*Drunella coloradensis*	6	0	0	0	0	0	0	0	0	0
5	*Paraperla frontalis*	6	0	0	0	15	0	0	0	0	0
5	Planariidae	8	0	0	0	0	0	0	0	0	0
5	*Epeorus deceptivus*	9	0	0	0	15	0	0	0	0	0
5	*Isoperla sp.*	6	0	0	0	15	0	0	0	55	30
6	*Epeorus longimanus*	0	0	0	0	0	0	0	0	0	0
6	*Perlomyia sp.*	0	0	0	0	0	0	0	0	0	0
6	*Podmosta obscura*	0	0	0	0	0	0	0	0	0	0
6	*Megarcys signata*	3	0	0	0	30	0	0	0	0	0
6	*Dicranota sp.*	0	5	0	10	0	10	0	0	0	120
6	Perlodidae	0	0	0	0	0	0	0	0	0	600
6	*Brachycentrus occidentalis*	0	0	0	0	0	0	0	0	262.5	0
6	*Lepidostoma sp.*	0	0	0	0	0	0	125.79	0	90	0
6	Brachycentridae	0	0	0	0	0	0	350.82	0	0	0
7	*Amiocentrus sp.*	0	0	0	0	0	0	0	0	0	0
7	*Blepharicera sp.*	0	0	80	0	0	0	0	0	0	0
7	*Ceratopsyche sp.*	0	0	0	0	0	0	0	0	0	0
7	Gastropoda	0	0	0	0	0	0	0	0	0	0
7	*Cheumatopsyche sp.*	0	0	0	0	0	0	0	0	0	0
7	*Nectopsyche sp.*	0	0	0	0	0	0	0	0	0	0
7	*Protoptila sp.*	0	0	0	0	0	0	0	0	0	0
7	*Stenelmis sp.*	0	5	0	0	0	0	0	30	0	0
7	*Hemerodromia sp.*	0	0	0	0	0	0	7.5	15	0	0
7	*Tricorythodes sp.*	0	0	0	0	0	0	0	0	0	0
7	Unionidae	0	0	10	0	0	0	0	150	0	0

7	*Dubiraphia sp.*	0	0	0	0	0	0	0	0	0	0
7	*Hyalella azteca*	0	0	0	0	0	0	0	0	0	0

		C1			C2	C3		C4		C5	
Group	**Taxa**	**LSRCHATT**	**DRAGOONC**	**LSRPINER**	**BEARCR**	**CALIFORN**	**MARSHALL**	**ELBERIF**	**TAHUYAR**	**GREENRIV**	**LYRERIVE**
1	*Acentrella insignificans*	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0	500.0	0.0
1	*Hydropsyche morosa*	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	380.0	22.5
1	*Baetis tricaudatus*	0.0	0.0	225.0	0.0	0.0	0.0	84.5	0.0	50.0	337.5
1	Chironomidae	30.0	0.0	30.0	52.5	1380.0	0.0	709.5	5655.0	630.0	577.5
1	*Simulium sp.*	30.0	6.0	120.0	82.5	1620.0	80.0	10.0	0.0	80.0	157.5
1	*Cinygmula sp.*	0.0	6.0	315.0	0.0	0.0	120.0	79.5	0.0	0.0	22.5
1	Oligochaeta	0.0	0.0	0.0	22.5	180.0	170.0	505.0	90.0	290.0	105.0
1	*Zapada cinctipes*	0.0	6.0	0.0	0.0	0.0	310.0	47.0	0.0	240.0	0.0
1	*Rithrogena hageni*	0.0	0.0	0.0	165.0	0.0	0.0	9.0	0.0	20.0	165.0
1	*Sweltsa Group*	0.0	0.0	0.0	0.0	0.0	0.0	39.5	135.0	20.0	15.0
1	*Drunella doddsi*	0.0	0.0	0.0	30.0	0.0	0.0	10.0	0.0	0.0	0.0
1	*Glossosoma sp.*	0.0	24.0	90.0	435.0	0.0	100.0	3.0	0.0	0.0	0.0
1	*Heterlimnius corpulentus*	0.0	0.0	0.0	0.0	0.0	40.0	201.0	645.0	330.0	120.0
1	*Hydracarina*	0.0	0.0	0.0	15.0	10.0	0.0	105.5	300.0	180.0	15.0
1	*Paraleptophlebia sp.*	0.0	0.0	0.0	0.0	0.0	0.0	146.5	15.0	10.0	7.5
1	*Pericoma sp.*	0.0	0.0	0.0	0.0	0.0	0.0	302.0	0.0	0.0	0.0
1	Planariidae	0.0	0.0	0.0	37.5	0.0	0.0	233.5	30.0	60.0	0.0
2	*Baetis bicaudatus*	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	7.5
2	*Epeorus grandis*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	*Skwala sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	15.0
2	*Micrasema sp.*	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0
2	*Moselia infuscata*	0.0	0.0	0.0	0.0	0.0	0.0	55.5	0.0	0.0	0.0
2	Nematomorpha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	*Rhyacophila vagrita*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0
2	*Diphetor hageni*	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0
2	*Ironodes nitidus*	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0
2	*Rhyacophila blarina*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	*Ceratopsyche sp.*	0.0	0.0	0.0	0.0	130.0	0.0	46.5	105.0	0.0	0.0
3	*Hexatoma sp.*	0.0	12.0	0.0	0.0	10.0	0.0	42.5	0.0	0.0	0.0
3	*Chelifera sp.*	0.0	0.0	0.0	15.0	0.0	0.0	44.5	30.0	0.0	7.5
3	*Dicranota sp.*	0.0	0.0	0.0	22.5	0.0	0.0	50.0	30.0	0.0	0.0

3	Sphaeriidae	0.0	0.0	0.0	0.0	0.0	0.0	51.5	30.0	10.0	0.0
3	*Doroneuria baumanni*	0.0	0.0	0.0	30.0	0.0	0.0	257.5	60.0	0.0	0.0
3	*Yoraperla mariana*	0.0	0.0	0.0	22.5	0.0	0.0	165.5	0.0	0.0	0.0
3	*Lepidostoma sp.*	0.0	0.0	0.0	0.0	0.0	0.0	49.0	0.0	490.0	0.0
3	*Rhyacophila brunnea*	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	50.0	0.0
3	*Rhyacophila narvae*	0.0	0.0	0.0	0.0	0.0	0.0	12.0	135.0	0.0	0.0
3	*Rhyacophila varula*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	150.0	0.0	0.0
4	*Brachycentrus occidentalis*	0.0	0.0	0.0	667.5	0.0	0.0	0.0	0.0	0.0	0.0
4	*Ephemerella grandis*	0.0	0.0	0.0	157.5	0.0	0.0	0.0	0.0	0.0	0.0
4	*Caudatella hystrix*	0.0	0.0	0.0	90.0	0.0	0.0	0.0	0.0	10.0	0.0
4	*Parapsyche almota*	0.0	0.0	0.0	105.0	0.0	0.0	0.0	0.0	20.0	0.0
4	*Dolophilodes sp.*	0.0	0.0	0.0	37.5	0.0	0.0	0.0	0.0	0.0	37.5
4	*Megarcys signata*	0.0	0.0	0.0	37.5	0.0	0.0	0.0	0.0	0.0	0.0
4	*Prostoia sp.*	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Taenionema sp.*	0.0	0.0	0.0	37.5	0.0	0.0	0.0	0.0	0.0	0.0
4	*Rhyacophila acropedes*	0.0	0.0	0.0	60.0	0.0	0.0	12.0	0.0	0.0	0.0
4	*Zapada Oregonensis group*	0.0	0.0	0.0	225.0	0.0	0.0	29.5	0.0	0.0	0.0
4	*Chimarra sp.*	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0
4	*Epeorus (Ironodes) sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Rhyacophila albertae*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Hesperoperla pacifica*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	7.5
5	*Agapetus sp.*	150.0	0.0	105.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Leucotrichia sp.*	165.0	0.0	75.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Cheumatopsyche sp.*	60.0	0.0	150.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0
5	*Ephemeroptera*	75.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
5	*Narpus concolor*	45.0	0.0	0.0	0.0	0.0	0.0	6.0	15.0	0.0	7.5
5	Odonata	30.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0
5	*Rhyacophila betteni*	1155.0	0.0	0.0	0.0	0.0	0.0	23.0	0.0	0.0	0.0
5	*Antocha monticola*	0.0	6.0	60.0	22.5	0.0	0.0	0.0	15.0	260.0	165.0
5	*Brachycentrus americanus*	420.0	90.0	375.0	0.0	0.0	0.0	0.0	0.0	130.0	495.0
5	*Rhyacophila sp.*	0.0	6.0	180.0	0.0	0.0	0.0	8.5	0.0	60.0	15.0
5	*Hydropsyche betteni*	0.0	210.0	2190.0	0.0	0.0	70.0	0.0	105.0	0.0	0.0
5	*Ochrotrichia sp.*	0.0	0.0	285.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5	*Petrophila sp.*	60.0	66.0	315.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0
5	*Tricoythodes sp.*	15.0	12.0	315.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Attenella margarita*	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Calineuria californica*	0.0	24.0	0.0	0.0	0.0	0.0	3.0	30.0	10.0	0.0
5	*Pteronarcys californica*	0.0	18.0	15.0	0.0	0.0	0.0	17.5	0.0	20.0	22.5
5	*Helicopsyche borealis*	150.0	120.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0
5	*Serratella tibialis*	60.0	84.0	0.0	0.0	0.0	160.0	10.0	0.0	0.0	0.0
6	*Alloperla sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	*Arctopsyche sp.*	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	*Claassenia sabulosa*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	*Polycentropus sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	*Ameletus sp.*	0.0	0.0	30.0	0.0	0.0	0.0	45.0	0.0	0.0	0.0
6	*Parapsyche almota*	0.0	0.0	0.0	0.0	0.0	0.0	58.0	0.0	0.0	0.0
6	Nematoda	0.0	0.0	0.0	0.0	0.0	0.0	85.5	0.0	0.0	0.0
6	*Epeorus sp.*	105.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	*Ampumixis dispar*	0.0	0.0	15.0	0.0	160.0	70.0	1.0	0.0	0.0	0.0
6	*Atherix variegata*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5
6	*Ceratopsyche sp.*	0.0	0.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	*Zaitzevia sp.*	60.0	0.0	165.0	0.0	0.0	40.0	0.0	0.0	80.0	22.5
6	*Cleptelmis sp.*	0.0	6.0	45.0	0.0	610.0	1190.0	0.0	0.0	0.0	0.0
6	*Optioservus sp.*	210.0	12.0	30.0	0.0	620.0	930.0	4.0	165.0	20.0	0.0
6	Capniidae	0.0	0.0	0.0	0.0	840.0	0.0	2.0	0.0	0.0	15.0
7	*Psychoglypha sp.*	0.0	0.0	0.0	0.0	80.0	0.0	1.0	0.0	0.0	0.0
7	*Hemerodromia sp.*	0.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
7	Heptageniidae	0.0	0.0	0.0	0.0	0.0	130.0	0.0	0.0	0.0	0.0
7	*Epeorus nitidus*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*Epeorus longimanus*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Group	Taxa	C5	C6							C7	
		SBRLITTL	CEDARCMR	DUCKABUS	DUNGENES	SEABECK	SIEBERTC	COVINGT	SIMMONS	CEDARCFS	TAYLORCR
1	*Acentrella insignificans*	192.0	0.0	0.0	276.0	735.0	0.0	0.0	0.0	0.0	0.0
1	*Hydropsyche morosa*	0.0	50.0	0.0	84.0	0.0	1035.0	0.0	7.0	191.3	0.0
1	*Baetis tricaudatus*	270.0	170.0	802.5	360.0	1065.0	780.0	770.0	699.0	105.0	285.0
1	Chironomidae	0.0	150.0	270.0	144.0	7065.0	900.0	130.0	416.0	15.0	285.0
1	*Simulium sp.*	24.0	350.0	157.5	138.0	1035.0	2010.0	50.0	36.0	375.8	1200.0
1	*Cinygmula*	18.0	0.0	82.5	60.0	540.0	270.0	560.0	27.0	60.0	660.0
1	Oligochaeta	54.0	0.0	0.0	72.0	480.0	375.0	650.0	131.0	127.5	210.0
1	*Zapada cinctipes*	0.0	110.0	120.0	72.0	1140.0	525.0	330.0	67.0	0.0	0.0
1	*Rithrogena hageni*	132.0	1080.0	30.0	126.0	390.0	780.0	50.0	10.0	0.0	0.0
1	*Sweltsa Group*	6.0	570.0	232.5	96.0	585.0	435.0	90.0	14.0	0.0	0.0
1	*Drunella doddsi*	222.0	50.0	30.0	6.0	0.0	0.0	110.0	49.0	30.0	285.0
1	*Glossosoma sp.*	222.0	480.0	90.0	0.0	75.0	285.0	60.0	45.0	26.3	105.0
1	*Heterlimnius corpulentus*	6.0	40.0	0.0	0.0	255.0	105.0	90.0	20.0	102.0	30.0
1	Hydracarina	30.0	0.0	15.0	6.0	45.0	30.0	10.0	7.0	22.5	30.0
1	*Paraleptophlebia sp.*	18.0	10.0	0.0	0.0	390.0	225.0	60.0	105.0	0.0	0.0
1	*Pericoma sp.*	6.0	0.0	0.0	0.0	120.0	15.0	50.0	6.0	30.0	0.0
1	Planariidae	6.0	0.0	15.0	0.0	225.0	15.0	10.0	2.0	0.0	0.0
2	*Baetis bicaudatus*	18.0	50.0	75.0	0.0	0.0	0.0	10.0	12.0	0.0	0.0
2	*Epeorus grandis*	126.0	150.0	90.0	0.0	0.0	0.0	40.0	6.0	0.0	0.0
2	*Skwala sp.*	12.0	60.0	7.5	0.0	75.0	15.0	0.0	17.0	0.0	0.0
2	*Micrasema sp.*	42.0	0.0	0.0	0.0	45.0	0.0	0.0	5.0	0.0	0.0
2	*Moselia infuscata*	42.0	0.0	0.0	0.0	45.0	0.0	0.0	51.0	0.0	0.0
2	Nematomorpha	18.0	40.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0
2	*Rhyacophila vagrita*	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	*Diphetor hageni*	0.0	0.0	0.0	0.0	0.0	0.0	40.0	178.0	0.0	0.0
2	*Ironodes nitidus*	6.0	0.0	0.0	0.0	0.0	0.0	0.0	32.0	0.0	0.0
2	*Rhyacophila blarina*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	0.0	0.0
3	*Ceratopsyche sp.*	0.0	0.0	7.5	0.0	75.0	0.0	0.0	2.0	0.0	0.0
3	*Hexatoma sp.*	0.0	10.0	7.5	6.0	30.0	0.0	0.0	1.0	0.0	0.0
3	*Chelifera sp.*	0.0	0.0	0.0	0.0	30.0	120.0	0.0	18.0	0.0	0.0
3	*Dicranota sp.*	0.0	0.0	7.5	0.0	45.0	30.0	0.0	10.0	0.0	0.0
3	Sphaeriidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	*Doroneuria baumanni*	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	*Yoraperla mariana*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	*Lepidostoma sp.*	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0
3	*Rhyacophila brunnea*	0.0	70.0	0.0	24.0	0.0	0.0	0.0	0.0	0.0	0.0
3	*Rhyacophila narvae*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	*Rhyacophila varula*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0

4	*Brachycentrus occidentalis*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Ephemerella grandis*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Caudatella hystrix*	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0
4	*Parapsyche almota*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0
4	*Dolophilodes sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
4	*Megarcys signata*	0.0	0.0	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Prostoia sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Taenionema sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Rhyacophila acropedes*	0.0	0.0	60.0	0.0	0.0	240.0	40.0	12.0	0.0	0.0
4	*Zapada Oregonensis group*	0.0	10.0	0.0	12.0	255.0	90.0	0.0	67.0	0.0	0.0
4	*Chimarra sp.*	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0
4	*Epeorus (Ironodes) sp.*	0.0	0.0	0.0	54.0	0.0	0.0	60.0	0.0	0.0	0.0
4	*Rhyacophila albertae*	0.0	0.0	0.0	42.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Hesperoperla pacifica*	0.0	0.0	0.0	36.0	0.0	15.0	120.0	15.0	42.0	0.0
5	*Agapetus sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Leucotrichia sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Cheumatopsyche sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	Ephemeroptera	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Narpus concolor*	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	15.0
5	Odonata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Rhyacophila betteni*	12.0	60.0	0.0	0.0	210.0	15.0	0.0	0.0	0.0	0.0
5	*Antocha monticola*	0.0	20.0	7.5	0.0	0.0	0.0	10.0	2.0	15.0	15.0
5	*Brachycentrus americanus*	0.0	20.0	0.0	0.0	15.0	0.0	20.0	0.0	0.0	0.0
5	*Rhyacophila sp.*	12.0	0.0	15.0	12.0	90.0	0.0	0.0	2.0	11.3	210.0
5	*Hydropsyche betteni*	0.0	0.0	0.0	0.0	0.0	0.0	460.0	0.0	0.0	0.0
5	*Ochrotrichia sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Petrophila sp.*	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Tricoythodes sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Attenella margarita*	0.0	0.0	0.0	0.0	255.0	0.0	10.0	5.0	0.0	0.0
5	*Calineuria californica*	0.0	0.0	0.0	0.0	45.0	0.0	60.0	19.0	3.8	0.0
5	*Pteronarcys californica*	0.0	0.0	0.0	0.0	0.0	0.0	20.0	1.0	0.0	0.0
5	*Helicopsyche borealis*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Serratella tibialis*	0.0	60.0	67.5	0.0	0.0	285.0	40.0	29.0	18.0	0.0
6	*Alloperla sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	240.0
6	*Arctopsyche sp.*	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	18.8	90.0
6	*Claassenia sabulosa*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	60.0
6	*Polycentropus sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0
6	*Amaletus sp.*	6.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	210.0
6	*Parapsyche almota*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	6.0	195.0
6	Nematoda	0.0	0.0	0.0	0.0	0.0	0.0	60.0	0.0	26.3	780.0
6	*Epeorus sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	315.0

6	*Ampumixis dispar*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.0	0.0
6	*Atherix variegata*	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	126.0	0.0
6	*Ceratopsyche sp.*	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	222.0	30.0
6	*Zaitzevia sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	162.0	0.0
6	*Cleptelmis sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	75.0
6	*Optioservus sp.*	6.0	0.0	0.0	0.0	0.0	0.0	20.0	1.0	30.0	45.0
6	Capniidae	0.0	10.0	7.5	0.0	0.0	0.0	10.0	1.0	0.0	0.0
7	*Psychoglypha sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*Hemerodromia sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	Heptageniidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0
7	*Epeorus nitidus*	0.0	0.0	0.0	0.0	0.0	750.0	0.0	0.0	0.0	0.0
7	*Epeorus longimanus*	0.0	0.0	52.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

		C1	C2		C3	C4				C5	
Group	**Taxa**	**LONGCR**	**ILLABOTC**	**PORTAGEC**	**DIOBSUD**	**DEERCR**	**GRANTCR**	**FINNEYC**	**JACKMANC**	**JIMCR**	**SAMMISHR**
1	*Acentrella insignificans*	5.0	0.0	0.0	30.5	453.7	870.0	79.0	255.0	37.5	110.0
1	*Simulium sp.*	2.3	10.0	0.0	1.3	64.2	1420.0	25.8	960.0	202.5	20.0
1	*Baetis bicaudatus*	71.8	590.0	540.0	82.8	64.2	220.0	27.8	255.0	0.0	0.0
1	*Baetis tricaudatus*	58.8	360.0	645.0	10.0	132.7	620.0	28.3	210.0	52.5	480.0
1	Chironomidae	20.5	1660.0	1305.0	42.8	462.2	2240.0	44.0	975.0	112.5	480.0
1	*Rithrogena sp.*	3.3	0.0	0.0	52.5	0.0	130.0	53.8	345.0	0.0	620.0
1	*Attenella margarita*	54.5	20.0	0.0	0.3	0.0	50.0	5.5	30.0	22.5	150.0
1	Hydracarina	13.0	70.0	105.0	2.3	4.3	40.0	11.8	60.0	22.5	90.0
1	*Sweltsa Group*	5.0	0.0	15.0	38.5	12.8	40.0	9.0	90.0	75.0	120.0
1	*Hydropsyche sp.*	11.5	40.0	405.0	2.8	55.6	20.0	20.0	255.0	135.0	40.0
1	*Zapada cinctipes*	21.3	70.0	765.0	23.5	17.1	180.0	0.3	90.0	112.5	60.0
1	*Heterlimnius corpulentus*	1.3	0.0	0.0	0.0	0.0	140.0	1.5	0.0	337.5	460.0
1	Oligochaeta	0.3	110.0	210.0	3.0	0.0	120.0	0.3	105.0	480.0	150.0
1	*Cinygmula sp.*	4.0	260.0	0.0	53.3	0.0	0.0	0.0	45.0	157.5	10.0
1	*Micrasema sp.*	1.0	250.0	0.0	0.5	0.0	0.0	0.0	0.0	15.0	0.0
1	*Ironodes nitidus*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	247.5	0.0
1	*Paraleptophlebia heteronea*	0.3	10.0	3450.0	0.0	17.1	0.0	0.0	0.0	135.0	0.0
1	*Dicranota sp.*	1.5	0.0	15.0	1.8	0.0	0.0	0.3	0.0	0.0	20.0
1	*Ephemeroptera*	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0
1	*Glossosoma sp.*	3.3	0.0	90.0	1.5	0.0	0.0	0.0	0.0	45.0	20.0
1	*Optioservus sp.*	0.0	0.0	60.0	0.0	0.0	0.0	0.0	0.0	37.5	110.0
2	*Brachycentrus sp.*	0.0	0.0	0.0	3.5	0.0	30.0	15.5	0.0	0.0	0.0
2	Heptageniidae	1.0	0.0	0.0	0.0	0.0	30.0	54.0	0.0	0.0	0.0
2	*Paraleptophlebia sp.*	0.0	0.0	0.0	1.5	0.0	330.0	9.0	0.0	7.5	20.0
2	*Zaitzevia parvula*	0.8	0.0	0.0	0.0	4.3	830.0	4.8	0.0	30.0	0.0
2	Capniidae	0.0	0.0	0.0	0.0	0.0	60.0	3.8	0.0	0.0	30.0
2	*Limnophila sp.*	0.0	0.0	0.0	0.0	4.3	50.0	1.3	0.0	0.0	0.0
2	Ceratopogonidae	0.0	0.0	0.0	0.0	0.0	10.0	5.0	0.0	15.0	0.0
2	*Ceratopsyche sp.*	0.0	0.0	105.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0
2	*Cleptelmis sp.*	0.0	0.0	15.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0
3	*Acentrella turbida*	0.0	0.0	0.0	6.8	0.0	0.0	5.3	165.0	0.0	0.0
3	*Epeorus deceptivus*	14.3	10.0	0.0	6.3	0.0	0.0	0.0	75.0	0.0	0.0
3	Lepidoptera	19.5	10.0	0.0	1.5	0.0	0.0	0.0	15.0	0.0	0.0

3	*Antocha monticola*	0.5	40.0	0.0	0.3	8.6	0.0	1.5	30.0	7.5	0.0
3	*Drunella doddsi*	6.5	60.0	0.0	3.3	4.3	0.0	0.3	0.0	0.0	0.0
3	*Serratella tibialis*	23.5	40.0	0.0	0.0	4.3	0.0	3.8	0.0	0.0	0.0
3	*Neophylax sp.*	47.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0
3	*Chelifera sp.*	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	*Clinocera sp.*	0.0	100.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	*Drunella spinifera*	0.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	*Isoperla sp.*	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0
4	*Arctopsyche grandis*	0.0	30.0	30.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
4	Ostracoda	1.0	10.0	45.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0
4	*Rhyacophila brunnea*	0.3	10.0	0.0	1.5	0.0	10.0	0.3	0.0	0.0	0.0
4	*Rhyacophila verrula*	0.0	0.0	15.0	1.3	0.0	0.0	0.3	0.0	0.0	0.0
4	*Cultus sp.*	2.0	0.0	180.0	1.8	0.0	20.0	0.3	0.0	0.0	0.0
4	*Epeorus albertae*	0.0	0.0	0.0	1.5	0.0	20.0	0.0	0.0	0.0	0.0
4	*Rhyacophila betteni*	0.0	0.0	0.0	1.3	0.0	70.0	0.0	0.0	0.0	0.0
4	Nematoda	0.3	10.0	30.0	0.0	0.0	80.0	0.0	0.0	0.0	0.0
4	*Cinygma sp.*	0.0	0.0	0.0	36.0	0.0	0.0	0.0	0.0	0.0	0.0
4	*Cheumatopsyche sp.*	0.0	0.0	0.0	0.0	21.4	0.0	4.3	0.0	0.0	0.0
4	*Haploperla sp.*	0.0	0.0	0.0	0.0	21.4	0.0	0.0	0.0	0.0	0.0
4	*Epeorus (Ironodes) sp.*	0.0	0.0	0.0	2.3	158.4	0.0	1.0	0.0	0.0	0.0
5	*Amiocentrus sp.*	2.5	0.0	0.0	0.3	0.0	0.0	1.5	0.0	0.0	0.0
5	*Rithrogena robusta*	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Apatania sp.*	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Utaperla sp.*	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	Limnephilidae	0.8	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
5	*Rhyacophila sibirica*	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Baetis sp.*	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Skwala sp.*	2.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	*Pericoma sp.*	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	*Hesperoperla pacifica*	0.0	0.0	0.0	0.5	4.3	0.0	0.0	0.0	22.5	0.0
6	*Paraleptophlebia memorialis*	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	0.0
6	*Rhyacophila sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.5	15.0	30.0	0.0
6	Sphaeriidae	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0
6	*Zapada Oregonensis group*	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0
6	*Wormaldia sp.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0
7	*Anagapetus sp.*	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
7	*Lara avara*	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0

7	Leuctridae	0.0	0.0	0.0	0.5	0.0	0.0	0.8	0.0	0.0	0.0