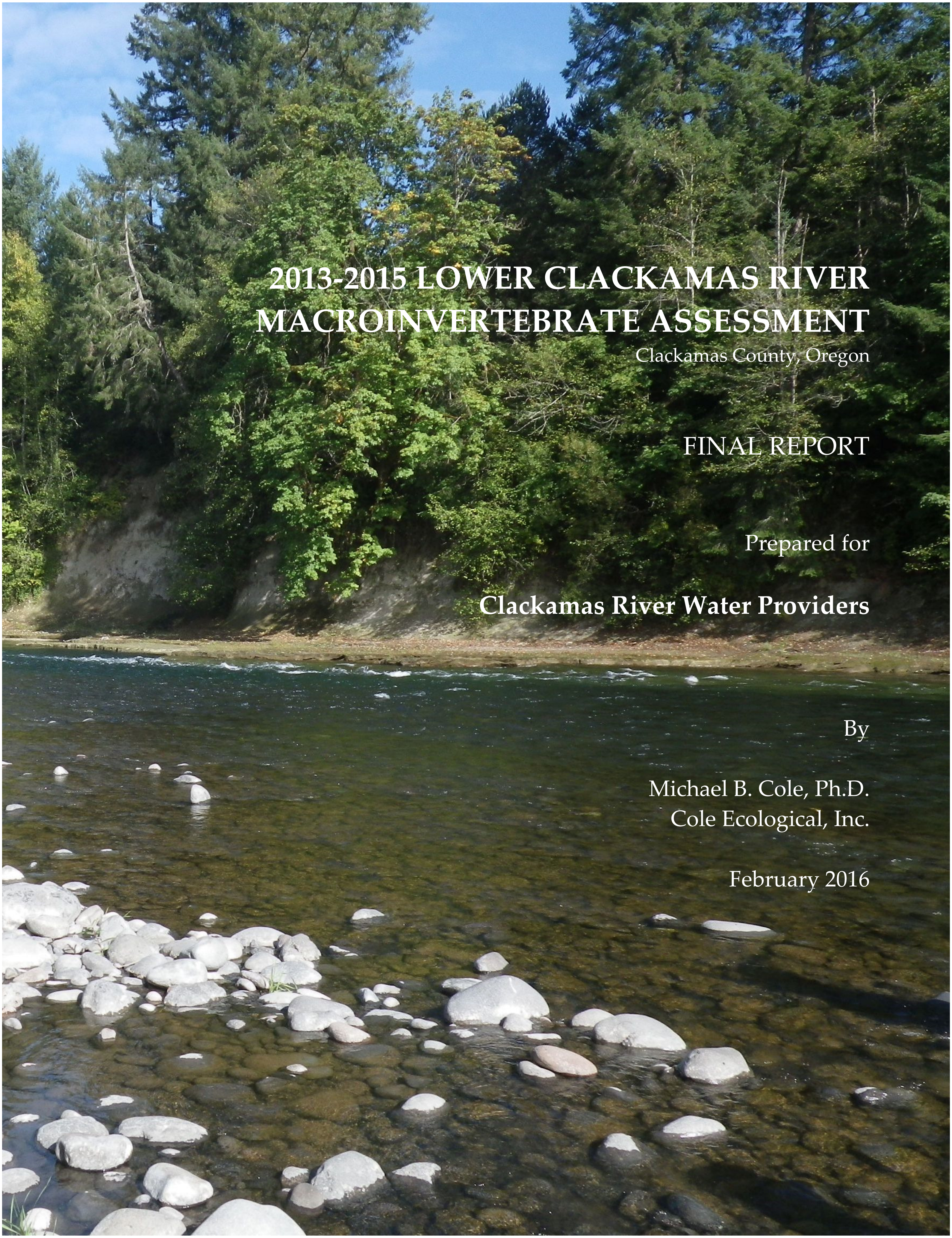

2013-2015 LOWER CLACKAMAS RIVER MACROINVERTEBRATE ASSESSMENT

Clackamas County, Oregon

FINAL REPORT

Prepared for

Clackamas River Water Providers

By

Michael B. Cole, Ph.D.
Cole Ecological, Inc.

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EXECUTIVE SUMMARY

In recognizing the value of biomonitoring to help inform water quality conditions and trends, Clackamas River Water Partners (CRWP) developed a long-term macroinvertebrate monitoring plan for the lower Clackamas River and its tributaries (Cole 2013). This plan recommends routine (annual or biannual) sampling from the lower mainstem Clackamas River and its major tributaries; over time 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, initial implantation of the monitoring plan has focused on the mainstem river. Since the program's inception in 2013, the river has been sampled each of the last three years. This report describes the methods, results, and conclusions from the first three years 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 in September of 2013, 2014, and 2015. Each of these sites had been selected for long-term monitoring during the development of the monitoring plan. Sampling was performed using standard field methods, and samples were processed using standard laboratory methods. Data were analyzed using macroinvertebrate community metrics known to be responsive to disturbance in western Oregon rivers and streams.

The first three years of CRWP macroinvertebrate monitoring in the lower Clackamas River suggest that community conditions 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. While the lack of a standard or reference condition for larger rivers in the region precludes an assignment of condition classes to these results, the presence of numerous mayfly, stonefly, and caddisfly taxa in the lower river is suggestive of current water quality and habitat conditions that are generally suitable for maintenance of diverse native aquatic communities.

Conditions measured in 2015 were similar to those measured in 2013 and 2014 at four of five sites. While temporal variability in community metrics was higher at some sample sites than at others, the measured variability was not beyond what would be expected for normal year-to-year variation (i.e., no obvious indication of increased or decreased biological conditions at any sites from 2013 to 2015). While conditions at CLKRM0.5 (as indicated by a number of community metrics) were lower in 2015 than in past years, the measured condition likely reflects the natural variability in the lower river and is not suggestive of a decline in condition immediately related to anthropogenic disturbance. Accordingly, these data represent average conditions and variability in these conditions over the range of environmental conditions occurring during the 2013-2015 sampling period.

These three years of baseline community data from the lower river were used to calculate several measures of variability to understand the relative sensitivity of metrics selected for monitoring and to exemplify how to use the data to detect future change. Results of these analyses suggest that OR DEQ multimetric scores, EPT richness, total community richness, and the Community Tolerance Index (CTI) show the most promise for detecting future changes in community conditions when they occur. Continued annual or biannual replicated sampling in the lower Clackamas River is recommended to ensure a robust data set. Future data will allow further characterization of spatial and temporal variability under a range of climatic and flow conditions, thereby improving the ability to detect change when change occurs. Future data will also be used to identify changes to benthic community conditions through comparison with conditions measured over the past three sampling years.

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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 sample the river and its many tributaries to monitor water quality relative to 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 sufficiently 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 biomonitoring 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 conducted by numerous organizations, 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 lack 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 biomonitoring 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, depending on availability of resources); these efforts are intended to 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 main objective of the first three 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 these first three years 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 of these six sites, CLKRM25, was dropped from the monitoring program in subsequent years 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 and 2015 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 upriver 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 and 2015 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 upriver of the POD at RM 3.1. The lower-most sample site is 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 section of river within 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 this study to those from these past studies are also included in this report.

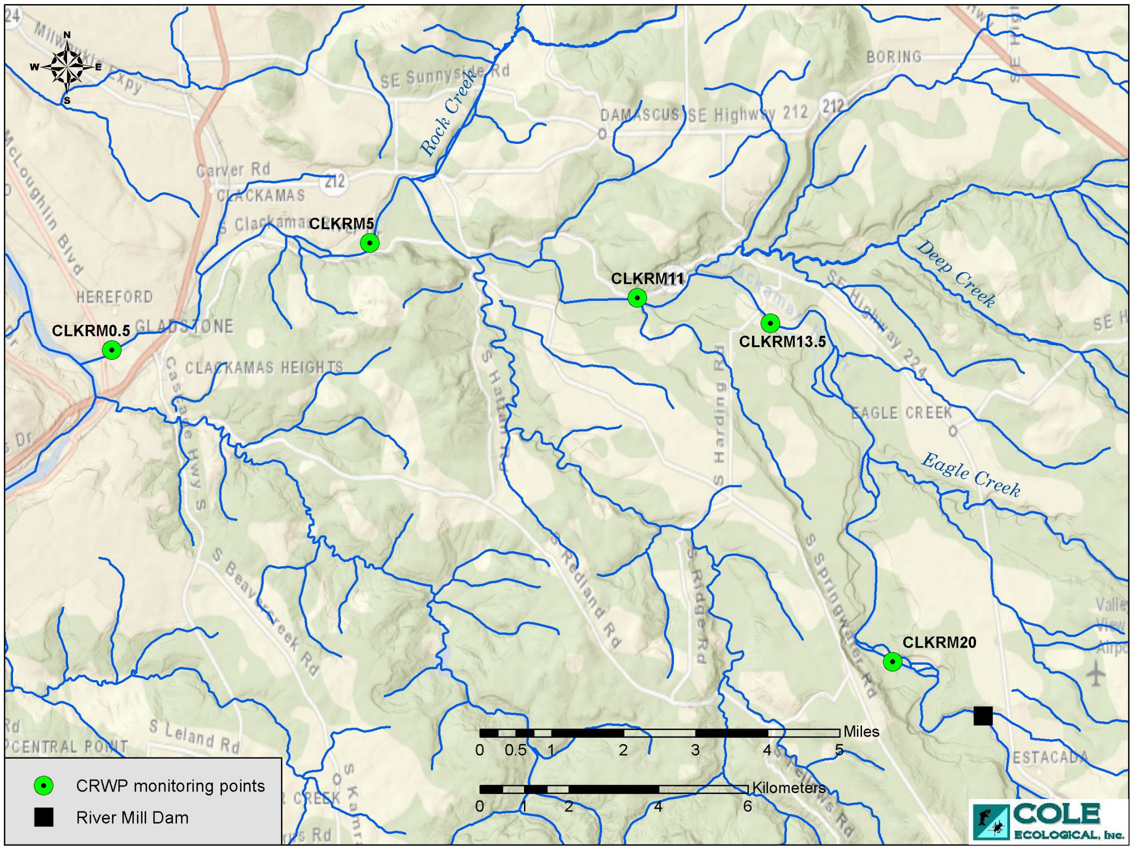

Figure 1. 2013-2015 lower Clackamas River macroinvertebrate sample sites.

FIELD DATA COLLECTION

For the third year of sampling, macroinvertebrates were sampled from these five sites on the lower Clackamas River on September 21, 2015. 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 2013-2015.

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 2013-2015.

	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

As with previous sampling years under this program in 2013 and 2014, streamflows during the 2015 sampling event (September 21, 2015) were at seasonal baseflows, as determined from data obtained from USGS gage station 14211010 on the Clackamas River near Oregon City (2015 data are presently provisional data). While flows under which macroinvertebrates were collected were similar among the three years, provisional discharge data collected from this gage station suggest that mid-to-late-summer flows were lower in 2015 than they had been during the last two years antecedent to sampling (Figure 2). In 2013 and 2014, August discharge at station 14211010 was typically 800 to 900 cfs, while discharge at this station was 600 to 700 cfs for much of August 2015, potentially producing more stressful ambient in-river conditions. However, provisional USGS water quality data collected at this same gage station suggest that neither late-summer temperature nor dissolved oxygen conditions notably differed between 2015 and the previous two years (Figure 3).

Rapid habitat scores from the five sites again ranged narrowly in 2015 from 141 to 182 (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 and 2014. Riffle bed materials were uniformly dominated by cobble substrate (Table 4 and Figure 4). 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 4). No significant changes in habitat conditions from 2013 to 2015 were noted at any of the five sample stations.

Water chemistry, based on limited instantaneous sampling of only a few parameters at the time of macroinvertebrate sampling, was also similar among the five reaches in 2015. Dissolved oxygen concentrations approached or exceeded complete saturation, and specific conductance ranged narrowly (between 68 and 71 µS/cm) across all sites (Table 4).

As in 2013 and 2014, DEQ macroinvertebrate multimetric (MM) scores calculated from the 2015 data indicated that community conditions were similar among the reaches, as mean total MM scores ranged only between 27 and 35 on a scale of 10 to 50 (Table 5 and Figure 5). Across the five sites, 2015 MM scores averaged 31.2, versus 32.8 in 2014 and 33.0 in 2013, suggesting similar lower-river-wide benthic ecological conditions across the three years.

Between 2013 and 2015, mean MM scores ranged by two points at CLKRM5.0 and CLKRM11, by five points at CLKRM20, by six points at CLKRM13.5, and by 8 points at CLKRM0.5. This generally narrow range of scores suggests that under the range of river conditions occurring over the past three seasons, macroinvertebrate community conditions, as represented by the samples collected, do not exhibit large within-site variability in condition, a desirable characteristic for detecting deleterious changes when they occur. A closer examination of *individual* MM scores by site over time reveals that the largest temporal change in MM scores, that at CLKRM0.5 from 2014 to 2015 of 8 points, occurred because both of the replicate samples scored lower in 2015 than in 2014 (Figure 6). This agreement in MM scores between the two replicates suggests that conditions in the lower river at CLKRM0.5 may have indeed been marginally reduced from 2014 to 2015.

In contrast to when duplicate samples are in agreement, and to illustrate the utility in collecting duplicate samples, one of two samples collected from CLKRM13.5 in 2015 received an MM score of 6 points higher than any other sample had scored from the site in three years. Examination of this score in relation to the others in Figure 5 suggests the possibility that this score is an outlier and may not necessarily be representative of average conditions at the site. This is an important consideration, as one objective of the first three years of Clackamas River macroinvertebrate sampling was to assess variability in macroinvertebrate community conditions in order to better understand what magnitude of change in metric values would suggest a real change in biological condition. When only one of two duplicate samples occurs outside the range of previous values (or threshold values based on this range), the occurrence of an outlier value must be considered.

Site pairs CLKRM0.5-CLKRM5 and CLKRM11-CLKRM13.5 serve as upstream-downstream pairs to detect changes in ecological conditions within each length of river bracketed by these pairs. Each of these site pairs exhibited similar mean total scores in 2015 (Table 5). Mean MM scores in 2015 differed between CLKRM0.5 and CLKRM5 by only 2 MM score points, while MM scores between CLKRM11 and CLKRM13.5 differed by 3 MM score points (Table 5), suggesting similar overall community conditions between sites within each pair. Unlike in past years, the 2015 MM score data suggest a slight decrease in macroinvertebrate community conditions in a downriver direction across the lower four sample sites (Figure 5).

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 21, 2015.

Side Code	CLKRM0.5	CLKRM5	CLKRM11	CLKRM13.5	CLKRM20
Date	9/21/2015	9/21/2015	9/21/2015	9/21/2015	9/21/2015
Water Quality					
WQ Time	720	1320	1130	1050	955
DO (% Sat)	87	115.3	108.5	107.9	104.1
DO (mg/L)	8.41	11.31	10.82	10.89	10.63
Cond (µS/cm)	60	59	56	56	55
Spec Con (µS/cm)	70	71	68	69	70
Temp (^{o}C)	16.96	16.32	15.53	15.03	14.39
Substrate in Area Sampled					
Sand	2	2	0	2	0
Fine Gravel	10	5	5	5	5
Coarse Gravel	30	10	20	25	10
Cobble	60	80	65	60	60
Boulder	0	5	10	10	25
Embeddedness	10	10	5	5	5
Sample Depth (cm)	15-25	20-30	20-35	20-30	20-35
Rapid Habitat Assessment (RHA) Scores					
Epifaunal Substrate/Cover	15	17	18	18	18
Embeddedness	17	17	18	18	19
Velocity/Depth Regimes	18	17	18	18	18
Sediment Deposition	17	18	18	18	19
Channel Flow Status	16	18	18	18	18
Channel Alteration	13	18	18	18	18
Frequency/Quality of Riffles	13	16	17	17	18
Bank Stability	12	14	15	16	18
Protective Vegetation	10	14	16	15	18
Riparian Zone Width	10	12	15	16	18
RHA Total Score	**141**	**161**	**171**	**172**	**182**

Total MM scores in this study were at least marginally higher than those measured in 2003 by Metro (Table 5; Cole 2004). MM scores at CLKRM5 have increased from 24 in 2003 to 31, 31, and 29 across the 3 years in this study. MM scores at CLKMR11 have increased at from 28 in 2003 to 32, 35, and 32 in this study. MM scores at CLKRM13.5 were very similar between 2003 (28) and 2013-14 (30 and 29), but the 2015 score of 35 is 7 points higher than the 2003 score. As previously discussed, this higher score may have resulted from an outlier score from one of the replicates collected in 2015. Similarly, results from the prior studies may also contain outlier results, which are more likely to unknowingly occur because samples were not collected in duplicate.

Individual DEQ metrics were also generally similar between 2013 and 2015 (Table 5; Figures 5 and 7). 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 5 and 7), lending support to results of the MMS scores that macroinvertebrate community conditions did not vary significantly among sites. 2015 marked the first year in which several metrics – including total richness and stonefly richness – appeared to exhibit upstream-downstream trends in values, although these were not pronounced, and may not necessarily reflect real gradients in community conditions.

Additional metrics used by PGE (PGE 2004) and selected for inclusion in this study consistently suggested generally similar conditions among reaches and did not indicate strong longitudinal trends in any attributes examined (Table 6 and Figure 8). As was the case with several DEQ metrics calculated in 2015, a few PGE metrics – including total richness and EPT richness – exhibited potential trends, but these were subtle. The Community Tolerance Index (CTI; Table 3) was similar among sites, ranging only from 6.2 to 6.7 on a scale of 0 to 10, a range similar to that exhibited in 2013 and 2014 (Table 6 and Figure 8). Total richness once again exhibited some variation among sites, ranging from 34 to 48; unlike in previous years, this metric consistently decreased between CLKRM13.5 and CLKRM0.5 in 2015. Tolerant taxa richness and percent tolerant organisms were once again variable among sites, and this third year of data collection indicated a larger amount of temporal variability expressed in these metrics than in others, as well (Figure 8). Interestingly, the percent tolerant organisms metric at CLKRM0.5 was notably higher in 2015 than in previous years, lending support to the possibility that lower DEQ MM scores in 2015 resulted from increased stress on the benthic community in the very lower river as compared to previous years.

Collector-gatherer and collector-filterer organisms (Table 3) once again dominated benthic communities across all sites in 2014 (Figure 9). 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.

2013-2015 PGE metric results were generally similar to those measured in 1999 and 2000 at the four sites where older data were available. Following the 2014 season, community richness appeared to potentially be trending higher at three of these sites (Table 7; Figure 10). However, community richness was reduced in 2015 relative to 2014 at two of these sites, suggesting that inter-annual variability and sampling error were likely responsible for these observed differences over time.

NMS produced a three-dimensional ordination that explained 73.4% of the variation in the original sample space (final stress = 11.17). Both year (correlation with axis 1: $r = -0.665$, $p = 0.00006$) and river mile (correlation with axis 2: $r = -0.809$; $p = <0.00001$; 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 11) reveal some clustering of samples (according to similar community composition) by both sample year (2013/2014 versus 2015) and by sample location (river mile). NMS results suggest that community conditions generally in 2015 were generally the least similar among the three sampling years, and that community conditions at CLKRM20 were the least similar among the five sites.

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, 2014, and 2015. 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**					**2015**				
DEQ Metric		**0.5**	**5**	**11**	**13.5**	**20**	**0.5**	**5**	**11**	**14**	**20**	**0.5**	**5**	**11**	**13.5**	**20**
Richness	Mean	28.5	35.5	31.5	26.0	33.5	33.0	32.5	31.0	26.0	40.0	23.5	28.5	33.5	39.5	34.0
	StDev	4.9	2.1	0.7	2.8	2.1	2.8	3.5	2.8	1.4	2.8	4.9	2.1	0.7	4.9	0.0
Mayfly Richness	Mean	9.0	11.5	9.0	7.0	9.5	9.0	7.5	7.5	7.5	9.5	6.0	8.5	9.0	9.0	9.0
	StDev	0.0	0.7	0.0	1.4	0.7	0.0	0.7	0.7	0.7	0.7	1.4	0.7	0.0	1.4	1.4
Stonefly Richness	Mean	1.5	1.0	1.5	3.0	2.0	3.5	1.5	3.5	1.5	2.5	2.0	2.5	2.5	4.5	2.5
	StDev	0.7	0.0	0.7	0.0	0.0	0.7	0.7	0.7	0.7	2.1	0.0	0.7	0.7	0.7	0.7
Caddisfly Richness	Mean	7.0	6.5	8.0	7.0	8.0	8.0	9.5	9.0	7.0	9.5	6.0	6.0	9.0	7.5	9.5
	StDev	1.4	0.7	0.0	1.4	1.4	1.4	0.7	1.4	0.0	0.7	0.0	2.8	1.4	2.1	2.1
Number Sensitive Taxa	Mean	0.5	0.0	0.5	1.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
	StDev	0.7	0.0	0.7	0.7	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	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	1.0	1.5	2.0	0.5	1.5
	StDev	0.7	0.0	0.7	0.0	0.7	0.7	0.7	1.4	0.0	0.0	0.0	0.7	0.0	0.7	0.7
Modified HBI1	Mean	4.0	4.1	3.6	3.7	4.3	4.0	4.1	3.3	3.6	4.3	4.6	4.5	4.3	4.1	4.5
	StDev	0.2	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.0	0.0	0.1	0.0	0.2	0.2
% Tolerant Taxa	Mean	34.6	46.3	42.6	49.9	53.0	28.1	46.3	31.2	39.6	27.4	46.7	57.7	55.1	36.4	43.4
	StDev	10.0	1.0	4.3	1.2	6.9	1.4	5.9	0.8	9.2	1.7	10.1	4.2	1.8	4.1	8.7
% Sed Tolerant Taxa	Mean	0.9	1.3	4.1	0.4	4.0	1.3	0.6	0.4	0.4	2.4	0.5	0.9	0.4	0.7	0.6
	StDev	0.8	1.0	3.4	0.5	2.1	0.5	0.5	0.5	0.3	1.1	0.7	0.3	0.3	0.3	0.4
% Dominant	Mean	23.8	19.1	27.5	23.0	27.7	20.6	25.1	32.5	32.6	26.0	35.7	31.2	24.8	16.8	16.3
	StDev	1.8	0.0	1.6	0.1	8.1	0.6	5.7	6.1	0.3	1.6	4.3	0.4	2.1	0.4	3.2
TOTAL SCORE	Mean	33.0	34.0	35.0	30.0	33.0	35.0	31.0	34.0	29.0	35.0	27.0	29.0	32.0	35.0	33.0
	StDev	1.4	0	1.4	0	4.2	1.4	1.4	2.8	1.4	1.4	1.4	1.4	2.8	4.2	1.4
Metro 2003 Total Score			24.0	28.0	28.0			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, 2014, and 2015. Metrics source: PGE 2004.

		2013					2014					2015				
PGE Metric		**0.5**	**5**	**11**	**13.5**	**20**	**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	34.0	35.5	39.5	48.0	43.5
	StDev	2.1	1.4	2.8	1.4	4.2	0.7	1.4	0.7	4.2	2.8	5.7	3.5	0.7	4.2	3.5
EPT Richness	Mean	17.5	19.0	18.5	17.0	19.5	13.5	18.5	20.0	16.0	21.5	14.0	17.0	20.5	21.0	21.0
	StDev	2.1	0.0	0.7	2.8	2.1	2.1	2.1	1.4	1.4	0.7	1.4	2.8	2.1	4.2	1.4
CTI	Mean	6.2	6.3	6.0	6.3	6.7	6.2	6.2	5.8	6.0	6.1	6.7	6.7	6.5	6.2	6.6
	StDev	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.2	0.0	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	51.5	64.1	55.5	36.4	38.3
	StDev	0.8	1.1	5.6	0.5	8.7	1.1	4.5	5.7	0.5	2.8	11.8	0.3	8.4	7.0	14.7
Percent Intolerant	Mean	0.5	1.6	0.3	0.2	1.1	0.3	1.8	0.1	0.1	1.0	0.4	0.9	0.0	0.2	0.4
	StDev	0.4	0.9	0.1	0.0	1.5	0.4	1.2	0.1	0.1	0.3	0.3	1.1	0.0	0.3	0.6
Percent Tolerant	Mean	33.0	36.6	26.2	32.6	48.4	31.0	25.8	13.7	17.4	20.0	54.4	46.9	38.2	33.9	40.5
	StDev	6.8	2.7	3.6	0.1	3.0	8.2	1.3	1.3	0.9	1.7	5.3	0.8	11.2	1.1	2.1
Intolerant Richness	Mean	1.0	1.0	1.5	1.0	0.5	0.5	1.5	0.5	0.5	1.0	1.0	1.0	0.0	0.5	0.5
	StDev	0.0	0.0	0.7	0.0	0.7	0.7	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.7	0.7
Tolerant Richness	Mean	13.5	17.0	13.0	9.5	15.0	15.5	14.0	11.0	10.5	17.5	10.5	14.5	13.5	18.0	15.5
	StDev	2.1	1.4	1.4	0.7	2.8	2.1	2.8	1.4	0.7	2.1	6.4	0.7	0.7	1.4	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	36.8	46.3	43.0	19.3	27.8
	StDev	10.1	0.6	8.7	2.5	10.5	2.0	6.4	1.2	8.6	0.1	14.3	4.1	3.8	10.1	9.8
% Collector-Gatherer	Mean	40.3	29.9	21.7	17.5	24.2	50.1	31.8	19.4	21.0	34.2	40.9	27.0	20.7	30.4	32.9
	StDev	6.6	2.9	0.5	0.4	2.0	1.8	4.6	5.1	0.7	3.6	13.5	2.2	2.6	9.7	6.7
% Shredder	Mean	0.9	1.0	3.4	2.3	1.3	2.0	6.6	31.7	23.9	7.3	0.2	0.2	4.2	15.3	0.9
	StDev	0.3	0.2	1.4	0.1	0.4	1.1	3.4	6.2	10.4	0.7	0.0	0.2	2.3	2.2	0.9
% Predator	Mean	5.8	9.3	10.2	10.4	9.9	11.5	10.9	8.0	9.9	15.0	3.7	7.1	10.5	12.1	9.9
	StDev	2.1	1.9	0.9	2.7	1.2	0.6	0.6	0.7	0.6	1.6	0.3	0.3	1.1	0.4	0.0
% Scraper	Mean	20.1	19.1	15.4	9.6	14.3	8.9	9.7	6.2	4.4	10.1	9.9	13.2	13.7	13.5	19.6
	StDev	4.8	0.4	3.3	3.7	2.0	0.4	0.2	0.3	1.3	0.4	1.6	0.7	2.8	4.5	3.3

Table 7. Comparison of PGE metrics calculated from 2013-2015 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**	**2015**	**2000**	**2013**	**2014**	**2015**	**2000**	**2013**	**2014**	**2015**	**1999**	**2013**	**2014**	**2015**
Richness	27.0	36.5	42.5	34.0	36.0	40.0	40.5	39.5	31.0	34.0	39.0	48.0	35.0	41.0	52.0	43.5
EPT Richness	13.0	17.5	18.5	14.0	21.0	18.5	20.0	20.5	20.0	17.0	16.0	21.0	16.0	19.5	21.5	21.0
CTI	6.4	6.2	6.2	6.7	6.1	6.0	5.8	6.5	6.2	6.3	6.0	6.2	6.1	6.7	6.1	6.6
Dom (3)	66.0	49.6	38.1	51.5	51.0	55.4	61.7	55.5	79.0	62.2	60.2	36.4	77.0	52.2	34.9	38.3
Percent Intolerant	0.4	0.5	0.3	0.4	0.0	0.3	0.1	0.0	0.0	0.2	0.1	0.2	0.5	1.1	1.0	0.4
Percent Tolerant	41.3	33.0	31.0	54.4	22.0	26.2	13.7	38.2	18.0	32.6	17.4	33.9	10.0	48.4	20.0	40.5
Intolerant Richness	1.0	1.0	0.5	1.0	0.0	1.5	0.5	0.0	0.0	1.0	0.5	0.5	1.0	0.5	1.0	0.5
Tolerant Richness	9.0	13.5	15.5	10.5	11.0	13.0	11.0	13.5	8.0	9.5	10.5	18.0	8.0	15.0	17.5	15.5
% Collector-Filterer	47.0	27.4	17.8	36.8	26.0	25.8	25.3	43.0	42.0	35.8	31.1	19.3	50.2	41.1	18.4	27.8
% Collector-Gatherer	25.0	40.3	50.1	40.9	29.0	21.7	19.4	20.7	16.0	17.5	21.0	30.4	20.0	24.2	34.2	32.9
% Shredder	1.0	0.9	2.0	0.2	3.3	3.4	31.7	4.2	3.5	2.3	23.9	15.3	0.3	1.3	7.3	0.9
% Predator	11.2	5.8	11.5	3.7	11.0	10.2	8.0	10.5	16.0	10.4	9.9	12.1	21.0	9.9	15.0	9.9
% Scraper	15.0	20.1	8.9	9.9	25.0	15.4	6.2	13.7	21.0	9.6	4.4	13.5	6.0	14.3	10.1	19.6

DISCUSSION

Results of the 2015 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 modest variation in community conditions among lower river locations. These results also generally suggest relatively uniform ambient environmental conditions within this 20-mile length of river. Observations of physical habitat conditions and water quality measurements made during this study from 2013 through 2015 also suggest a lack of obvious 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 river 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 analyses in both 2014 and 2015 revealed measurable differences in community *composition* among sites, and that these subtle differences do correspond with river mile. NMS analysis also revealed that composition was influenced by sampling year, with larger differences occurring in 2015 relative to the other two years. 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 used in conjunction with community metric analysis.

This study included metrics from two sources – PGE's 2004 report and OR DEQ – to allow comparison of the present data set with the results of several historic data sets. While the first few years of monitoring utilized this larger number of metrics from both sources, future monitoring of the river can focus on a smaller set based on the results of these first three years of monitoring and also based on redundancy in certain metrics between the two sets. First, 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, among metrics that are redundant between the two sets, use of the PGE metrics is recommended. Furthermore, the 2004 PGE report includes an example Benthic Index of Biotic Integrity (B-IBI) that could be used to provide a single multi-metric index score for the lower river that may be 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 (source: 2004 PGE report; not calculated herein)
- OR DEQ Multimetric Index Score

Among these metrics, those showing the smallest variation among sites and years will likely hold the most promise for detection of changes in benthic community conditions when they occur. In order to evaluate and compare variation across metrics, measured variation must be normalized relative to the mean value of each metric. This normalization is achieved by dividing the standard deviation by the mean. Multiplying this result by 100 yields the coefficient of variation (CV), which can be compared among metrics to assess the relative precision of each. The signal-to-noise ratio is simply the mean divided by the standard deviation. The coefficient of variation (CV) and the signal-to-noise ratio (SNR) were calculated for each of these core metrics from the 2013-2015 data (Table 8).

Among the six metrics tested, the Community Tolerance Index (CTI) had the lowest CV (and therefore highest SNR), while the percent tolerant and tolerant richness metrics had the highest CV and correspondingly lowest SNR. DEQ MM scores, EPT richness, and total richness each had intermediate CV values relative to these extremes. This exercise was not intended to determine which metrics to retain or to exclude from future analyses, but to illustrate which metrics are likely to be less precise ("noisier") and therefore less likely to detect change in community conditions when they occur. These metrics will not be equally sensitive to every type of disturbance, underscoring the importance of maintaining a number of metrics in future analyses. Based on these results, the CTI, DEQ MM scores, and total richness metric hold the most promise for detecting change when change occurs.

Table 8. Coefficients of variation (CV) and signal-to-noise ratios (SNR) of select macroinvertebrate community metrics calculated from samples collected from the lower Clackamas River 2013-2015.

Metric	Source	CV	SNR
CTI	PGE 2004	4.2	25.5
DEQ MM Score	DEQ	9.0	11.8
Total Richness	PGE 2004	11.7	11.6
EPT Richness	PGE 2004	12.8	8.9
Tolerant Richness	PGE 2004	20.2	5.9
Percent Tolerant	PGE 2004	34.7	3.0

Generally, conditions appear to be similar among lower-river reaches and do not vary considerably over time (and over the range of environmental conditions that occurred during this two-year sampling period). The lower MM scores for both replicates at CLKRM0.5 in 2015 suggest that the result is representative of conditions at the site at the time of sampling. As this site occurs furthest downriver in the system, where environmental extremes are likely to be largest, it would be expected that this site could experience larger temporal variability than would the other sites. This larger variability in scores at CLKRM0.5 highlights the need to use a statistically based approach for determining when such deviations in scores from those of previous years represent a change in ecological condition that occurs outside "normal" range.

One such approach compares new values to the range of previous values in order to determine the likelihood that the new and old values derive from the same population (signifying no change). The data collected over the past three years are considered to be representative of the "natural" variability within sites, among sites, and across the three years, and have been collected in the absence of any known significant disturbances. Accordingly, quantification of this variability within each site over the three years allows one to estimate the value of each metric that would be sufficiently outside this range so as to likely be the result of a change in condition. When data are normally distributed (will need to be tested once each site has amassed a larger sample size), 95% percent of values should occur within two standard deviations of the mean. Any values occurring outside this range of metric values collected from each site would be cause for further investigation of this likely decline in biological condition.

The DEQ multimetric score was used to demonstrate how each metric can be used in change-of-condition detection in this manner (Table 9). MM scores larger than two standard deviations below the mean would be an indication that a change in biological condition has occurred because the probability of such a value occurring under "natural" conditions (i.e., in the absence of disturbance) would be 0.05 (with normally distributed data). Because a wider range of scores has occurred at some sites than at others, threshold metric values for detecting change will differ among sites using this approach. Sites with larger "natural" variability, such as CLKRM0.5, will have lower threshold values to indicate a change. When such changes occur, the data should first be examined to determine whether a potential outlier sample contributed to the result, or if the duplicate sample results correspond with each other. Follow-up investigation could include additional biological sampling to corroborate the initial results, as well as water quality testing, particularly if follow-up biological sampling continues to indicate a likely impact. Of course, as additional data are collected in future years (and those data are determined not to indicate any change in condition to the benthic community), these additional data can be used to refine these criteria for detecting potential impacts.

Table 9. Multimetric score overall mean, standard deviation, and mean minus two standard deviations for each of five macroinvertebrate sample sites on the Clackamas River, 2013-2015 (n = 6 each site).(*) indicates a value that is potentially biased low from a likely outlier metric value being retained in the data set used to derive the mean and SD.

Site	Mean	SD	Mean - 2 SD
CLKRM0.5	31.7	3.9	23.9
CLKRM5.0	31.3	2.4	26.5
CLKRM11	33.7	2.3	29.0
CLKRM13.5	31.3	3.5	24.3*
CLKRM20	33.7	2.3	29.0
OVERALL MEAN	32.3	2.9	26.5

The data collected in this study represent the most comprehensive baseline assessment to date of macroinvertebrate communities in the lower Clackamas River. Their utility will only be realized if monitoring efforts occur regularly, such as every year or two. The lower Clackamas River supports a rich macroinvertebrate community. While the lower river doesn't support the same abundance or variety of intolerant taxa supported by upriver reaches (upriver of River Mill Dam; PGE 2004), the lower river's thermal regime is sufficiently cool on an annual basis to preclude tolerant species from fully exploiting the lower river (PGE 2004). The lower river's thermal regime may be just so that even modest changes could result in shifts in the river's benthic community composition. Furthermore, 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). Accordingly, understanding inter-annual variability in the benthic communities relative to natural year-to-year variation in the thermal and flow regimes will continue to be paramount to detecting changes unrelated to natural variability. Any deleterious changes to the benthic community are likely to manifest as one or more metrics (or multimetric scores) falling outside of their measured "normal" range of variability. Sampling at least biannually (preferably annually) will continue to build a dataset that will allow a 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.

CONCLUSIONS & RECOMMENDATIONS

- The first three years of CRWP macroinvertebrate monitoring in the lower Clackamas River suggest that community conditions 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 conditions may be slightly improved at some sites 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 current water quality and habitat conditions that are generally suitable for maintenance of diverse native aquatic communities.

- Conditions measured in 2015 were generally similar to those measured in 2013 and 2014 at most sites. While temporal variability in community metrics was higher at some sample sites than at others, the measured variability 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 2015). While conditions at CLKRM0.5 (as indicated by a number of metrics) were lower in 2015 than in past years, the measured condition likely reflects the natural variability in conditions in the lower river and is not suggestive of a decline in condition immediately related to anthropogenic disturbance. Accordingly, these data represent average conditions and variability in these conditions over the range of environmental conditions occurring during the 2013-2015 sampling period.

- These three years of baseline macroinvertebrate community conditions in the lower Clackamas River were used to calculate several measures of variability, including the coefficient of variation and signal-to-noise ratio, to understand the relative sensitivity of metrics selected for monitoring and to exemplify how to use the data to detect future change.

- Continue annual or biannual replicated sampling in the lower Clackamas River. These additional data will further characterize spatial and temporal variability under a range of climatic and flow conditions, thereby improving the ability to detect change when change occurs. Future data will also be used to identify changes to benthic community conditions through comparison with measured variation in conditions over the past three sampling years.

- Continue testing the selected monitoring metrics for changes in condition and for further characterization of variability as additional data are amassed. Focus analyses on the set of core metrics and multimetric indexes identified and examined in this report.

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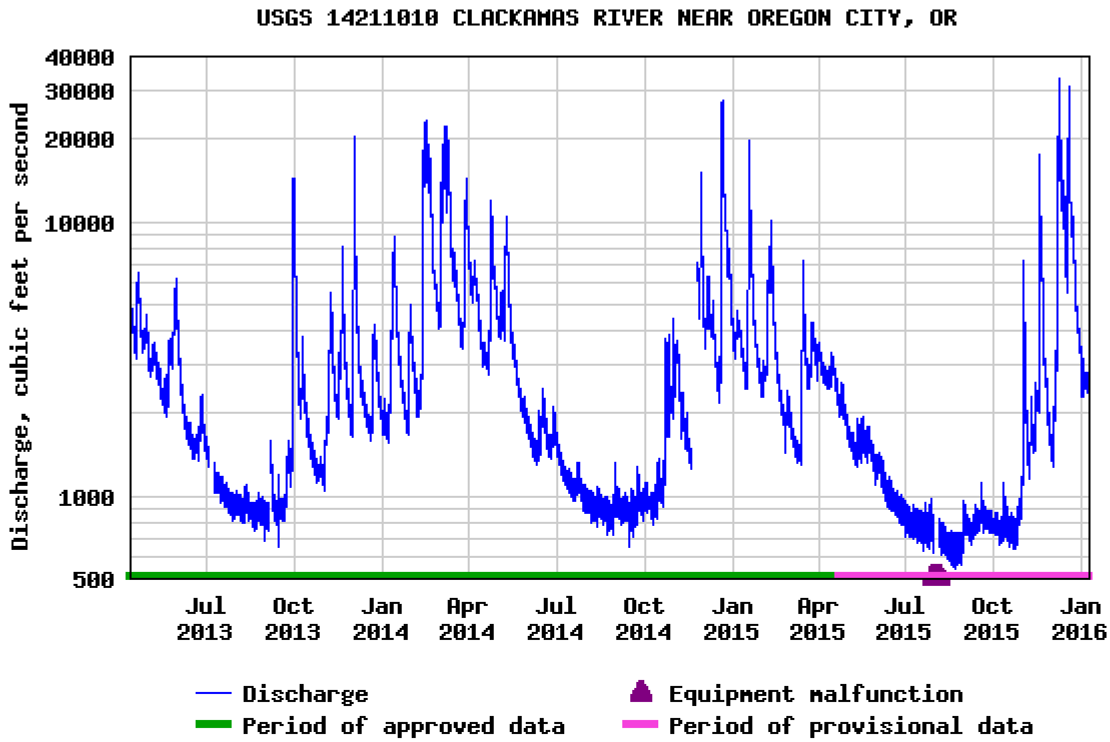
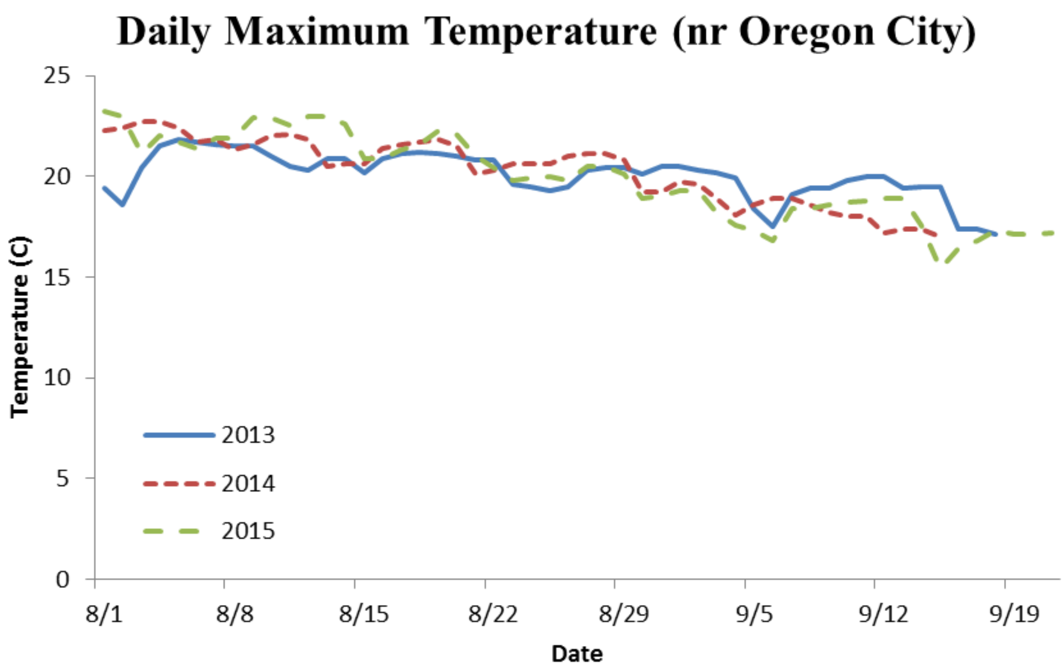


Figure 2. Summer 2013 through December 2015 Clackamas River discharge as measured at USGS gage station 14211010. Data collected after March 2015 are provisional.



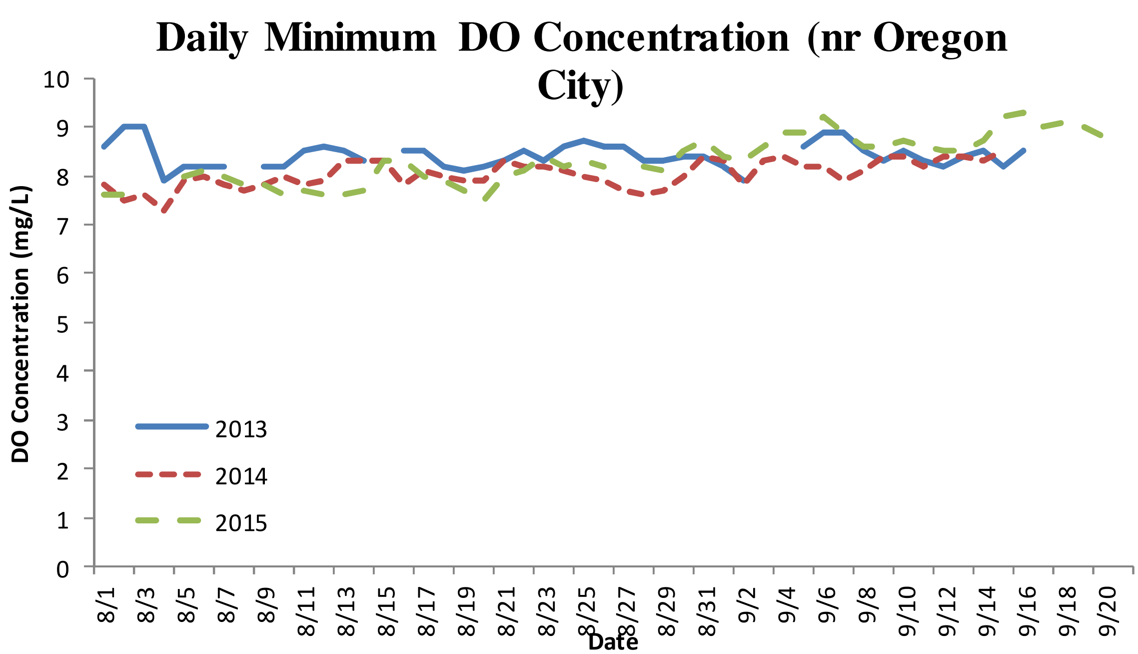


Figure 3. Clackamas River daily maximum water temperatures and daily minimum dissolved oxygen concentrations measured at USGS gage station 14211010, August 1 through September 20, 2013-2015. Data collected after March 2015 are provisional.

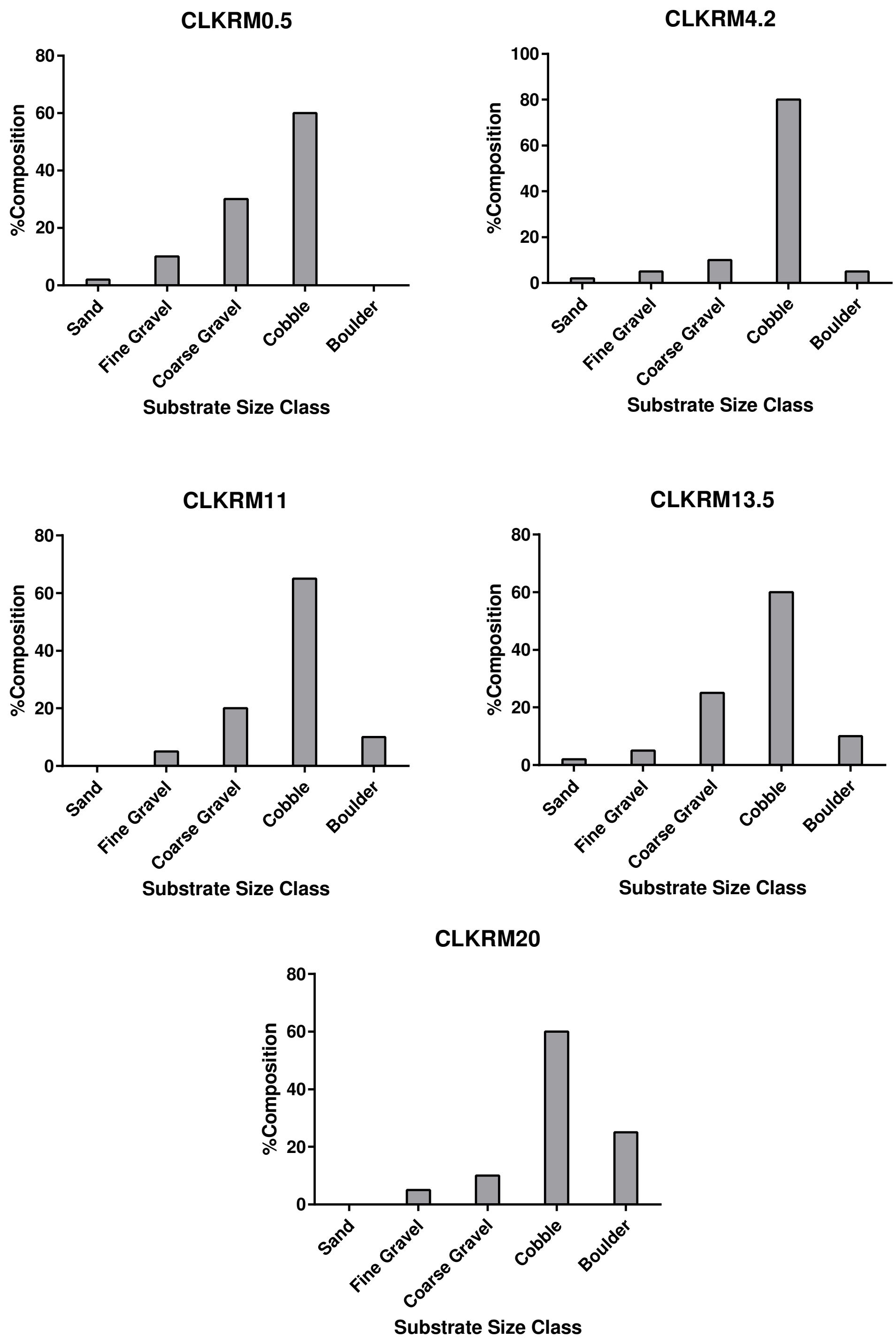


Figure 4. Substrate composition at six Clackamas River macroinvertebrate samples sites, September 2015.

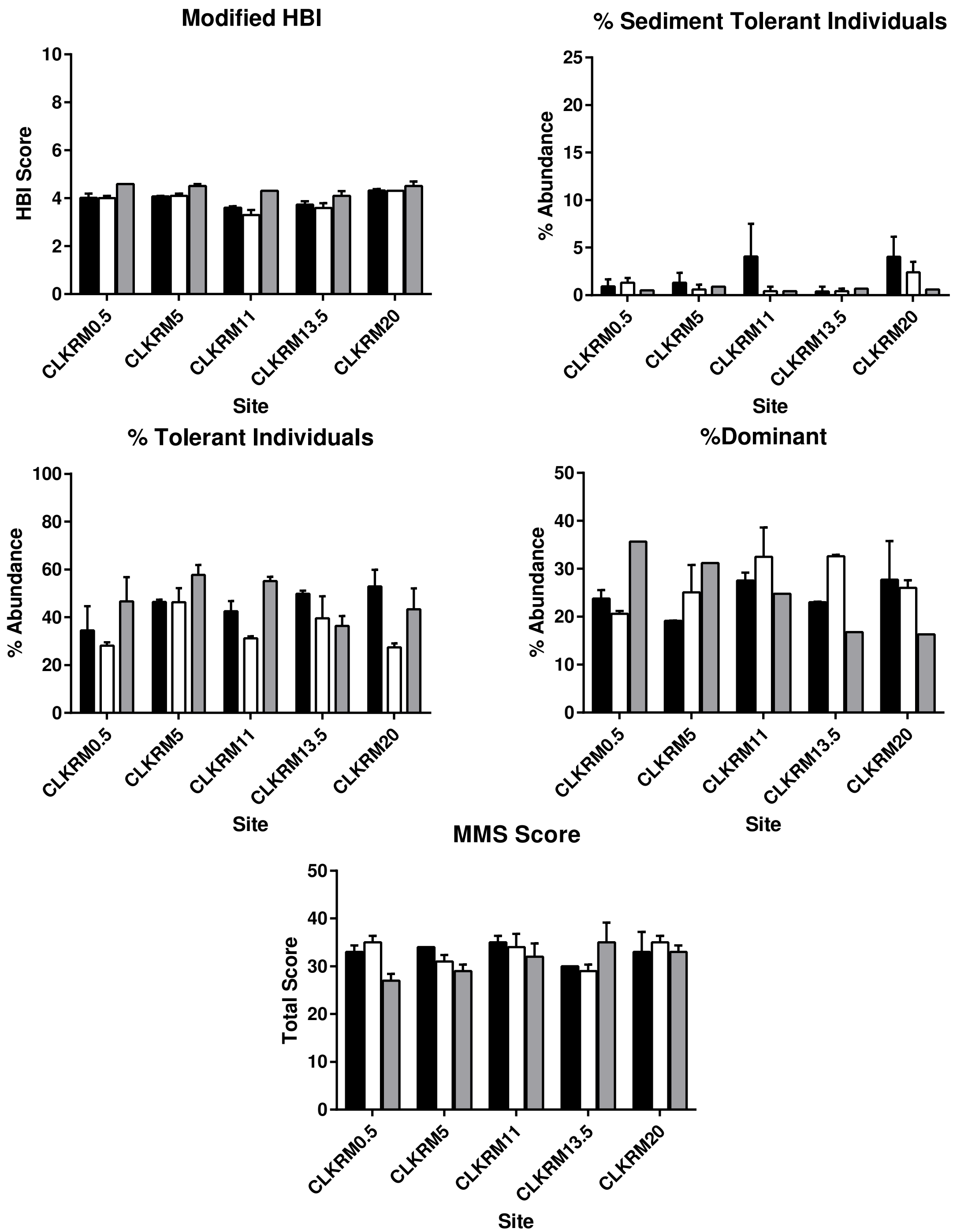


Figure 5. Mean (+SD) macroinvertebrate community metric scores and total multimetric scores (MMS) calculated from duplicate samples collected from the lower Clackamas River in September 2013 (black bars), 2014 (white bars), and 2015 (grey bars).

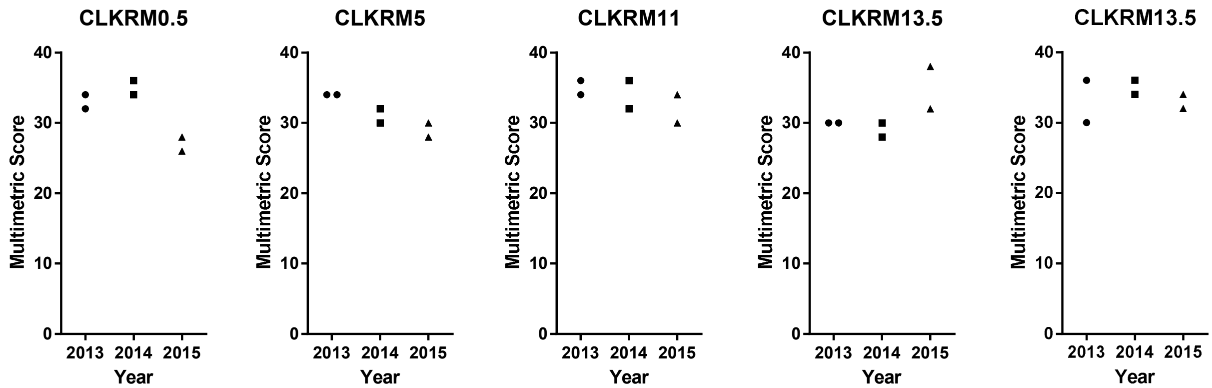


Figure 6. Macroinvertebrate multimetric scores (y axis) calculated from individual duplicate macroinvertebrate samples collected from five locations in the lower Clackamas River in 2013, 2014, and 2015. Squares represent the first sample collected, and diamonds represent the second sample collected. Each graph represents a single sample site.

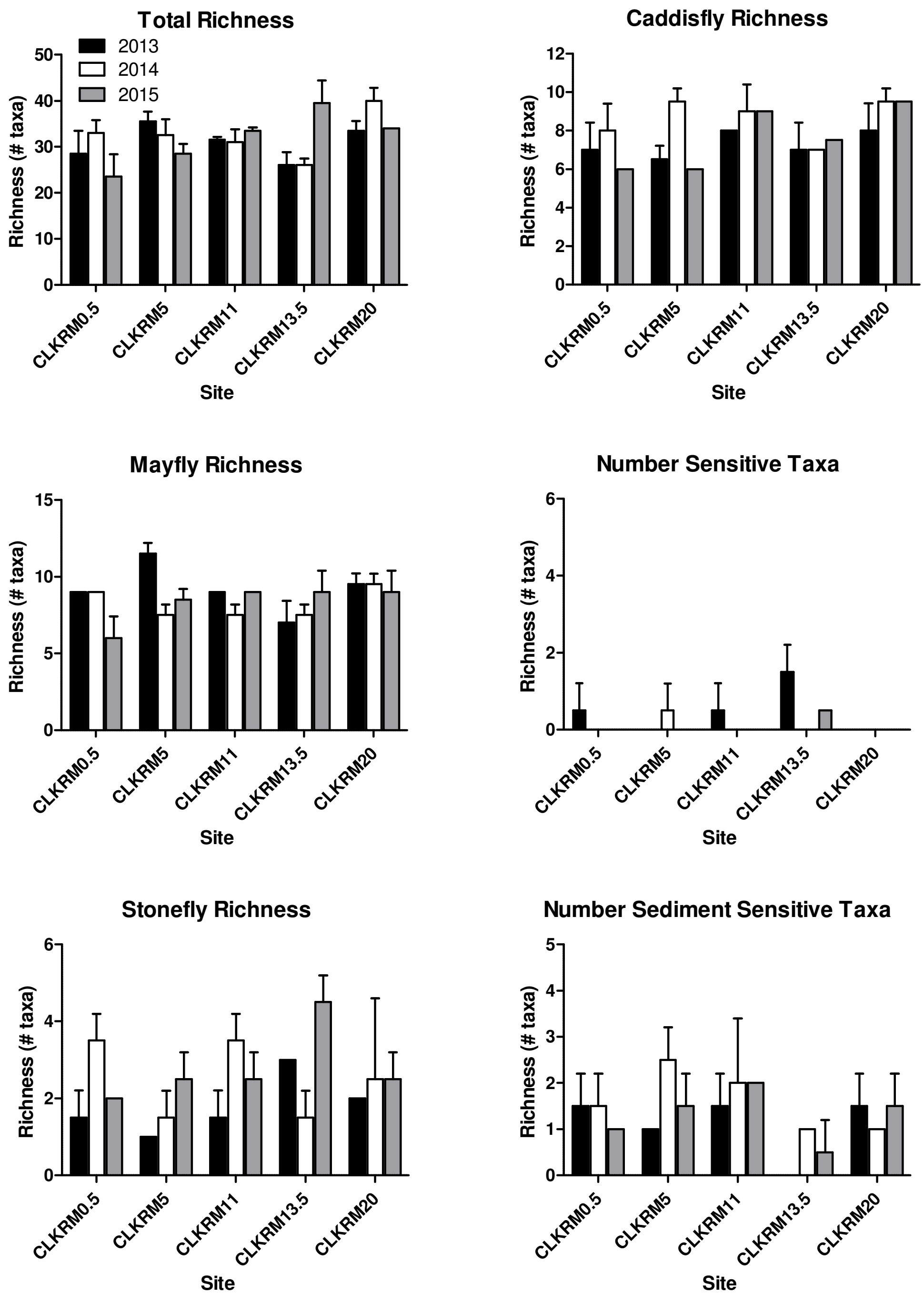


Figure 7. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013 (black bars), 2014 (white bars), and 2015 (grey bars).

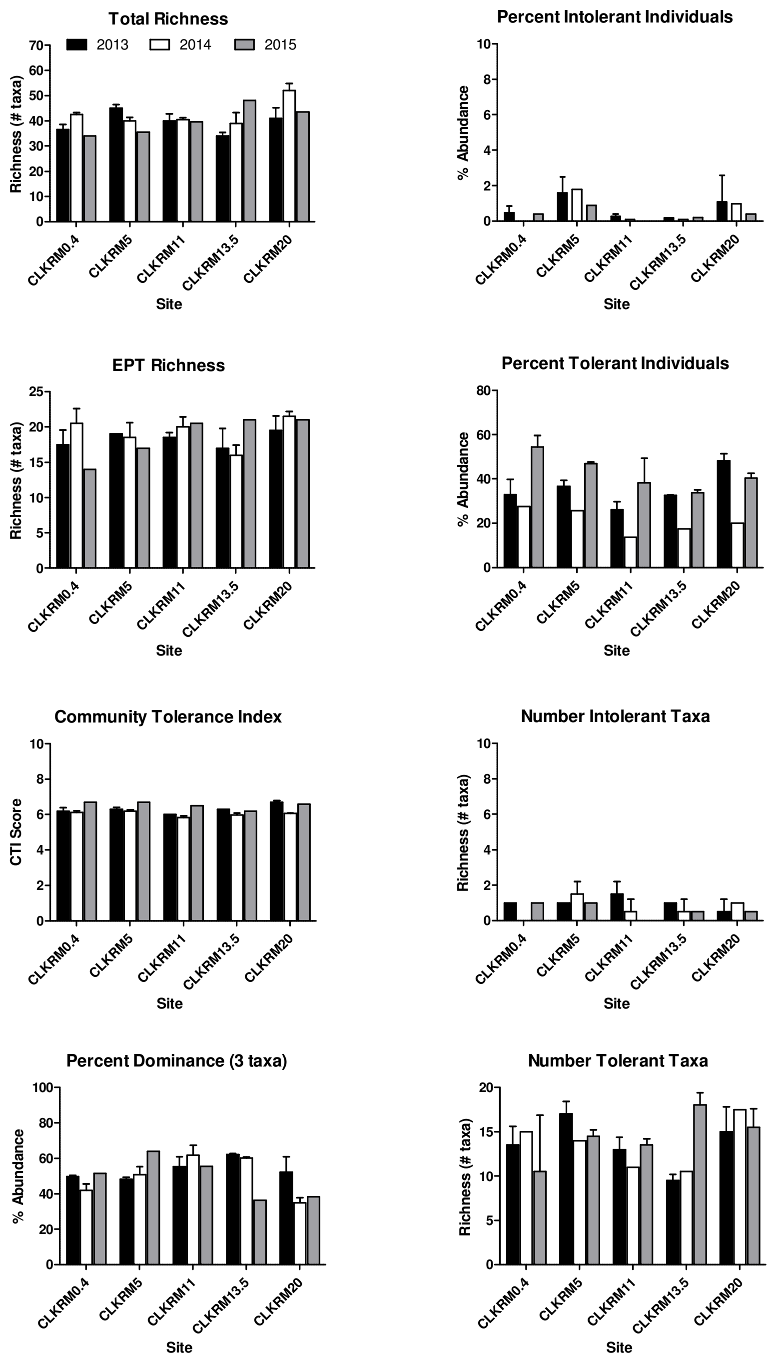


Figure 8. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013 (black bars), 2014 (white bars), and 2015 (grey bars). Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

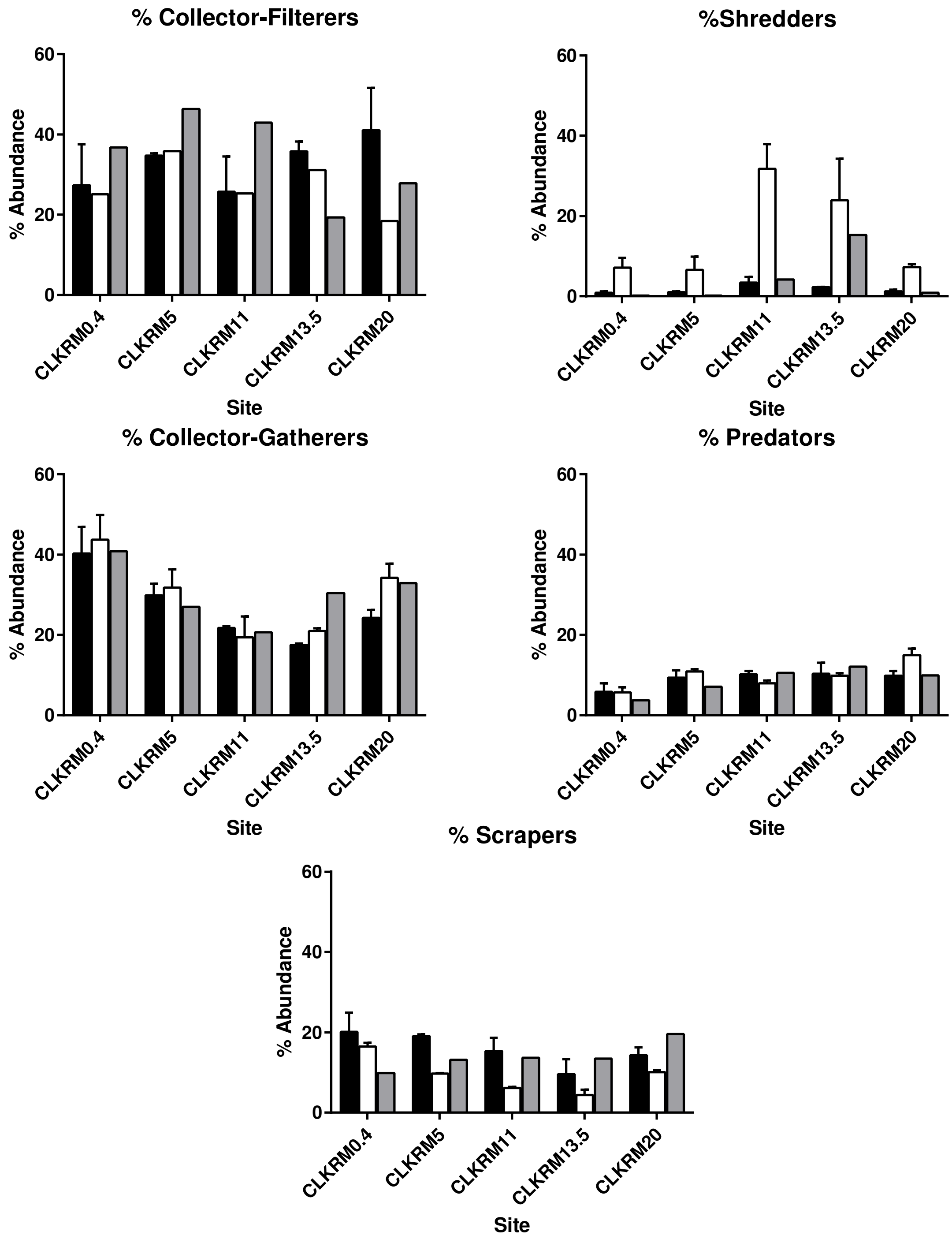


Figure 9. Mean (+SD) abundance of macroinvertebrate functional feeding groups calculated from duplicate samples collected from the lower Clackamas River in September 2013 (black bars), 2014 (white bars), and 2015 (grey bars). Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

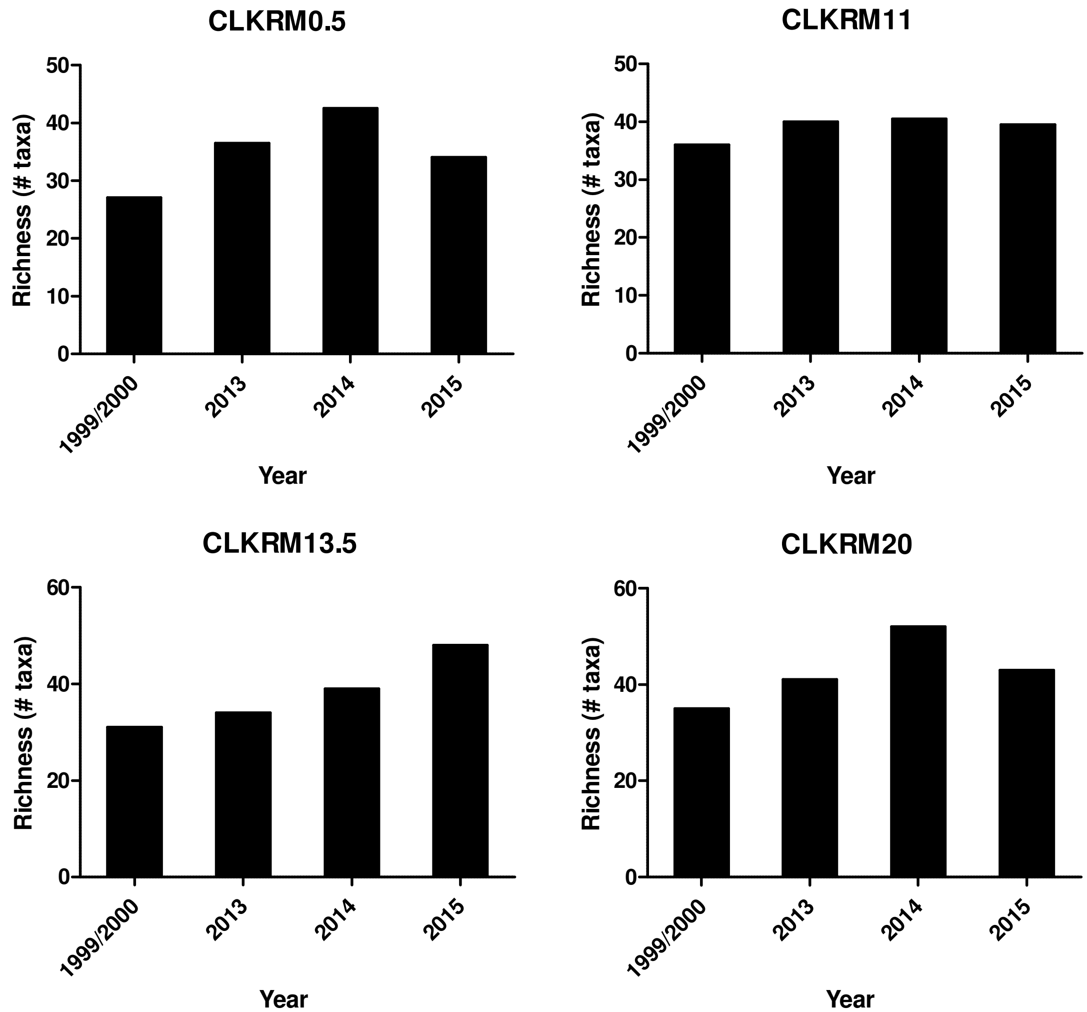
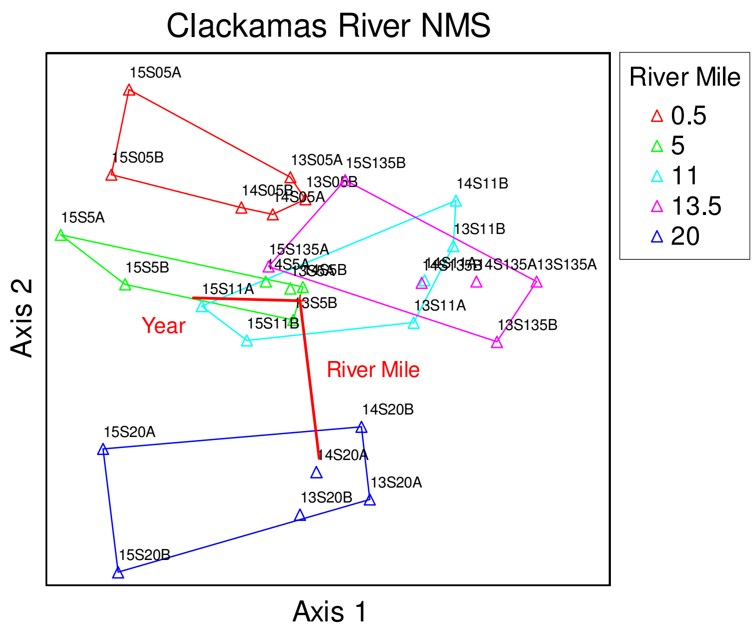


Figure 10. Mean total taxa richness calculated from macroinvertebrate samples collected from the Clackamas River in 1999/2000 and 2013-2015.



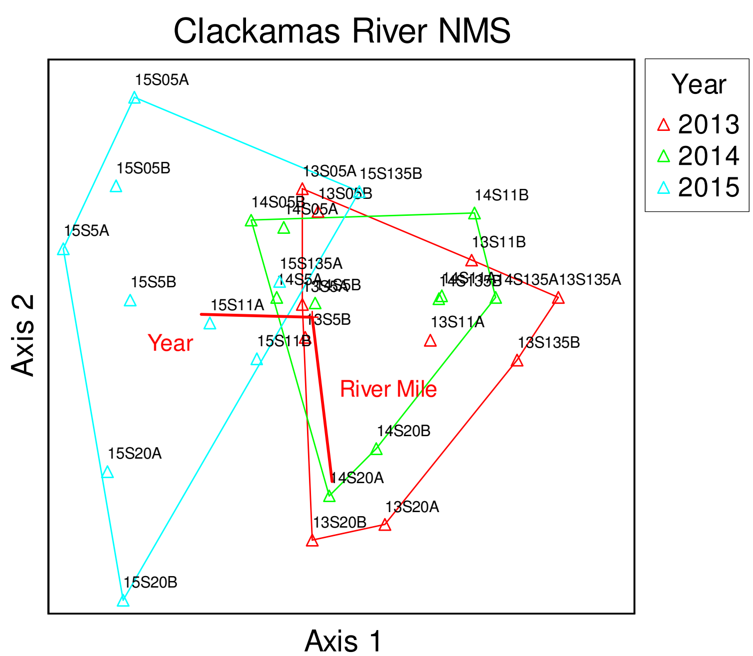


Figure 11. NMS ordination bi-plots of macroinvertebrate communities sampled from five reaches in the lower Clackamas River, Oregon, in September 2013, 2014, and 2015. Each point in each bi plot represents a single sample. Samples in the upper bi-plot are color-coded by river mile, while points in the 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 2015 site photos

CLKRM0.5

CLKRM5

CLKRM11

CLKRM13.5

CLKRM20