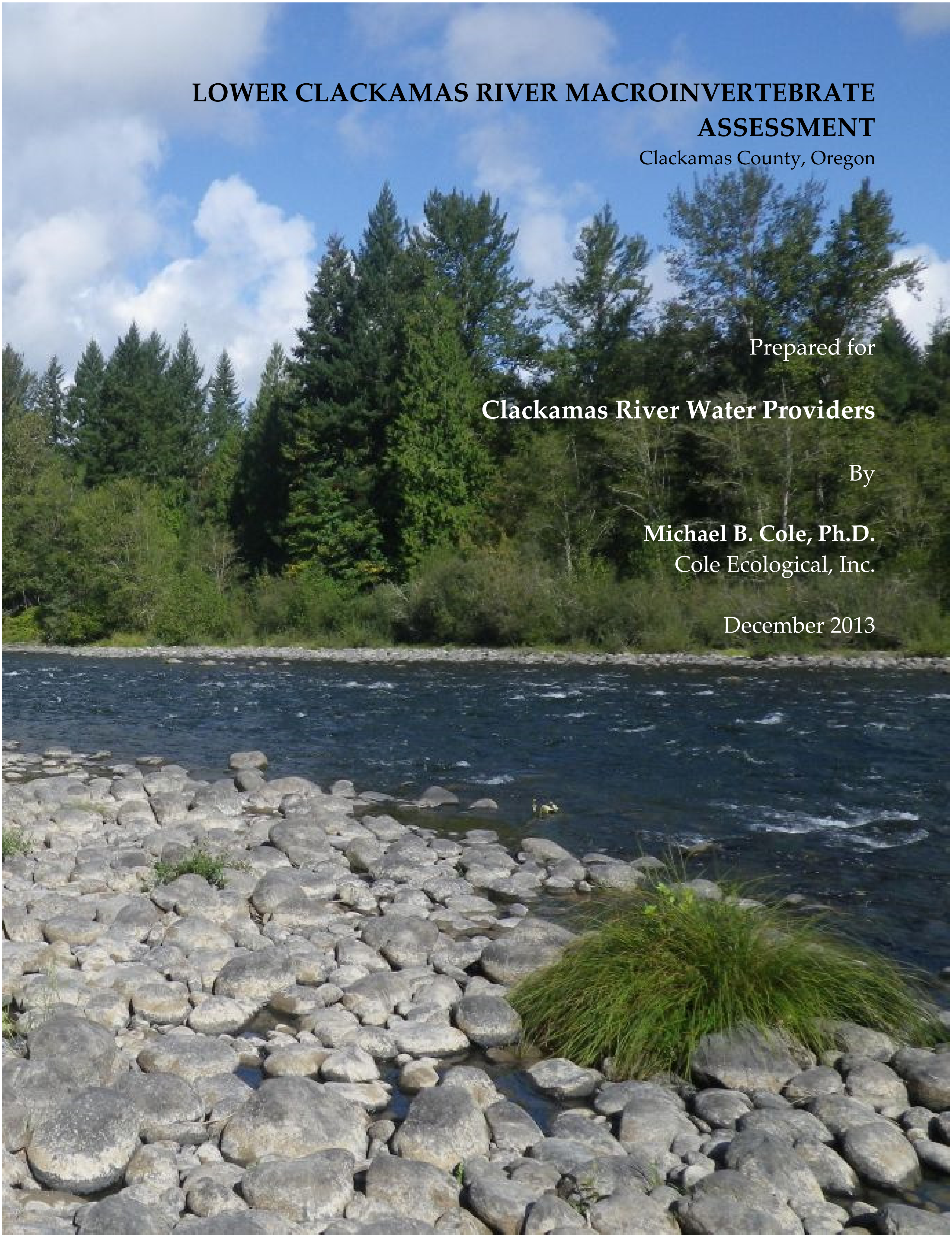

LOWER CLACKAMAS RIVER MACROINVERTEBRATE ASSESSMENT

Clackamas County, Oregon

Prepared for

Clackamas River Water Providers

By

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EXECUTIVE SUMMARY

In recognizing the value of bio-monitoring for informing water quality conditions and trends, CRWP developed a long-term macroinvertebrate monitoring plan for the lower Clackamas River and its tributaries (Cole 2013). This plan calls for sampling from the lower mainstem Clackamas River and its major tributaries once every year or two; these efforts will produce a robust dataset necessary to identify changes in biological conditions when they occur. Because the lower mainstem Clackamas River is the primary focus of CRWP's monitoring, the plan recommended sampling the mainstem river in the first year of monitoring. This report describes the methods, results, and conclusions for this first year of monitoring macroinvertebrate communities on the lower mainstem of the Clackamas River.

Macroinvertebrates were sampled from six sites in the lower Clackamas River between river miles 0.5 and 25 on September 17 and 18, 2013. Sites were selected to bracket the four drinking water points of diversion between river miles 0.8 and 3.1, the Deep Creek subwatershed, and the cumulative impacts of the Estacada WWTP and River Mill Dam.

Benthic macroinvertebrate community conditions in the lower Clackamas River are generally similar between river miles 0 and 22. DEQ macroinvertebrate multimetric scores indicated similar community conditions among reaches, as mean total multimetric scores ranged only between 28 and 32 on a scale of 10 to 50. Site pairs CLKRM0.5-CLKRM5, CLKRM11-CLKRM13.5, and CLKRM20-CLKRM25 serve as upstream-downstream pairs to detect changes in ecological conditions within each interceding length of river. Each of these site pairs exhibited similar mean total scores. Among all ten individual DEQ metrics, only stonefly richness showed any evidence of longitudinal trends, and even this trend was subtle. Metrics used by PGE in their 2000 study of the Clackamas River and selected for inclusion in this study suggested generally similar conditions among reaches and did not indicate strong longitudinal trends in any attributes examined. The Community Tolerance Index (CTI) was remarkably similar among sites, ranging only from 6.0 to 6.7 on a scale of 0 to 10. Total richness showed more variation among sites than most other metrics, ranging from 34 to 42, but in no particular order in relation to upriver-downriver location. Furthermore, these conditions are similar to those reported by others in 1999, 2000, and 2003.

These data provide an initial baseline for lower Clackamas River macroinvertebrate community conditions. Repeated annual or biannual replicated sampling in the mainstem is recommended to further characterize spatial variability and assess temporal variability under different climatic and flow conditions. Such information will be necessary to reliably detect changes or trends when they occur.

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INTRODUCTION

The lower Clackamas River is a valuable ecological and economic resource to the communities of Clackamas County, providing drinking water; fishing, boating and other recreation; and hydro-power. Numerous local, state, and federal agencies monitor the river and its many tributaries to track water quality conditions necessary to support these beneficial uses. The Clackamas River Water Providers (CRWP) is a coalition of municipal water providers that receives drinking water from the Clackamas River. CRWP receives water from the lower Clackamas River at five points of diversion (POD) at river miles 0.8, 1.7, 2.7, 3.1, and 22.7. CRWP is working to ensure that the river and its tributaries are monitored to adequately assess and protect water quality.

Biological monitoring of rivers and streams is widely recognized as an effective tool for measuring and monitoring overall ecological integrity of these systems. Macroinvertebrate communities lend particularly well to bio-monitoring because they are diverse, they range widely in sensitivity to water pollution and other perturbations, and they are easy to collect. Macroinvertebrate communities simultaneously integrate the effects of multiple stressors and therefore provide an index of the aggregate effects of all pollutants and other stressors in a system. For these reasons, macroinvertebrate assessment and monitoring is widely used by water resource management agencies for assessing the condition of rivers and streams.

In the lower Clackamas River basin, macroinvertebrate assessments have been performed at various spatial scales by numerous agencies and entities, including PGE, Clackamas Water Environment Services, the University of Washington, the United States Geological Survey, and Portland METRO, among others (Cole 2013). Owing chiefly to differing geographic foci and a lack of coordination among entities, each of these efforts have gone on largely independently of the others, resulting in a paucity of reliable long-term data that might inform trending of these conditions in the Clackamas River or its tributaries (Cole 2013).

In recognizing the value of bio-monitoring for informing water quality conditions and trends, CRWP developed a long-term macroinvertebrate monitoring plan for the lower Clackamas River and its tributaries (Cole 2013). This plan calls for sampling from the lower mainstem Clackamas River and its major tributaries once every year or two; these efforts will produce a robust dataset necessary to identify changes in biological conditions when they occur. Because the lower mainstem Clackamas River is the primary focus of CRWP's monitoring, the plan recommended sampling the mainstem river in the first year of monitoring. This report describes the methods, results, and conclusions for this first year of monitoring macroinvertebrate communities on the lower mainstem of the Clackamas River.

METHODS

SAMPLE SITE SELECTION

Five drinking water points-of-diversion (POD) are located along the lower Clackamas River (including one immediately upriver of the River Mill Dam) at river miles 0.8, RM 1.7, RM 2.7, RM 3.1, RM 22.7. Furthermore, a single WWTP discharges directly into the Clackamas River immediately upriver of the River Mill Dam. To the extent possible, stations on the mainstem Clackamas River were selected to assess water quality immediately upriver of PODs and bracketing WWTPs. Accordingly, a single site (CLKRM25) was established upriver of both the Estacada WWTP and Estacada POD to assess ecological conditions of river upon entry into the lower river. This site was located approximately 2¾ miles upriver from River Mill Dam, immediately upriver of the section of river impounded by the dam (Figure 1 and Table 1). Because the Estacada WWTP discharge and POD intake occur along the reach impounded by River Mill Dam, the downriver location bracketing the Estacada WWTP was necessarily located below the dam (CLKRM20). As such this sample site below the River Mill Dam could only serve to monitor the aggregate (and un-separable) effects of the dam and the WWTP on the ecology of the river.

Deep Creek enters the Clackamas River at RM 11.6, approximately midway between River Mill Dam and the uppermost of the series of 4 drinking water PODs in the lower 3.1 miles of river. Because Deep Creek carries treated effluent from the Boring WWTP (via North Fork Deep Creek) and seasonally from the Sandy WWTP (via Tickle Creek), two sample sites (upriver: CLKRM13.5 and downriver: CLKRM11) were established on the river to bracket this large tributary system.

Rock Creek enters the Clackamas River at RM 6.4. A sample site was established on the river below the confluence with Rock Creek (CLKRM5) to monitor ecological conditions directly upriver of the POD at RM 3.1. The lower-most sample site was located at river mile 0.5 (CLKRM0.5), below the series of 4 PODs to monitor water quality flowing through this 2.6-mile-long section of river. This site serves to inform ecological conditions within this 2.6-mile-long section of river, along which water is being withdrawn for municipal use.

These sites were also selected because macroinvertebrates have been sampled using standardized field and laboratory methods from or nearby (within ½ mile) each of these sites in the past (Table 1), providing some historic baseline of past conditions. The USGS sampled from CLKRM0.5 and CLKRM20 in 1999. PGE sampled in close proximity to CLKRM11 and at CLKRM13.5 and CLKRM25 in 2000 (PGE 2004), and Metro sampled close to CLKRM5, CLKRM11, and CLKRM13.5 in 2003. Comparisons of the results of this study to those from these past studies are included in this report.

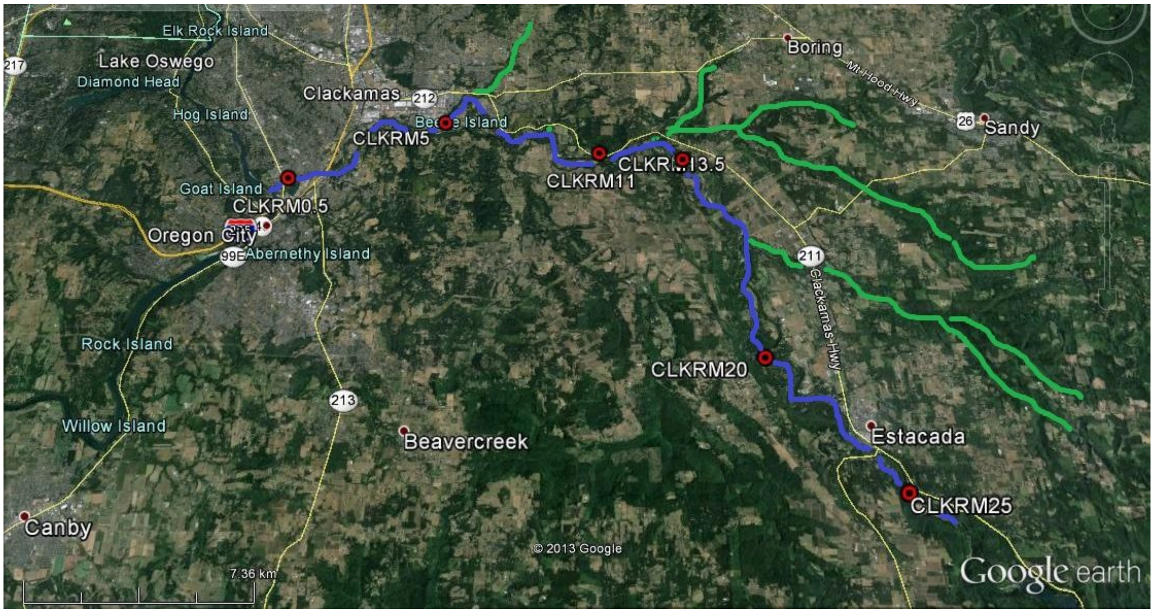

Figure 1. 2013 lower Clackamas River macroinvertebrate sample sites.

FIELD DATA COLLECTION

Macroinvertebrates were sampled from these six sites on the lower Clackamas River on September 17 and 18, 2013. Macroinvertebrate sample collection, physical habitat assessment, and water quality sampling were performed using as described below.

Physical Habitat Assessment

Owing to the large size and non-wadeable character of the Clackamas River reaches, a visual-estimate-based Rapid Habitat Assessment was used to semi-quantitatively characterize physical habitat at these reaches. Habitat surveys were limited to a visual habitat assessment of the observable extent of the river form the macroinvertebrate sampling location. A standard Rapid Habitat Assessment Form was used for this assessment (USEPA 2000).

Additionally, substrate in the immediate area from which macroinvertebrate samples was visually estimated to semi-quantitatively characterize percent composition of boulders, cobbles, gravels, and sand/fines, as well as embeddedness of coarse substrates. Furthermore, the range of depths from which samples were collected in riffle habitats was recorded for each site.

Water Chemistry Sampling

Water chemistry parameters including temperature (°C), dissolved oxygen (DO) saturation (percent), dissolved oxygen concentration (mg/L), conductivity (µS/cm), and specific conductance (µS/cm) were measured at each reach. Water temperature, dissolved oxygen, conductivity, and specific conductance were measured in situ with a multi-parameter YSI Model 85 water chemistry meter, calibrated for DO on a daily basis.

Table 1. List of macroinvertebrates sample sites in the Clackamas River, Oregon, September 2013.

Site Code	Location	Lat	Long	Elev (m)	Purpose	Historic Sites in Close Proximity
CLKRM0.5	200 m US McLaughlin Blvd Bridge	45.3746316	-122.59901	4	Monitor WQ immed downriver of PODs	USGS @ Gladstone nr mouth (1999)
CLKRM5	East side of Sah-Hah-Lee Golf Course	45.395961	-122.5252	20	Monitor WQ immed upriver of PODS	Metro Site 55 (2003)
CLKRM11	0.5 miles US 197th Ave	45.384545	-122.44883	37	DS bracket for Deep Creek system (1.1 mi DS)	Metro Site 52 (2003) and PGE site 11.2 (2000)
CLKRM13.5	Barton Park	45.379247	-122.41082	48	US bracket for Deep Creek system (1.25 mi US)	Metro Site 53 (2003) and PGE site 13.5 (2000)
CLKRM20	Milo McIver State Park	45.31087	-122.37666	79	DS bracket Estacada WWTP and River Mill Dam	USGS McIver Pk (1999)
CLKRM25	below Faraday power house	45.268835	-122.32079	119	Monitor WQ entering lower mainstem	PGE Faraday tailrace (2000)

Macroinvertebrate Sample Collection

Macroinvertebrates were collected using the Oregon Department of Environmental Quality's (DEQ) Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams (DEQ 2003). Duplicate 8-kick composite samples were collected from shallow riffle habitat (15-40 cm deep) at each sampling station. Macroinvertebrates were collected with a D-frame kicknet (30 cm wide, 500 µm mesh opening) from a 30 x 30 cm (1 x 1 ft) area at each sampling point. Larger pieces of substrate, when encountered, 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 ~10 cm. The eight samples from the reach were composited and carefully washed through a 500 µm sieve to strain fine sediment and hand remove larger substrate and leaves after inspection for clinging macroinvertebrates. The composite sample was placed into one or more 1-L polyethylene wide-mouth bottles, labeled, and preserved with 80% denatured ethanol for later sorting and identification at the laboratory.

SAMPLE SORTING AND MACROINVERTEBRATE IDENTIFICATION

Samples were sorted to remove a 500-organism subsample from each preserved following the procedures described in the DEQ Level 3 protocols (Water Quality Interagency Workgroup [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 transferred to a Petri dish, which was examined under a dissecting microscope at 7–10X magnification 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 generally identified to the level of taxonomic resolution recommended for Level 3 macroinvertebrate assessments by the Northwest Biological Assessment Working Group (NBAWG 2002).

DATA ANALYSIS

A number of standardized analytical approaches exist for assessing the condition of macroinvertebrate communities in Oregon. These approaches can be broadly classified as multimetric indexes and predictive models. Multimetric analysis employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that has been shown to be responsive to environmental condition gradients. 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 an index of overall biological integrity. Multimetric index scores are converted to condition classes corresponding to specific bins of scores. The DEQ Level 3 multimetric assessment utilizes a 10-metric set that includes six positive metrics that score higher with improved biological conditions, and four negative metrics that score lower with improved conditions (Table 2). 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 reach. Values of the index range from 1 to 10; higher scores are interpreted as an indication of a macroinvertebrate community more tolerant to fluctuations in water temperature, fine sediment inputs, and organic enrichment. 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. Taxa in the dataset are assigned attribute codes and values using the most recent version of DEQ's taxa coding (DEQ, unpublished information).

Predictive models evaluate macroinvertebrate community conditions based on a comparison of observed (O) to expected (E) taxa (Hawkins et al. 2000, Hubler 2008). The observed taxa are those that occurred at the site, whereas the expected taxa are those commonly occurring (>50% probability of occurrence) at reference sites. Biological condition is determined by comparing the O/E score to the distribution of reference reach O/E scores in the model. Predictive models used in Oregon are collectively known as PREDATOR models. Three regional PREDATOR models are currently in use in Oregon (Hubler 2008).

Table 2. Metric set and scoring criteria (WQIW 1999) used to assess condition of macroinvertebrate communities in the Clackamas River, Oregon, fall 2013.

	Scoring Criteria		
Metric	**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

Neither the multimetric index nor the PREDICTIVE models have been developed for use on large rivers such as the lower Clackamas, a consequence of larger rivers in the region having been uniformly affected by human impacts, precluding the development of either reference conditions or biological condition gradients relative to environmental gradients. Use of PREDATOR was not considered for use in the mainstem Clackamas River because the model's accuracy and relevance is based on similarity of taxonomic composition of the benthic invertebrate assemblage between test site and reference conditions, while the benthic community composition of the Clackamas River would be expected to naturally differ from that of the smaller rivers and streams used to calibrate the model to reference conditions.

The DEQ multimetric set was used in this study to assess macroinvertebrate community conditions in the lower Clackamas River; however, the analysis focused on graphically examining individual metrics and the total multi-metric score for overall longitudinal trends in macroinvertebrate community conditions in the river and for obvious deviations from trends or ranges in values among sample sites. Un-standardized metric scores were used in the data analyses; standardized metric scores were calculated only to produce a composite multi-metric score for each sample. Condition classes were not assigned to sample sites for reasons cited earlier. As duplicate samples were collected from each site in this first year of sampling, site means and standard deviations were calculated to assist with interpretation of data and inferring differences and trends among sites. Because DEQ historically performed this multimetric analysis using Chironomidae data left at subfamily/tribe levels of taxonomic resolution, these metrics were calculated with this family backed up to these higher taxonomic levels to allow direct comparison with results of a 2003 assessment of the lower Clackamas River.

This assessment of the mainstem Clackamas River also warranted further analyses by which a number of additional individual metrics were examined. Metrics selected consisted of those used by PGE in a 2000-2001 study of the mainstem Clackamas River and selected major tributaries (Table 3, PGE 2004). A complete explanation of these metrics can be found in PGE's 2004 repot. Source coding for calculating these metrics was provided by Bob Wisseman of Aquatic Biology Associates (B. Wisseman, personal communication). Chironomidae were identified to genus or species group levels for these analyses. These metrics were analyzed in the same manner as described above for the DEQ metric set.

RESULTS

Streamflows during sampling (September 17 and 18, 2013) were at seasonal baseflows, as determined from data obtained from USGS gage station 14211010 on the Clackamas River near Oregon City. Streamflow at this station on both days was approximately 900 cfs (http://wdr.water.usgs.gov/wy2012/pdfs/14211010.2012.pdf). Rapid habitat scores from the six sites ranged narrowly from 155 to 183 (on scale of 10 to 200), indicating generally similar habitat conditions with respect to sediment deposition, substrate composition, riparian condition, and habitat complexity across the six sites (Table 4). Substrate conditions were also similar among the six sites, as riffle bed materials were uniformly dominated by cobble substrate (Table 4 and Figure 2). Substrates were secondarily dominated by coarse gravels at all sites other than CLKRM20, located approximately 2.5 miles downriver from River Mill Dam. This section of river, depleted of smaller substrates as a result of the upriver impoundment, was secondarily dominated by boulders (Table 4 and Figure 2).

Water chemistry, based on limited instantaneous sampling of only a few parameters, was also similar among the six reaches. Dissolved oxygen concentrations approached or were at complete saturation, and specific conductance ranged between 52 and 60 µS/cm across all sites (Table 4 and Figure 2).

DEQ macroinvertebrate multimetric scores indicated similar community conditions among reaches, as mean total MMS scores ranged only between 28 and 32 on a scale of 10 to 50 (Table 5 and Figure 3). Site pairs CLKRM0.5-CLKRM5, CLKRM11-CLKRM13.5, and CLKRM20-CLKRM25 serve as upstream-downstream pairs to detect changes in ecological conditions within each interceding length of river. Each of these site pairs exhibited similar mean total scores. Mean MMS scores showed the largest

Table 3. Supplemental metric set used to further assess the condition of macroinvertebrate communities in the Clackamas River, Oregon, fall 2013 (source: PGE 2004).

PGE Study Metric	Metric Description
Total Richness	Total number of benthic macroinvertebrate taxa identified in the sample
EPT Richness	Number of taxa identified in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
Community Tolerance Index (CTI)	A weighted average of the combined tolerance of the community to environmental stress (primarily warm water, low dissolved oxygen, and nutrient enrichment)
Percent Dominance (by three most abundant taxa)	Combined relative abundance (%) of the three most numerous taxa in the sample
Percent Intolerant Individuals	Relative abundance of the most intolerant taxa identified in the sample (CTI scores 0-3)
Percent Tolerant Individuals	Relative abundance of the most tolerant taxa identified in the sample (CTI scores 7-10)
Intolerant Taxa Richness	Number of taxa that typically occur in cool, well-oxygenated, nutrient-limited waters
Tolerant Taxa Richness	Number of taxa that typically occur in warmer, poorly-oxygenated, nutrient-rich waters
Percent Collector-Filterers	Relative abundance (%) of macroinvertebrates belonging to the collector-filterer feeding group
Percent Collector-Gatherers	Relative abundance (%) of macroinvertebrates belonging to the collector-gatherer feeding group
Percent Shredders	Relative abundance (%) of macroinvertebrates belonging to the shredder feeding group
Percent Predators	Relative abundance (%) of macroinvertebrates belonging to the predator feeding group
Percent Scrapers	Relative abundance (%) of macroinvertebrates belonging to the scraper feeding group

difference between CLKRM11 and CLKRM13.5, yet even these scores varied by a mere three MMS points: within the range of variation at times exhibited by duplicate samples within a single sample site. Total MMS scores suggest that no strong longitudinal trends in community condition are occurring among these 25 miles of river (excepting unmeasured conditions within the section impounded by the River Mill Dam). MMS scores in this study were generally similar to those measured in 2003 by Metro (Cole

Table 4. Water quality and physical habitat conditions measured from six macroinvertebrate sample sites in the Clackamas River, Oregon, September 2013.

Side Code	CLKRM0.5	CLKRM5	CLKRM11	CLKRM13.5	CLKRM20	CLKRM25
Date	9/17/2013	9/17/2013	9/17/2013	9/18/2013	9/18/2013	9/18/2013
Water Quality						
WQ Time	1035	1235	1345	850	1045	1325
DO (% Sat)	94.2	100.8	101	98.9	100.9	101.5
DO (mg/L)	9.18	10.01	10.15	9.96	9.98	10.1
Cond (µS/cm)	54.1	55.3	54.6	47.1	53.6	53.1
Spec Con (µS/cm)	59.8	60.1	59.1	52	58.7	58.4
Temp (^{o}C)	16.5	16.5	17	15.2	16	15.5
Substrate in Area Sampled						
Sand	2	2	0	2	0	2
Fine Gravel	5	5	5	5	5	5
Coarse Gravel	30	10	15	25	10	20
Cobble	65	80	70	60	60	60
Boulder	0	5	10	10	25	10
Embeddedness	10	10	5	5	5	5
Sample Depth (cm)	15-30	15-30	20-40	20-40	25-40	25-40
Rapid Habitat Assessment (RHA) Scores						
Epifaunal Substrate/Cover	16	17	17	18	18	18
Embeddedness	18	18	18	18	20	19
Velocity/Depth Regimes	18	18	18	18	18	17
Sediment Deposition	18	18	18	18	20	18
Channel Flow Status	18	18	18	17	18	18
Channel Alteration	18	18	18	18	18	10
Frequency/Quality of Riffles	13	14	17	16	17	13
Bank Stability	14	15	15	15	18	17
Protective Vegetation	12	14	16	17	18	18
Riparian Zone Width	10	12	15	18	18	20
RHA Total Score	155	162	170	173	183	168

2004). 2013 MMS scores differed from 2003 scores at CLKRM11 by three points and at CLKRM13.5 by only one point. MMS scores differed by a wider margin from 2013-2003 at CLKRM5, as the score increased from 24 to 32 in the ten-year period. However, without additional data points, whether this difference results from real improvement in benthic condition or from other sources of variability (climatic and flow conditions, sampling error, etc.) will remain unknown.

Individual DEQ metrics showed more variation among sites, and patterns were inconsistent among metrics (Table 5 and Figure 3 and 4), lending support to results of the MMS scores that macroinvertebrate community conditions did not vary significantly among sites. Among all ten DEQ metrics, only stonefly richness showed any evidence of longitudinal trends, and even this trend was subtle (Figure 3)

Additional metrics used by PGE (PGE 2004) and selected for inclusion in this study suggested generally similar conditions among reaches and did not indicate strong longitudinal trends in any attributes examined. The Community Tolerance Index (CTI; Table 3) was remarkably similar among sites, ranging only from 6.0 to 6.7 on a scale of 0 to 10. Total richness showed more variation among sites than most other metrics, ranging from 34 to 42, but in no particular order in relation to upriver-downriver location. The "Number of Tolerant Taxa" metric (Table 3) included in the additional metric data set indicated that much of this variation in total taxa richness among sites is attributed to the number of tolerant taxa occurring at a site (Table 5 and Figure 5). Excluding these tolerant taxa, mean taxa richness ranged between 22.5 and 28 among all six sites.

Collecter-gathering and collector-filtering organisms (Table 3) dominated benthic communities across all sites (Figure 6). Both metrics exhibited moderate variation among sites, suggesting that these metrics may not be as suitable as some others for detecting changes in benthic community conditions in the river. Percent scraper organisms exhibited a subtle trend in increasing relative abundance from upriver to downriver, while percent predator and percent shredder values were generally similar among sites.

Among the six sites, benthic community conditions differed most markedly at the uppermost site, CLKRM25, immediately below PGE's Faraday Powerhouse. Figures 3 through 6 indicate that a number of metric values at this site occur outside the range of values expressed among the other sites. Examples include EPT richness, percent dominance, percent tolerant individuals, and percent sediment tolerant individuals. Total macroinvertebrate densities were also notably lower in this reach than in the others, as densities ranged between 4167 and 6185 individuals/m2 among the five reaches spanning river miles 0.5 to 19.6, yet were only 632 individuals/m2 at river mile 25 below the Faraday power house.

These additional metrics calculated in this study were generally similar to those measured in 1999 and 2000 at these same locales (Table 7). None of these 1999/2000 versus 2013 pairs show any differences that would not be expected to occur in duplicate samples simultaneously collected from the same location.

Table 5. Means and standard deviations of OR DEQ community metrics and total multi-metric scores calculated from duplicate macroinvertebrate samples collected from six sites along the lower Clackamas River, Oregon, in fall 2013. Metrics source: Oregon DEQ. Multimetric scores from the 2003 Metro study are included in the last row of the table for comparative purposes.

		CLKRM Sample Site					
DEQ Metric		**0.5**	**5**	**11**	**13.5**	**20**	**25**
Richness	Mean	31.5	39.0	34.5	29.5	33.0	29.0
	StDev	4.9	2.8	0.7	6.4	1.4	5.7
Mayfly Richness	Mean	8.5	11.5	9.0	7.0	8.5	7.0
	StDev	0.7	0.7	0.0	1.4	0.7	1.4
Stonefly Richness	Mean	1.5	1.0	1.5	3.0	2.0	3.0
	StDev	0.7	0.0	0.7	0.0	0.0	0.0
Caddisfly Richness	Mean	7.0	6.5	8.0	7.0	8.0	3.5
	StDev	1.4	0.7	0.0	1.4	1.4	0.7
Number Sensitive Taxa	Mean	0.5	0.0	0.5	1.5	0.0	0.5
	StDev	0.7	0.0	0.7	0.7	0.0	0.7
# Sediment Sensitive Taxa	Mean	1.5	1.0	1.5	0.0	1.5	0.0
	StDev	0.7	0.0	0.7	0.0	0.7	0.0
Modified HBI1	Mean	4.0	4.1	3.6	3.7	4.3	4.5
	StDev	0.2	0.0	0.1	0.1	0.1	0.1
% Tolerant Taxa	Mean	34.6	46.3	42.6	49.9	53.0	26.0
	StDev	10.0	1.0	4.3	1.2	6.9	11.1
% Sediment Tolerant Taxa	Mean	0.9	1.3	4.1	0.4	4.0	13.8
	StDev	0.8	1.0	3.4	0.5	2.1	8.8
% Dominant	Mean	23.8	19.1	27.5	23.0	27.7	16.4
	StDev	1.8	0.0	1.6	0.1	8.1	2.5
TOTAL SCORE	Mean	31.0	32.0	32.0	29.0	29.0	28.0
	StDev	1.4	0.0	0.0	1.4	4.2	0.0
Metro 2003 Total Score			24.0	28.0	28.0		

Table 6.Means and standard deviations of community metrics calculated from duplicate macroinvertebrate samples collected from six sites along the lower Clackamas River, Oregon, in fall 2013. Metrics source: PGE 2004.

		CLKRM Sample Site					
PGE Metric		**0.5**	**5**	**11**	**13.5**	**20**	**25**
Richness	Mean	36.0	45.0	40.0	34.0	40.5	38.5
	StDev	2.8	1.4	2.8	1.4	3.5	6.4
EPT Richness	Mean	17.0	19.0	18.5	17.0	18.5	13.5
	StDev	1.4	0.0	0.7	2.8	2.1	2.1
CTI	Mean	6.2	6.3	6.0	6.3	6.7	6.2
	StDev	0.2	0.1	0.0	0.0	0.1	0.1
Dom (3)	Mean	49.6	48.2	55.4	62.2	52.2	38.1
	StDev	0.8	1.1	5.6	0.5	8.7	1.1
Percent Intolerant	Mean	0.5	1.6	0.3	0.2	1.1	0.3
	StDev	0.4	0.9	0.1	0.0	1.5	0.4
Percent Tolerant	Mean	33.0	36.6	26.2	32.6	48.4	31.0
	StDev	6.8	2.7	3.6	0.1	3.0	8.2
Intolerant Richness	Mean	1.0	1.0	1.5	1.0	0.5	0.5
	StDev	0.0	0.0	0.7	0.0	0.7	0.7
Tolerant Richness	Mean	13.5	17.0	13.0	9.5	15.0	15.5
	StDev	2.1	1.4	1.4	0.7	2.8	2.1
% Collector-Filterer	Mean	27.4	34.7	25.8	35.8	41.1	17.8
	StDev	10.1	0.6	8.7	2.5	10.5	2.0
% Collector-Gatherer	Mean	40.3	29.9	21.7	17.5	24.2	50.1
	StDev	6.6	2.9	0.5	0.4	2.0	1.8
% Shredder	Mean	0.9	1.0	3.4	2.3	1.3	2.0
	StDev	0.3	0.2	1.4	0.1	0.4	1.1
% Predator	Mean	5.8	9.3	10.2	10.4	9.9	11.5
	StDev	2.1	1.9	0.9	2.7	1.2	0.6
% Scraper	Mean	20.1	19.1	15.4	9.6	14.3	8.9
	StDev	4.8	0.4	3.3	3.7	2.0	0.4

Table 7. Comparison of PGE metrics calculated from 2013 Clackamas River samples to samples collected in 1999 (USGS) and 2000 (PGE 2004) from the same locales. Source of 1999 and 2000 data: PGE 2004.

	CLKRM0.5		CLKRM11		CLKRM13.5		CLKRM20		CLKRM25	
Metric	**1999**	**2013**	**2000**	**2013**	**2000**	**2013**	**1999**	**2013**	**2000**	**2013**
Richness	27.0	36.0	36.0	40.0	31.0	34.0	35.0	40.5	45.0	38.5
EPT Richness	13.0	17.0	21.0	18.5	20.0	17.0	16.0	18.5	19.0	13.5
CTI	6.4	6.2	6.1	6.0	6.2	6.3	6.1	6.7	6.3	6.2
Dom (3)	66.0	49.6	51.0	55.4	79.0	62.2	77.0	52.2	62.0	38.1
Percent Intolerant	0.4	0.5	0.0	0.3	0.0	0.2	0.5	1.1	1.3	0.3
Percent Tolerant	41.3	33.0	22.0	26.2	18.0	32.6	10.0	48.4	37.0	31.0
Intolerant Richness	1.0	1.0	0.0	1.5	0.0	1.0	1.0	0.5	1.0	0.5
Tolerant Richness	9.0	13.5	11.0	13.0	8.0	9.5	8.0	15.0	14.0	15.5
% Collector-Filterer	47.0	27.4	26.0	25.8	42.0	35.8	50.2	41.1	19.0	17.8
% Collector-Gatherer	25.0	40.3	29.0	21.7	16.0	17.5	20.0	24.2	57.0	50.1
% Shredder	1.0	0.9	3.3	3.4	3.5	2.3	0.3	1.3	0.5	2.0
% Predator	11.2	5.8	11.0	10.2	16.0	10.4	21.0	9.9	8.3	11.5
% Scraper	15.0	20.1	25.0	15.4	21.0	9.6	6.0	14.3	4.0	8.9

DISCUSSION

Results of the 2013 lower Clackamas River macroinvertebrate assessment suggest that macroinvertebrate communities inhabiting shallow riffle habitat of the lower Clackamas River between river miles 0 and 22 presently exhibit little variation in community condition. These results generally suggest uniform ambient environmental conditions within this reach of river. Observations of physical habitat conditions and water quality measurements made during this study also suggest a lack of significant environmental gradients in the lower river that would be expected to exert a significant effect on benthic communities. PGE’s 2000 study of macroinvertebrate communities revealed that the most distinct changes in benthic community conditions occurred upriver of the mainstem impoundments where the river transitions from a mid-order montane stream to a larger, lower-gradient riverine environment (PGE 2004).

Habitat conditions at the uppermost site below the Faraday Powerhouse at river mile 25 differed from those observed elsewhere, particularly with respect to the extent of well-developed riffle habitat. This section of the river occurs at the upper end of the section impounded by River Mill Dam. Water fluctuations through this section of river result in regular changes in the extent of riffle habitat. Macroinvertebrate densities in this section of river were particularly low relative to other sections, a condition not unexpected given the highly variable habitat template occurring at this location. Accordingly, omitting this site from future monitoring for purposes of trending conditions in the lower river is recommended.

While a lack of available raw data precluded a complete comparison of all metrics between the present and past studies, comparison to 2003 DEQ multimetric scores at three sites and to 1999-2000 USGS/PGE individual metric scores at five sites suggested generally similar macroinvertebrate community conditions in the lower river over the past 10-14 years. The higher MMS score at CLKRM5 in 2013 than in 2003 is likely the result of variability introduced by sampling error and annual differences in climate, flows, etc. This difference between 2003 and 2013 scores at CLKRM5 underscores the need for more frequent monitoring to discern real trends or changes from other sources of variability.

The data collected in this study represent the most comprehensive baseline assessment of macroinvertebrate communities in the lower Clackamas River. Their utility will only be realized if monitoring efforts occur routinely, perhaps as frequently as every year or two. Importantly, any changes that occur in the benthic community are likely to manifest as one or more metrics falling out of phase from those from upriver reaches. Only through thorough characterization of temporal and spatial variability will such deviations be detected. Sampling at least biannually will allow for a more robust characterization and partitioning of variation in macroinvertebrate community conditions and in turn will allow for more reliable detection of changes or trends when they occur.

This study included metrics from two sources to provide an opportunity to compare the present data set with several historic data sets. Future monitoring could continue to utilize both metric sets, but sufficient redundancy between the two allows one to be dropped. Macroinvertebrate attribute coding used to derive the DEQ metrics is not as well researched or accurate as is the coding used to calculate the PGE source metrics. As such, continued use of the PGE metrics is recommended. Furthermore, while this study utilized a core set of 13 metrics included in the PGE study, additional metrics could be assessed for their use in discerning patterns, changes, and trends following the collection of additional years of data and further characterization of variability of each metric. Also, Wisseman includes an example Benthic Index of Biotic Integrity (B-IBI) in the 2004 PGE report that could be used to provide a single multi-metric index score for the lower river that is more relevant to large rivers than is the DEQ multimetric index (PGE 2004). As such, the following set of core metrics is recommended for continued monitoring of benthic macroinvertebrate communities in the lower Clackamas River:

- Total Richness
- EPT Richness
- Community Tolerance Index (CTI)

- Percent Tolerant Individuals (and total abundance)
- Tolerant Taxa Richness
- Total B-IBI Score
- OR DEQ Multimetric Index (no need to report individual metric scores)

Among these metrics, those showing the smallest variance among sites and years will likely hold the most promise for detection of changes in benthic community conditions when they occur. These presently include total richness, EPT richness, CTI, and total MMS scores. As each of these metrics is also known to be responsive to various physical and chemical perturbations, these are likely to yield relatively favorable signal-to-noise ratios in response to community change in the face of stress.

Other metrics worth examining upon amassing a larger data set include percent long-lived individuals, number of long-lived taxa, abundance of long-lived individuals, abundance of short-lived individuals, and further exploration of various functional feeding group metrics. Other metrics such as the number of intolerant taxa or abundance of intolerant organisms have little relevance to monitoring in the lower river because such taxa are already scarce in the lower Clackamas.

CONCLUSIONS & RECOMMENDATIONS

- Benthic macroinvertebrate community conditions in the lower Clackamas River are generally similar between river miles 0 and 22. Furthermore, these conditions are similar to those reported by others in 1999, 2000, and 2003. While the lack of a standard or reference condition for larger rivers in the region precludes an assignment of a condition class to these results, the presence of numerous EPT taxa is suggestive of water quality and habitat conditions generally suitable for maintenance of diverse native aquatic communities.

- These data provide an initial baseline for lower Clackamas River macroinvertebrate community conditions. Repeated annual or biannual replicated sampling in the mainstem is recommended to further characterize spatial variability and assess temporal variability under different climatic and flow conditions. Such information will be necessary to reliably detect changes or trends when they occur.

- Future changes to lower Clackamas River macroinvertebrate sampling for this study include omitting the Faraday Powerhouse location. A substitute location for this upriver-most location in the lower river is currently deemed unnecessary.

- Continue testing metrics for trends and characterization of variability as additional data are amassed. Refine metrics used to track and trend river conditions based on these findings.

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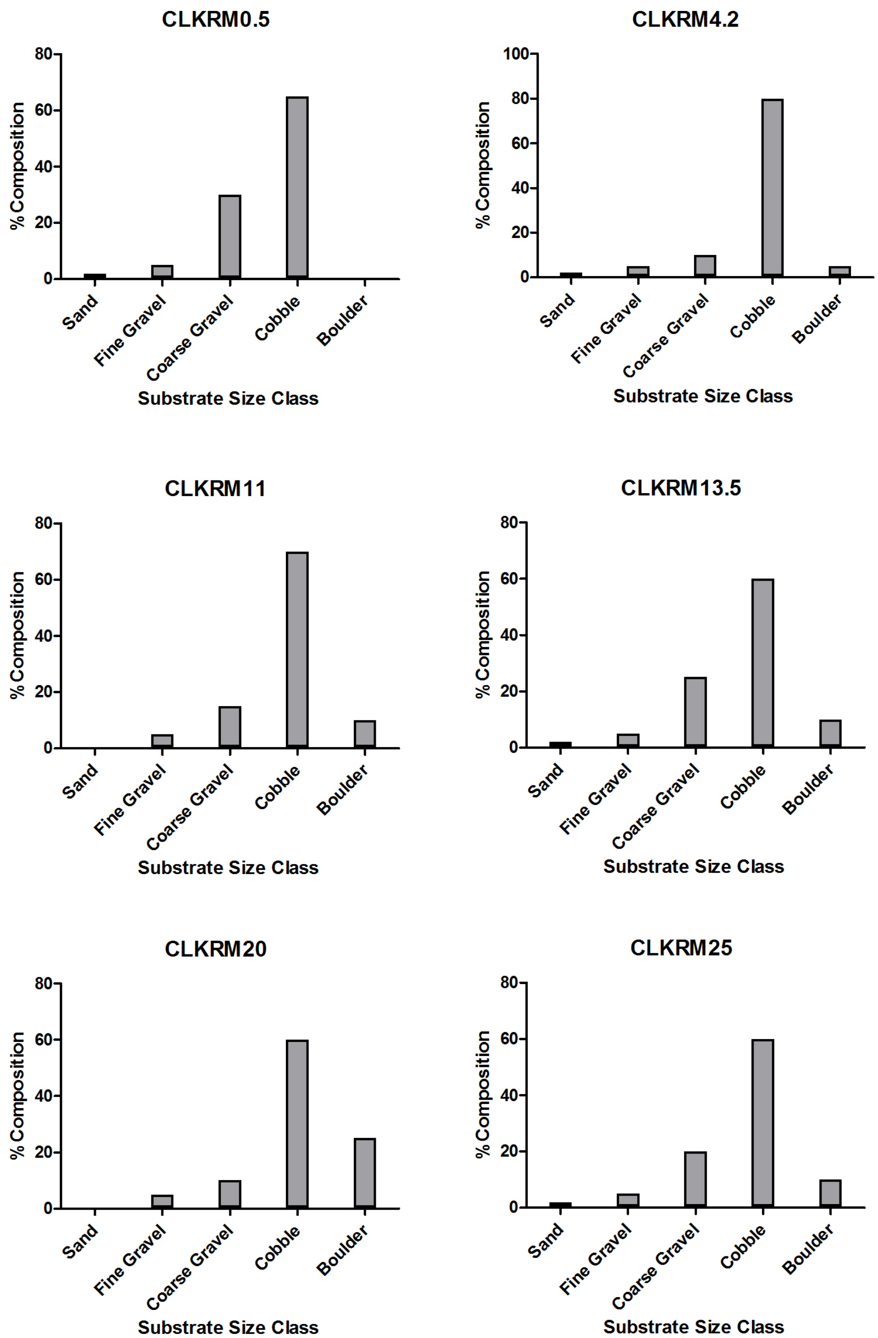

Figure 2. Substrate composition at six Clackamas River macroinvertebrate samples sites, September 2013.

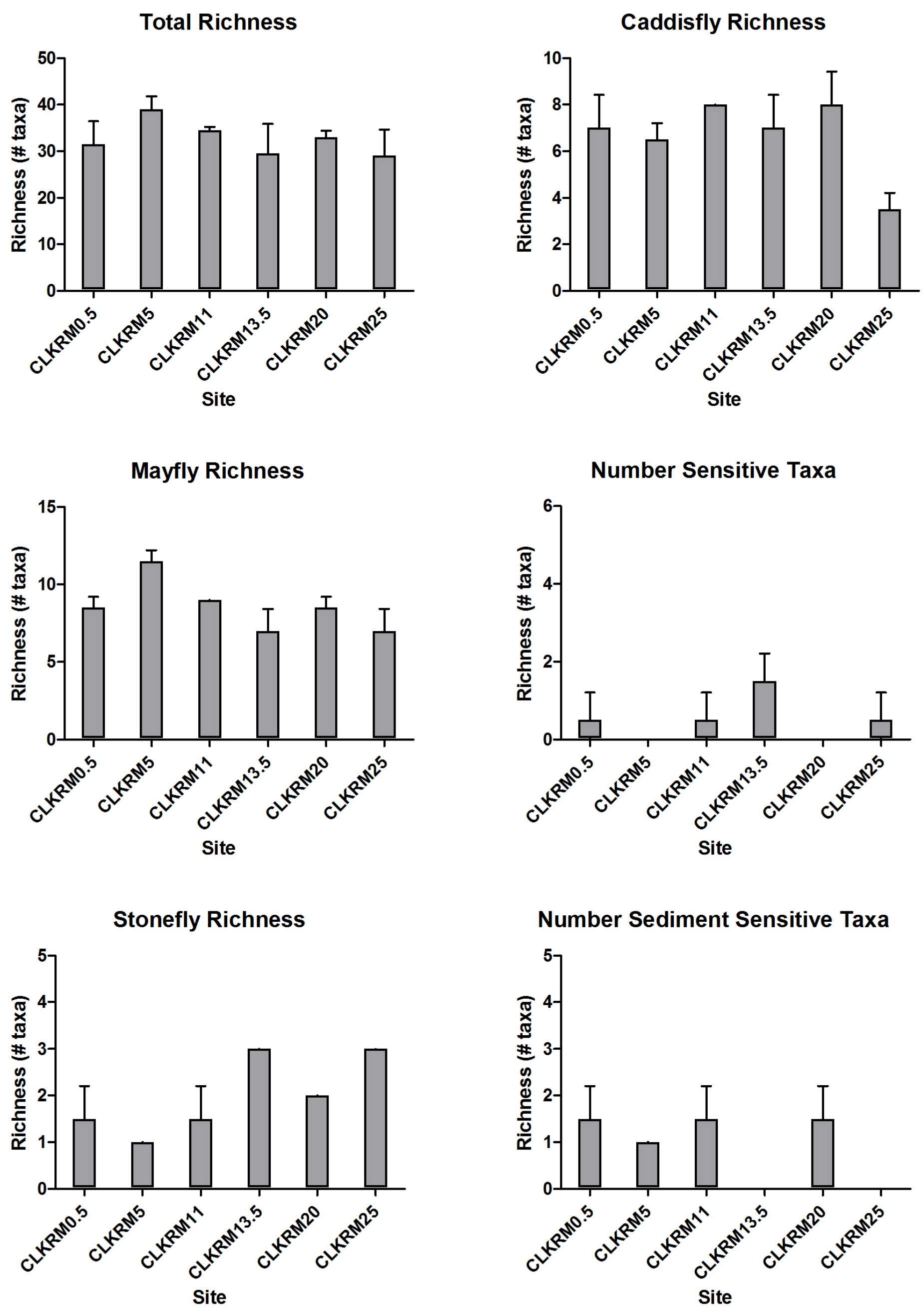

Figure 3. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013.

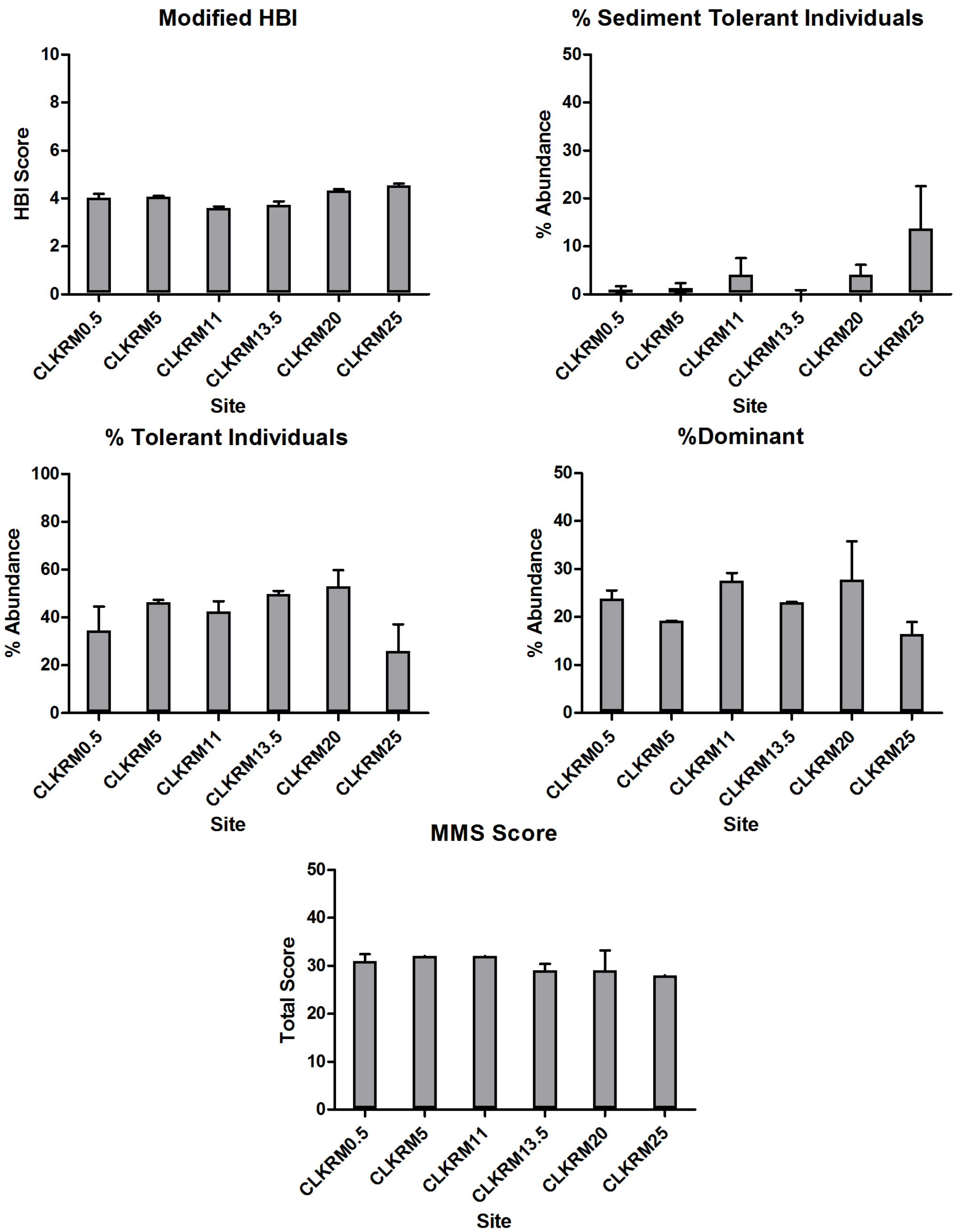

Figure 4. Mean (+SD) macroinvertebrate community metric scores and total multimetric scores (MMS) calculated from duplicate samples collected from the lower Clackamas River in September 2013.

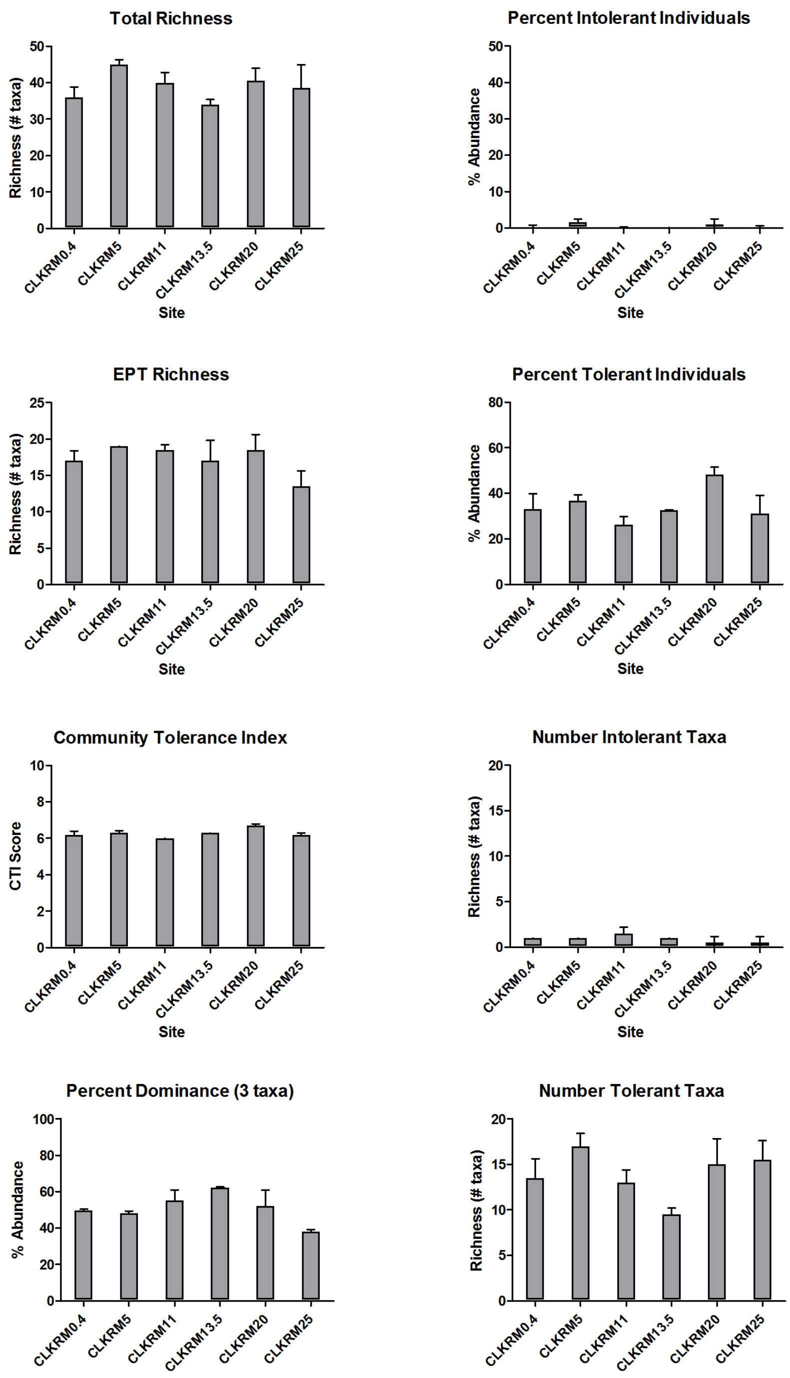

Figure 5. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013. Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

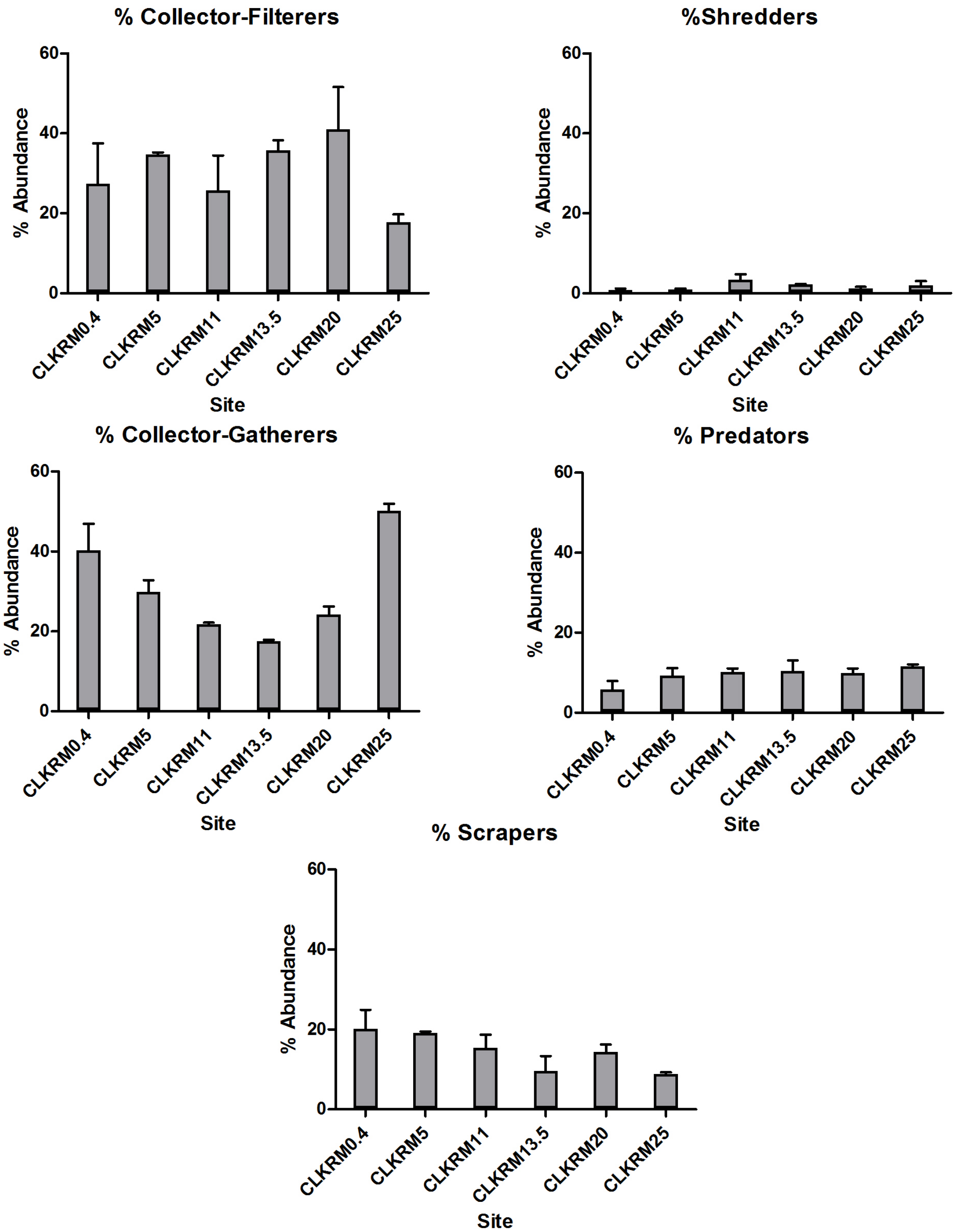

Figure 6. Mean (+SD) abundance of macroinvertebrate functional feeding groups calculated from duplicate samples collected from the lower Clackamas River in September 2013. Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

APPENDIX A.

Location maps and site photos

CLKRM0.5

CLKRM5

CLKRM11

CLKRM13.5

CLKRM20

CLKRM25