ASSESSMENT OF MACROINVERTEBRATE COMMUNITIES IN STREAMS OF NORTH CLACKAMAS COUNTY, OREGON, 2002

FINAL REPORT

Prepared for

Water Environment Services
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EXECUTIVE SUMMARY

- Macroinvertebrate communities, physical habitat, and water chemistry were sampled from 26 stream reaches in two Water Environment Services management areas (SWMACC and CCSD#1) occurring in north Clackamas County in fall 2002 to assess the condition of macroinvertebrate communities in relation to instream physical and chemical conditions.
- Macroinvertebrate communities were assessed using multimetric analysis, followed by correlation of environmental variables with multimetric scores to examine associations between environmental conditions and benthic community conditions. Riffle samples from high-gradient (>1.5% slope) reaches were examined using standard metrics and scoring criteria developed by the Oregon Department of Environmental Quality (DEQ). Glide samples from low-gradient reaches were examined using a modified multimetric approach that ranks metric scores in the absence of scoring criteria for samples collected from glides.
- Macroinvertebrate communities sampled from riffles in the two study areas were most often moderately to severely impaired. Impaired communities generally were characterized by low taxonomic richness, high collective community tolerance to disturbance, low EPT (mayfly, stonefly, and caddisfly) richness, and few or no sensitive taxa.
- Only one stream reach in each study area was classified as slightly impaired based on multimetric scores. These two reaches, occurring in primarily forested areas, were characterized by high EPT richness, low proportions of tolerant organisms, high sensitive-taxa richness, low collective tolerance to disturbance, and high total taxonomic richness.
- Metric values derived from riffle samples were highly correlated with a number of environmental variables indicative of impairment, including several measures of stream substrate composition, water temperature, dissolved oxygen, and specific conductance.
- Glide samples from low-gradient reaches showed less variability in community composition than did riffle samples. These reaches occurred exclusively in areas dominated by urban or agricultural land uses. Low-gradient reaches were characterized by low taxonomic richness; few or no EPT taxa; high dominance by a few taxa; large proportions of oligochaetes, chironomids, and mollusks; and a large proportion of tolerant organisms.
- Across all study reaches, macroinvertebrate community overall condition ranks from glide samples were correlated with canopy cover and water temperature. Analyzed separately, macroinvertebrate community ranks from CCSD#1 low-gradient reaches (glide samples) were positively correlated with riparian zone conditions, whereas ranks from SWMACC glide samples were positively correlated with percent riffle habitat.
- We recommend restoration efforts that first focus on areas where benthic conditions are not yet severely impaired and communities are better able to respond to smaller-scale restoration efforts. Monitoring biological responses to restoration should be included in restoration efforts to both monitor the success of specific restoration projects and to better understand the effects of such efforts on biological functioning in streams.

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This study was funded by a grant from the U.S. Fish & Wildlife Service's Green Spaces Program to Water Environment Services (WES), a Department of Clackamas County. We thank Karen Streeter of WES for supporting this work, administering the contract, and serving as the WES project manager. We also thank all landowners who kindly allowed us access to their properties to gain access to study reaches. Suzanne Cloutier and Ry Thompson of ABR, Inc. performed much of the field work and processed macroinvertebrate samples. Jena Lemke of ABR, Inc., also processed macroinvertebrate samples and entered field data. Rich Blaha of ABR, Inc., provided GIS support. Drafts of this report were reviewed by Bob Burgess and Steve Murphy of ABR.

INTRODUCTION

Steadily increasing human influence and development in northern Clackamas County (NCC) has degraded water quality and aquatic habitat (Friesen and Zimmerman 1999). In response to increasing concern over clean water, threatened salmonids, and other aquatic resources in the region, Water Environment Services (WES), a department of Clackamas County has initiated assessments of aquatic life and habitat quality in area streams. The Oregon Department of Fish and Wildlife (ODFW) conducted surveys of stream fish communities and habitat in seven streams (Kellogg, Mt. Scott, Phillips, Dean, Cow, Sieben, and Rock creeks) in North Clackamas County from 1997 to 1999 (Friesen and Zimmerman 1999). These surveys indicated that fish communities were moderately to severely impaired in most of the sampled stream reaches. Significant alteration likely has occurred to other components of these aquatic communities, as well.

Examining macroinvertebrate communities has gained wide acceptance as a reliable tool for measuring the condition of surface waters. Because these biological communities integrate the effects of multiple stressors—excess nutrients, toxic chemicals, increased temperature, excessive sediment loading, and others—they provide a reliable measure of the overall ability of a water body to support aquatic life. A study of macroinvertebrate communities in the upper and middle Tualatin River basin in 2001 indicated that macroinvertebrate communities in the region respond measurably to degraded stream conditions, and that their condition can be related to surrounding land-use conditions (Cole 2002). A number of other regional assessments of macroinvertebrate communities in northern Willamette Valley streams have been performed in efforts to characterize the current condition of aquatic resources and to establish baseline data for comparison with future monitoring efforts.

In this study, streams in two WES water management areas, the Surface Water Management Agency of Clackamas County (SWMACC) district and Clackamas County Service District #1 (CCSD#1), were examined with the goal of determining the condition of macroinvertebrate communities in relation to physical habitat and water quality. The information is intended to be used by water resource managers to help prioritize stream protection and restoration efforts and as baseline data to help determine the effects of restoration projects in years to come. Importantly, future monitoring of benthic communities at these sites will measure long-term trends in the biological condition of surface waters in NCC.

STUDY AREAS

Both SWMACC and CCSD#1 are located in northern Clackamas County, Oregon. SWMACC encompasses the lower Tualatin River Basin; CCSD#1 includes a number of smaller drainages that drain into the Clackamas or Willamette rivers (Figure 1). The Mt. Scott/Kellogg creeks watershed is the largest drainage entirely contained within CCSD#1. The watershed drains in a westerly direction to the Willamette River. Rock Creek, located to the east of Mt. Scott Creek, occurs primarily outside of CCSD#1, with only the lower portion of the drainage occurring inside the Service District. Rock Creek, and two smaller drainages to the west, Sieben and Cow Creeks, discharge into the Clackamas River, which bisects northern Clackamas County on its course to the Willamette River. The topography within CCSD#1 primarily is gently rolling hills. Land use varies from urban to rural with some small remaining tracts of forested lands. Areas of more topographic relief within CCSD#1 support streams with higher gradients, more heterogeneous habitat (riffle/pool complexes), and larger and more heterogeneous substrate, whereas areas with little or no topographic relief contain low-gradient streams with primarily pool and glide habitat and finer substrates.

SWMACC occurs entirely within the lower Tualatin River Basin. The lower reaches of the Tualatin River are bound by hillsides from which a number of small 1st and 2nd order tributaries discharge into the river. Within this area, land use includes small tracts of forested land, agriculture, and residential and commercial development. Lower streams draining from the south side of the Tualatin River mostly course through agricultural and wooded areas, whereas the upper streams on the south side of the river occur in areas more

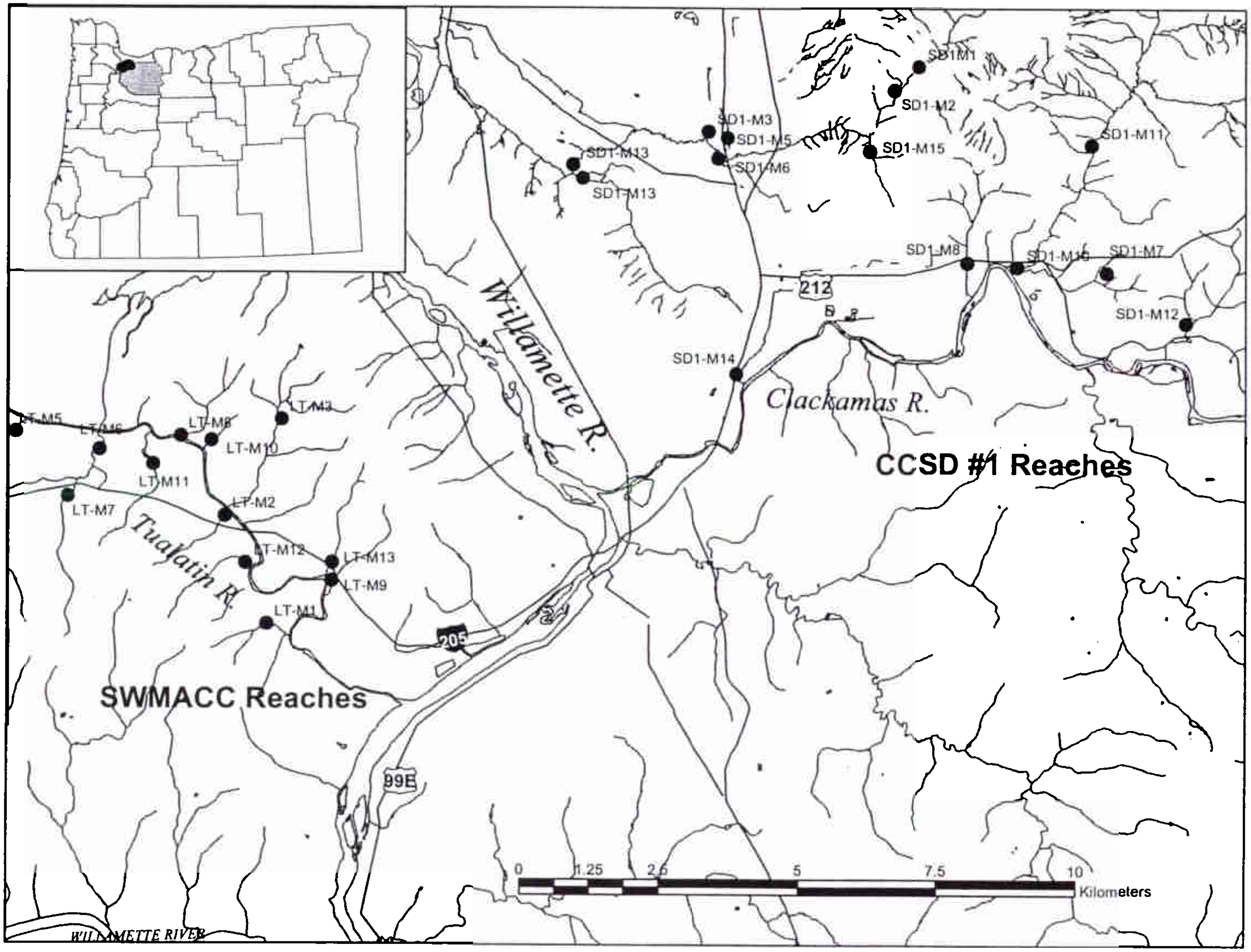

Figure 1. Map of 26 stream reaches sampled for macroinvertebrates, water quality, and physical habitat in northern Clackamas County, Oregon, fall 2002. Study reaches occur in two water management districts, SWMACC and CCSD#1.

intensively developed with farms and subdivisions (Beatty and Streeter 1999).

METHODS

STUDY REACH SELECTION

Stream reaches sampled for this study were selected, in part, to represent a range of physical conditions and levels of human influence, to better examine macroinvertebrate community conditions with respect to gradients in environmental conditions. Fields visits and maps were used to inspect stream, riparian, and surrounding land-use conditions. At each reach inspected during reconnaissance surveys, overall gradient, dominant stream substrate, and dominant habitats were noted and used to group reaches by stream type (gravel- and cobble-dominated high-gradient reaches versus sand- and silt-dominated low-gradient reaches). Reach selection also was based on ease of access, adequate stream flow, and proximity to WES water quality monitoring stations. In total, 26 reaches were selected for sampling: 12 reaches in tributaries draining into the lower Tualatin River Basin (SWMACC) and 14 reaches within CCSD#1 (Table 1). Across both study areas, 15 high-gradient (>1.5% stream slope) and 11 low-gradient reaches were sampled.

FIELD DATA COLLECTION

Macroinvertebrate communities, physical habitat, and water chemistry were sampled at the 26 study reaches between September 16 and 26, 2002. First, each study reach was marked and reach length was measured. Each sample reach measured 10 times the average wetted width or 50 m, whichever length was greater. Reach gradient was then measured with a clinometer and percent riffle, pool, and glide habitat was visually estimated. These parameters were used to categorize the study reach as low gradient or high gradient (Table 1). Generally, reaches with gradients exceeding 1.5% contained coarse (gravel, cobble, and boulder) substrate that allowed riffles to occur at a frequency sufficient to sample from them (>10-15% total habitat area). Glides were sampled from reaches that had gradients lower than 1.5%, no or infrequent riffles (<10-15% total habitat area) and predominantly sand and finer substrates. Five streams had characteristics that prevented assignment to one of these two reach types; in these reaches macroinvertebrate samples were collected from both riffles and glides. Both riffle and glide samples from these five reaches were included in analyses and reported. As a result, analyses included 15 samples from riffles and 16 samples from glides.

Macroinvertebrates were collected using the Level 3 sampling protocols, as described in WQIW (1999). At each of the 63 study reaches, two units of the same habitat type (riffles or glides, as described above) were randomly selected for sampling. From each of these two units, two instream sampling points were selected using a random numbers table. Two four-digit numbers were selected: the first two digits represented the percent distance upstream through the unit and the second two digits represented the percent of stream width across the unit. In reaches with only one continuous unit (most often glides in low-gradient reaches), four instream sampling points were selected from within this single habitat unit.

Macroinvertebrates were collected with a D-frame kicknet (12-in wide, 500-µm mesh opening) from a 30 x 60 cm (1 x 2 ft) area at each sampling point. A 1 x 2 ft metal frame with sheet-metal sides and open front and rear ends was placed over each sample point to contain the sample material and prevent organisms and debris from escaping the net. Larger substrates, when present, were first hand-washed inside the net, and then placed outside of the sampled area. Then the area was thoroughly disturbed by hand (or by foot in deeper water) to a depth of ~5 cm. In areas with little or no discernible streamflow, the kicknet was pulled back and forth through the water column over the disturbed area to collect suspended materials.

The four samples from a reach were placed together into a 500-µm sieve and carefully washed to remove larger substrate and leaves after inspection for clinging macroinvertebrates. The composite sample then was placed into one or more 1-L polyethylene wide-mouth jars, labeled, and preserved with 70% isopropyl alcohol for later sorting and identification at the laboratory.

Following macroinvertebrate sample collection at each reach, we collected the following water chemistry data: pH, temperature, dissolved

Table 1. Stream reaches sampled for macroinvertebrates, physical habitat, and water quality in northern Clackamas County, Oregon for Water and Environment Services in September, 2002.

Site Code	Stream	Location	High/Low Gradient	Riffle/Glide Sample*
CCSD#1				
SD1-M1	Mt. Scott Creek	Above dam removal project	H	R
SD1-M2	Mt. Scott Creek	Below dam removal project	H	R
SD1-M3	Mt. Scott Creek	Three Creeks restoration project site	H**	R, G
SD1-M4	Mt. Scott Creek	Above confluence with Kellogg Creek	L	G
SD1-M5	Phillips Creek	Phillips Cr Regional Detention Facility	H**	R, G
SD1-M6	Deer Creek	Deer Creek Restoration Project Site	H**	R, G
SD1-M7	Trillium Creek	Trillium Creek Restoration Project Site	H	R
SD1-M8	Sieben Creek	Crossing with Hwy 212/224	H	R
SD1-M10	Rock Creek	Reid Property	H	R
SD1-M11	Rock Creek	Sunnyside Road crossing	H	R
SD1-M12	Richardson Creek	Crossing with Highway 224	H	R
SD1-M13	Kellogg Creek	At confluence with Mt. Scott Creek	L	G
SD1-M14	Cow Creek	Above mouth	L	G
SD1-M15	Cedar Creek	Mather Road Crossing	H**	R, G
SWMACC				
LT-M1	Fields Creek	Above Bosky Dell Lane	H	R
LT-M2	Ek Creek	Below Borland Road	L	G
LT-M3	Upper Wilson Creek	Below Long Farm Road	L	G
LT-M5	Nyberg Creek	Below 65th Ave	L	G
LT-M6	Lower Saum Creek	Above Halcyon Road	L	G
LT-M7	Middle Saum Creek	Above Prindle Road	L	G
LT-M8	Pecan Creek	Above Mossy Brae	H	R
LT-M9	Tate Creek	Above Johnson Road	L	G
LT-M10	Shipley Creek	Above Hillcrest Drive	L	G
LT-M11	Athey Creek	Above Borland Road	H	R
LT-M12	Unnamed Trib 2	Above Ribera Lane	L	G
LT-M13	Unnamed Trib 4	Below Johnson Road	H**	R, G

* Riffle samples were collected from high-gradient reaches; glide samples were collected from low-gradient reaches.
**In five reaches that exhibited intermediate habitat characteristics (between high- and low-gradient), both riffles and glides were sampled.

oxygen, and specific conductance. Temperature, dissolved oxygen, and conductivity were measured in the field using a YSI Model 85 water chemistry meter. We measured pH in the field with an Oakton pHTestr 3.

Physical habitat information was collected at each reach with both visual estimate and quantitative measurement techniques (Table 2). First, valley type was categorized by landscape features as U, V, or open floodplain. At each of six evenly spaced channel cross sections, wetted width, bankfull width, bankfull and incised heights (measured with a surveyor's rod and fiberglass measuring tape), and bank angles (measured with a clinometer) were measured. Canopy cover was measured with a spherical densiometer on the left and right bank, and in four directions (upstream, downstream, left, and right) in the center of the channel cross section. Stream water depth was measured at five equally-spaced locations along each cross section (30 total depth measurements for each reach), and substrate composition (10 size categories) and embeddedness were recorded at each of 15 equally-spaced locations along each

Table 2. Environmental variables collected in the field and generated using geographical information systems (GIS) for characterizing streams in the northwest Clackamas County, Oregon, fall 2002.

Variable	Quantitative or Categorical	Data Source (GIS or Field)	Visual Estimate or Measured Variable
Reach Length	Q	F	M
Valley Type	C	F	V
Reach Gradient (%)	Q	F	M
Wetted Width	Q	F	M
Bankfull Width	Q	F	M
Bankfull height	Q	F	M
Mean Water Depth	Q	F	M
Riffles (% area)	Q	F	V
Glides (% area)	Q	F	V
Pools (% area)	Q	F	V
Dominant Erosional Material	C	F	V
Dom. Depositional Material	C	F	V
Substrate Composition	Q	F	M
Embeddedness (%)	Q	F	M
Large Wood Tally	Q	F	M
Organic layer Accumulation	Q	F	V
Filamentous algae Cover (%)	Q	F	V
Macrophyte Cover (%)	Q	F	V
Overhead Canopy Cover	Q	F	M
Dominant Bank Material	C	F	V
Stable Banks (%)	Q	F	V
Undercut Banks (%)	Q	F	V
Mean Riparian Buffer Width	Q	F	V
Riparian Zone Tree Cover (%)	Q	F	V
Nonnative Riparian Veg Cover (%)	Q	F	V
Dom Adjacent Land Use	C	F	V
Water Temperature (°C)	Q	F	M
pH	Q	F	M
Specific Conductance (µS/cm)	Q	F	M
Dissolved Oxygen (mg/L)	Q	F	M

cross section (90 total substrate size tallies for each reach). Substrate composition was determined by tallying particles by size class, performed by placing a finger into the water and classifying the size of the particle first touched as bedrock (> 4000 mm), boulder (250-4000 mm), cobble (64-250 mm), coarse gravel (16-64 mm), fine gravel (2-16 mm), sand (0.06-2.00 mm), fines (<0.06 mm), wood, hardpan (firm, consolidated fines), or other. Embeddedness (%) was visually estimated from the area immediately surrounding each sampled particle.

Immediately following cross section surveys, large wood (>6 in diameter) was tallied and organic layer accumulation in depositional zones was measured. Visual estimates or classifications were then made of dominant bank material, percent stable bank, percent undercut bank, dominant erosional bed material and dominant depositional bed material, erosional habitat embeddedness (%), and depositional habitat embeddedness (%), and instream filamentous algae cover (%) and macrophyte cover (%). On each bank, the riparian zone buffer width (defined for this study as the area within which natural mature vegetative communities occurred) and the dominant adjacent land use outside the riparian buffer area were recorded.

SAMPLE SORTING AND MACROINVERTEBRATE IDENTIFICATION

Samples were sorted to remove a 500-organism subsample from each preserved sample following the procedures described in the Level 3 protocols (WQIW 1999) and using a Caton gridded tray, as described by Caton (1991). Contents of the sample were first emptied onto the gridded tray and then floated with water to evenly distribute the sample material across the tray. Squares of material from the 30-square gridded tray were removed to a Petri dish which then was placed under a dissecting microscope at 7-10X to sort aquatic macroinvertebrates from the sample matrix. Macroinvertebrates were removed from each sample until at least 500 organisms were counted, or until the entire sample had been sorted.

Following sample sorting, all macroinvertebrates were identified to the level of taxonomic resolution recommended for Level 3 macroinvertebrate assessments (WQIW 1999). Larval Chironomidae from low-gradient reaches were identified to genus to provide further characterization of aquatic macroinvertebrate communities in those reaches. Aquatic insects were keyed using Merritt and Cummins (1996) and a number of regional and taxa-specific keys. Chironomidae were identified to genus using Weiderholm (1983).

QUALITY ASSURANCE

Following Level 3 protocols (WQIW 1999), we collected duplicate composite samples at 10% of the sampled reaches in the field (three samples). Duplicate samples were compared to assess within-site sample variability. Additionally, a voucher collection of all macroinvertebrate taxa identified in the study was assembled as a standard reference for the project identification work

DATA ANALYSIS

ANALYSIS OF RIFFLE SAMPLES (FROM HIGH-GRADIENT REACHES)

Riffle samples from high-gradient reaches were analyzed using multimetric scoring and analysis to determine the condition of macroinvertebrate communities sampled from this reach type. Multimetric analysis employs a set of community metrics, each of which describes an attribute of the macroinvertebrate community that is known to be responsive to one or more types of pollution or habitat degradation. Each community metric is converted to a standardized score; standardized scores of all metrics are then summed to produce a single multimetric score that is a numeric measure of overall biological integrity. Reference condition data are required to develop and use this type of assessment tool. Metric sets and standardized metric scoring criteria are developed and calibrated for specific community types, based on both geographic location and stream/habitat type. The Oregon Department of Environmental Quality (DEQ) currently employs a 10-metric set for use with riffle samples from higher-gradient streams in western Oregon (WQIW 1999).

The DEQ 10-metric set includes six positive metrics that score higher in less disturbed systems, and four negative metrics that score lower as conditions improve (Table 3). The Modified Hilsenhoff Biotic Index (HBI), originally developed by Hilsenhoff (1982), computes an index to organic enrichment pollution based on the relative abundance of various taxa at a site. Values of the index range from 1 to 10; higher scores are interpreted as an indication of a degraded (i.e., pollution tolerant) macroinvertebrate community. Sensitive taxa are those that are intolerant of warm water temperatures, high sediment loads, and organic enrichment; tolerant taxa are adapted to persist under such adverse conditions. We used DEQ's taxa attribute coding system to assign these classifications to taxa in the data set (DEQ, unpublished information).

Metric values first were calculated for each sample, then were converted to standardized scores using DEQ scoring criteria for riffle samples from western Oregon streams (Table 3). The standardized scores were summed to produce a

Table 3. Metric set and scoring criteria (WQIW 1999) used to assess condition of macroinvertebrate communities sampled from riffles in northern Clackamas County, Oregon, fall 2002.

Metric	Scoring Criteria 5	3	1
	POSITIVE METRICS		
Taxa Richness	>35	19–35	<19
Mayfly Richness	>8	4–8	<4
Stonefly Richness	>5	3–5	<3
Caddisfly Richness	>8	4–8	<4
Number Sensitive Taxa	>4	2–4	<2
# Sediment Sensitive Taxa	≥2	1	0
	NEGATIVE METRICS		
Modified HBI[1]	<4.0	4.0–5.0	>5.0
% Tolerant Taxa	<15	15–45	>45
% Sediment Tolerant Taxa	<10	10–25	>25
% Dominant	<20	20–40	>40

[1] Modified HBI = Modified Hilsenhoff Biotic Index

multimetric score ranging between 10 and 50. Reaches were then assigned to a level of impairment based on these total scores.

Finally, relationships between multimetric scores and selected environmental variables were examined using nonparametric correlation analysis (Spearman's Rho) to determine what environmental attributes were related to macroinvertebrate community condition.

ANALYSIS OF GLIDE SAMPLES (FROM LOW-GRADIENT REACHES)

Glide samples also were evaluated using multimetric analysis, but because standardized scoring criteria are not available for samples from glide habitats in low gradient streams, samples were scored in relation to one another by converting raw metric values to ranks based on quartiles. For each metric, the first through fourth quartiles were calculated from the data, then each raw value was scored one through four, based on the quartile in which the value occurred. Increasing quartile ranks correspond to decreasing biological integrity. The overall macroinvertebrate community condition was determined by calculating the mean quartile rank for each site, referred to hereafter as the overall condition rank (OCR).

Nine metrics, some of which differed from those used for analysis of riffle samples, were used to evaluate glide samples from low-gradient reaches (Table 4). In general, glides and pools (depositional habitats) support a lower diversity of aquatic macroinvertebrates and the organisms occurring in these habitats tend to be more tolerant of disturbance than organisms occurring in riffles. Metrics that previously have been shown to effectively characterize macroinvertebrate communities in low-gradient streams (Cole 2002) and that provided a range of values among glide samples were selected for inclusion in the set; metrics that showed little variation among low-gradient reaches, such as sensitive taxa richness, were excluded from the set.

Following calculation of overall condition ranks of each sample, ranks were correlated with measured environmental variables using nonparametric correlation analysis to examine whether gradients in biological conditions from low-gradient reach glide samples were associated with gradients in environmental conditions.

Table 4. Metric set used to assess condition of macroinvertebrate communities sampled from glides in northern Clackamas County, Oregon, fall 2002.

Metric
Taxa Richness
EPT Taxa Richness
% Dominant (1 taxon)
Modified HBI
% Sediment Tolerant
% Tolerant
% Chironomidae
% Mollusca
% Oligochaeta

RESULTS

ENVIRONMENTAL CONDITIONS OF CCSD#1 STUDY STREAM REACHES

CCSD#1 study reaches encompassed a wide range of land use, riparian, and stream channel conditions. Of 14 study reaches, undeveloped open space was the dominant adjacent land-use type along seven reaches, residential at four, commercial/industrial at two, and forested at only one reach. This forested reach on lower Richardson Creek occurs outside the CCSD#1 jurisdictional boundary. We included Richardson Creek in the study as a potential reference reach for comparison with other riffle-pool type streams. Most CCSD#1 stream reaches occur in gently sloping U-shaped valleys without well-developed floodplains (Figure 2). Four study reaches occurred in well-developed floodplains; none occurred in V-shaped valleys that are typically associated with higher-gradient streams in areas of more topographic relief. Reach gradient in most CCSD#1 reaches ranged from one to three percent (Figure 2); only two reaches exceeded three percent channel slope. Canopy cover was high across most CCSD#1 study reaches; canopy cover was less than 80% in four CCSD#1 reaches, and less than 60% in only one reach (Figure 2). Riparian zone tree cover varied, particularly among high-gradient reaches, ranging from 25 to 80%. Nonnative vegetative cover in the riparian zone also ranged widely, from 0 to 76% along high gradient reaches and 0 to 55% along lower gradient reaches (Table 5).

Stream habitat varied considerably among CCSD streams (Figure 2). In high-gradient reaches, riffle area averaged 52%, whereas in low-gradient streams, riffle area averaged only 5%. Conversely, glide area averaged only 38% in high-gradient stream reaches, and averaged 80% in low-gradient reaches (Table 5).

Substrate composition also varied widely, ranging from dominance by cobble and coarse gravel in high-gradient reaches to dominance by sand and fines in low-gradient reaches. Percent fine substrate averaged only 2% in high-gradient reaches, while averaging 31% in low-gradient reaches (Table 5). Across all CCSD#1 study reaches, substrate composition varied widely (Figure 2). Mean substrate embeddedness across all habitats also ranged widely (Figure 2), and was generally higher in low-gradient reaches (mean = 71%) than in high-gradient reaches (mean = 49%).

ENVIRONMENTAL CONDITIONS OF SWMACC STUDY STREAM REACHES

SWMACC study reaches also occurred within a wide range of land uses, and exhibited a range of riparian, and stream channel conditions. Of 12 study reaches, residential development was the dominant adjacent land use type along nine reaches, agriculture along two, commercial/industrial at one; no reaches occurred in primarily forested areas. Most SWMACC stream reaches occur in gently sloping U-shaped valleys without well-developed floodplains (Figure 3). One study reach occurred in a well-developed floodplain. The gradient of most stream reaches

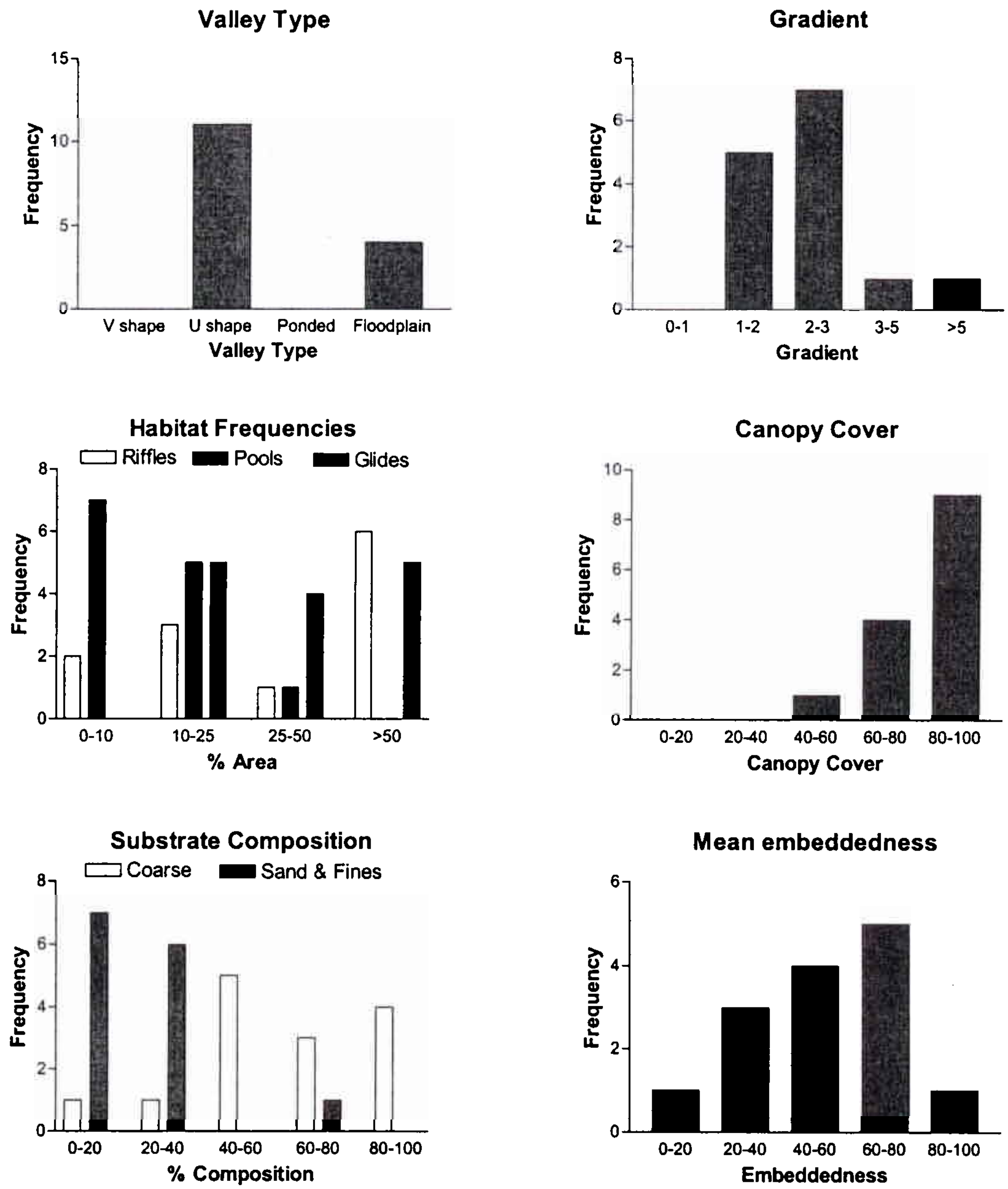

Figure 2. Frequency distribution (number of stream reaches) of selected habitat attributes measured at 14 macroinvertebrate study stream reaches in CCSD#1 in northwestern Clackamas County, Oregon, fall 2002.

Table 5. Environmental conditions (mean (range)) of selected low-gradient and high- gradient stream reaches in CCSD#1, Clackamas County, Oregon, fall 2002. Only glide samples were collected from low-gradient reaches. Both riffle and glide, or only riffle samples were collected from high-gradient stream reaches.

	Reach Type Mean (Range)	
Environmental Variable	Low-gradient	High-gradient
Reach Gradient (%)	1.2 (1.0 – 1.5)	3.0 (1.5 – 10.0)
Wetted Width (m)	4.2 (1.2 – 6.3)	3.0 (0.8 – 6.3)
Bankfull Width (m)	4.8 (2.1 – 6.8)	4.5 (1.7 – 7.6)
Mean Water Depth (cm)	14.9 (6.7 – 21.2)	8.4 (3.1 – 21.2)
Riffle Area (%)	5 (0 – 10)	52 (10 – 80)
Glides Area (%)	80 (70 – 90)	38 (15 – 90)
Pool Area (%)	15 (0 – 30)	10 (0 – 50)
Coarse Substrate (%)	50 (9 – 86)	62 (27 – 96)
Sand and Fines (%)	38 (9 – 79)	18 (1 – 39)
Fines (%)	31 (0 – 64)	2 (0 – 22)
Hardpan (%)	2 (0 – 6)	1 (0 – 6)
Embeddedness (%)	71 (50 – 97)	49 (9 – 75)
Large Wood Tally	3.8 (2 – 6)	3.7 (0 – 8)
Filamentous Algae (%)	0 (0 – 0)	0.2 (0 – 2)
Macrophytes (%)	0.5 (0 – 2)	0.2 (0 – 2)
Canopy Cover (%)	81 (71 – 94)	82 (59 – 94)
Bank Stability (%)	46 (20 – 70)	71 (0 – 90)
Mean Riparian Buffer Width (m)	7 (2 – 13)	11 (1 – 61)
Riparian Zone Tree Cover (%)	38 (25 – 50)	58 (25 – 80)
Riparian Nonnative Veg Cover (%)	25 (0 – 55)	39 (0 – 76)
Water Temperature (°C)	15.9 (13.6 – 17.6)	15.1 (13.4 – 17.6)
Specific Conductance (µS/cm)	219 (189 – 238)	159 (103 – 199)
Dissolved Oxygen (% sat)	74 (61 – 94)	83 (49 – 97)

sampled in the SWMACC study area ranged between one and two percent (Figure 3); only four reaches exceeded two percent channel slope. Canopy cover was high across most SWMACC study reaches; canopy cover was less than 80% in only two SWMACC reaches (Figure 2).

Habitat frequencies reflected the low-gradient nature of most of these reaches, as glides exceeded 50% of the stream habitat area in seven of the SWMACC reaches, whereas riffles and pools each exceeded 50% of the habitat area in only two reaches (Figure 3). In high-gradient reaches, riffle frequency averaged 45%, whereas in low-gradient reaches, riffle frequency averaged only 3%. Conversely, glide frequency averaged only 43% in high-gradient reaches, and averaged 59% in low-gradient reaches (Table 6).

Substrate composition also varied widely, ranging from dominance by cobble and coarse gravel in high-gradient reaches to dominance by sand, silt, and clay (variable name: sand and fines) in low-gradient reaches. Percent fine substrate averaged only 9% in high gradient reaches, while averaging 26% in low-gradient reaches (Table 6). Across all SWMACC study reaches, most reaches contained low proportions of coarse gravel or larger substrates, while proportions of fine substrate varied widely among reaches (Figure 3).

MACROINVERTEBRATE COMMUNITY CONDITIONS–CCSD#1 RIFFLE SAMPLES

Riffle samples were collected from 11 high-gradient stream reaches in CCSD#1. Multimetric scores of macroinvertebrate

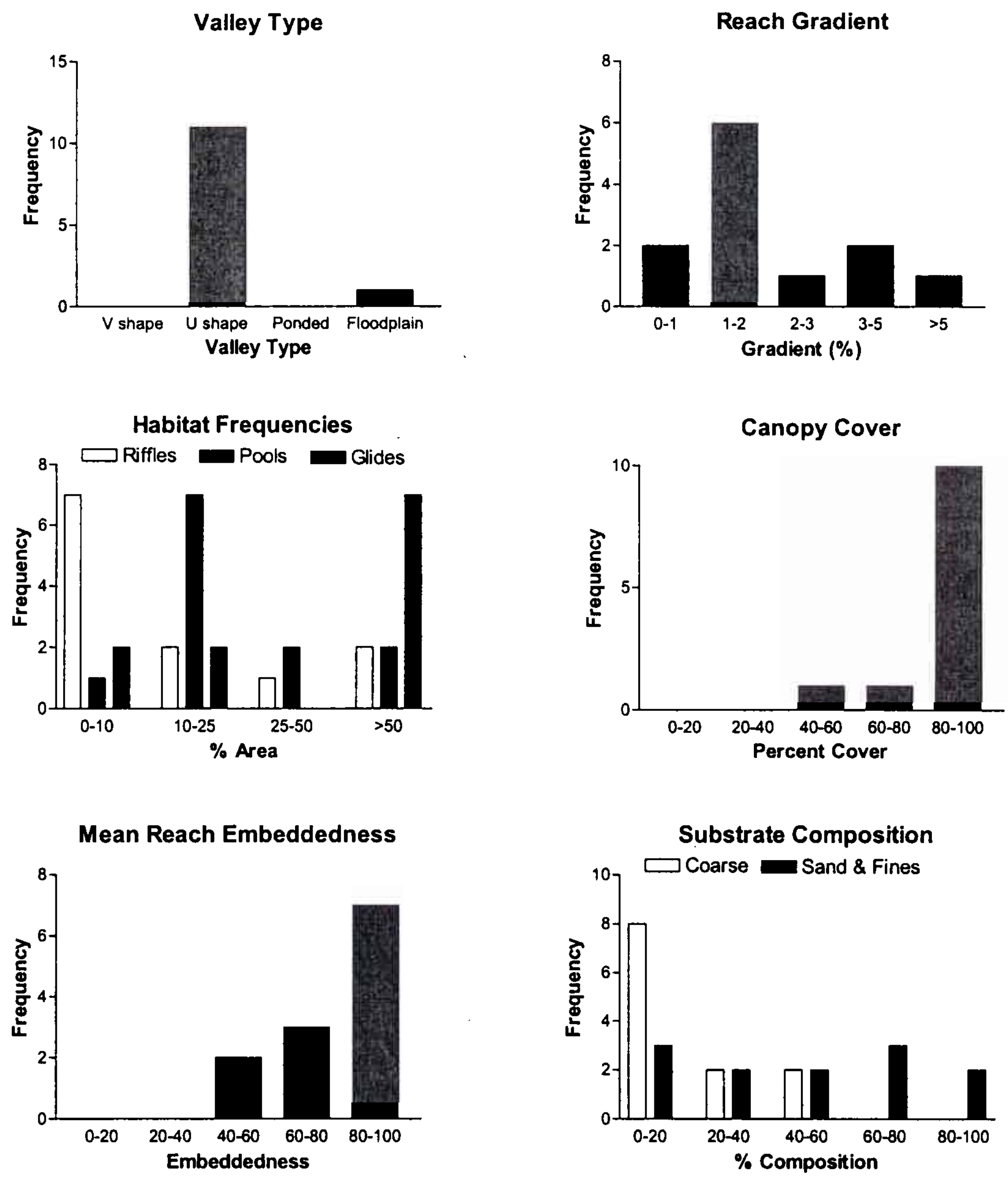

Figure 3. Frequency distribution (number of stream reaches) of selected habitat attributes measured at 12 macroinvertebrate study stream reaches in the SWMACC in northwestern Clackamas County, Oregon, fall 2002.

Table 6. Environmental conditions (mean (range)) of low-gradient and high- gradient stream reaches in the lower Tualatin River basin (SWMACC), Oregon, fall 2002.

	Reach Type Mean (Range)	
Environmental Variable	Low-gradient	High-gradient
Reach Gradient (%)	1.6 (0.5 – 2.0)*	3.5 (1.5 – 6.0)
Wetted Width (m)	2.4 (0.6 – 14.0)	1.3 (1.2 – 1.6)
Bankfull Width (m)	3.6 (1.2 – 14.7)	2.2 (2.0 – 2.7)
Mean Water Depth (cm)	7.5 (0.5 – 37.5)	3.0 (1.2 – 3.9)
Riffle Area (%)	3.1 (0.0 – 10.0)	45 (20 – 70)
Glides Area (%)	59 (0 – 90)	43 (25 – 70)
Pool Area (%)	37 (10 – 100)	12.5 (5 – 20)
Coarse Substrate (%)	12 (0 – 27)	38 (19 – 59)
Sand and Fines (%)	54 (4 – 86)	26 (12 – 47)
Fines (%)	26 (0 – 85)	9 (0 – 27)
Hardpan (%)	9 (0 – 57)	1 (0 – 3)
Embeddedness (%)	88 (56 – 100)	67 (49 – 84)
Large Wood Tally	4.2 (0 – 11.0)	4.3 (2 – 6)
Filamentous Algae (%)	0 (0 – 0)	0 (0 – 0)
Macrophytes (%)	9 (0 – 80)	0 (0 – 0)
Canopy Cover (%)	86 (44 – 100)	94 (89 – 99)
Bank Stability (%)	36 (0 – 50)	25 (10 – 40)
Mean Riparian Buffer Width (m)	13 (3 – 27)	22 (7 – 42)
Riparian Zone Tree Cover (%)	51 (25 – 70)	60 (50 – 70)
Riparian Nonnative Veg Cover (%)	33 (4 – 63)	47 (27 – 63)
Water Temperature (°C)	13.8 (12.2 – 15.5)	13.4 (12.1 – 14.3)
Specific Conductance (µS/cm)	180 (91 – 263)	153 (83 – 239)
Dissolved Oxygen (% sat)	59 (7 – 86)	79 (77 – 81)

* includes one stream (Fields Creek) reach that was high gradient (4%), but no flowing water at the time of sampling required collecting glide samples.

communities sampled from riffles ranged from 14 to 30, indicating that macroinvertebrate community conditions range from only slightly to severely impaired among sampled reaches in the study area (Table 7). Deer Creek (SD1-M6) received the lowest multimetric score among all reaches in CCSD#1 from which riffles were sampled. Cedar Creek (SD1-M15), and Phillips (SD1-M5) and Mt. Scott (SD1-M1, M2, and M3) creeks also scored in the severely impaired range. Trillium Creek (SD1-M7), Sieben Creek (SD1-M8), and Rock Creek (SD1-M10 & M11) scored in the moderately impaired range, while Richardson Creek, the only stream reach occurring in a primarily forested area, scored in the slightly impaired range.

Individual measures of community condition (using individual metrics) ranged widely among riffle samples (Table 6). Total taxa richness ranged from 12 taxa from Deer Creek to 31 taxa from Richardson Creek, and averaged 21 taxa across all reaches. Mayfly, stonefly, and caddisfly richness ("EPT taxa", orders generally regarded as sensitive) also varied widely among riffle samples. Seventeen EPT taxa were sampled from Richardson Creek, while only one EPT taxon occurred in Deer, Phillips, and Sieben Creek riffle samples. Sensitive taxa richness was low in all CCSD#1 riffle samples, as no sensitive taxa, or only one sensitive taxon was sampled from each reach (Table 8). Percent dominance by one taxon, percent tolerant organisms, and percent sediment tolerant organisms also varied widely among reaches, further reflecting the range in macroinvertebrate community conditions in riffles among sampled reaches in CCSD#1 (Table 6).

Table 7. Multimetric scores of riffle samples from streams sampled in northern Clackamas County, Oregon, fall 2002. Level of impairment: <20 = severe , 20-29 = moderate, 30-39 = slight, >39 = none.

Site Code	Stream	Multimetric score
	CCSD#1	
SD1-M1	Mt. Scott Creek	18
SD1-M2	Mt. Scott Creek	16
SD1-M3	Mt. Scott Creek	16
SD1-M5	Phillips Creek	16
SD1-M6	Deer Creek	14
SD1-M7	Trillium Creek	22
SD1-M8	Sieben Creek	24
SD1-M10	Rock Creek	22
SD1-M11	Rock Creek	20
SD1-M12	Richardson Creek	30
SD1-M15	Cedar Creek	16
	SWMACC	
LT-M1	Fields Creek	30
LT-M8	Pecan Creek	18
LT-M11	Athey Creek	22
LT-M13	Unnamed Trib 4	16

Table 8. Means (and ranges) of macroinvertebrate community metrics calculated from riffle samples collected from study stream reaches in northwest Clackamas County, Oregon, fall 2002.

Metric	CCSD#1 ($n = 11$)	SWMACC ($n = 4$)
Taxa Richness	21.4 (12.0 – 31.0)	27.8 (22.0 – 32.0)
Mayfly Richness	2.5 (1.0 – 6.0)	2.5 (2.0 – 3.0)
Stonefly Richness	1.4 (0.0 – 5.0)	3.5 (3.0 – 5.0)
Caddisfly Richness	1.6 (0.0 – 6.0)	2.5 (0.0 – 5.0)
Number Sensitive Taxa	0.4 (0.0 – 1.0)	1.3 (0.0 – 3.0)
# Sediment Sensitive Taxa	0.2 (0.0 – 2.0)	0.5 (0.0 – 2.0)
Modified HBI[1]	5.6 (4.2 – 6.8)	5.4 (5.0 – 5.8)
% Tolerant Taxa	32.1 (3.3 – 54.9)	30.6 (16.3 – 44.8)
% Sediment Tolerant Taxa	15.3 (1.4 – 30.8)	26.2 (7.1 – 45.7)
% Dominant	30.6 (17.1 – 56.0)	26.8 (21.2 – 40.3)

[1] Modified HBI = Modified Hilsenhoff Biotic Index

Modified HBI scores averaged 5.6 across all CCSD#1 study reaches, indicating that macroinvertebrate communities in the high-gradient study reaches generally are composed of taxa that are tolerant to organic enrichment pollution.

MACROINVERTEBRATE COMMUNITY CONDITIONS–SWMACC RIFFLE SAMPLES

Riffle samples were collected from four stream reaches in SWACC. Multimetric scores of macroinvertebrate communities sampled from riffles ranged from 16 to 30, indicating that macroinvertebrate community conditions range from only slightly to severely impaired among sampled reaches in the study area (Table 7). Unnamed tributary #4 (LT-M13) and Pecan Creek (LT-M8) were scored as severely impaired, Athey Creek (LT-M11) scored as moderately impaired, and Fields Creek (LT-M1) scored as slightly impaired (Table 7).

Individual measures of community condition (using individual metrics) also ranged widely among SWMACC riffle samples (Table 8). Total taxa richness ranged from 22 to 32 taxa and averaged 28 taxa across all reaches. Mayfly, stonefly, and caddisfly also varied widely among riffle samples. Thirteen EPT taxa were sampled from Fields Creek, while only five EPT taxa occurred in Unnamed tributary #4. Three sensitive taxa occurred in Fields Creek, while the other riffle samples from SWMACC contained only one or no sensitive taxa. Percent dominance by one taxon, percent tolerant organisms, and percent sediment tolerant organisms varied among reaches, and were generally similar to those calculated from CCSD#1 samples (Table 8). Modified HBI scores averaged 5.4, and ranged from 5.0 to 5.8 across the four CSWMAC riffle sample reaches, indicating that macroinvertebrate communities in the study reaches are generally comprised of taxa that are tolerant to organic enrichment pollution.

MACROINVERTEBRATE COMMUNITY CONDITIONS–CCSD#1 GLIDE SAMPLES

Glide samples were collected from seven CCSD#1 reaches. Overall condition ranks ranged from 2.4 to 3.0 (on a scale of 1-4), indicating that macroinvertebrate community conditions did not vary considerably among low gradient study reaches (Table 9) in CCSD#1. Kellogg (SD1-M13) and Cedar (SD1-M15) creeks received the highest ranks of 2.4 and 2.6, respectively, while Phillips (SD1-M5), Mt. Scott (SD1-M3 & 4), and Deer (SD1-M6) creeks received the lowest ranks of 2.8-3.0 (Table 9).

Macroinvertebrate communities sampled from glides in low gradient reaches were characterized as having few or no EPT taxa, low taxa richness, a high proportion of tolerant organisms, high HBI scores, and high percent dominance by a single taxon (Table 10). EPT richness averaged fewer than two taxa per reach, and ranged from zero to five taxa (Table 10). Dominance by a single taxon averaged 56%, tolerant organisms averaged 63% and ranged from 15 to 93% (Table 10).

MACROINVERTEBRATE COMMUNITY CONDITIONS - SWMACC GLIDE SAMPLES

Macroinvertebrates were collected from glides in nine low-gradient reaches in SWMACC. Glide samples from SWMACC reaches generally indicated that macroinvertebrate communities are less impaired in lower Tualatin River tributaries than in CCSD#1 streams. Six SWMACC stream reaches scored better than the highest ranked CCSD#1 stream reach. Tate (LT-M9) and Shipley (LT-M10) creeks scored mean ranks of 1.4 and 1.8, respectively; middle Saum (LT-M7), unnamed tributary #4 (LT-M13), Nyberg Creek (LT-M5), and unnamed tributary #2 (LT-M12) scored 1.9 – 2.3 (Table 9). Lower Saum (LT-M6), Ek (LT-M2), and upper Wilson (LT-M3) creeks received the lowest ranks, ranging from 2.6 to 2.8. In Upper Wilson Creek, the reach that was ranked lowest among streams from which glides were sampled is noteworthy in that the reach sampled averaged >4% in channel gradient and contained a large proportion of larger substrates. At the time of sampling, however, upper Wilson Creek had almost no discernable streamflow; only standing water occurred in pools between dry riffle segments. Macroinvertebrate communities sampled from these isolated pools reflected these extreme environmental conditions.

Taxa richness from SWMACC glide samples averaged 23 taxa/sample and ranged from 9 to 30 taxa (Table 10). Tolerant organisms averaged 30%

Table 9. Overall condition ranks of metric scores derived from glide samples from streams sampled for macroinvertebrate communities in northern Clackamas County, Oregon, fall 2002. Ranking scale ranges from 1 (best condition) to 4 (worst condition).

Site Code	Stream	Mean Rank
	CCSD#1	
SD1-M13	Kellogg Creek	2.4
SD1-M15	Cedar Creek	2.6
SD1-M14	Cow Creek	2.7
SD1-M6	Deer Creek	2.8
SD1-M4	Mt. Scott Creek	2.8
SD1-M3	Mt. Scott Creek	2.9
SD1-M5	Phillips Creek	3.0
	SWMACC	
LT-M9	Tate Creek	1.4
LT-M10	Shipley Creek	1.8
LT-M7	middle Saum Creek	1.9
LT-M13	Unnamed tributary #4	1.9
LT-M12	Unnamed tributary #2	2.2
LT-M5	Nyberg Creek	2.3
LT-M2	Ek Creek	2.6
LT-M6	lower Saum Creek	2.8
LT-M3	upper Wilson Creek	2.9

Table 10. Means (and ranges) of macroinvertebrate community metrics calculated from glide samples collected from study stream reaches in northwest Clackamas County, Oregon, fall 2002.

Metric	CCSD#1 ($n = 7$)	SWMACC ($n = 9$)
Taxa Richness	17.1 (13.0 – 27.0)	22.8 (9.0 – 30.0)
EPT Richness	1.9 (0.0 – 5.0)	3.8 (0.0 – 8.0)
% Dominant	54 (32 – 75)	43 (22 - 91)
% Tolerant Taxa	63.3 (15.7 – 93.8)	30.1 (2.5 – 73.3)
% Sediment Tolerant Taxa	43.6 (7.6 – 84.2)	19. (0.8 – 70.5)
Modified HBI[1]	6.5 (6.1 – 7.5)	6.0 (4.5 – 7.9)
% Dominant	54.1 (32.1 – 75.3)	42.8 (22.2 – 91.1)
% Chironomidae	16.0 (3.8 – 27.2)	31.9 (7.5 – 72.6)
% Mollusca	21.9 (4.4 – 76.3)	28.9 (4.0 – 91.1)
% Oligochaeta	39.7 (6.6 – 74.6)	8.4 (0.6 – 22.2)

[1] Modified HBI = Modified Hilsenhoff Biotic Index

of the total macroinvertebrate abundance and ranged widely from 2 to 73% among reaches. Percent sediment tolerant organisms also varied widely among reaches, ranging from <1% to 71% among SWMACC glide samples. Modified HBI scores averaged 5.9 and ranged from 4.0 to 7.8 (Table 10).

COMPARISON OF RIFFLE AND GLIDE SAMPLES FROM SAME REACHES

When both riffle and glide samples were collected from the same reach (5 reaches between both study areas), macroinvertebrate community conditions generally corresponded well between the two sample types. Riffle samples from reaches within which both riffles and glides were sampled always indicated that macroinvertebrate communities were severely impaired, with multimetric scores of 14 or 16. Likewise, ranks of metrics from glide samples from these same reaches indicated more severe impairment among those glides sampled in this study, as 4 of the 5 ranks ranged from 2.6 to 3.0 (across all glide samples, scores ranged from 1.6 to 3.0).

CORRELATION OF COMMUNITY CONDITIONS WITH ENVIRONMENTAL CONDITIONS

Among environmental variables, a number were significantly correlated with riffle sample multimetric scores (Figure 4). Both reach gradient ($p = 0.008$) and riffle frequency ($p = 0.023$) were positively correlated with multimetric scores, while percent fine substrate ($p = 0.044$) and mean substrate embeddedness ($p = 0.014$) were negatively correlated with multimetric scores. Three water quality variables also were significantly correlated with multimetric scores of macroinvertebrate communities (Figure 5). Water temperature ($p = 0.015$) and specific conductance ($p = 0.039$) were both negatively correlated with macroinvertebrate multimetric scores, while dissolved oxygen ($p = 0.034$) exhibited a positive correlation with macroinvertebrate community condition (Figure 5).

Canopy cover ($p = 0.014$) and water temperature ($p = 0.024$) were correlated with overall condition ranks of glide samples from across both study areas (Figure 6). When analyzed separately, reach buffer width ($p = 0.044$), overhead canopy cover ($p = 0.024$), and percent tree cover in the riparian zone ($p = 0.024$) were significantly correlated with metric ranks from CCSD#1 glide samples. Glide samples from SWMACC were significantly correlated only with percent riffles ($p = 0.016$), with better scoring samples tending to occur in reaches with higher proportions of riffles.

DISCUSSION

Macroinvertebrate community conditions varied widely among stream reaches in both SWMACC and CCSD#1 study areas and generally reflected the wide range of stream types and conditions occurring in the study area. This wide variation is related to both natural variation in land form and the resulting physical template to which macroinvertebrate communities respond, as well as to degraded physical habitat and water quality and altered hydrology resulting from human activities. Riffle samples from both SWMACC and CCSD#1 were typically scored as moderately to severely impaired.

Only the reach sampled in Richardson Creek scored high enough to be classified as only slightly impaired in CCSD#1. Richardson Creek was selected as a reference reach for this study because its instream and riparian conditions are less disturbed by human activity than those of other streams in the area. Lower Richardson Creek contains large amounts of course substrate with low embeddedness; an intact riparian zone and adjacent woodlands help buffer the stream from water quality impairment and high sediment loading.

Among SWMACC study reaches, only Fields Creek scored in the slightly impaired range. Fields Creek also contained a large proportion of coarse substrate and low embeddedness, and flows through woodlands upstream of Bosky Dell Lane, where the stream was sampled. Richardson and Field Creeks should continue to be used as reference reaches for comparison with other area riffle-pool dominated streams. Communities occupying these stream reaches can be characterized as generally having a high taxa richness, high EPT richness, several sensitive taxa, low proportions of taxa tolerant to disturbance, and

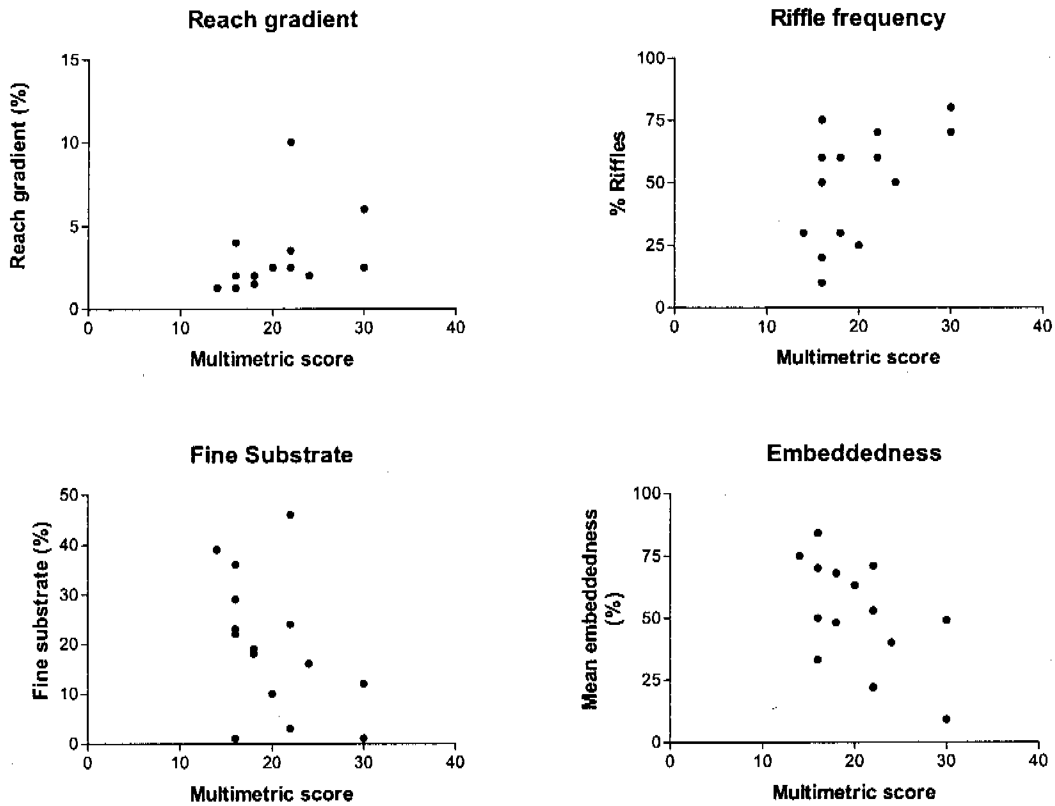

Figure 4. Relationships between macroinvertebrate community multimetric scores and measured physical variables that were significantly correlated with multimetric scores calculated from macroinvertebrate samples collected from riffles in WES study streams from northwest Oregon, fall 2002 (n = 15).

a low collective tolerance to organic enrichment pollution (as indicated by the modified HBI).

Multimetric scores of riffle samples collected from both study areas were related to a number of measured physical and chemical parameters, including measures of stream gradient, several measures of substrate composition, water temperature, dissolved oxygen, and specific conductance. These correlations do not establish cause and effect, as they indicate only that a directional change in one variable corresponds to a directional change in another. They do, however, offer insight into what variables are likely influencing the condition of the macroinvertebrate community.

Substrate composition, for example, has long been recognized as an important determinant of macroinvertebrate community composition and condition (Waters 1995). Changes in substrate composition, primarily through increased loading of fine sediments to streams, have been shown to produce changes in macroinvertebrate community composition (Waters 1995). Stream reaches in this study varied in the amount of deposited fine sediment and substrate embeddedness, but these values generally were high across the study reaches, indicating that delivery of sediment to streams in the study areas due to land-use practices is likely impairing aquatic communities.

Both water temperature and dissolved oxygen can affect macroinvertebrate community condition, and both were correlated with multimetric scores from riffle samples in this study; water temperatures also were correlated with ranks from glide samples, further indicating that elevated temperatures likely are affecting area macroinvertebrate communities. Elevated summer water temperatures often occur in rural and urban areas as a result of altered hydrology and impaired riparian function. Macroinvertebrate taxa vary in

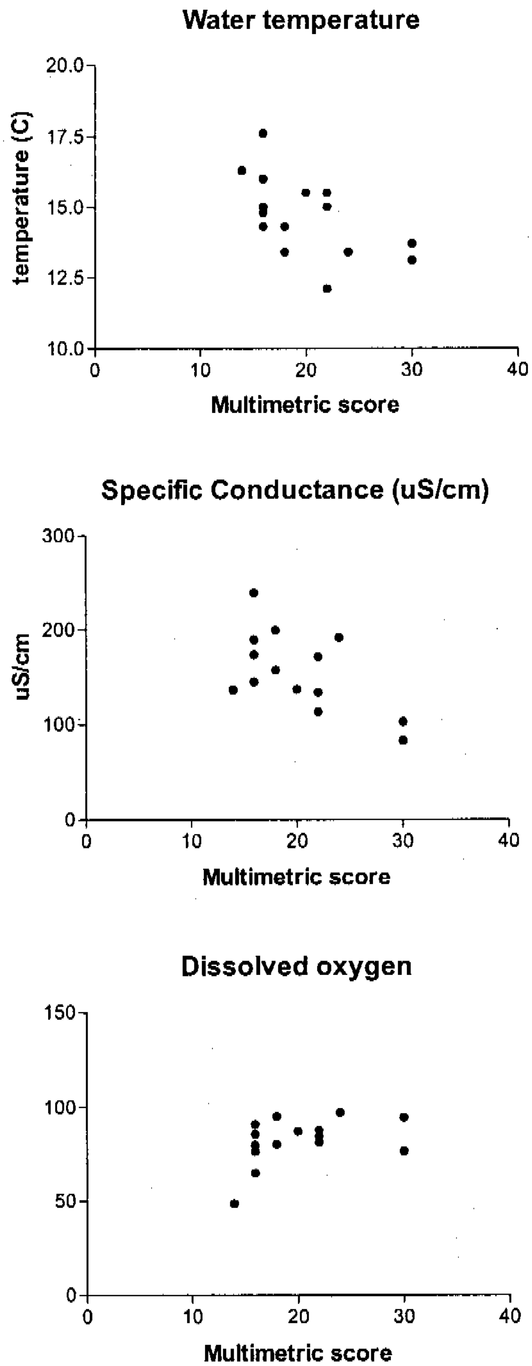

Figure 5. Relationships between macroinvertebrate community multimetric scores and measured chemical variables that were significantly correlated with multimetric scores calculated from macroinvertebrate samples collected from riffles in WES study streams from northwest Oregon, fall 2002 (*n* = 15).

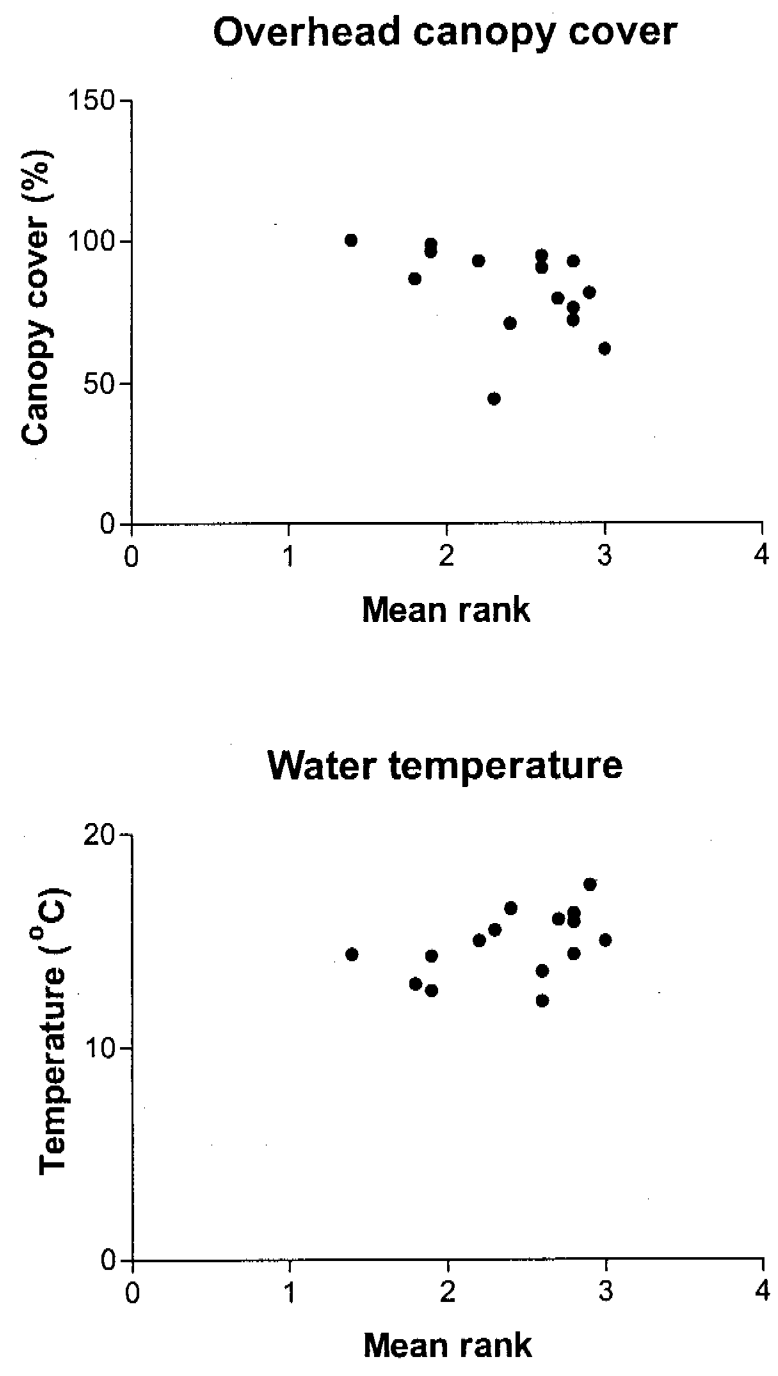

Figure 6. Relationships between overall condition ranks of macroinvertebrate communities sampled from glides and environmental variables that were significantly correlated with these ranks. Data were collected from study streams in north Clackamas County (NCC), Oregon, fall 2002 ($n = 15$).

their tolerance to high water temperatures and recurrent elevated temperatures are known to produce changes in macroinvertebrate communities. Although our temperature data ranged only as high as 17.6°C, it is likely that maximum temperatures during summer may exceed 20°C in some study reaches (Friesen and Zimmerman 1999); our data reflect only relative temperatures among reaches and still provide some insight into what streams likely have higher summer water temperatures.

Dissolved oxygen also can be a limiting factor to benthic communities, particularly where high biological or chemical oxygen demand severely depletes oxygen in surface waters. Although dissolved oxygen concentrations averaged 7.45 mg/L (73% saturation) across all study reaches, concentrations as low as 0.69 mg/L were recorded, which are similar to values recorded in other streams in developed basins in the Willamette Valley (Cole 2002). Current Oregon dissolved oxygen standards range from 5.5 mg/L for water bodies supporting warm-water aquatic life to 11.0 mg/L for water bodies providing salmonid spawning. Dissolved oxygen levels in four study reaches were lower than even the 5.5 mg/L standard (Mt. Scott Creek, Phillips Creek, Unnamed Tributary #2, and Deer Creek), indicating that dissolved oxygen likely is impairing even warm-water aquatic life in a number of area streams.

Riffle samples from streams with the most impaired benthic communities, including Deer, Cedar, Phillips, and lower Mt. Scott creeks in CCSD#1, were so impaired that their taxonomic composition and metric scores were similar to those of glide samples. Communities in these reaches are characterized as having low taxonomic richness, few or no EPT taxa, high proportions of tolerant and sediment tolerant taxa, dominance by only one or a few tolerant taxa, few or no sensitive taxa, and a high tolerance to organic enrichment pollution.

Macroinvertebrate community samples from glides of low-gradient stream reaches showed less variability in community attributes than those from riffle samples. This low variability among glide-sample attributes resulted in fewer and weaker associations with measured environmental variables. Also, environmental gradients across low-gradient reaches were less variable than they were across high-gradient reaches. Glide samples from the lower Tualatin tributaries were correlated only with percent riffle habitat, and glide samples from CCSD#1 were correlated with only riparian zone characteristics. All sample reaches from which glides were sampled occurred in areas where adjacent land uses have likely impaired instream physical, chemical, and biological components. Although sampling macroinvertebrates from glides in low-gradient reaches can provide useful data for biological monitoring and assessment, relating biological conditions to environmental conditions is difficult in this study area because these reach types tend to occur exclusively in more developed areas on valley floors.

Generally, both riffle and glide macroinvertebrate communities were in better condition in SWMACC streams than in CCSD#1 streams, as indicated by both overall scores and individual metrics. Still, both study areas were dominated by moderately to severely impaired macroinvertebrate communities. Stream restoration and protection should help prevent further degradation of local and regional aquatic communities, and in some cases aid in the recovery of these communities. Efforts should focus on restoring stream conditions and functions that appear to be most closely related to losses in biological conditions, and where efforts are most likely to result in improvement in environmental conditions. Restoration efforts should first focus on areas where benthic conditions are not yet severely impaired and communities are better able to respond to smaller-scale restoration efforts. Monitoring biological responses to restoration efforts should be included in restoration efforts to both monitor the success of specific restoration projects and to better understand the effects of such efforts on biological functioning in streams.

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Appendix 1. Environmental variables measured from 14 stream reaches in CCSD#1, Clackamas County, Oregon in fall 2002.

Site Code	Reach Length (m)	Valley Type	Reach Gradient (%)	Wetted Width (m)	Bankfull Width (m)	Bankfull Height (m)	Mean Water Depth (cm)	% Riffles	% Pools	% Glides/Runs	Dominant Eros Material	Dominant Depositional Material	% Coarse Substrate	% Fine Gravel/Sand/Fines	% Sand/Fines
SD1-M1	50	2	2	2.5	4.9	0.4	5.7	60.0	10.0	30.0	4	3	53	31	18
SD1-M2	50	2	4	3.7	5.6	0.5	6.5	75.0	5.0	20.0	4	3	82	10	1
SD1-M3	50	4	1.25	4.7	5.6	0.7	21.2	10.0	0.0	90.0	4	3	62	31	23
SD1-M4	50	4	1	6.3	6.8	0.5	20.2	0.0	20.0	80.0	4	3	86	11	9
SD1-M5	50	2	2	3.0	4.6	0.6	13.2	50.0	10.0	40.0	4	2	63	36	22
SD1-M6	50	4	1.25	1.9	2.3	0.6	11.7	30.0	0.0	70.0	4	2	27	69	39
SD1-M7	50	2	10	0.8	1.7	0.4	3.1	70.0	5.0	25.0	4	2	59	41	24
SD1-M8	50	2	2	1.8	2.7	0.6	3.7	50.0	5.0	45.0	1	3	42	51	16
SD1-M10	50	2	2.5	6.3	7.6	0.5	6.3	70.0	5.0	25.0	4	4	92	8	3
SD1-M11	50	2	2.5	3.8	6.3	0.5	6.6	25.0	50.0	25.0	4	3	70	24	10
SD1-M12	50	2	2.5	2.8	5.9	0.5	8.8	80.0	5.0	15.0	4	4	96	2	1
SD1-M13	50	4	1.5	4.5	4.8	0.4	11.6	0.0	30.0	70.0	4	3	43	52	39
SD1-M14	50	2	1	1.2	2.1	0.6	6.7	10.0	10.0	80.0	2	1	9	80	79
SD1-M15	50	2	2	1.4	2.0	1.2	6.1	60.0	10.0	30.0	4	3	41	52	36

Appendix 1. (Continued).

Site Code	% Fines	% Bedrock	% Hard Pan	% Embeddedness	Large Wood Tally	Organic Layer Accumulation (cm)	% Filamentous Algae	% Macrophytes	Overhead Canopy Cover (%)	Dominant Bank Material	% Stable Bank	% Undercut Bank	Mean Riparian Buffer Width (m)	% Tree Cover	% NonNative Vegetation	Dominant Adjacent Land Use	Temperature (C)	pH	Dissolved Oxygen (% sat)	Specific Conductance (µS/cm)	Macroinvertebrate Sample
SD1-M1	0	16	0	48	1	0	0	0	93.5	2	90	10	6	70	12.5	3	13.4	7.41	95.1	199	R
SD1-M2	0	6	0	33	6	0	0	0	86.6	2	90	5	14	57.5	65	3	14.8	7.38	85.6	173	R
SD1-M3	22	0	6	70	4	0	0	0	81.5	2	70	5	2	37.5	0	3	17.6	7.00	76.4	189	RG
SD1-M4	0	0	0	50	3	0.25	0	0	76.3	2	35	5	13	50	27.5	1	15.9		65.9	238	G
SD1-M5	0	0	0	50	6	2	0	0	61.9	2	90	5	2	25	50	1	15	7.25	90.8	190	RG
SD1-M6	0	0	4	75	1	0	0	0	92.5	1	50	0	3	60	20	2	16.3	6.48	48.6	136	RG
SD1-M7	0	0	0	53	2	0	0	0	83.3	2	75	0	4	55	25	3	15	7.02	87.6	113	R
SD1-M8	0	0	1	40	2	0	1	0	94.1	2	0	25	1	45	75	3	13.4	7.70	97.2	192	R
SD1-M10	0	0	0	22	8	0	0	0	59.3	2	90	0	6	65	70	2	15.5	7.50	84.6	171	R
SD1-M11	0	4	0	63	0	0	0	0	83.5	2	80	0	15	70	50	1	87.8	7.41	87.3	137	R
SD1-M12	0	1	0	9	7	0	0	0	83.8	2	90	0	61	80	45	4	13.7	7.30	94.5	103	R
SD1-M13	36	0	0	66	2	0.25	0	2	94.4	2	60	10	9	37.5	55	3	13.6		94.2	222	G
SD1-M14	64	0	4	97	6	0.5	0	0	70.8	1	20	20	2	25	17.5	3	16.5		61.1	226	G
SD1-M15	0	0	0	70	4	0	0	2	79.6	2	60	5	5	75	12.5	1	16	7.58	65	145	RG

Appendix 2. Environmental variables measured from 12 stream reaches in SWMACC, Clackamas County, Oregon in fall 2002.

Site Code	Reach Length (m)	Valley Type	Reach Gradient (%)	Wetted Width (m)	Bankfull Width (m)	Bankfull Height (m)	Mean Water Depth (cm)	% Riffles	% Pools	% Glides/Runs	Dominant Eros Material	Dominant Depositional Material	% Coarse Substrate	% Fine Gravel/Sand/Fines	% Sand/Fines
LT-M1	50	2	6	1.3	2.0	0.4	1.2	70.0	5.0	25.0	4	3	59	33	12
LT-M2	50	2	1.5	0.7	2.2	0.5	2.7	0.0	25.0	75.0	1	1	8	74	64
LT-M3	50	2	4	0.6	3.2	0.3	0.5	0.0	100.0	0.0	5	3	27	13	4
LT-M5	50	4	0.5	14.0	14.7	0.5	37.4	0.0	100.0	0.0	1	1	14	86	86
LT-M6	50	2	1	1.9	3.6	0.5	6.0	0.0	10.0	90.0	2	1	0	83	83
LT-M7	50	2	0.5	0.9	1.8	0.4	4.9	0.0	30.0	70.0	2	1	6	32	32
LT-M8	50	2	1.5	1.3	2.2	0.3	3.9	30.0	20.0	50.0	2	3	47	40	19
LT-M9	50	2	1.5	1.0	1.5	0.5	8.0	10.0	30.0	60.0	1	1	12	76	66
LT-M10	50	2	1.5	0.7	2.0	0.3	2.7	3.0	17.0	80.0	4	2	8	83	62
LT-M11	50	2	3.5	1.6	2.7	0.4	3.3	60.0	15.0	25.0	4	1	29	54	46
LT-M12	50	2	1.5	0.8	1.2	0.3	2.0	5.0	15.0	80.0	1	1	18	70	58
LT-M13	50	2	2	1.2	2.0	0.5	3.4	20.0	10.0	70.0	3	1	19	60	29

Appendix 2. (Continued).

Site Code	% Fines	% Bedrock	% Hard Pan	% Embeddedness	Large Wood Tally	Organic Layer Accumulation (cm)	% Filamentous Algae	% Macrophytes	Overhead Canopy Cover (%)	Dominant Bank Material	% Stable Bank	% Undercut Bank	Mean Riparian Buffer Width (m)	% Tree Cover	% NonNative Vegetation	Dominant Adjacent Land Use	Temperature (C)	Dissolved Oxygen (% sat)	Specific Conductance (µS/cm)	Macroinvertebrate Sample
LT-M1	6	0	1	49	4	1	0	0	90.2	2	10	10	18	50	47.5	1	13.1	76.6	83.2	R
LT-M2	48	0	14	96	8	0	0	0	90.4	2	20	5	11	52.5	57.5	2	12.2	86	169	G
LT-M3	0	60	0	56	1	0.5	0	0	96.9	2	25	50	23	55	35	3	12.8	23.5	129	G
LT-M5	86	0	0	100	0	2	0	80	44.3	2	80	0	3	32.5	25	3	15.5	7.1	263	G
LT-M6	9	0	3	97	11	1	0	0	71.9	2	30	20	27	50	22.5	1	14.4	75.3	186	G
LT-M7	11	0	57	97	7	1	0	0	95.9	2	40	5	3	60	22.5	1	12.7	70.2	140	G
LT-M8	4	0	3	68	2	0.25	0	0	98.2	2	40	20	42	70	27.5	1	14.3	80.3	157	R
LT-M9	42	0	4	94	0	0	0	0	100	2	0	25	13	55	40	1	14.4	69.6	185	G
LT-M10	9	0	1	88	2	0.5	0	0	86.4	2	60	10	8	25	25	1	13	80.9	218	G
LT-M11	27	6	0	71	6	0	0	0	88.9	2	30	3	8	50	50	1	12.1	81.2	134	R
LT-M12	31	0	0	77	4	0.5	0	0	92.6	2	50	15	4	57.5	3.75	1	15	40.5	90.9	G
LT-M13	0	0	0	84	5	0.5	0	0	98.5	2	20	10	22	70	62.5	1	14.3	79.8	239	RG

Appendix 3. Metrics calculated from macroinvertebrate communities sampled from glides in 16 streams in north Clackamas County (both CCSD#1 and SWMACC management areas), Oregon, fall 2002.

Site Code	Taxa Richness	EPT Richness	# Sensitive Taxa	% Tolerant Taxa	% Sediment Tolerant Taxa	Modified HBI	% Dominant	% Chironomidae	% Molluska	% Oligochaeta
					SWMACC					
LT-M2	27	4	0	0	27.0	6.3	31.8	11.8	39.9	18.4
LT-M3	19	0	0	0	52.4	7.0	33.2	59.2	16.0	14.8
LT-M5	9	0	1	0	2.6	7.8	91.1	7.5	91.1	0.8
LT-M6	21	2	1	0	73.7	6.8	67.0	10.0	79.7	3.1
LT-M7	22	3	0	0	9.1	5.1	38.7	65.5	9.6	5.2
LT-M9	26	8	1	0	15.4	4.5	25.0	15.4	5.1	4.0
LT-M10	25	8	2	0	51.0	5.4	47.9	10.9	8.2	0.6
LT-M12	30	6	2	0	31.7	5.7	22.2	34.3	6.1	22.2
LT-M13	27	4	1	0	7.9	4.0	27.9	72.6	4.0	6.5
					CCSD#1					
SD-M3	21	2	1	0	93.8	6.1	74.6	3.8	9.8	74.6
SD-M4	13	0	1	0	87.6	6.2	68.0	8.7	4.4	68.0
SD-M5	18	1	1	0	58.4	6.2	55.8	19.0	17.8	55.8
SD-M6	15	1	1	0	15.7	7.5	75.3	15.4	76.3	6.6
SD-M13	22	5	0	0	58.5	6.3	40.0	14.0	30.0	8.0
SD-M14	27	2	0	0	68.4	6.7	32.1	23.8	8.3	32.1
SD-M15	16	2	2	0	60.4	6.3	32.8	27.2	6.8	32.8

Appendix 4. Metrics calculated from macroinvertebrate communities sampled from riffles in 15 streams in north Clackamas County (both CCSD#1 and SWMACC management areas), Oregon, fall 2002.

Site Code	Taxa Richness	Mayfly Richness	Stonefly Richness	Caddisfly Richness	# Sensitive Taxa	# Sediment Sensitive Taxa	Modified HBI	% Tolerant Taxa	% Sediment Tolerant Taxa	% Dominant (1 taxon)
SWMACC										
LT-M1	32	3	5	5	3	2	5.4	19.6	7.1	22.5
LT-M8	27	3	3	2	1	0	5.8	41.8	41.2	23.2
LT-M11	30	2	3	3	0	0	5.0	16.3	11.0	21.2
LT-M13	22	2	3	0	1	0	5.5	44.8	45.7	40.3
CCSD#1										
SD-M1	22	3	1	3	0	0	5.6	38.0	13.1	23.5
SD-M2	18	2	0	1	0	0	6.8	33.6	8.5	56.0
SD-M3	18	2	0	1	0	0	6.3	32.4	16.0	34.7
SD-M5	12	1	0	0	0	0	5.9	32.0	24.0	28.0
SD-M6	17	1	0	1	0	0	6.5	37.3	28.2	30.7
SD-M7	26	4	2	2	1	0	5.2	19.4	21.9	17.1
SD-M8	19	1	0	0	0	0	4.8	3.3	1.4	37.4
SD-M10	21	3	4	1	1	0	4.8	17.2	12.3	28.2
SD-M11	29	3	3	2	1	0	5.0	54.9	4.9	27.4
SD-M12	31	6	5	6	1	2	4.2	49.5	7.1	23.7
SD-M15	22	2	0	1	0	0	6.5	35.8	30.8	30.0