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Ambient Monitoring Instream Biological Assessment:

Progress Report of 1993 Pilot Survey

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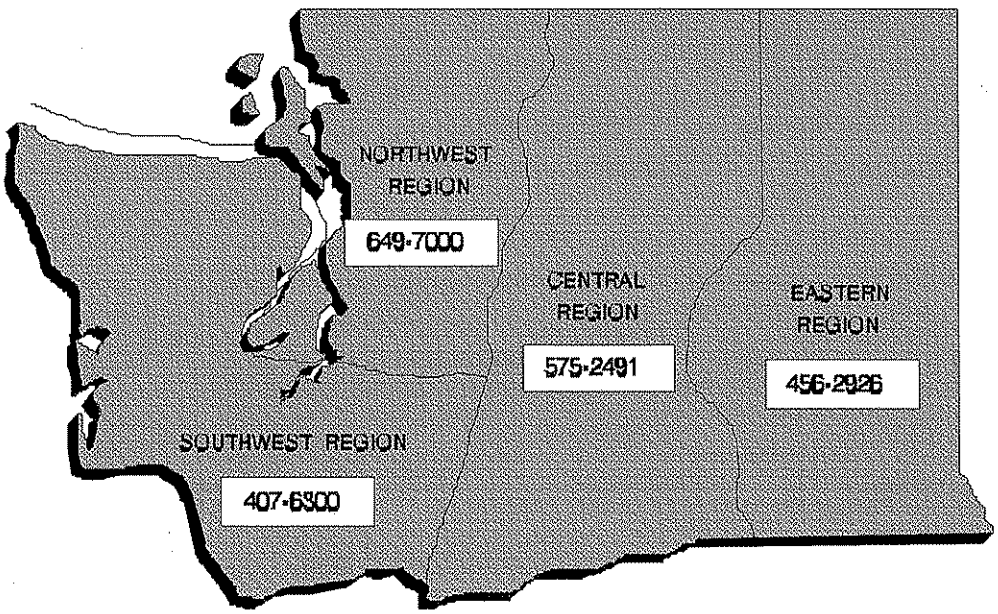

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Ambient Monitoring Instream Biological Assessment:

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Ambient Monitoring Section

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Acknowledgements

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Abstract

Biological assessment of 20 stream sites was completed in the Columbia Basin and Cascade ecoregions during the summer of 1993. A multi-habitat sampling protocol was used to describe benthic macroinvertebrate assemblages in riffles and pools. Synoptic taxa lists were developed for three ecoregions of Washington State. Biological condition of riffle and pool habitat was determined for each site and ranked in two sets using several biometrics.

A disturbance continuum was described from the sites surveyed in each ecoregion. The disturbance may have been naturally influenced or human caused. Protected sites, such as those in National Parks, can appear to have degraded conditions. Ohanapecosh River, in the Mt. Rainier National Park, did not contain a diverse riffle assemblage, but had a species-rich pool condition. Physical features such as a broad channel width and dominance of finer substrate material indicated a capacity to assimilate depositional materials. Additional physical features that explained biological conditions were: proportion of available cobble substrate, flow, average current velocity, wetted width/bankfull width, and proportion of forested land in a montane region. Taxa richness and the EPT Index represented biological condition in regression analysis with stream reach and watershed characteristics. A strong relationship was found between taxa richness and the proportion of forested land (r=0.83). The relationship between taxa richness and wetted width/bankfull width ratio was strong in Cascade (r=0.72) and Columbia Basin (r=0.73) streams.

Variability of replicate samples collected within a stream reach indicated consistent levels of repeatability (coefficient of variation for taxa richness was 6% among four replicate samples). The high level of precision using this biological assessment method provided some indication for sensitivity in applying regional biological metrics. Identification of three biological condition categories (poor, fair, good) were suggested for riffle habitat in the Cascade ecoregion of Washington State.

Introduction

This report summarizes biological conditions in several streams located in the Columbia Basin, Eastern Cascades Slopes and Foothills, and the Cascade ecoregions of Washington State. The specific objectives for this summary of results and their interpretations are:

1. to provide an update/progress report from the biological monitoring program,

2. to compare site rankings of several biometrics,

3. to determine relationships between physical characteristics of the stream and the biology, and

4. to examine the accuracy of visual assessment of stream segments.

Information generated from the 1993 biological survey was used for two purposes: 1) provide additional information to permit writers for specific watersheds, and 2) to determine the appropriate biometrics for use in narrative and numeric biological criteria development.

This document summarizes benthic macroinvertebrate (aquatic insect) conditions for 20 sites. Biological condition among all sites was compared by using a common biometric (*i.e.*, taxa richness). Similar comparisons were also made among sites with several other biometrics.

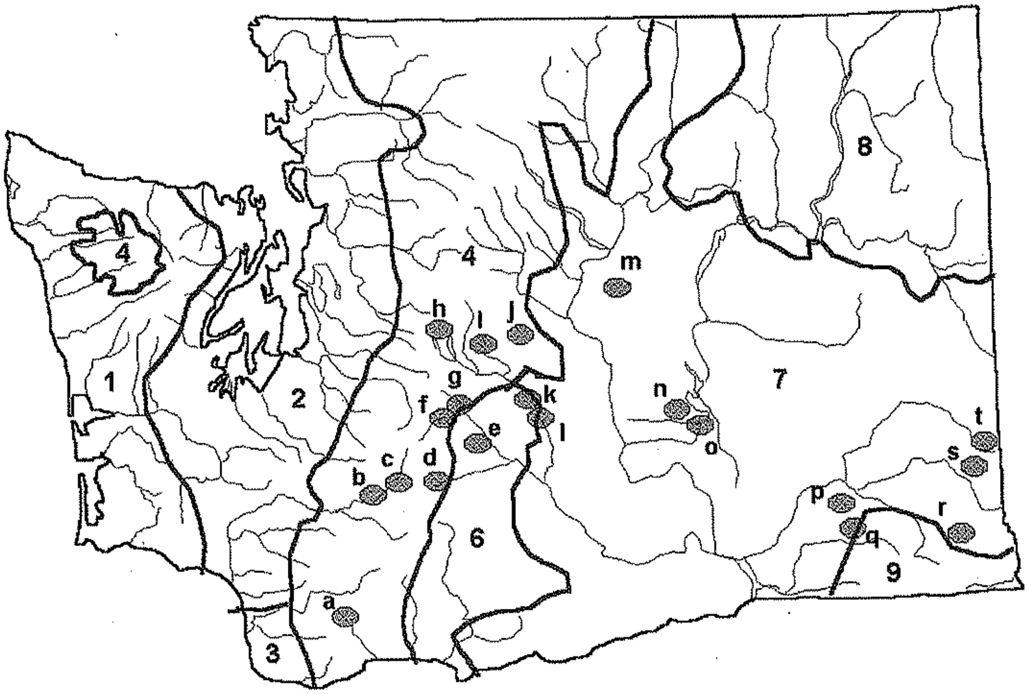
Relationships between biological condition and physical characteristics of the stream or watershed were also analyzed. The purpose for exploring these relationships was to identify possible causative factors in stream biological degradation. Additional years of monitoring information will be needed to validate preliminary observations and hypotheses.

Finally, site selection was evaluated to determine how well the sampling network represented a continuum of stream conditions (degraded through reference).

Methods

Field

Field methods for biological, physical, and chemical data collection are summarized here, but have been extensively described in Plotnikoff (1994). Collection of samples from 47 sites were made during August-October 1993 and 20 of those sites are analyzed in this report (Figure 1). Benthic macroinvertebrates were collected from stream reaches that were 40 times the average stream width. A D-frame kicknet was used to collect macroinvertebrates from four riffle habitats and four pool (depositional) habitats. The net mesh size for the



Survey Sites

a. Trapper Creek	k. Upper Yakima River
b. Butler Creek	l. Umtanum Creek
c. Ohanapecosh River	m. Douglas Creek
d. Indian Creek	n. Sand Dunes Creek
e. Rattlesnake Creek	o. Lower Crab Creek
f. American River	p. Tucannon River
g. Little Naches River	q. Cummings Creek
h. Gold Creek	r. North Fork Asotin Creek
i. Middle Fork Teanaway River	s. South Fork Palouse River
j. Swauk Creek	t. Palouse River

Ecoregions

1. Coast Range
2. Puget Lowland
3. Willamette Valley
4. Cascades
6. Eastern Cascades Slopes & Foothills
7. Columbia Basin
8. Northern Rockies
9. Blue Mountains

Figure 1. Survey site locations for summer 1993 ambient biological assessments.

sampler was 500 microns. Stratification of habitat type, riffle and pool, guided sample site location within the reach. Riffles were stratified based on water depth and substrate size. Pools or depositional areas were stratified by depth and location within the stream reach (e.g., side channel, behind a boulder, center of the channel). Riffle samples were composited in a single container and pool samples were composited in a separate container. Within site variability of riffle macroinvertebrate communities was measured at two sites (Ohanapecosh River and Hangman Creek). Four riffle samples collected at each site were placed and preserved in separate containers (not composited) for estimation of within site variability.

Macroinvertebrate samples were sorted with a sub-sampling technique. A minimum of two squares and 300 organisms were picked from each field sample. A dissecting stereomicroscope was used for sorting field samples and identification of benthic macroinvertebrates.

Physical characterization of stream reaches focused on stream morphology and riparian vegetation composition. Quantitative measurements were restricted to stream morphology characters while qualitative measurements were used to describe riparian vegetation. Stream morphometrics included: flow, wetted stream width, bankfull stream width, depth, average current velocity, substrate size, and gradient. The quantitative morphometrics characterized conditions at the specific sites of macroinvertebrate collection within a reach. Riparian vegetation was described for the overhead canopy, understory, and ground cover. Canopy cover was measured with a densiometer that estimated light transmission to the stream surface. Human influence was recorded by type and proximity to the stream reach.

Surface water variables measured were temperature, conductivity, pH, and dissolved oxygen (Appendix A). Water samples were collected at the base of the stream reach and immediately analyzed or preserved for later analysis (e.g., dissolved oxygen). Dissolved oxygen samples were analyzed with the Winkler titration method at the laboratory.

Data Analysis

Site Condition Ranking

Several biometric scores were generated for each site (Taxa richness, EPT Index, % Dominant Taxon, % Dominant Taxa (two species), Plecoptera Species, Ephemeroptera Species). Sites were then ranked for each biometric. These biometrics were chosen because they have consistently detected stream degradation under a variety of conditions in previous studies (Fore and Karr, 1994; Lenat, 1983). Riffle and pool condition was also compared at each site. For example, taxa richness may be high in riffles but low in pools at a stream reach because 1) pool quality is low, or 2) pool habitat location may be transient in the reach. The opposite condition may hold true where pool habitat is of higher quality than riffles. Generally, taxa richness indicates the "quantity" of a particular habitat type and the EPT Index elaborates on the "quality" of a habitat type.

Stream Habitat Types (Riffle and Pool)

Stream habitat was delineated as either riffle (broken surface water) or pool (still or very slow-moving surface water) in this survey. Specific pollutants introduced into a stream can influence the biological community in a manner dependent on habitat type. Stream size and land uses were compared to community biometrics for each of the habitat conditions. Generally, pool habitats were expected to show lower taxa richness than riffle habitats.

Synoptic Lists

Species lists were compiled for each of the three ecoregions sampled: Columbia Basin, East Cascades Slopes and Foothills, and Cascades. Taxa collected from each ecoregion were added to the list, regardless of the number of sites in which they were present. The Cascade and Eastern Cascade Slopes and Foothills (ECS&F) stream were eventually combined as a single region for biometric analysis, primarily because the ECS&F was not adequately surveyed and streams there resembled montane conditions.

Relationships Between Physical and Biological Variables

Although additional monitoring information will be needed before final regional descriptions of biological assemblages are made, some preliminary hypotheses were derived from: 1) comparison of physical stream channel characteristics with community biometrics, and 2) biometrics that identify the reference condition. Some of the physical stream channel characters include wetted stream width, bankfull width, stream gradient, flow, average current velocity, and substrate size distribution. Watershed complexity per site was characterized by total area contained within a 100 meter buffer zone upstream from where samples were collected. The same community biometrics listed above are used throughout the analytical phases of this survey. Least squares regression analysis was used to determine existing relationships between physical variables (fixed effects) and the dependent biological variables. Normal probability plots were constructed for each regression. Relationships between physical and biological variables were not strict statistical derivations.

Detecting Stream Degradation from Land Use

Land use within the watershed upstream of the biological collection site was compared to individual biometrics. The relationship between individual biometrics and land use types was subsequently explored to identify possible degradation mechanisms. A standardized expression of forested land was determined for each watershed and direct comparisons were made among all Cascade ecoregion sites.

Biological Variability Within a Stream Reach

Replicate biological samples from a site were preserved in separate storage containers. Instead of compositing the four riffle samples, a measure for within stream reach variability was calculated from a reference condition. Low variability of taxa richness and the EPT Index among four replicate samples collected from within a reach was expected to increase the ability for detection of biological impacts when used on a regional scale. High variability of individual collections in a stream may indicate that certain habitat types have been degraded.

Visual Assessment of Stream Segments

An *a priori* ranking of site conditions was compared to a list of sites ranked by taxa richness and the EPT Index. The objective for this exercise was to compare best professional judgement based on visual analysis to rankings of two commonly reported biometrics. Pre-survey site condition lists were compiled and compared to the biometric lists generated for the Cascade and Columbia Basin ecoregions.

Results and Discussion

Work Completion

A total of 47 sites were surveyed during summer 1993 (Plotnikoff, 1994). Sample sorting and identification were conducted during winter 1993 and spring 1994. Samples from 20 of the summer 1993 sites were sorted and identified, generally to species, except for taxa belonging to the following groups: Chironomidae, Lumbriculidae, Naididae, select families of Coleoptera, Planariidae, and Hydracarina.

One composite pool and one composite riffle habitat sample were processed for each site. Samples processed are found in Table 1.

Site Condition Ranking

Basic physical descriptions of streams surveyed are listed in Table 2. Taxa richness and EPT Index scores at East Cascade streams were highest for Little Naches River, Trapper Creek, and American River (Table 3). Columbia Basin streams consistently ranked taxa richness and EPT Index scores highest in riffle and pool habitat at North Fork Asotin Creek, Cummings Creek, and Tucannon River (Table 3). The remaining biometrics calculated for these Columbia Basin sites in riffle habitat received the top scores (Table 4). Previous work conducted at North Fork Asotin Creek and Cummings Creek (Plotnikoff, 1992) identified these streams as reference. Consistent high scores confirmed these streams as least degraded from those sampled in the Columbia Basin.

Pool condition at East Cascade stream sites had considerable differences in ranking than site rankings for riffle habitat. The Little Naches River pool condition ranked poorest for several biometrics (Tables 3 and 4), but maintained the highest ranking for riffle condition among several biometrics. The discrepancy in biological condition collected in pool and riffle habitat suggested that activities in the catchment (e.g., forest practices, recreation) affected the benthic community. The American River had consistently good biological conditions for all biometrics in both riffle and pool habitats (Table 3). Pool habitat in the Ohanapecosh River appeared to be a more important refuge for macroinvertebrate species than the riffle environment (Tables 3 and 4).

Table 1. Identification and location of biological assessment survey sites analyzed from summer 1993 collections.

Site Name	Ecoregion	Basin	Condition
Trapper Creek	Cascades	Wind-White Salmon	Reference
American River	Cascades	Naches	Reference
Ohanapecosh River	Cascades	Cowlitz	Reference
Middle Fork Teanaway R.	Cascades	Upper Yakima	Reference
Indian Creek	Cascades	Naches	Reference
Rattlesnake Creek	Cascades	Naches	Forest Practices
Little Naches River	Cascades	Naches	Forest Practices
Butler Creek	Cascades	Cowlitz	Forest Practices
Swauk Creek	Cascades	Upper Yakima	Utilities/Mining
Gold Creek	Cascades	Upper Yakima	Forest Practices
North Fork Asotin Cr.	Columbia Basin	Middle Snake	Reference
Cummings Creek	Columbia Basin	Middle Snake	Reference
Tucannon River	Columbia Basin	Middle Snake	Grazing
Sand Dunes Creek	Columbia Basin	Lower Crab	Recreation
Lower Crab Creek	Columbia Basin	Lower Crab	Irrigation Return Flow
Upper Palouse River	Columbia Basin	Palouse	Dryland Wheat
South Fork Palouse R.	Columbia Basin	Palouse	Dryland Wheat
Douglas Creek	Columbia Basin	Moses Coulee	Dryland Wheat
Umtanum Creek	Columbia Basin	Upper Yakima	Reference
Upper Yakima River	Columbia Basin	Upper Yakima	Irrigation Return Flow

Table 2. Physical description of streams surveyed for the biological assessment program during summer 1993.

Site	Stream Order	Gradient (%)	Flow (CFS)
East Cascades			
Trapper Creek	2	2	7.15
American River	3	2	36.9
Ohanapecosh River	3	1.5	75.8
Middle Fork Teanaway R.	3	2	2.96
Indian Creek	1	1.75	20.5
Rattlesnake Creek	3	1	40.5
Little Naches River	3	1	32.6
Butler Creek	2	2	18.5
Swauk Creek	2	2.5	0.83
Gold Creek	2	1	7.81
Columbia Basin			
North Fork Asotin Cr.	3	2.5	18.7
Cummings Creek	2	2	2.37
Tucannon River	3	2	74.8
Sand Dunes Creek	1	1.5	116.8
Lower Crab Creek	2	1.5	90.9
Upper Palouse River	2	1	0.73
South Fork Palouse R.	2	1	0.63
Douglas Creek	2	0.8	0.22
Umtanum Creek	1	1	0.27
Upper Yakima River	4	0.5	3,146

Table 3. Ranking of riffle and pool sites surveyed during summer 1993.

Site	Taxa Richness		EPT Index		%Dominant Species	
	Riffle	Pool	Riffle	Pool	Riffle	Pool
East Cascades						
Trapper Creek	2	5	2	5	5	7
American River	3	2	3	1	1	3
Ohanapecosh River	8	3	8	3	8	2
Middle Fork Teanaway R.	9	4	9	4	3	1
Indian Creek	5	10	5	9	6	9
Rattlesnake Creek	4	1	4	2	2	5
Little Naches River	1	9	1	10	4	6
Butler Creek	7	6	6	6	9	10
Swauk Creek	6	8	7	8	7	8
Gold Creek	10	7	10	7	10	4
Columbia Basin						
North Fork Asotin Cr.	2	1	1	2	3	7
Cummings Creek	3	2	2	1	2	1
Tucannon River	1	3	3	3	1	6
Sand Dunes Creek	10	6	6	5	6	4
Lower Crab Creek	9	8	9	6	7	5
Upper Palouse River	8	4	8	4	10	2
South Fork Palouse R.	7	7	10	9	9	9
Douglas Creek	4	5	7	7	5	3
Umtanum Creek	5	9	5	8	8	8
Upper Yakima River	6	*	4	*	4	*

* Unable to sample pool habitat in this stream reach.

Table 4. Ranking of riffle and pool sites surveyed during summer 1993.

Site	%Two-Dominant		Plecoptera		Ephemeroptera	
	Riffle	Pool	Riffle	Pool	Riffle	Pool
East Cascades						
Trapper Creek	5	7	2	3	3	10
American River	1	5	4	2	4	2
Ohanapecosh River	7	2	3	1	10	4
Middle Fork Teanaway R.	3	1	10	9	7	3
Indian Creek	6	8	8	5	6	1
Rattlesnake Creek	2	4	5	4	2	8
Little Naches River	4	6	1	10	1	9
Butler Creek	9	10	7	8	8	7
Swauk Creek	8	9	6	6	5	5
Gold Creek	10	3	9	7	9	6
Columbia Basin						
North Fork Asotin Cr.	3	5	2	2	3	3
Cummings Creek	2	1	1	1	2	2
Tucannon River	1	4	3	3	1	1
Sand Dunes Creek	6	6	8	6	7	5
Lower Crab Creek	9	8	9	8	8	7
Upper Palouse River	8	2	7	4	6	4
South Fork Palouse R.	10	9	10	9	9	9
Douglas Creek	5	3	5	5	10	8
Umtanum Creek	7	7	6	7	5	6
Upper Yakima River	4	*	4	*	4	*

* Unable to sample pool habitat in this stream reach.

Stream Habitat Types (Riffle and Pool)

Cascade mountain and Columbia Basin sites were ranked in descending order from highest number of species collected (Figure 2). The differences between riffle and pool taxa richness can be substantial (e.g., Little Naches River and Indian Creek). There are many reasons why such discrepancies in pool and riffle assemblages occur. Depressed community conditions in riffles or pools result from natural or anthropogenic influences. Substantial differences between the highest and lowest biometric scores allowed stream conditions to be ranked in both regions. Site ranking was the first phase of analysis that would indicate the severity of natural or anthropogenic disturbance.

Pools in montane streams are important habitat to evaluate. They may contain the best habitat for survival during the most stressed portions of the year and they may have the largest nutritive food source incorporated within the depositional material. Montane reference streams in the Cascades generally have low nutrient concentrations (Plotnikoff, 1992) and do not always present rich primary food sources (e.g., periphyton). Food sources entering the food chain from outside the stream (e.g., leaf litter) are often deposited in slackwater zones in larger concentrations. These slackwater zones or pools are where detritivores (which consume dead animal and plant material) flourish.

Synoptic Lists and Biometrics

Synoptic lists of benthic macroinvertebrate species were compiled for the three ecoregions where streams were surveyed: Cascades, Columbia Basin, Eastern Cascades Slopes and Foothills. Two sites were surveyed in the Eastern Cascades Slopes and Foothills (ECS&F) ecoregion (Little Naches River and Rattlesnake Creek). A synoptic list was derived for species surveyed from these two sites, but other analyses incorporated both sites as part of the Cascades ecoregion. The synoptic list represents an initial, although incomplete, description of species distribution in this ecoregion. Assemblages at these sites were sub-sets of the Cascade ecoregion synoptic list. It was determined that an inadequate description of the ECS&F ecoregion would be made with only two sites surveyed.

Species numbers varied among the surveyed ecoregions. Cascade streams contained the largest number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) species (Appendix B). The greatest number of Coleoptera (beetles) and Diptera (black flies, mosquitoes, midges) species were collected at Columbia Basin streams (Appendix C). The Eastern Cascade Slopes and Foothills streams had the shortest species list, but only two streams were surveyed in that ecoregion.

The matrix of community biometrics generated for each surveyed site is located in Table 5. Use of this table is primarily for comparative purposes and the numbers are provided for independent analysis. When comparing a benthic macroinvertebrate assemblage condition to

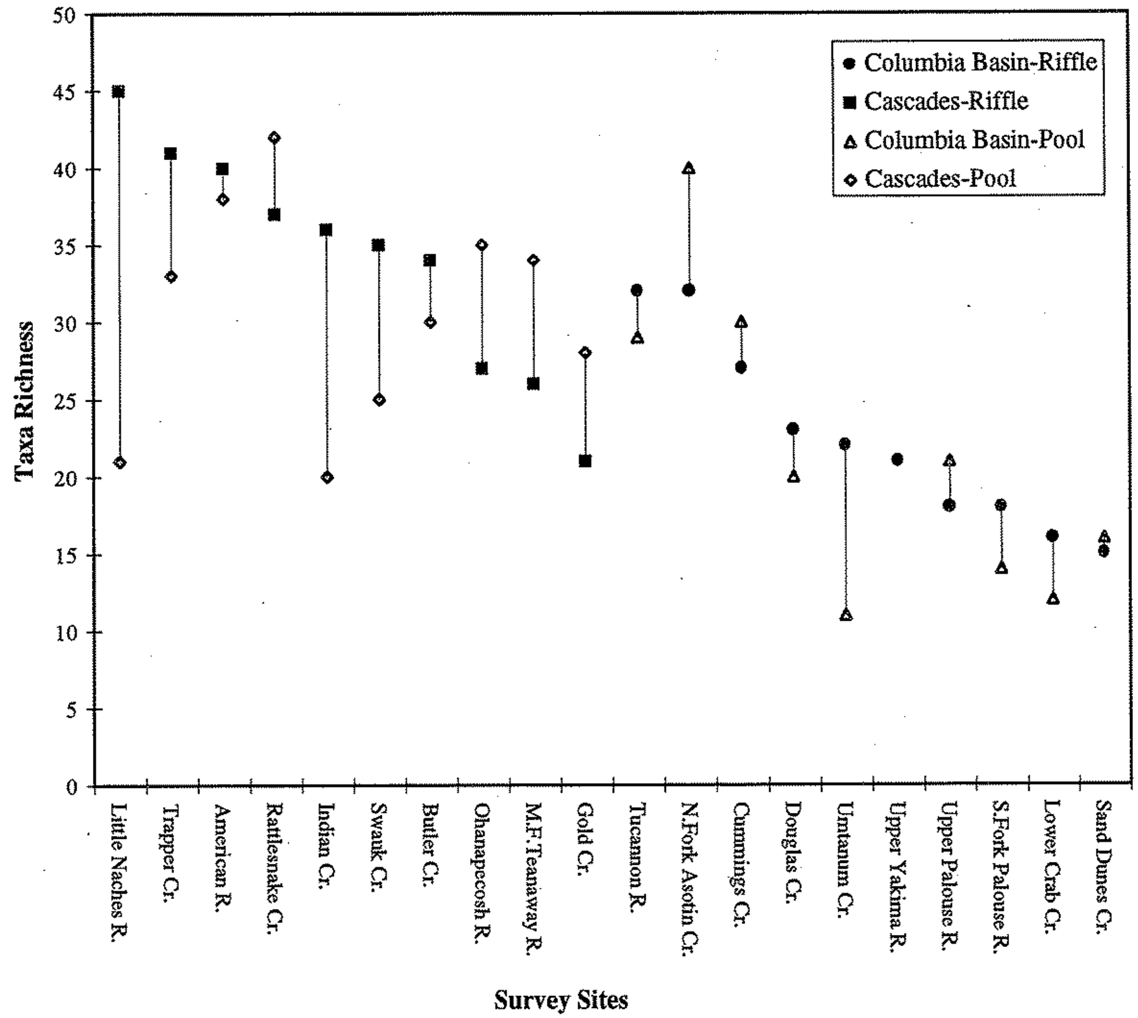


Figure 2. Taxa richness in riffle and pool habitat from Columbia Basin and Cascade ecoregion streams.

Table 5. Matrix describing community biometrics for sites surveyed during summer 1993.

Site	Taxa Richness	EPT Index	% Dominant Taxon	% Top Two Dominant Taxa	Plecoptera Species	Ephemeroptera Species
Pool Habitat						
Rattlesnake Creek	42	24	21	34	5	13
N.Fork Asotin Creek	40	17	51	59	3	6
American River	38	25	18	35	7	10
Ohanapecosh River	35	23	17	29	11	7
M. Fork Teanaway River	34	18	15	27	2	10
Trapper Creek	33	17	27	42	6	4
Butler Creek	30	16	44	68	3	7
Cummings Creek	30	19	19	37	6	6
Tucannon River	29	14	44	54	2	7
Gold Creek	28	16	18	32	4	7
Swauk Creek	25	15	27	53	5	7
Little Naches River	21	8	26	40	1	5
Palouse River	21	6	23	42	1	3
Indian Creek	20	11	28	49	5	5
Douglas Creek	20	5	32	49	0	2
Sand Dunes Creek	16	6	40	62	0	3
S.Fork Palouse River	14	3	68	84	0	1
Lower Crab Creek	12	6	41	73	0	3
Umtanum Creek	11	5	62	67	0	3
Riffle Habitat						
Little Naches River	45	32	14	27	12	11
Trapper Creek	41	27	15	27	11	9
American River	40	27	11	20	7	9
Rattlesnake Creek	37	23	11	22	7	10
Indian Creek	36	23	20	29	5	9
Swauk Creek	35	20	21	39	6	9
Butler Creek	34	22	41	52	6	7
Tucannon River	32	16	14	24	4	7
N.Fork Asotin Creek	32	19	23	40	5	6
Ohanapecosh River	27	20	24	37	8	6
Cummings Creek	27	17	22	39	6	6
M. Fork Teanaway River	26	17	12	22	3	8
Douglas Creek	23	7	28	46	2	1
Umtanum Creek	22	9	39	54	2	4
Gold Creek	21	16	53	60	4	7
Yakima River	21	13	30	41	1	6
Palouse River	18	7	49	56	1	4
S.Fork Palouse River	18	5	42	62	0	3
Lower Crab Creek	16	6	38	59	0	3
Sand Dunes Creek	15	8	36	54	0	4

this table, reference should be made to Table 2 that describes physical characteristics of each stream. Comparisons should be made to streams that closely approximate physical similarity, habitat type (pool or riffle), and season sampled.

Relationships Between Physical and Biological Variables

Macroinvertebrate community conditions are influenced by several physical features in streams. These features generally belong to four categories describing stream characteristics: hydrology (flow, average current velocity), stream morphology (substrate availability, wetted width, bankfull width, wetted width/bankfull width), watershed land use, and stream disturbance.

Hydrologic Influence on Stream Communities

Two independent variables were used in regression analysis: flow and average current velocity. The dependent biological variables used were taxa richness and the EPT Index. Regression pairs were: taxa richness x flow, EPT Index x flow, and taxa richness x average current velocity.

Cascade streams with flow rates of between 18 and 45 cubic feet per second (cfs) contained species-rich communities (Figure 3). Sites such as Butler Creek had the lowest taxa richness in the range of flow conditions. Stream channelization was identified as the major physical impact. In other instances, streams with flow rates less than 18 cfs contained fewer species either as a direct result of smaller water quantities (if flow rate potential is periodically higher) or through physical stream alterations. Trapper Creek flows were low when stream biology was surveyed, but this Wilderness area stream was species rich (Figure 3). Increased water temperature may limit the type of benthic macroinvertebrate assemblage in these streams even though ideal physical habitat may be available for colonization.

Streams in the Columbia Basin contained fewer species than those in the Cascade region. Water availability in streams draining this region effects the potential for extensive benthic macroinvertebrate colonization. Flow rates in streams between 18 cfs and 75 cfs contained the highest number of macroinvertebrate species. Streams with flows below 18 cfs appeared to be degraded (Figure 3). Low current velocities resulted in high water temperatures and probably increased deposition of sediment onto substrates. Three Columbia Basin streams surveyed had low average current velocities, low taxa richness, and some of the highest stream temperatures measured (Figure 4). Umtanum Creek, Douglas Creek, and South Fork Palouse River had stream temperatures of 16.2°C, 19.3°C, and 20.2°C, respectively. Excessive or regulated flows were observed at lower Crab Creek and Sand Dunes Creek (Figure 3). Altered timing of high flow conditions in these stream channels may have precluded expected development of the macroinvertebrate communities (Figure 5).

Taxa considered to be intolerant of pollution and physical stream disturbance were diverse in Cascade region streams. The same relationship between total taxa richness and flow was

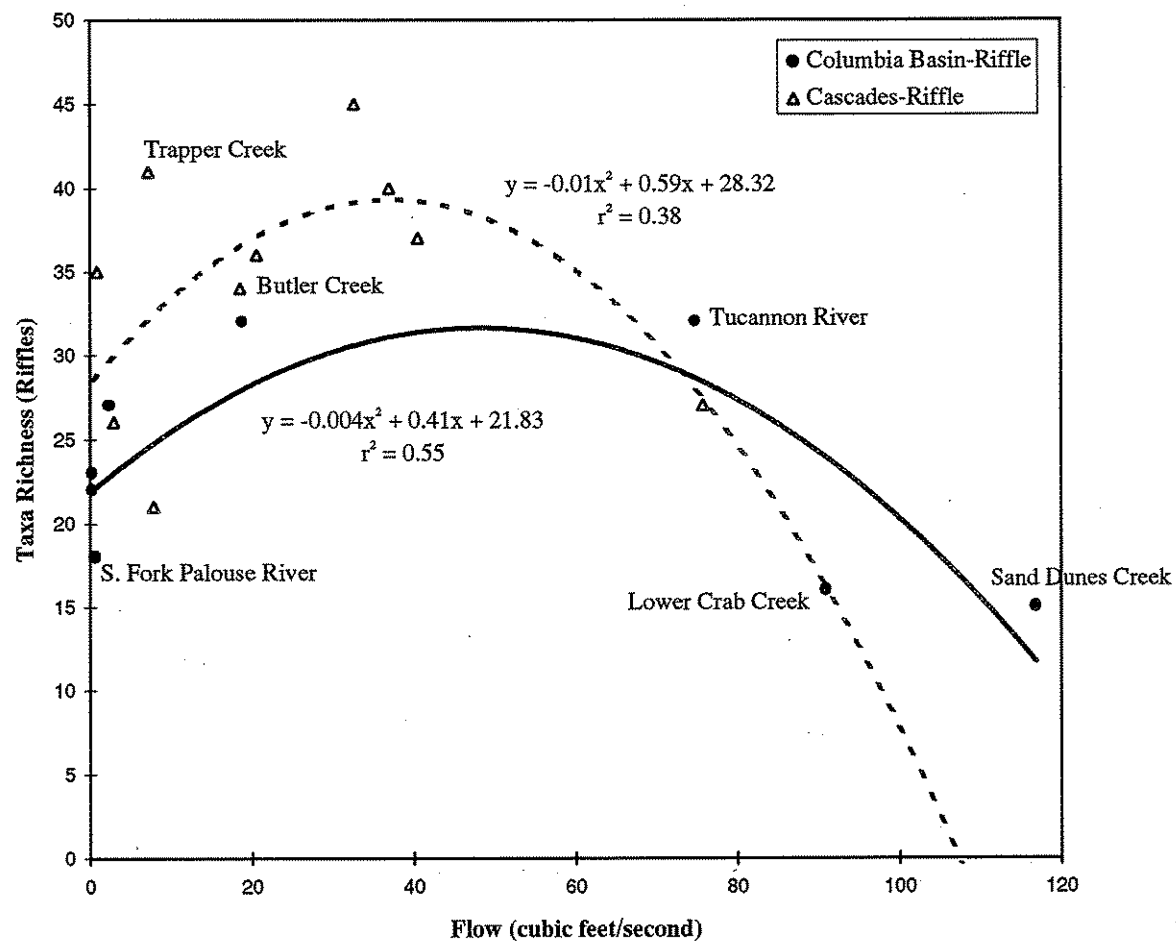


Figure 3. Relationship between taxa richness and flow (cfs) in Columbia Basin and Cascade ecoregion streams.

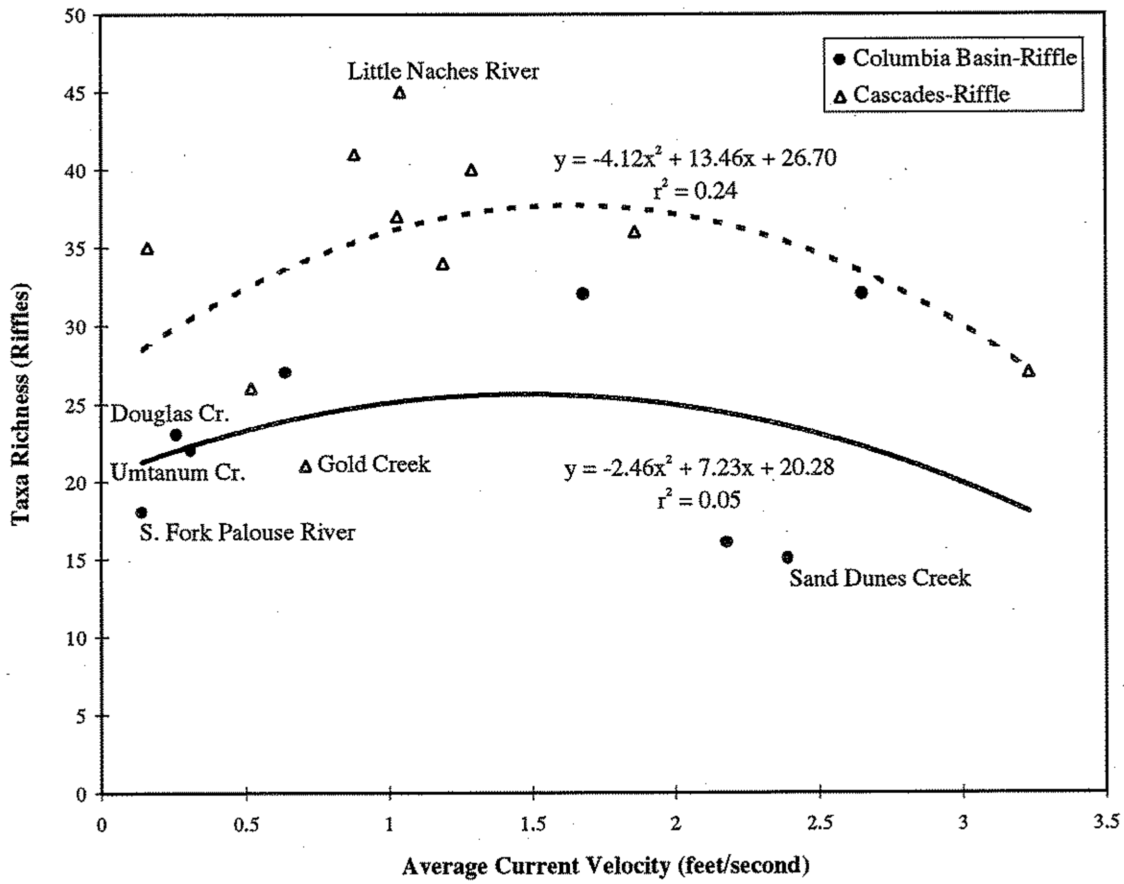


Figure 4. Relationship between taxa richness and average current velocity (cfs) in Columbia Basin and Cascade ecoregion streams.

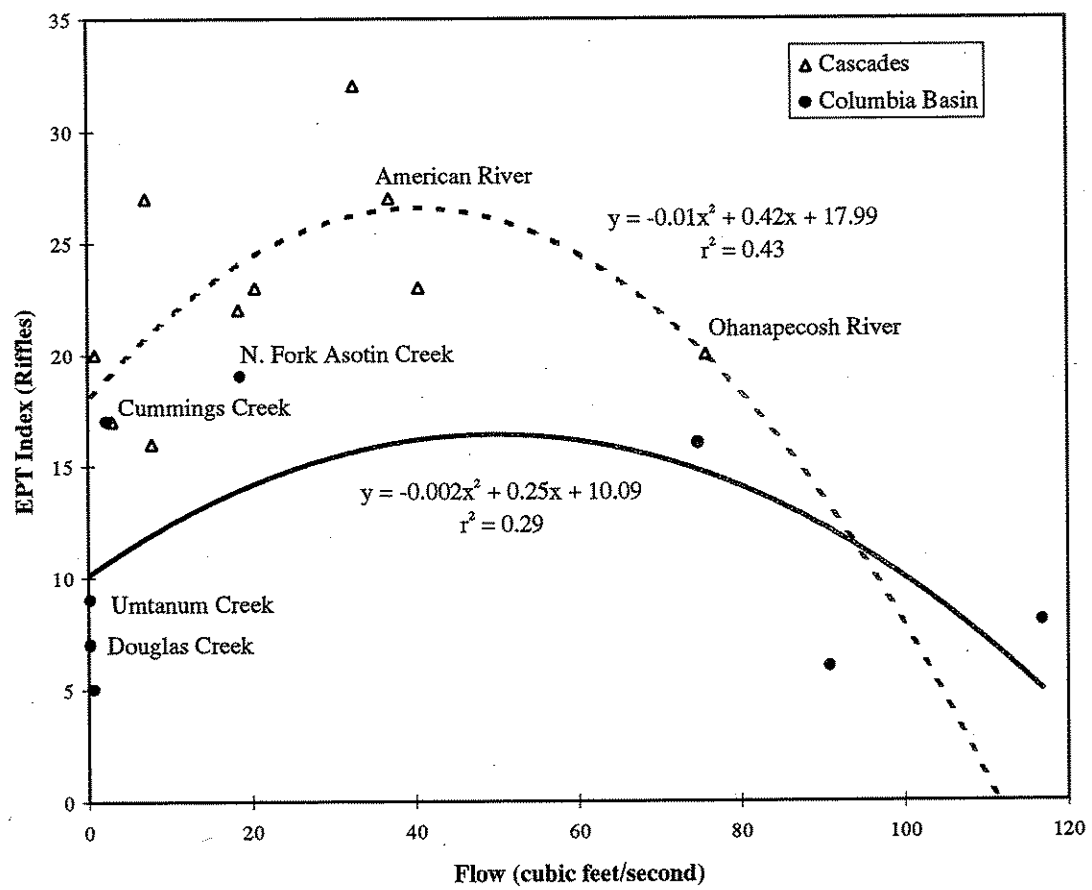


Figure 5. Relationship between EPT Index values and flow (cfs) in Columbia Basin and Cascade ecoregion streams.

found between the EPT Index and flow (Figures 3 and 5). Columbia Basin streams were dominated by dipteran taxa and had fewer Ephemeroptera, Plecoptera, and Trichoptera species (Appendix C). Most of the EPT taxa reported from Columbia Basin collections were found at sites near the edge of the ecoregion (*i.e.*, Cummings Creek, North Fork Asotin Creek, Tucannon River).

Stream Morphology

Composition of substrates is important to benthic macroinvertebrate colonization (Hynes, 1970; Cummins and Lauff, 1969). Cobble was identified as the optimal substrate size inhabited by macroinvertebrates in Cascade streams (Figure 6). As expected, wilderness area streams (Trapper Creek and American River) had large proportions of cobble substrate and high taxa richness. Ohanapecosh River is located within Mt. Rainier National Park and contained a small proportion of cobble in riffles (Figure 6). In contrast with species-rich pool habitat, the Ohanapecosh River riffles contained fine-grained substrate materials that reduced habitat complexity and macroinvertebrate community diversity.

Taxa richness in Columbia Basin streams was inversely related to proportion of available cobble substrate (Figure 6). The dipteran-dominated communities in these streams require fine-grained substrates for burrowing. Streams with high proportions of cobble had depressed communities resulting from other impacts. Upper Palouse River and South Fork Palouse River had very low flow rates. High flows resulting from irrigation return were characteristic of Sand Dunes Creek and Lower Crab Creek. High flows may have scoured fine-grained sediments from riffles in these streams exposing larger substrate particles. Turbulent flow patterns and high current velocity may have limited colonization of endemic species. Examination of several key variables that influence macroinvertebrate community development (e.g., substrate, flow, current velocity) begin to explain biological response to physical alterations.

Stream size measurements estimated by wetted stream width and bankfull width showed strong relationships with taxa richness and total number of Plecoptera species. The ratio wetted width/bankfull width (ww/bw) describes the shape of a stream channel. Channels that have a low ww/bw ratio have broad floodplains. A direct relationship was found between taxa richness and ww/bw in Cascade streams (Figure 7). The range of ww/bw ratios determined for optimal Cascade stream conditions was greater than 0.40 (Figure 7). Ratios of ww/bw in this range contained the richest communities (*i.e.*, Trapper Creek). Moderate constraint of a channel probably encourages some removal of fine interstitial sediments from riffle substrate and promotes richer communities. Cascade streams that have finer sediments in riffles (*i.e.*, Ohanapecosh River) are partially a result of channels that have broad floodplains and function as sediment traps.

Relationships of stream size (ww/bw) to biological community condition varied in Columbia Basin streams. Optimal channel constraint conditions were 0.45 to 0.90 (Figure 7). The presence of some floodplains at the North Fork Asotin Creek and Tucannon River sites indicated periodic high flows occurred. Columbia Basin streams have diverse macroinvertebrate communities under two possible conditions: 1) in streams that have

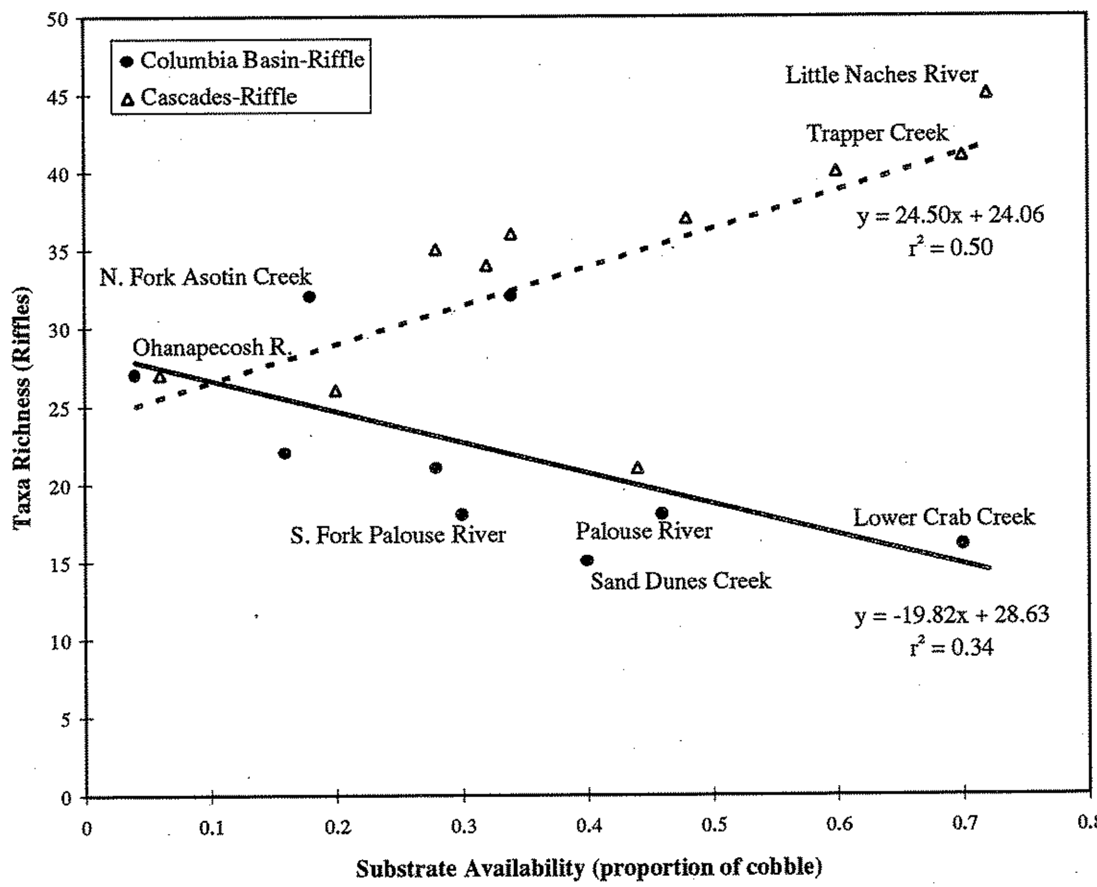


Figure 6. Relationship between taxa richness and a substrate size in Columbia Basin and Cascade ecoregion streams.

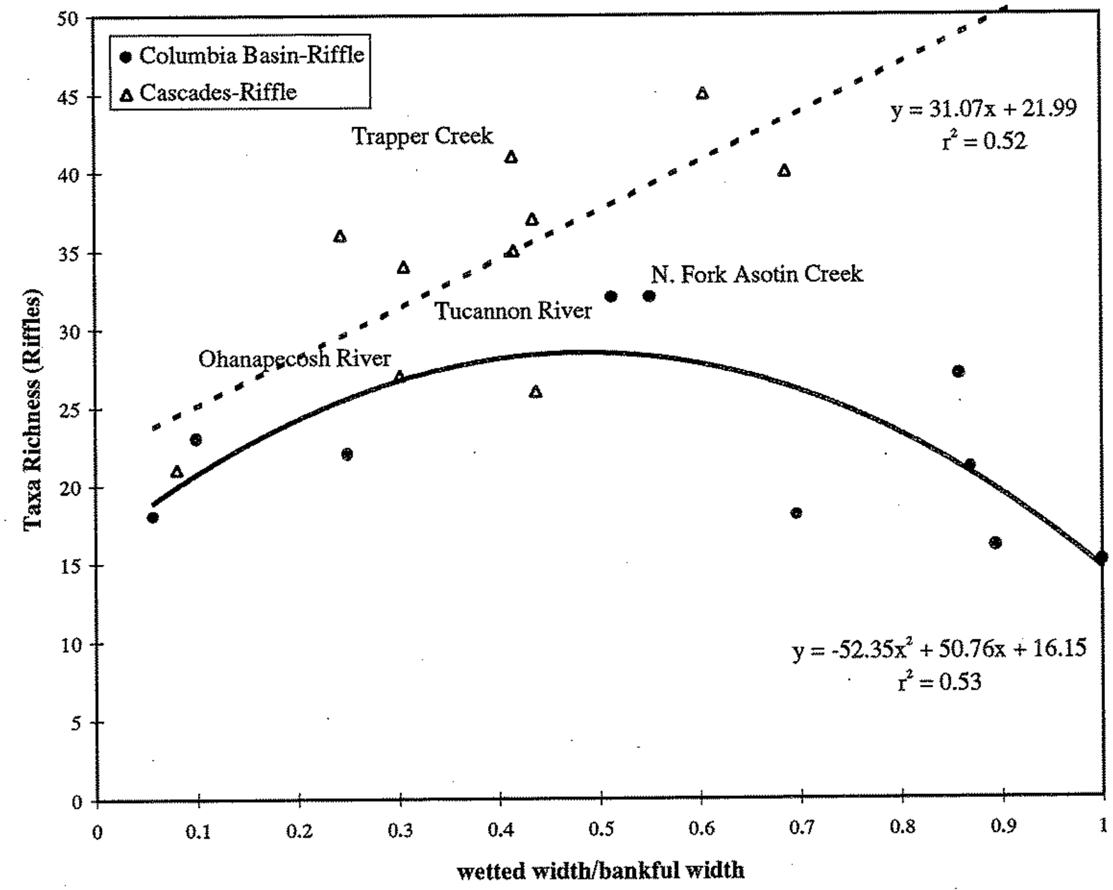


Figure 7. Relationship between taxa richness and the ratio wetted width/bankful width in stream riffles.

moderate sized floodplains and periodically experience moderate- to high flows, or 2) in streams that have constrained channels and have uniform annual flows (*i.e.*, Cummings Creek). The latter condition may occur in streams that have groundwater influence and a capacity to receive moderate to low volumes of surface runoff (*i.e.*, rain or melting snow).

The number of Plecoptera species in Cascade and Columbia Basin streams was influenced by stream size (ww/bw). Stoneflies (plecopterans) generally require cool, clear water for stream survival (Stewart and Stark, 1989). Cascade region streams contained more stonefly species than Columbia Basin streams (Figure 8).

Stonefly presence in Columbia Basin streams was optimal in channels whose water source was spring snowmelt or primarily a groundwater source (Cummings Creek). Columbia Basin streams that are more constrained contain surface water for a longer period of time than streams with broad floodplains. Sub-surface flow is a natural characteristic of streams in this arid region of the state when the water table drops during the latter part of the summer season. Some stonefly species are able to survive in Columbia Basin streams where cool groundwater is the primary contributor to summer surface flow.

Conceptual Stream Disturbance Models

Disturbance of benthic macroinvertebrate assemblages in streams can be related to natural causes or may be anthropogenically (human) induced. Generalized descriptions of regional stream biology must consider physical channel type and adjacent land use. Physical and chemical variability in streams is used to identify any amount of change from the expected condition that is not determined due to natural causes.

Anthropogenic impacts appeared to effect riffles differently than pools. The sensitivity of stream habitat differs between riffles and pools based on a physical ability to assimilate impacts. Assessment of stream biology in both habitat types is important for detection of degradation and to ensure false conclusions are not drawn (Kerans and Karr, 1994).

Pool and riffle assemblages were compared to infer habitat-specific impacts at a stream site. The ratio between riffle and pool taxa richness indicated biological condition. When taxa richness in a riffle was greater than in a pool at the same stream reach, a number of greater than one was calculated and implied potential pool habitat degradation (Figure 9). The optimal riffle/pool ratio for non-degraded Cascade region streams (1.15) was derived from two streams in Wilderness reserves (Trapper Creek and American River) (Figure 9). Stream site location on the ordinal axis was based on best judgement for type and severity of disturbance.

The diagnostic stream disturbance matrix in Figure 9 displays a continuum of stream conditions, based on natural and anthropogenic disturbances. Candidate reference sites had a large number of species in riffles and pools, and had little or no land uses present in the watershed (e.g., Trapper Creek and American River). Ohanapecosh River is located in a

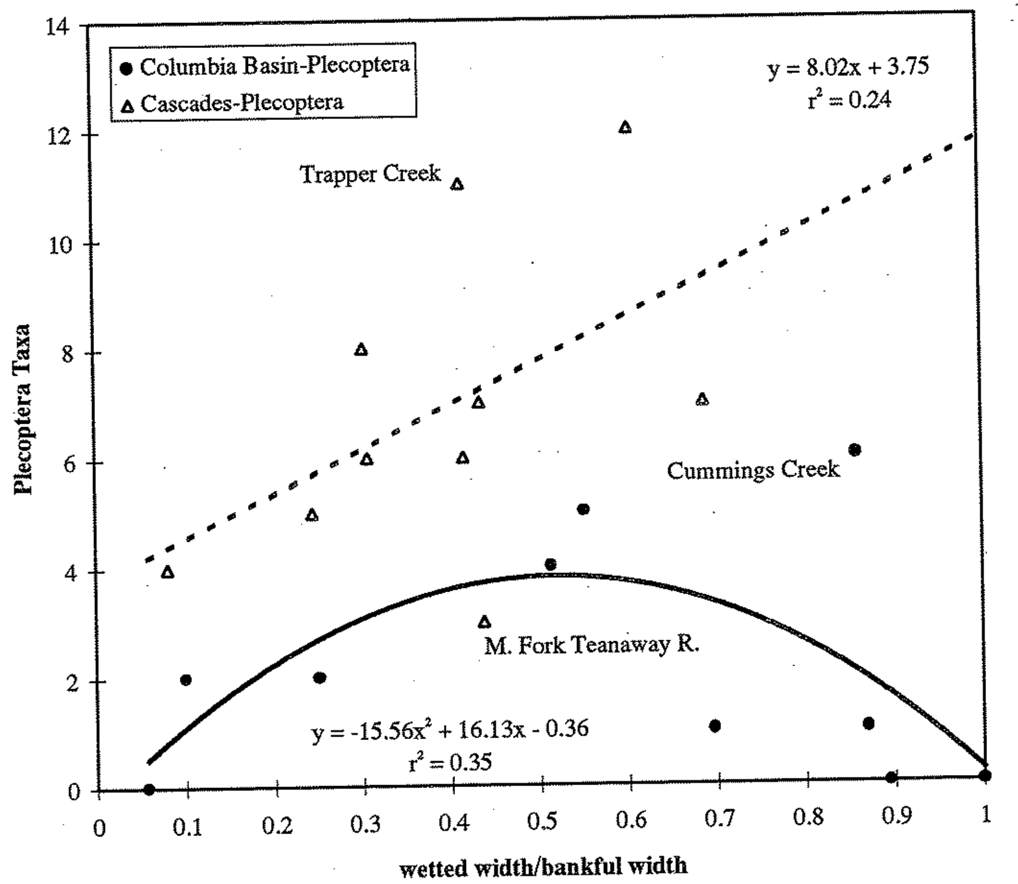


Figure 8. Relationship between total number of Plecoptera (stonefly) taxa and wetted width/bankful ratio in stream riffles.

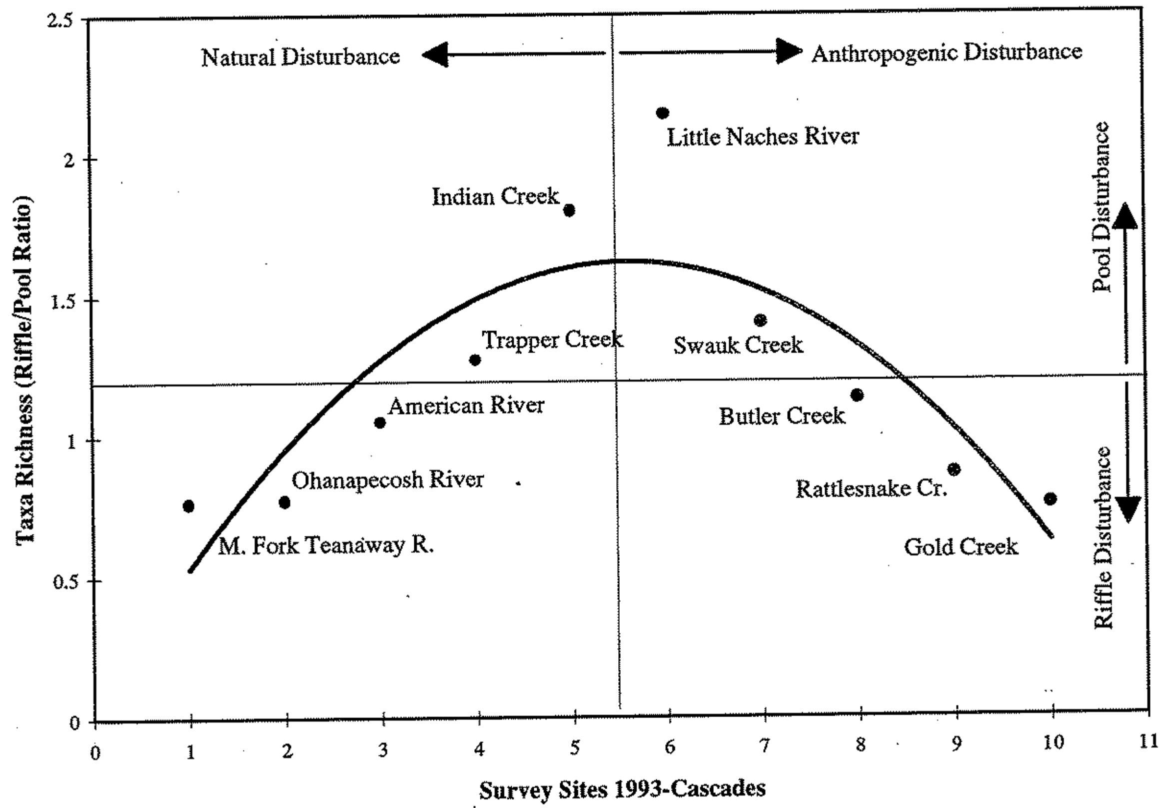


Figure 9. A gradient of stream biological conditions that reflect natural and anthropogenic disturbance. Habitat-specific disturbance is identified by using a ratio expressing number of taxa in riffles versus pools.

National Park and was expected to maintain good biological conditions. A combination of a broad floodplain and predominance of fine substrate particles in riffles indicated that this stream reach received a larger quantity of transported sediment than was removed by scour. In contrast, Rattlesnake Creek had the same general taxa richness ratio as Ohanapecosh River. The braided channel in Rattlesnake Creek suggested that excess bedload was contributed (Carling, 1988) by land use in the drainage. Dominant substrate size classes were coarse gravel in both these streams. Sites suffering from natural disturbance and anthropogenic disturbance often had similar impacts and biological communities.

Degraded pool conditions were apparent at the Little Naches River site. Taxa richness was very low in pools despite collection of samples from four locations within the reach. Forest practice impacts were probably manifested in pool biological assemblages, but did not influence riffle habitat. Availability of interstitial habitat for macroinvertebrate assemblages was apparent in riffles at the Little Naches River site based on the high number of species collected there.

Columbia Basin stream biological conditions were compared based on a disturbance continuum (Figure 10). The ratio of taxa richness in riffles/pools from a stream reach distinguished habitat-specific disturbance. Two streams were used to distinguish pool disturbance from riffle disturbance (North Fork Asotin Creek and Cummings Creek). A riffle/pool taxa richness ratio of 0.85 identified habitat-limited conditions. A vertical line was drawn to divide sites that were least impacted (natural disturbance) from those with obvious visual alterations (anthropogenic disturbance)(Figure 10).

Low flow conditions in Umtanum Creek resulted in reduction of riffle habitat. During the time of sampling, riffles were difficult to locate and difficult to sample. A combination of factors made pool habitat suitable for colonization of more species. Flow contributed from groundwater sources and maintenance of water in pool areas created one of the more suitable refuges for benthic macroinvertebrates.

In contrast, Lower Crab Creek is used as an irrigation return flow conduit where extreme high flows are present during summer months. The quantity of water in the stream channel was high enough to severely reduce pool habitat. The stream channel primarily contained runs (moving, unbroken surface water) that resulted from regulated flow.

A single stream appeared to be affected by flow-related degradation at each habitat type (riffles and pools). Upper Palouse River had representative riffle and pool habitat, but experienced high water temperatures (19.0°C). Riffles sampled were dominated by the caddisfly, *Hydropsyche sp.* The quantity of suspended solids in the streams was visually apparent. Abundance of this caddisfly was so high that it probably outcompeted other species for living space on substrate.

Detecting Stream Degradation from Land Use

A single land use category was selected for exploring relationships with the biological community. The proportion of forested land was related to taxa richness at Cascade region

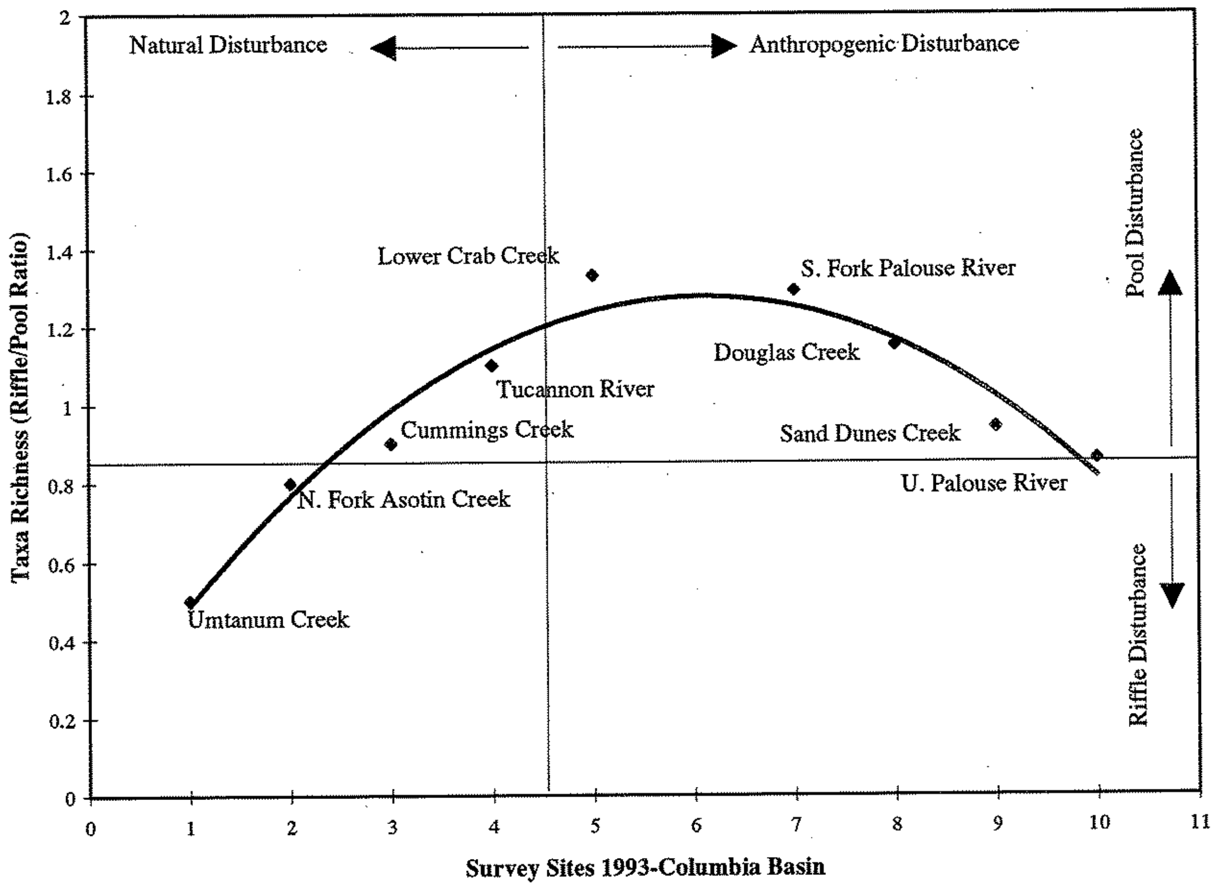


Figure 10. A gradient of stream biological conditions that reflect natural and anthropogenic disturbance. Habitat-specific disturbance is identified by using a ratio expressing number of taxa in riffles versus pools.

streams (Figure 11). Land use representation was standardized among the sites by expressing land use type/total area examined. Some streams had broad floodplains within the 100 m buffer (*i.e.*, Gold Creek and Ohanapecosh River) or had naturally eroding banks (*i.e.*, Middle Fork Teanaway River).

Most stream sites had 94% to 100% of these predetermined 100 m buffers covered by forests. The narrow distribution of forested land use (*i.e.*, 83% to 100% forested) conditions reported from all sites may preclude the use of a whole-watershed description in identifying subtle macroinvertebrate assemblage disturbance. Also, subtle instream habitat conditions may mitigate impacts expressed at the watershed scale. The Little Naches River illustrates this example where forest practice activities are extensive in areas of the watershed (Figure 11).

Biological Variability Within a Stream Reach

The replicate sample variability from four riffles at a candidate reference stream site was determined using taxa richness and EPT Index biometrics. Taxa richness from four replicate samples at Ohanapecosh River (Mt. Rainier National Park) was: 24, 27, 25, and 27 taxa. Relative abundance estimates for the set of replicates was: 721 organisms/m^2, 1,342 organisms/m^2, 5,253 organisms/m^2, and 261 organisms/m^2. Variability in relative abundance estimates for each replicate did not reflect community composition. Sub-sampled assemblages were similar in taxa composition and are reflected by taxa richness biometrics. EPT Index values for the replicates were: 16, 20, 17, and 20 taxa. The Ohanapecosh River site was found to be unexpectedly disturbed by natural processes, yet still had low variability among replicate samples.

Taxa richness and the EPT Index are community biometrics that were used to describe site variability of benthic macroinvertebrate condition. The mean and standard deviation for taxa richness was 25.75 ± 1.5 and for the EPT Index was 18.25 ± 2.1 taxa. Repeatability of community level descriptions was favorable. The difference between replicate results can be described in terms of a coefficient of variation (s.d./mean). Coefficient of variation for taxa richness was 6% and for the EPT Index was 12%.

Biocriteria Development

Three categories are suggested for determining condition of benthic macroinvertebrate assemblages. The Cascade streams data indicate two natural divisions in taxa richness observations; the 25^{th} and 75^{th} percentiles. Partitioning of biological condition categories was derived by considering within-site variability and error through misclassifying community condition. Suggested categories for determining biological condition using taxa richness are: poor (<28 taxa), fair (28-39 taxa), and good (>39 taxa). Suggested categories for determining biological condition in Cascade region streams using the EPT Index are: poor (<20 taxa), fair (20-25 taxa), and good (>25 taxa). These delineations describing biological conditions are based on a limited number of sites (n=10).

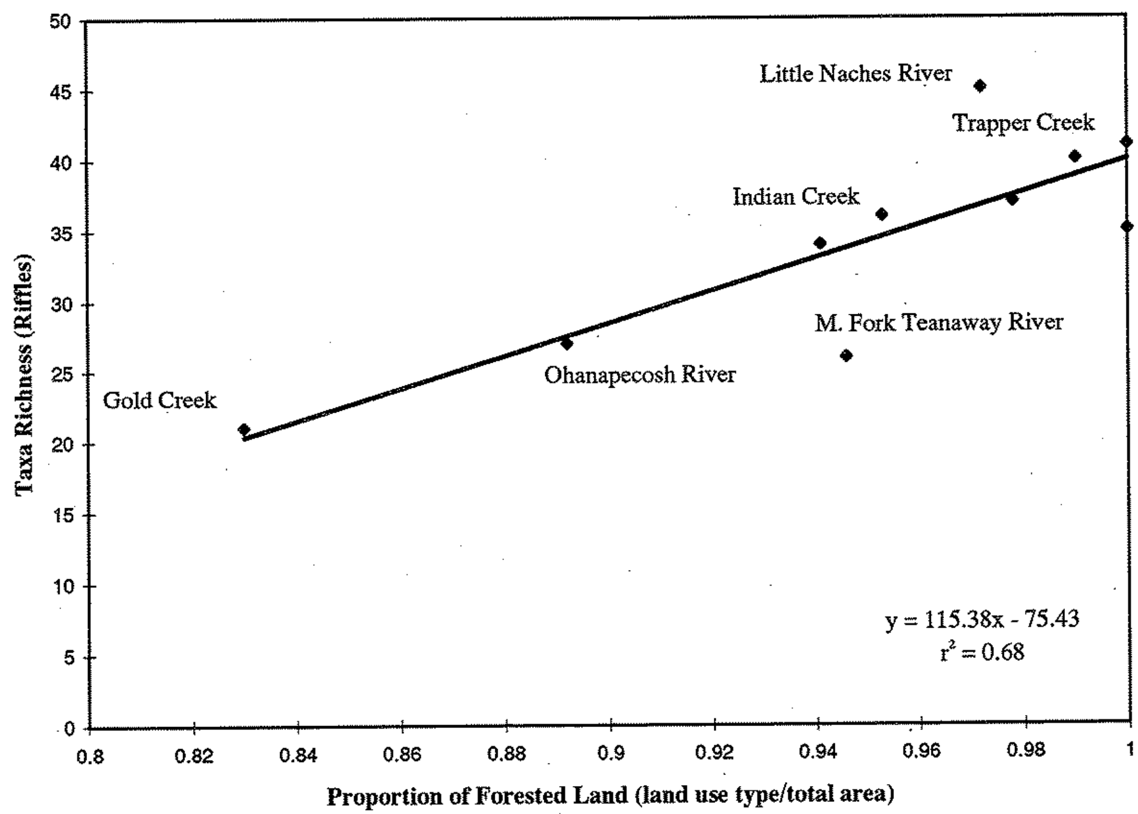


Figure 11. Relationship between taxa richness of Cascade ecoregion streams and the proportion of forested land in a 100m buffer throughout the entire watershed upstream of the survey site.

Division of these community condition levels (poor, fair, good) that describe taxa richness in Cascade streams was based on: 1) the distribution of observations, and 2) within-site variability measured from one stream in the data set. The hypothetical 25th and 75th percentile observations were chosen as divisions because within-site variability for taxa richness was not large enough to misclassify actual observations. For example, a hypothetical range of 28-39 invertebrate species found in a Cascade region stream would be considered a "fair" community condition. The "actual" range of observations is 34-37 invertebrate species (Table 5). A within site community variability estimate of 1.5 organisms would not re-classify community condition of the highest and lowest actual observations made.

Visual Assessment of Stream Segments

Streams on the east slope of the Cascade mountains with high overall scores in riffle habitat (taxa richness & EPT Index) included: Little Naches River, Trapper Creek, and American River (Table 3). My subjective prioritization of streams with best overall conditions included only one of these three; Trapper Creek (Table 6). Ohanapecosh River and Indian Creek were considered higher quality primarily because visual cues for human activity were scarce. These two had extreme natural disturbance potential (e.g., debris flows, sediment deposition).

Species diversity is generally low, and abundance of tolerant species high, in stream environments that contain a high level of disturbance. Stream environments that experience moderate levels of disturbance (*i.e.*, frequency, intensity, or predictability of disturbance; predation intensity; resource variability; environmental heterogeneity) generally maintain the highest levels of biotic diversity (Ward and Stanford, 1983). A survey of riparian condition indicated that natural disturbance intensity was severe at Indian Creek and at Ohanapecosh River and this limited biodiversity. The stream reach surveyed on the Ohanapecosh River served as a temporary settling basin before subsequent stream disturbances (e.g., floods) scoured much of the sediment further downstream. Sand and gravel bars on stream margins and presence of shallow riffles at the tailout of deep pools indicated the magnitude of fluvial processes that characterized the reach.

Condition of Columbia Basin stream sites was also visually assessed before monitoring and analysis of field survey information was completed. Sites with the least degraded biological conditions were: North Fork Asotin Creek, Cummings Creek, and Tucannon River (Table 6). The best biological conditions surveyed in riffle habitat from Columbia Basin streams were found at these same sites (Table 3). All sites that ranked high for taxa richness and EPT Index in Columbia Basin streams were located in piedmont transition zones between montane and plateau landscape. This piedmont zone is the only region of the Columbia Basin that contains least degraded stream channels. North Fork Asotin Creek, Cummings Creek, and Tucannon River are not entirely representative of streams located in central portions of the Columbia Basin. Alteration of pre-existing aquatic biological conditions has resulted from riparian vegetation removal and introduction of tremendous sediment loads in streams of the central plateau. The piedmont streams have experienced less intense and limited types of land use.

Table 6. Ranking of site condition by visual assessment before monitoring and interpretation of results.

Cascade Streams		Description
Best	Trapper Creek	Trapper Creek Wilderness
	Ohanapecosh River	Rainier National Park
	Indian Creek	Edge of William O. Douglas Wilderness
	American River	Edge of William O. Douglas Wilderness
	Little Naches River	Forest Practice activity on tributary streams
↓	Rattlesnake Creek	Forest Practice activity on tributary streams
	Middle Fork Teanaway River	Minor Forest Practices; very low water levels
	Swauk Creek	Bordering Highway 97; periodic stream channel modifications
	Butler Creek	Channelization; moderate Forest Practice activity
Degraded	Gold Creek	Moderate Forest Practice activity; modified hydrology (discharge sustained in summer by abandoned water-filled gravel pit)

Columbia Basin Streams		
Best	North Fork Asotin Creek	Department of Fish and Wildlife Management Area (restricted access); semi-annual grazing
	Cummings Creek	Light Forest Practice activity on Umatilla National Forest Land
	Tucannon River	Grazing; recreational activity (hunting/fishing)
↓	Umtanum Creek	Wheat crops; recreation (hiking/hunting)
	Palouse River (upper watershed)	Wheat crops; rural townsite
	Sand Dune Creek	Recreational activity (off-road vehicles/ fishing)
	Yakima River (middle drainage)	return flow irrigation; agricultural practices; cold-water environment
	Douglas Creek	Wheat Crops
	South Fork Palouse River	Wheat crops; urban impact
Degraded	Lower Crab Creek (middle drainage)	Irrigation return flow; agricultural activity

Plateau streams of the Columbia Basin maintain very low numbers of the intolerant species (EPT Index, Table 5). Taxa richness is low compared to piedmont and montane streams. Substrate material in plateau streams is primarily muck, basalt bedrock, very little cobble, or a combination of these materials. I had based visual estimation of central Columbia Basin stream quality on presence of riparian vegetation and substrate heterogeneity. Substrates in the arid plateau tended toward homogeneity. Riparian vegetation was present at a few sites and influenced the visual scoring estimate. An example was the Upper Palouse River site where dense and diverse overstory and understory were present. The site biological condition ranked low because there were additional stream impacts not immediately interpretable by an observer. The dominant taxon found in riffle habitat at this site consumed suspended organic matter by filtering. Stream degradation is attributed to activities that introduced particulate organics into the water column.

Conclusions

Physical measures, and consequently the quality of the biological community, were not easily assessed by visual appearance alone. Thus, differences between visual assessment and actual sample measurement indicate that evaluation of biological communities through simple visual observation can be misleading. Subtle influences of stream channel type on the biotic community may be overlooked when performing visual analysis of stream condition.

Site-specific biological conditions, not unexpectedly, were related to physical conditions. These relationships successfully discriminated degrees of stream disturbance. Relationships between physical and biological variables successfully discriminated reference from degraded conditions. Natural disturbance logically maintains a larger role in limiting biological communities.

Variability of physical and climatological conditions in montane regions (*i.e.*, Cascades) may require alternative approaches for describing expected biotic conditions. The range of macroinvertebrate conditions for least impacted sites suggests that the Cascade ecoregion contains many subregions. Establishment of reference sites in key drainages or survey of paired watersheds are an appropriate design for diagnosing type and severity of disturbance in the montane regions.

Stream condition evaluation was effective by using several relational curves developed in this program. The best biotic conditions often occurred at mid-range of the physical observations made for a set of streams. Degraded site conditions were often consistently confirmed by several of the individual physical variables (e.g., flow, % cobble, wetted width/bankfull width). Discrimination between reference and degraded sites was, therefore, accurate and consistent.

Discriminating stream alterations using biological information is an important continuation of this work. Montane landscapes may reveal degradation rapidly. Lowland or plateau landscapes contain streams that are naturally influenced by depositional sediments. These natural fluvial processes in lowland streams limit the type of biological assemblage; usually species with broad tolerances. Therefore, slight physical alterations in the stream may not be quickly reflected in biological response. In most cases, aquatic biology data have a great deal of interpretive power and reveal the recent history of a stream.

The following conclusions were derived from the summer 1993 biological assessment effort:

1. The multihabitat sampling approach (riffles and pools) was effective in identifying degradation associated with specific habitat types.

2. Two biometrics, taxa richness and EPT Index, were consistent in differentiating reference from impact conditions in Columbia Basin and Cascade streams.

3. The relationship between biological condition and three physical characteristics of a stream (flow, % cobble, wetted width/bankfull width) increased diagnostic power for determining type and severity of a stream impact.

4. The biological/physical relationships provided an estimate for <u>sensitivity</u> of impact detection.

5. Variability among within-site sample replication was very low for community-level descriptions.

6. An ecoregion reference condition can be described in lowland ecoregions *(i.e.,* Columbia Basin) where topographical relief is not that variable.

7. A hierarchical breakdown of spatial and physical characteristics in Cascade streams is necessary for describing biological condition within stream sets (e.g., ecoregion, sub-region, channel segment type, predominant water source).

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Appendix A

Water Quality Information for Ambient Biological Survey 1993 Sites

Appendix A. Water quality information for Ambient Biological Assessment 1993 survey sites.

Site	Temperature (°C)	pH (units)	Conductivity (umhos/cm)	Dissolved Oxygen (mg/L)
East Cascades				
Trapper Creek	11.7	7.4	107	10.0
American River	5.1	7.8	79	11.6
Ohanapecosh River	9.5	8.0	55	10.1
Middle Fork Teanaway R.	17.5	8.1	128	8.4
Indian Creek	6.9	7.9	89	10.9
Rattlesnake Creek	19.8	8.3	103	8.9
Little Naches River	9.3	8.2	83	10.7
Butler Creek	12.5	8.5	69	10.6
Swauk Creek	11.4	8.4	225	9.7
Gold Creek	12.7	7.4	38	*
Columbia Basin				
North Fork Asotin Cr.	13.5	8.4	107	9.3
Cummings Creek	14.0	8.4	380	9.2
Tucannon River	15.2	8.4	103	9.6
Sand Dunes Creek	24.0	8.4	352	8.5
Lower Crab Creek	22.6	8.4	288	8.4
Upper Palouse River	19.0	8.9	100	6.7
South Fork Palouse R.	20.2	8.0	425	5.8
Douglas Creek	19.3	9.2	490	9.1
Umtanum Creek	16.2	9.4	239	9.3
Upper Yakima River	17.4	7.7	98	9.2

* dissolved oxygen measurement not available

Appendix B

Synoptic List of Benthic Macroinvertebrate Species Collected from East Slope Cascades Ecoregion Streams

Appendix B. Synoptic list of benthic macroinvertebrate species collected from east slope Cascades ecoregion streams during the summer 1993 biological survey.

Order	Family	Genus/Species
Oligochaeta	Lumbriculidae	*sp.*
	Naididae	*sp.*
Acari	Hydracarina	*sp.*
Coleoptera	Elmidae	*Heterlimnius sp.*
		Narpus sp.
		Optioservus sp.
		Optioservus sp.- adult
		Stenelmis sp.
		Zaitzevia sp.
		Cleptelmis sp.
		Ampumixis sp.
	Dytiscidae	*Hydrovatus sp.*
		Hydrovatus sp.-adult
		Oreodytes sp.
Diptera	Tipulidae	*Antocha sp.*
		Clinocera sp.
		Dicranota sp.
		Hexatoma sp.
		Tipula sp.
		Tipula sp.-pupae
	Simuliidae	*Prosimulium sp.*
		Simulium canadense
		Simulium venustum
		Simulium vittatum
		Simulium sp.-pupae
	Athericidae	*Atherix variegata*
	Blephariceridae	*Agathon sp.*
		Philorus sp.
	Ceratopogonidae	*Bezzia sp.*
	Chironomidae	Chironominae
		Tanypodinae
		pupae
	Dixidae	*Dixa sp.*
	Empididae	*Chelicera sp.*
		Chelifera sp.
		Oreogeton sp.

Appendix B. Continued.

Order	Family	Genus/Species
Diptera	Pelecorhynchidae	*Glutops sp.*
		Hesperoconopa sp.
	Psychodidae	*Pericoma sp.*
	Tabanidae	*Tabanus sp.*
Ephemeroptera	Baetidae	*Acentrella sp.*
		Baetis bicaudatus
		Baetis tricaudatus
	Ephemerellidae	*Attenella margarita*
		Caudatella hystrix
		Drunella coloradensis
		Drunella doddsi
		Drunella spinifera
		Ephemerella aurivillii
		Serratella teresa
		Serratella tibialis
		Timpanoga hecuba hecuba
	Heptageniidae	*Epeorus deceptivus*
		Epeorus longimanus
		Epeorus sp. (s.g. *Iron*)
		Epeorus sp.
		Rithrogena hageni
		Cinygmula sp.
	Leptophlebiidae	*Paraleptophlebia bicornuta*
		Paraleptophlebia sp.
		Leptophlebia sp.
	Siphlonuridae	*Siphlonurus sp.*
		Amaletus sp.
Hemiptera	Gerridae	*Gerris sp.*
Lepidoptera	Pyralidae	*sp.*
Megaloptera	Sialidae	*Sialis sp.*
Pelecypoda	Sphaeriidae	*Pisidium sp.*
Plecoptera	Perlidae	*Claassenia sabulosa*
		Diura sp.
		Calineuria californica
		Doroneuria baumanni
		Hesperoperla pacifica

Appendix B. Continued.

Order	Family	Genus/Species
Plecoptera	Perlodidae	*Isoperla fulva*
		Isoperla sp.
		Cultus pilatus
		Megarcys signata
		Megarcys subtruncata
		Osobenus sp.
		Perlinodes frontalis
		Perlinodes aureus
		Rickera sorpta
		Skwala curvata
	Nemouridae	*Malenka sp.*
		Zapada cinctipes
		Podmosta obscura
		Amphinemura sp.
		Soyedina interrupta
	Chloroperlidae	*Kathroperla perdita*
		Neaviperla forcipata
		Paraperla frontalis
		Suwallia sp.
		Sweltsa sp.
	Taeniopterygidae	*Taenionema pacificum*
		Doddsia occidentalis
	Capniidae	*Capnia sp.*
	Leuctridae	*Despaxia augusta*
		Perlomyia sp.
	Peltoperlidae	*Yoraperla mariana*
	Pteronarcyidae	*Pteronarcys californica*
Trichoptera	Brachycentridae	*Amiocentrus sp.*
		Brachycentrus americanus
		Brachycentrus occidentalis
		Micrasema sp.
	Glossosomatidae	*Agapetus sp.*
		Agapetus sp.-pupae
		Glossosoma sp.
		Glossosoma sp.-pupae
	Hydropsychidae	*Arctopsyche sp.*
		Hydropsyche betteni
		Parapsyche sp.

Appendix B. Continued.

Order	Family	Genus/Species
Trichoptera	Hydroptilidae	*Hydroptila sp.*
		Ochrotrichia sp.
	Limnephilidae	*Ecclisomyia sp.*
		Neophylax sp.
		Pedomoecus sp.
		Psychoglypha sp.
		Moselyana sp.
	Lepidostomatidae	*Lepidostoma sp.*
	Philopotamidae	*Chimarra sp.*
		Dolophilodes sp.
		Wormaldia sp.
	Rhyacophilidae	*Rhyacophila acropedes*
		Rhyacophila angelita
		Rhyacophila coloradensis
		Rhyacophila hyalinata
		Rhyacophila rotunda
		Rhyacophila vaccua
		Rhyacophila verrula
		Rhyacophila sp.-pupae
Turbellaria	Planariidae	*sp.*

Appendix C

Synoptic List of Benthic Macroinvertebrate Species Collected from Columbia Basin

Appendix C. Synoptic list of benthic macroinvertebrate species collected from Columbia Basin ecoregion streams during the summer 1993 biological survey.

Order	Family	Genus/Species
Acari	Hydracarina	*sp.*
Oligochaeta	Lumbriculidae	*sp.*
		Rhynchelmis sp.
Amphipoda	Talitridae	*Hyalella azteca*
Coleoptera	Elmidae	*Cleptelmis sp.*
		Dubiraphia sp.
		Heterlimnius sp.
		Heterlimnius sp.-adult
		Optioservus sp.
		Ordobrevia sp.
		Stenelmis sp.
		Narpus sp.
		Microcylloepus sp.
		Zaitzevia sp.
		Zaitzevia sp.-adult
	Dytiscidae	*Dytiscus sp.*
		Hydrovatus sp.
		Hydrovatus sp .-adult
		Oreodytes sp.
	Haliplidae	*Brychius sp.*
		Peltodytes sp.
	Hydrophilidae	*Heleophorus sp.*
		Tropisternus sp
	Psephenidae	*Psephenus sp.*
Collembola		*sp.*
Copepoda		*sp.*
Decapoda	Astacidae	*Pacifasticus leniusculus*
Diptera	Chironomidae	Chironominae
		Chironominae-pupae
		Tanypodinae
	Tipulidae	*Tipula sp.*
		Dicranota sp.
		Antocha sp.
	Psychodidae	*Pericoma sp.*
		Maruina sp.

Appendix C. Continued.

Order	Family	Genus/Species
Diptera	Simuliidae	*Simulium canadense*
		Simulium venustum
		Simulium sp.-pupae
		Prosimulium sp.
	Athericidae	*Atherix variegata*
	Blephariceridae	*Agathon sp.*
		Blepharicera sp.
	Canaceidae	unidentified sp.
	Ceratopogonidae	*Bezzia sp.*
		Atrichopogon sp.
	Dixidae	*Dixa sp.*
	Empididae	*Hemerodromia sp.*
		Chelifera sp.
		Clinocera sp.
	Ephydridae	unidentified *sp.*
	Muscidae	unidentified *sp.*
	Pelecorhynchidae	*Glutops sp.*
	Ptychopteridae	*Ptychoptera sp.*
	Tabanidae	*Tabanus sp.*
Ephemeroptera	Baetidae	*Acentrella sp.*
		Baetis bicaudatus
		Baetis tricaudatus
		Callibaetis sp.
	Ephemerellidae	*Attenella margarita*
		Drunella spinifera
		Serratella tibialis
		Timpanoga hecuba hecuba
	Heptageniidae	*Cinygma sp*
		Cinygmula sp.
		Epeorus sp.
		Epeorus s.g.(*Iron*)
		Epeorus longimanus
		Rithrogena hageni
	Leptophlebiidae	*Paraleptophlebia sp.*
	Siphlonuridae	*Amaletus sp.*
	Tricorythidae	*Tricorythodes sp.*

Appendix C. Continued.

Order	Family	Genus/Species
Pelecypoda	Ancylidae	*Ferrissia rivularis*
	Sphaeriidae	*Pisidium sp.*
	Unionidae	*Anadonta sp.*
		Corbicula fluminea
Gastropoda		unidentified *spp.*
Hemiptera	Corixidae	unidentified *sp.*
Lepidoptera	Pyralidae	unidentified *sp.*
Megaloptera	Sialidae	*Sialis sp.*
Odonata	Coenagrionidae	*Argia sp.*
		Zoniagrion sp.
	Gomphidae	*Ophiogomphus sp.*
	Lestidae	*Lestes sp.*
Plecoptera	Perlidae	*Claassenia sabulosa*
		Hesperoperla pacifica
	Perlodidae	*Skwala curvata*
		Isoperla sp.
	Pteronarcyidae	*Pteronarcys californica*
	Nemouridae	*Malenka sp.*
		Zapada cinctipes
	Chloroperlidae	*Suwallia sp.*
		Triznaka sp.
	Capniidae	*Eucapnopsis sp.*
Trichoptera	Brachycentridae	*Brachycentrus americanus*
		Brachycentrus occidentalis
		Micrasema sp.
	Hydropsychidae	*Cheumatopsyche sp.*
		Hydropsyche betteni
		Arctopsyche sp.
		Ceratopsyche sp.
	Limnephilidae	*Ecclisomyia sp.*
		Dicosmoecus sp.-pupae
		Neophylax sp.
		Psychoglypha sp.
	Glossosomatidae	*Glossosoma sp.*
		Glossosoma sp.-pupae
		Protoptila sp.

Order	Family	Genus/Species
Trichoptera	Rhyacophilidae	*Rhyacophila acropedes*
		Rhyacophila bifila
		Rhyacophila repulsa
		Rhyacophila angelita
		Rhyacophila sp.-pupae
	Hydroptilidae	*Agraylea sp.*
		Hydroptila sp.
		unidentified *sp.*-pupae
	Lepidostomatidae	*Lepidostoma sp.*
	Leptoceridae	*Nectopsyche sp.*
	Philopotamidae	*Chimarra sp.*

Appendix D

Synoptic List of Benthic Macroinvertebrate Species Collected from East Cascades Slopes and Foothills Ecoregion Streams

Appendix D. Synoptic list of benthic macroinvertebrate species collected from East Cascades Slopes and Foothills ecoregion streams during the summer 1993 biological survey.

Order	Family	Genus/species
Oligochaeta	Lumbriculidae	*sp.*
		Rhynchelmis sp.
Acari	Hydracarina	*sp.*
Coleoptera	Dytiscidae	*Hydrovatus sp.*
	Elmidae	*Cleptelmis sp.*
		Heterlimnius sp.
		Optioservus sp.
		Zaitzevia sp.
Diptera	Tipulidae	*Clinocera sp.*
		Hexatoma sp.
		Antocha sp.
	Tabanidae	*Tabanus sp.*
	Simuliidae	*Simulium sp.*- pupae
		Simulium sp.
	Chironomidae	Tanypodinae
		Chironominae
	Athericidae	*Atherix variegata*
	Blephariceridae	*Bibiocephala sp.*
	Ceratopogonidae	*Culicoides sp.*
	Deuterophlebiidae	*Deuterophlebia sp.*
	Empididae	*Chelifera sp.*
		Hemerodromia sp.
	Pelecorhynchidae	*Glutops sp.*
Ephemeroptera	Baetidae	*Acentrella sp.*
		Baetis bicaudatus
		Baetis tricaudatus
	Ephmerellidae	*Attenella margarita*
		Attenella delantala
		Serratella tibialis
		Drunella flavilinea
		Timpanoga hecuba hecuba
	Heptageniidae	*Epeorus sp.*
		Cinygmula sp.
	Leptophlebiidae	*Paraleptophlebia bicornuta*
		Paraleptophlebia sp.
	Siphlonuridae	*Amaletus sp.*
	Tricorythidae	*Tricorythodes minutus*

Appendix D. Continued.

Order	Family	Genus/Species
Plecoptera	Perlidae	*Claassenia sabulosa*
		Hesperoperla pacifica
		Calineuria californica
	Perlodidae	*Skwala curvata*
		Perlinodes aureus
	Chloroperlidae	*Suwallia sp.*
		Sweltsa sp.
	Pteronarcyidae	*Pteronarcys californica*
Trichoptera	Limnephilidae	*Neophylax sp.*
		Ecclisomyia sp.
	Hydropsychidae	*Hydropsyche sp.*- pupa
		Hydropsyche betteni
	Brachycentridae	*Micrasema sp.*
		Brachycentrus americanus
	Glossosomatidae	*Agapetus sp.*
	Lepidostomatidae	*Lepidostoma sp.*
	Polycentropodidae	*Polycentropus sp.*
	Rhyacophilidae	*Rhyacophila angelita*
		Rhyacophila vaccua