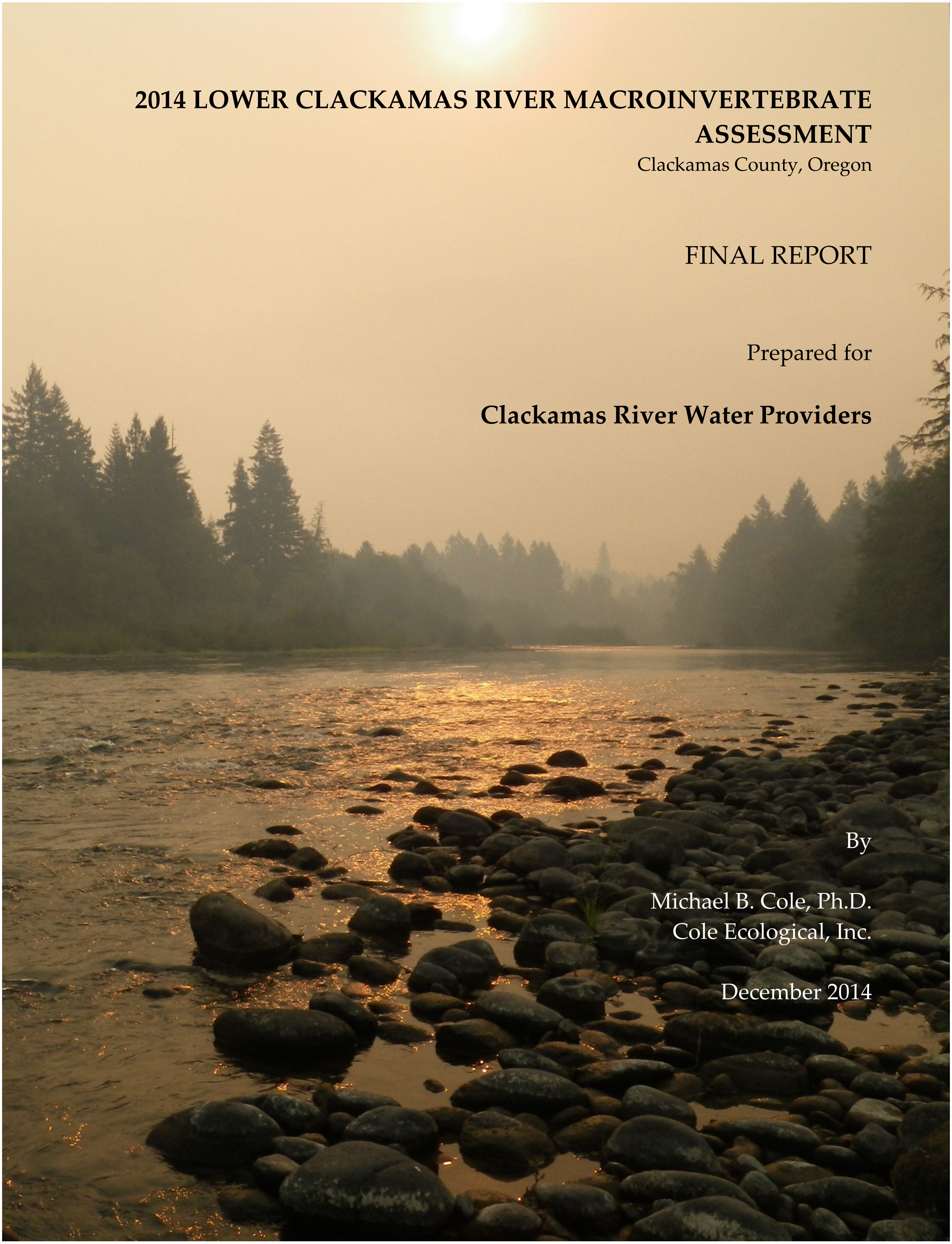

2014 LOWER CLACKAMAS RIVER MACROINVERTEBRATE ASSESSMENT

Clackamas County, Oregon

FINAL REPORT

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 recommends sampling from the lower mainstem Clackamas River and its major tributaries annually; these efforts will produce a robust long-term 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, initial implantation of the monitoring plan has focused on the river since fall 2013. A second year of lower mainstem Clackamas River sampling was performed in September 2014. This report describes the methods, results, and conclusions for this second year of monitoring macroinvertebrate communities on the lower Clackamas River.

Macroinvertebrates were sampled from five sites in the lower Clackamas River between river miles 0.5 and 20 on September 15, 2014. Each of these sites had been selected for long-term monitoring during the development of the monitoring plan and had been previously sampled in the fall of 2013.

Benthic macroinvertebrate community conditions in the lower Clackamas River are generally similar between river miles 0 and 20. DEQ macroinvertebrate multimetric (MM) scores once again indicated similar community conditions among these reaches in 2014, as mean total multimetric scores ranged only between 29 and 35 on a scale of 10 to 50. Site pairs CLKRM0.5-CLKRM5 and CLKRM11-CLKRM13.5 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; total MM scores were slightly higher at the downstream sites in each pair. Metrics used by PGE in their 2000 study of the Clackamas River and selected for inclusion in this monitoring program also again suggested generally similar conditions among reaches and did not indicate strong longitudinal trends in any attributes examined.

MM scores and individual metric values were generally similar between 2013 and 2014; mean total MM scores averaged 32.8 in 2013 versus 30.8 in 2014. While community conditions were generally similar both among sites and between years, non-metric multidimensional scaling (NMS) ordination revealed measurable influences of both river mile and year sampled on taxonomic composition. These results underscore the importance of 1) maintaining the same sampling locations over time and 2) annual sampling. Use of the same sampling stations will reduce spatial variation introduced by sampling from different locations, while annual sampling will help quantify and account for temporal variation.

These data provide the second year of baseline information on lower Clackamas River macroinvertebrate community conditions. Continued annual and 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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ACKNOWLEDGMENTS

This project was funded by the Clackamas River Water Providers (CRWP) and managed by CRWP Water Resources Manager, Kim Swan. Field assistance with 2014 sample collection was provided by Kim Swan, and Clackamas River Water (CRW) Water Quality Manager, Suzanne DeLorenzo. Macroinvertebrate samples were processed by Cole Ecological, Inc. (CE) Technicians Matthew Apling and Christopher Burtch. Project taxonomy was performed by CE taxonomists Michael Cole and Ann Gregoire.

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 relative to those 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 occurred 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 major tributaries (Cole 2013). This plan recommends sampling from the lower mainstem Clackamas River and its major tributaries once every year or two; these efforts are intended produce a long-term dataset necessary to identify persistent 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 river in each of the first three years of monitoring. The objective of the initial annual monitoring efforts in the mainstem Clackamas River is to characterize and quantify temporal variability in macroinvertebrate community conditions at each monitoring location in order to better understand data needs for detecting changes in biological conditions over time. This report describes the methods, results, and conclusions for the second 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 initially selected in 2013 to assess water quality immediately upriver of PODs and bracketing WWTPs. Six sites were sampled in fall 2013 during the first year of monitoring. One these six sites, CLKRM25, was dropped from the monitoring program in 2014 because habitat conditions at this site differed markedly from those at the other sites, primarily because this site was located in a very short reach of river occurring between two impounded sections of river. Accordingly, the uppermost site in 2014 occurred at CLKRM20 below the River Mill Dam (Figure 1). This site serves to monitor the aggregate (and un-separable) effects of the dam, the Estacada WWTP, and potential sources of stress further upstream on the ecology of the river in this reach.

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 in 2013 and resampled in 2014 to bracket this large tributary system.

Rock Creek enters the Clackamas River at RM 6.4. A sample site was established on the river in 2013 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 in 2013 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 the 2014 study to those from these past studies are included in this report.

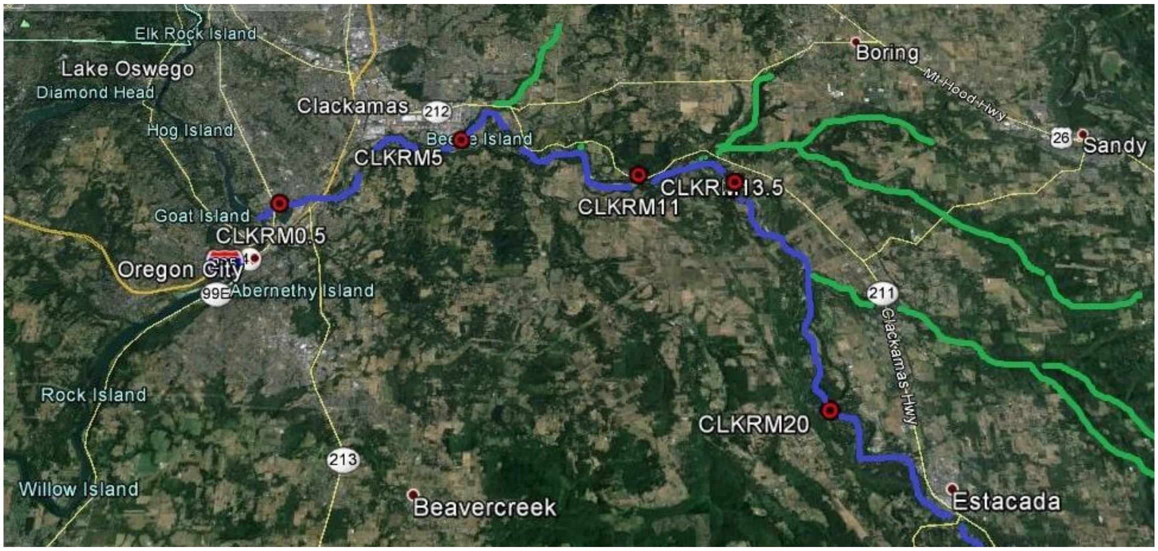

Figure 1. 2014 lower Clackamas River macroinvertebrate sample sites.

FIELD DATA COLLECTION

Macroinvertebrates were sampled from these five sites on the lower Clackamas River on September 15, 2014. 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 556 water chemistry meter.

Table 1. List of macroinvertebrates sample sites in the Clackamas River, Oregon, September 2014.

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)

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 2014.

	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 these first two years 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.

Macroinvertebrate data were also analyzed using non-metric multidimensional scaling (NMS) ordination to examine patterns in community composition in relation to river mile and year sampled. NMS, a non-parametric ordination technique, was used because it assumes no underlying distribution of the data, is robust to data departures from normality, and therefore is suggested for use with ecological data (McCune & Mefford, 1999). NMS multivariate analysis was performed in PC-Ord Version 6.08 statistical software. Macroinvertebrate data were log-transformed (using log10 [x+1]) to reduce the influence of numerically-dominant taxa (Krebs, 1989). This type of transformation is useful when there is a high degree of variation in the number of organisms represented by different taxa (McCune & Mefford, 1999) and has routinely been used on macroinvertebrate community data prior to performing multivariate analysis (e.g., Jackson, 1993; Reece & Richardson, 2000; Rempel, Richardson & Healey, 2000). NMS was performed using the Sorenson (Bray-Curtis) distance measure and a minimum of 400 iterations.

RESULTS

Streamflows during sampling (September 15, 2014) 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 September 15 was approximately 800-900 cfs. Rapid habitat scores from the five sites again ranged narrowly in 2014 from 146 to 181 (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 five sites (Table 4). Substrate conditions were also similar among the five sites and appeared largely unchanged relative to those observed in 2013. 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). No significant changes in habitat conditions from 2013 to 2014 were noted at any of the five sample stations.

Water chemistry, based on limited instantaneous sampling of only a few parameters, was also similar among the five reaches. Dissolved oxygen concentrations approached or exceeded complete saturation, and specific conductance ranged narrowly (between 65 and 67 µS/cm) across all sites (Table 4 and Figure 2).

As in 2013, DEQ macroinvertebrate multimetric (MM) scores indicated similar community conditions among reaches, as mean total MM scores ranged only between 29 and 35 on a scale of 10 to 50 (Table 5 and Figure 3). Across the five sites, total MM scores averaged 32.8 in 2014 versus 30.8 in 2013. Mean total 2014 MM scores differed from 2013 MM scores by 2 or fewer points at three sites, 3 points at one site, and by 5 points at one site.

Site pairs CLKRM0.5-CLKRM5 and CLKRM11-CLKRM13.5 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 MM scores showed the largest difference between CLKRM11 and CLKRM13.5, yet even these scores varied by only five MM score points, and the downstream site received a higher score than did the upstream site. Also as in 2013, total MM scores suggest that no significant longitudinal trends in community condition are occurring among these 20 miles of river.

Total MM scores in both 2013 and 2014 in this study were generally similar to those measured in 2003 by Metro (Cole 2004). The largest difference from 2003 to 2014 occurred at CLMRM5, where total MM scores have increased from 24 in 2013 to 31 in both 2013 and 2014. Total MM scores have increased at CLKEM11 by a narrower margin from 28 in 2003 to 32 and 34 in 2013 and 2014, respectively.

Table 3. Supplemental metric set used to further assess the condition of macroinvertebrate communities in the Clackamas River, Oregon, fall 2014 (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

Table 4. Water quality and physical habitat conditions measured from five macroinvertebrate sample sites in the Clackamas River, Oregon, September 2014.

Side Code	CLKRM0.5	CLKRM5	CLKRM11	CLKRM13.5	CLKRM20
Date	9/15/2014	9/15/2014	9/15/2014	9/15/2014	9/15/2014
Water Quality					
WQ Time	1425	1320	1120	1025	920
DO (% Sat)	109.6	112.5	107	104.4	100
DO (mg/L)	10.91	11.25	10.86	10.6	10.34
Cond (µS/cm)	55	54	54	53	51
Spec Con (µS/cm)	67	65	67	66	65
Temp (^{o}C)	15.6	15.4	14.6	14.3	13.8
Substrate in Area Sampled					
Sand	2	2	0	2	0
Fine Gravel	10	5	5	5	5
Coarse Gravel	30	10	15	25	10
Cobble	60	80	70	60	60
Boulder	0	5	10	10	25
Embeddedness	10	10	5	5	5
Sample Depth (cm)	15-25	20-30	20-35	20-35	20-35
Rapid Habitat Assessment (RHA) Scores					
Epifaunal Substrate/Cover	15	16	17	18	18
Embeddedness	17	17	18	18	19
Velocity/Depth Regimes	18	18	18	18	18
Sediment Deposition	17	18	18	18	19
Channel Flow Status	17	18	18	18	18
Channel Alteration	13	18	18	18	18
Frequency/Quality of Riffles	13	15	17	17	17
Bank Stability	14	15	15	16	18
Protective Vegetation	12	14	16	15	18
Riparian Zone Width	10	12	15	18	18
RHA Total Score	146	161	170	174	181

Individual DEQ metrics were also generally similar between 2013 and 2014 (Table 5; Figures 3 and 4). Individual DEQ metrics once again showed more variation among sites than did total MMS scores, 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. While in 2013, stonefly richness showed a potential longitudinal trend from upriver to downriver, no such trend was evident in 2014 (Figure 3).

Additional metrics used by PGE (PGE 2004) and selected for inclusion in this study again in 2014 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 similar among sites, ranging only from 5.8 to 6.2 on a scale of 0 to 10, a narrower range than that exhibited in 2013. Total richness once again showed more variation among sites than most other metrics, ranging from 39 to 52, 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 27.0 and 33.5 among all five sites.

Collecter-gathering and collector-filtering organisms (Table 3) once again dominated benthic communities across all sites in 2014 (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.

While 2013 PGE metrics results were generally similar to those measured in 1999 and 2000 at the four sites where older data were available, 2014 community richness was higher in 2014 than in 2013 at three of these sites, resulting in larger differences from 1999/2000 richness values (Table 7; Figure 7). While changes in community conditions from 1999/2000 to present are possible, inter-annual variability and differences in sampling approaches may also be responsible for these observed differences.

NMS produced a three-dimensional ordination that explained 87% of the variation in the original sample space (final stress = 9.14). Both river mile (correlation with axis 2: $r = 0.751$, $p = 0.00014$) and sample year (correlation with axis 2: $r = 0.506$; $p = 0.022$; correlation with axis 3: $r = 0.805$, $p < 0.0001$) were significantly correlated with one or more ordination axes, indicating a measurable effect of both variables on patterns in community composition. NMS bi plots (Figure 8) reveal some clustering of samples (according to similar community composition) by both sample year (2013 versus 2014) and by sample location (river mile).

Table 5. Means and standard deviations of OR DEQ community metrics and total multi-metric scores calculated from duplicate macroinvertebrate samples collected from five sites along the lower Clackamas River, Oregon, in fall 2013 and fall 2014. Metrics source: Oregon DEQ. Multimetric scores from the 2003 Metro study are included in the last row of the table for comparative purposes.

		2013					**2014**				
DEQ Metric		**0.5**	**5**	**11**	**13.5**	**20**	**0.5**	**5**	**11**	**14**	**20**
Richness	Mean	28.5	35.5	31.5	26.0	33.5	31.0	31.0	29.0	25.5	40.0
	StDev	4.9	2.1	0.7	2.8	2.1	4.2	2.8	1.4	2.1	2.8
Mayfly Richness	Mean	9.0	11.5	9.0	7.0	9.5	9.0	7.5	7.5	7.5	9.5
	StDev	0.0	0.7	0.0	1.4	0.7	0.0	0.7	0.7	0.7	0.7
Stonefly Richness	Mean	1.5	1.0	1.5	3.0	2.0	3.5	1.5	3.5	1.5	2.5
	StDev	0.7	0.0	0.7	0.0	0.0	0.7	0.7	0.7	0.7	2.1
Caddisfly Richness	Mean	7.0	6.5	8.0	7.0	8.0	8.0	9.5	9.0	7.0	9.5
	StDev	1.4	0.7	0.0	1.4	1.4	1.4	0.7	1.4	0.0	0.7
Number Sensitive Taxa	Mean	0.5	0.0	0.5	1.5	0.0	0.0	0.5	0.0	0.0	0.0
	StDev	0.7	0.0	0.7	0.7	0.0	0.0	0.7	0.0	0.0	0.0
# Sed Sensitive Taxa	Mean	1.5	1.0	1.5	0.0	1.5	1.5	2.5	2.0	1.0	1.0
	StDev	0.7	0.0	0.7	0.0	0.7	0.7	0.7	1.4	0.0	0.0
Modified HBI1	Mean	4.0	4.1	3.6	3.7	4.3	4.0	4.1	3.3	3.6	4.3
	StDev	0.2	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.0
% Tolerant Taxa	Mean	34.6	46.3	42.6	49.9	53.0	28.1	46.3	31.2	39.6	27.4
	StDev	10.0	1.0	4.3	1.2	6.9	1.4	5.9	0.8	9.2	1.7
% Sed Tolerant Taxa	Mean	0.9	1.3	4.1	0.4	4.0	1.3	0.6	0.4	0.4	2.4
	StDev	0.8	1.0	3.4	0.5	2.1	0.5	0.5	0.5	0.3	1.1
% Dominant	Mean	23.8	19.1	27.5	23.0	27.7	20.6	25.1	32.5	32.6	26.0
	StDev	1.8	0.0	1.6	0.1	8.1	0.6	5.7	6.1	0.3	1.6
TOTAL MM SCORE	Mean	32.0	31.0	32.0	29.0	30.0	35.0	31.0	34.0	29.0	35.0
	StDev	0.0	1.4	0.0	1.4	2.8	1.4	1.4	2.8	1.4	1.4
Metro 2003 Total MM Score			24.0	28.0	28.0			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 and fall 2014. Metrics source: PGE 2004.

		2013					2014				
PGE Metric		**0.5**	**5**	**11**	**14**	**20**	**0.5**	**5**	**11**	**14**	**20**
Richness	Mean	36.5	45.0	40.0	34.0	41.0	42.5	40.0	40.5	39.0	52.0
	StDev	2.1	1.4	2.8	1.4	4.2	0.7	1.4	0.7	4.2	2.8
EPT Richness	Mean	17.5	19.0	18.5	17.0	19.5	13.5	18.5	20.0	16.0	21.5
	StDev	2.1	0.0	0.7	2.8	2.1	2.1	2.1	1.4	1.4	0.7
CTI	Mean	6.2	6.3	6.0	6.3	6.7	6.2	6.2	5.8	6.0	6.1
	StDev	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
Dom (3)	Mean	49.6	48.2	55.4	62.2	52.2	38.1	50.9	61.7	60.2	34.9
	StDev	0.8	1.1	5.6	0.5	8.7	1.1	4.5	5.7	0.5	2.8
Percent Intolerant	Mean	0.5	1.6	0.3	0.2	1.1	0.3	1.8	0.1	0.1	1.0
	StDev	0.4	0.9	0.1	0.0	1.5	0.4	1.2	0.1	0.1	0.3
Percent Tolerant	Mean	33.0	36.6	26.2	32.6	48.4	31.0	25.8	13.7	17.4	20.0
	StDev	6.8	2.7	3.6	0.1	3.0	8.2	1.3	1.3	0.9	1.7
Intolerant Richness	Mean	1.0	1.0	1.5	1.0	0.5	0.5	1.5	0.5	0.5	1.0
	StDev	0.0	0.0	0.7	0.0	0.7	0.7	0.7	0.7	0.7	0.0
Tolerant Richness	Mean	13.5	17.0	13.0	9.5	15.0	15.5	14.0	11.0	10.5	17.5
	StDev	2.1	1.4	1.4	0.7	2.8	2.1	2.8	1.4	0.7	2.1
% Collector-Filterer	Mean	27.4	34.7	25.8	35.8	41.1	17.8	35.9	25.3	31.1	18.4
	StDev	10.1	0.6	8.7	2.5	10.5	2.0	6.4	1.2	8.6	0.1
% Collector-Gatherer	Mean	40.3	29.9	21.7	17.5	24.2	50.1	31.8	19.4	21.0	34.2
	StDev	6.6	2.9	0.5	0.4	2.0	1.8	4.6	5.1	0.7	3.6
% Shredder	Mean	0.9	1.0	3.4	2.3	1.3	2.0	6.6	31.7	23.9	7.3
	StDev	0.3	0.2	1.4	0.1	0.4	1.1	3.4	6.2	10.4	0.7
% Predator	Mean	5.8	9.3	10.2	10.4	9.9	11.5	10.9	8.0	9.9	15.0
	StDev	2.1	1.9	0.9	2.7	1.2	0.6	0.6	0.7	0.6	1.6
% Scraper	Mean	20.1	19.1	15.4	9.6	14.3	8.9	9.7	6.2	4.4	10.1
	StDev	4.8	0.4	3.3	3.7	2.0	0.4	0.2	0.3	1.3	0.4

Table 7. Comparison of PGE metrics calculated from 2014 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		
Metric	**1999**	**2013**	**2014**	**2000**	**2013**	**2014**	**2000**	**2013**	**2014**	**1999**	**2013**	2014
Richness	27.0	36.5	42.5	36.0	40.0	40.5	31.0	34.0	39.0	35.0	41.0	52.0
EPT Richness	13.0	17.5	13.5	21.0	18.5	20.0	20.0	17.0	16.0	16.0	19.5	21.5
CTI	6.4	6.2	6.2	6.1	6.0	5.8	6.2	6.3	6.0	6.1	6.7	6.1
Dom (3)	66.0	49.6	38.1	51.0	55.4	61.7	79.0	62.2	60.2	77.0	52.2	34.9
Percent Intolerant	0.4	0.5	0.3	0.0	0.3	0.1	0.0	0.2	0.1	0.5	1.1	1.0
Percent Tolerant	41.3	33.0	31.0	22.0	26.2	13.7	18.0	32.6	17.4	10.0	48.4	20.0
Intolerant Richness	1.0	1.0	0.5	0.0	1.5	0.5	0.0	1.0	0.5	1.0	0.5	1.0
Tolerant Richness	9.0	13.5	15.5	11.0	13.0	11.0	8.0	9.5	10.5	8.0	15.0	17.5
% Collector-Filterer	47.0	27.4	17.8	26.0	25.8	25.3	42.0	35.8	31.1	50.2	41.1	18.4
% Collector-Gatherer	25.0	40.3	50.1	29.0	21.7	19.4	16.0	17.5	21.0	20.0	24.2	34.2
% Shredder	1.0	0.9	2.0	3.3	3.4	31.7	3.5	2.3	23.9	0.3	1.3	7.3
% Predator	11.2	5.8	11.5	11.0	10.2	8.0	16.0	10.4	9.9	21.0	9.9	15.0
% Scraper	15.0	20.1	8.9	25.0	15.4	6.2	21.0	9.6	4.4	6.0	14.3	10.1

DISCUSSION

Results of the 2014 lower Clackamas River macroinvertebrate assessment once again suggest that macroinvertebrate communities inhabiting shallow riffle habitat of the lower Clackamas River between river miles 0 and 20 presently exhibit little variation in community conditions. 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 in both 2013 and 2014 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). Despite the lack of major longitudinal gradients in community *conditions*, NMS ordination analysis revealed measurable differences in community *composition* between sites, and that these subtle differences do correspond with river mile. NMS analysis also revealed that composition was also influenced by sampling year, but not to the extent as to affect any indices of community condition. Owing to its ability to reveal these less obvious patterns in community composition, NMS ordination analysis could prove useful for elucidating future deviations from current conditions when use in conjunction with community metric analysis.

Comparison of 2014 data to USGS/PGE individual metric scores at four sites suggested generally similar macroinvertebrate community conditions in the lower river over the past 10-14 years, with some indication that community richness or evenness has slightly improved. Only continued sampling will reveal whether those lower richness values measured in 1999/2000 will again occur, possibility as a result of year-to-year variation in climatic and hydrologic conditions. Recent work in several coastal Oregon streams suggests that broad-scale climatic conditions such as air temperature and precipitation may be important drivers that influence year-to-year variability of lotic macroinvertebrate communities (Edwards 2014). Whatever the underlying cause, these inter-annual differences in measured community attributes underscore the need for regular monitoring to discern real trends 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, likely 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 of upriver reaches. Only through thorough characterization of temporal and spatial variability will such deviations be detected. Sampling at least biannually (preferably annually) 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. While the first few years of monitoring will continue to utilize this larger number of metrics, sufficient redundancy between the two will likely allow one to eventually 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, use of the PGE metrics is tentatively recommended, following the initial three years of data collection and examination of spatial and temporal variability of each metric. Furthermore, while the first two years of this study has 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 MM 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 20. Furthermore, these conditions are generally similar to those reported by others in 1999, 2000, and 2003, with some indication that richness may be slightly improved since 1999/2000. 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.

- Conditions measured in 2014 were generally similar to those measured in 2013, and variability observed was not beyond what would be expected as normal year-to-year variation (i.e., no obvious indication of increased or decreased biological conditions at any sites from 2013 to 2014).

- These data provide a second year of baseline conditions 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.

- 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.

- Continue use of NMS ordination analysis to help identify deviations from baseline conditions.

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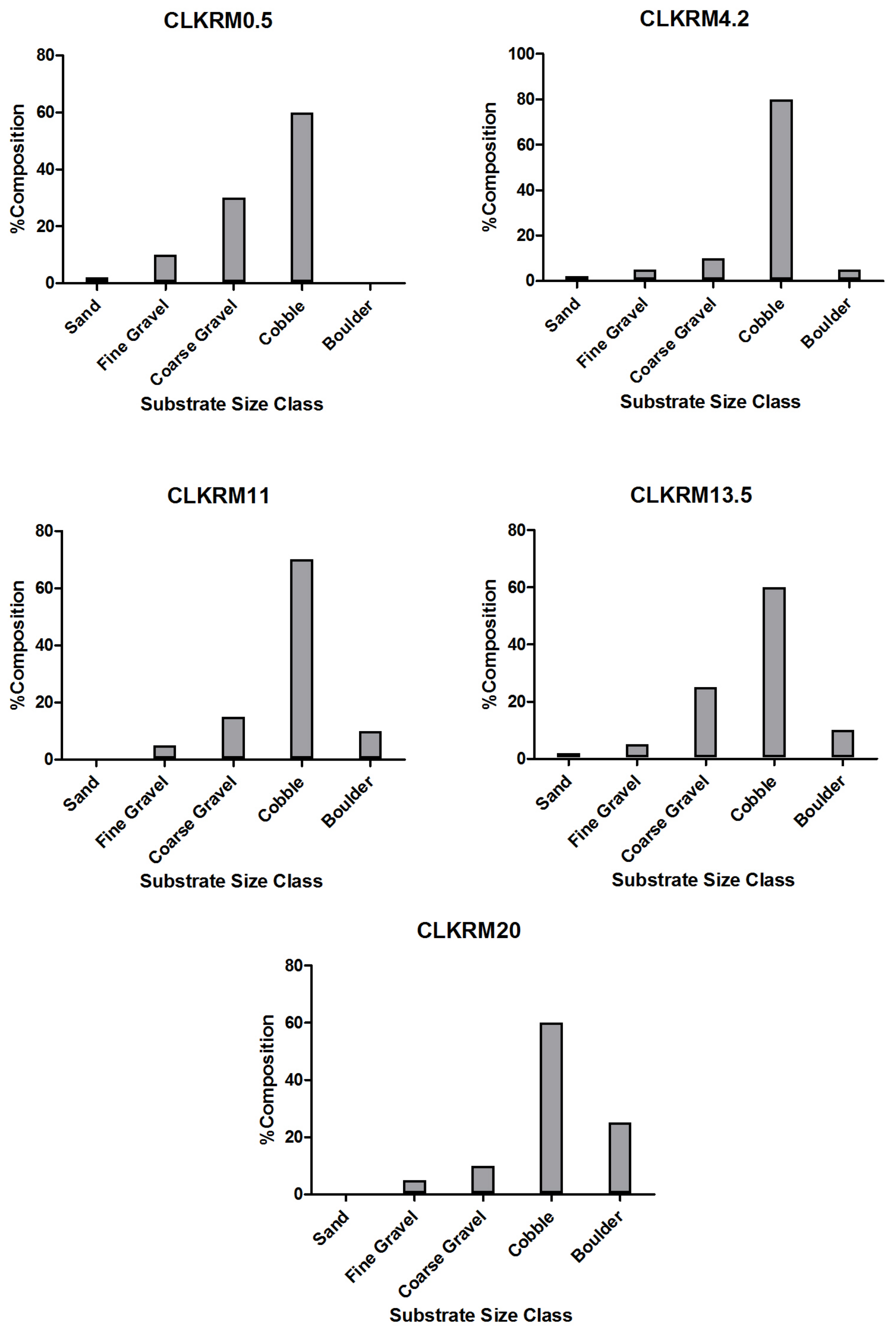


Figure 2. Substrate composition at six Clackamas River macroinvertebrate samples sites, September 2014.

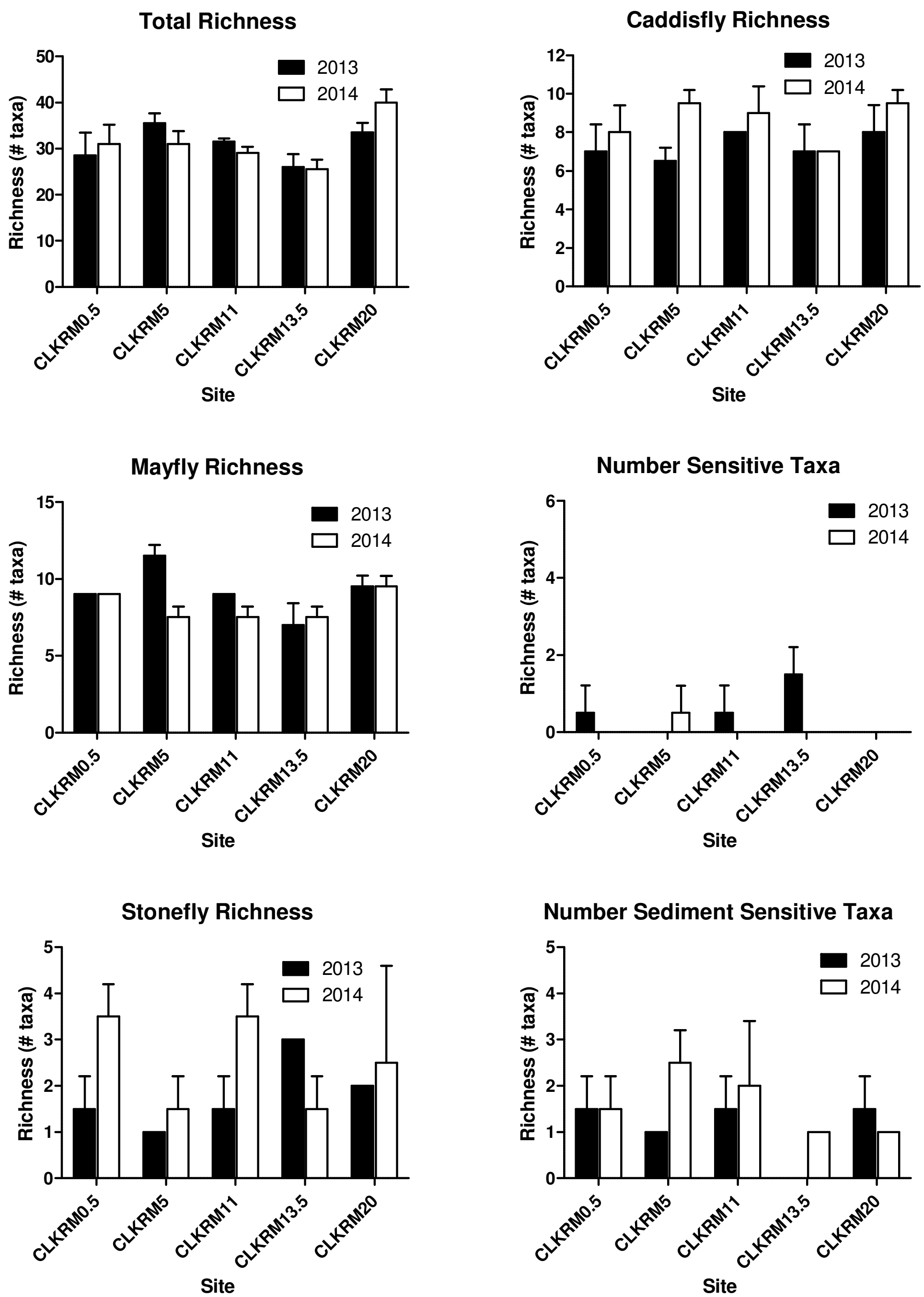


Figure 3. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013 and September 2014.

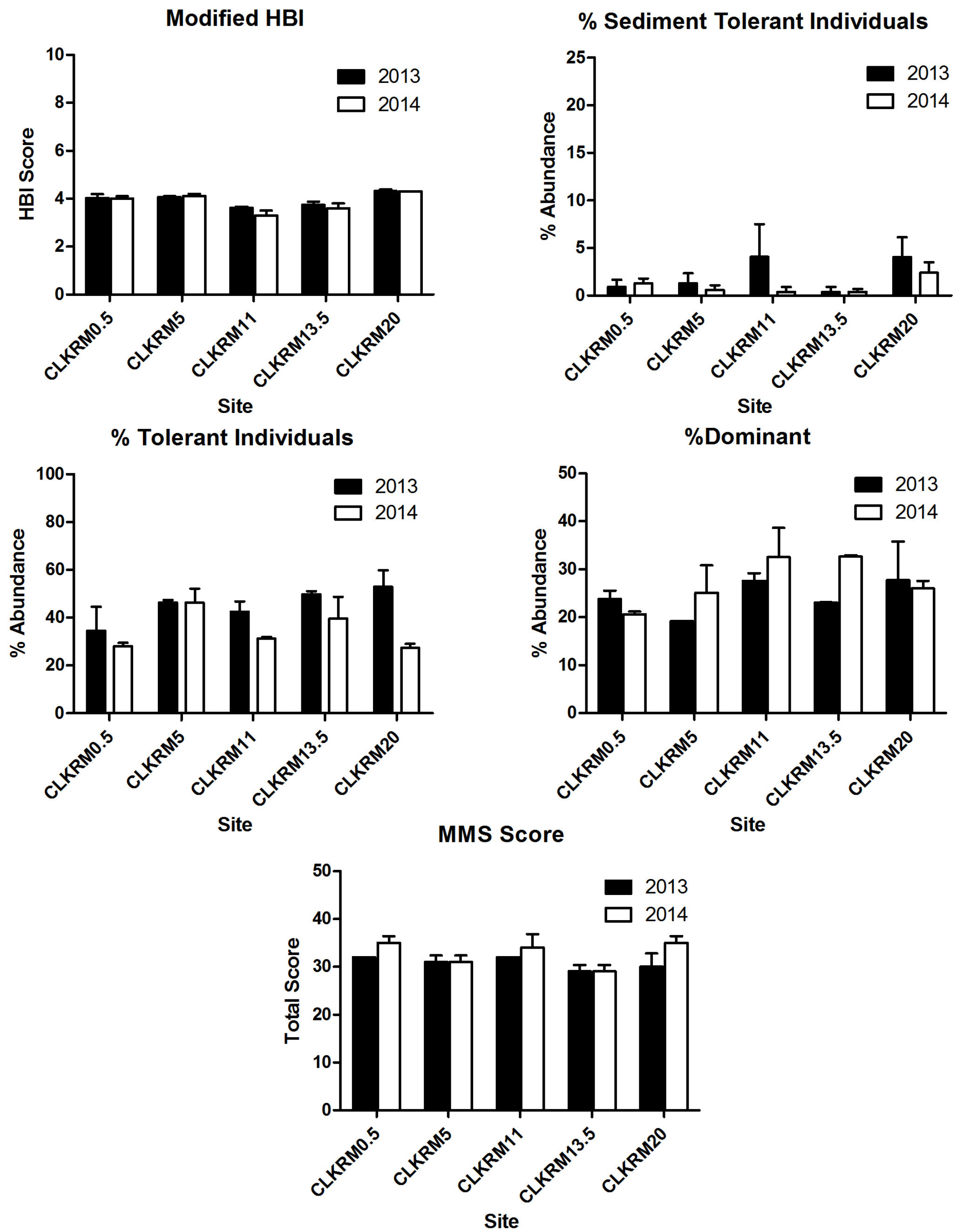


Figure 4. Mean (+SD) macroinvertebrate community metric scores and total multimetric scores (MMS) calculated from duplicate samples collected from the lower Clackamas River in September 2013 and September 2014.

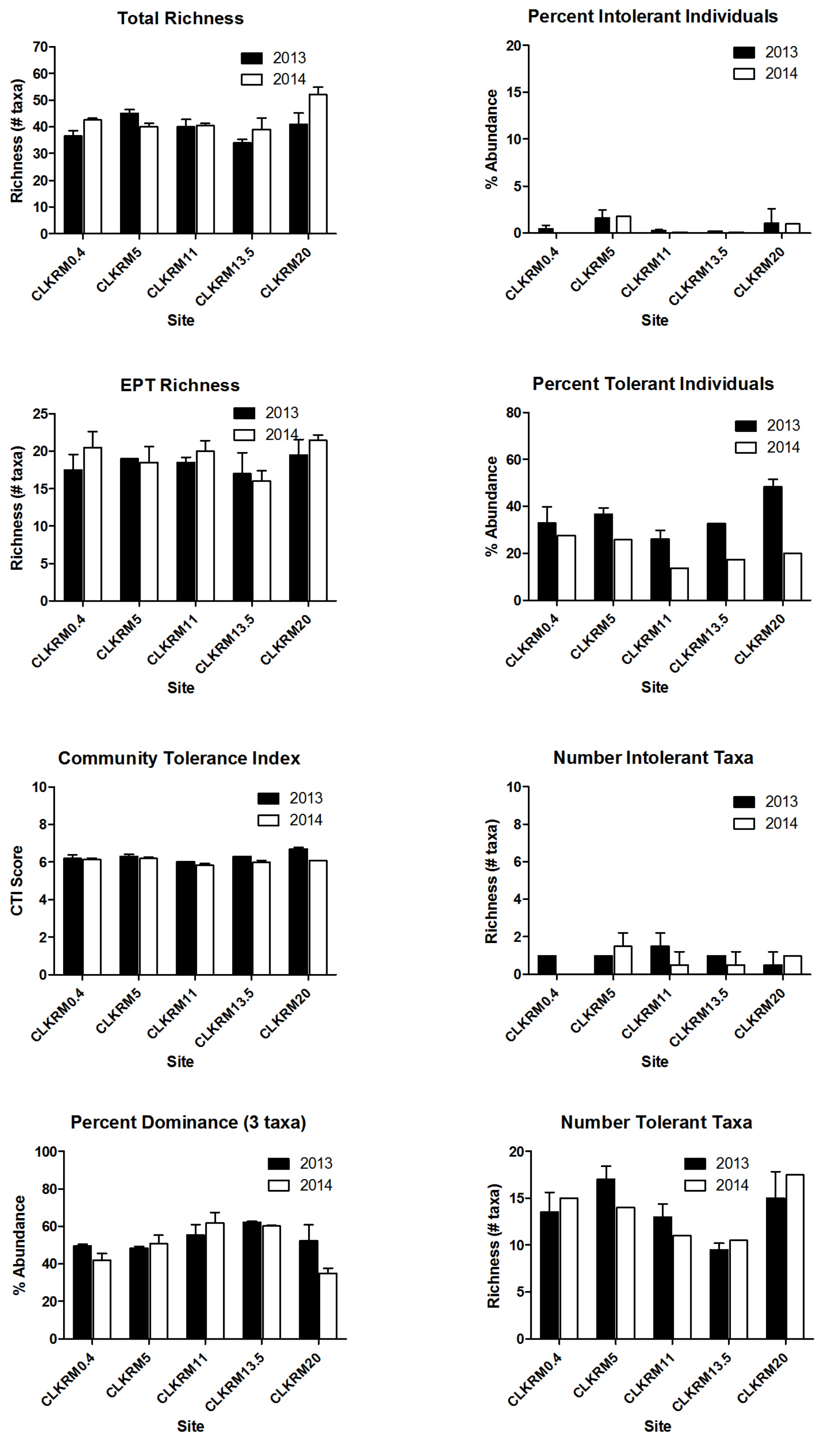


Figure 5. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013 and September 2014. Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

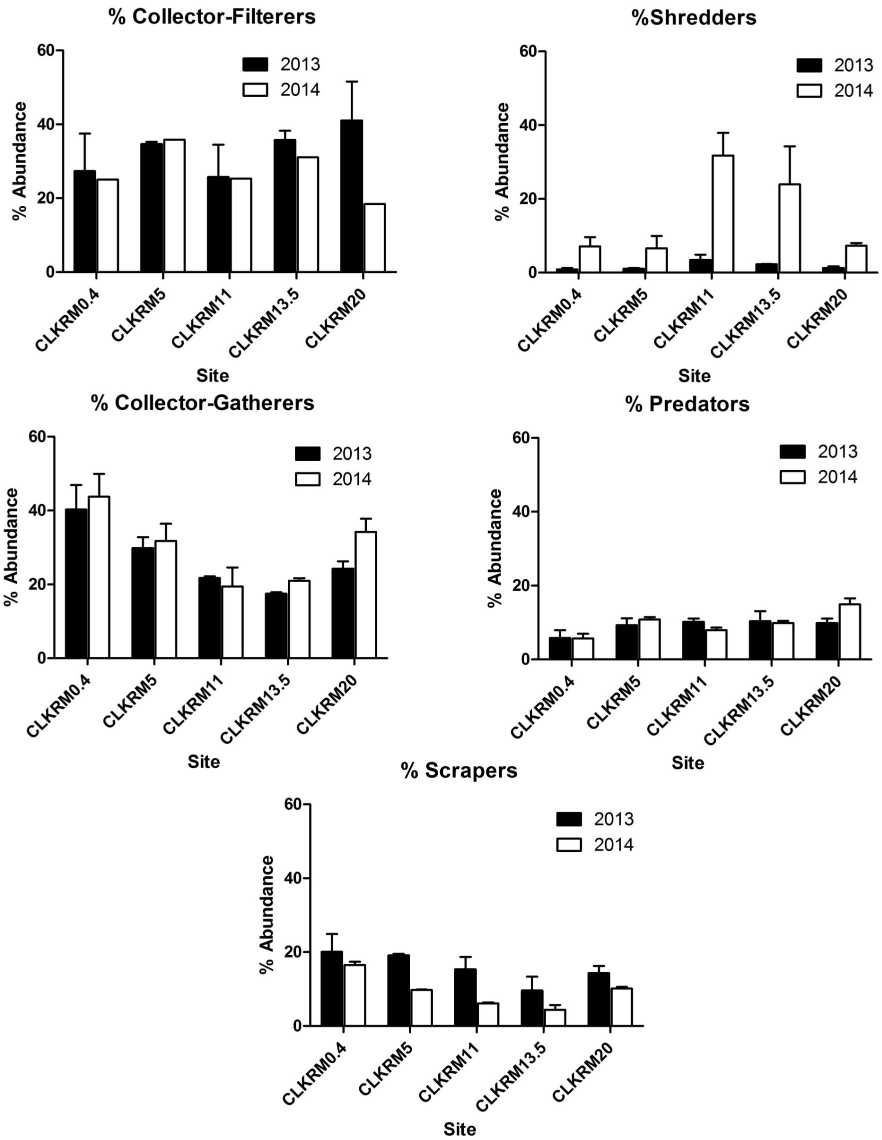


Figure 6. Mean (+SD) abundance of macroinvertebrate functional feeding groups calculated from duplicate samples collected from the lower Clackamas River in September 2013 and September 2014. Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

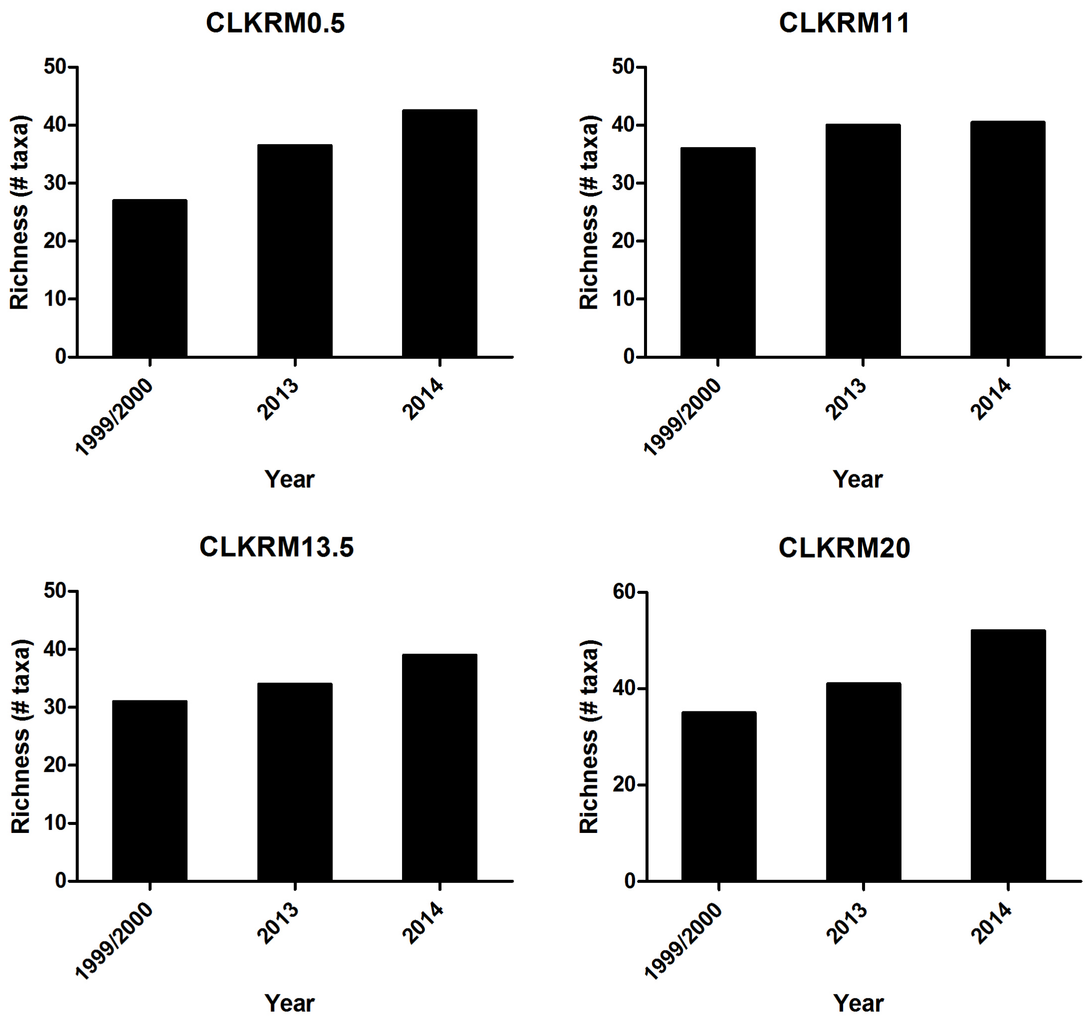
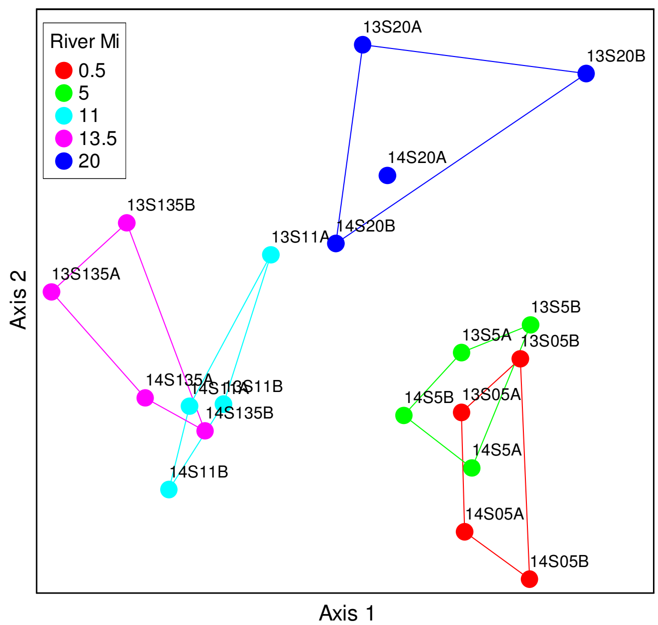


Figure 7. Mean total taxa richness calculated from macroinvertebrate samples collected from the Clackamas River in 1999/2000, 2013, and 2014.



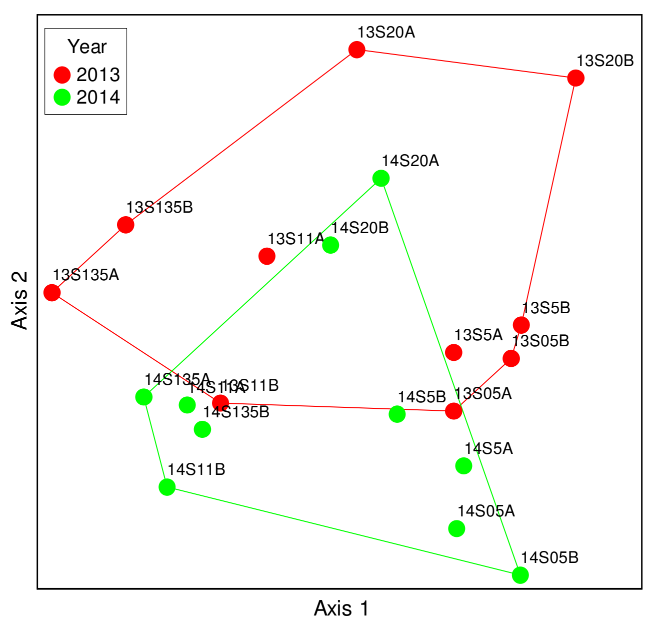


Figure 8. NMS ordination bi-plots of macroinvertebrate communities sampled from five reaches in the lower Clackamas River, Oregon, in September 2013 and 2014. Each points in each bi plot represents a single sample. Samples in the upper bi-plot are color coded by river mile, while points in the lower bi plot are color coded by year sampled. Points occurring closer together have more similar macroinvertebrate communities than do points occurring farther apart.

APPENDIX A.

Location maps and 2014 site photos

CLKRM0.5

CLKRM5

CLKRM11

CLKRM13.5

CLKRM20