

# 2019 LOWER CLACKAMAS RIVER MACROINVERTEBRATE ASSESSMENT

Clackamas County, Oregon

## FINAL REPORT

Prepared for

**Clackamas River  
Water Providers**

By

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April 2020



## 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; over time these efforts will produce a robust dataset necessary to identify changes in biological conditions when they occur. Under this plan, the lower Clackamas River has been sampled in 2013, 2014, 2015, 2018, and 2019. Each year, macroinvertebrates were sampled from five sites in the lower Clackamas River between river miles 0.5 and 20. 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.

These five years of CRWP macroinvertebrate monitoring in the lower Clackamas River suggest that community conditions are generally similar between river miles 0 and 20, but some minor longitudinal gradients/changes community composition do occur. 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 since these earlier studies. 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 mayfly, stonefly, and caddisfly (EPT) taxa throughout the lower river suggests that current water quality and habitat conditions are generally suitable for maintenance of diverse native aquatic communities.

Community conditions measured in 2019 were generally similar to the range of conditions measured from 2013 to 2018. These five years of data collectively suggest that no notable changes have occurred in macroinvertebrate community conditions in the lower 20 miles of the Clackamas River since 2013. Therefore, these 2013-2019 data are considered to represent natural variability in these conditions over the range of environmental conditions that have occurred during this period. Accordingly, these five years of 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 continue 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 these past sampling years.

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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 sampling in 2020 was led by Christopher Burtch of Cole Ecological, Inc. with assistance from Kim Swan of CRWP and Suzanne DeLorenzo, Water Quality Manager for Clackamas River Water (CRW). Macroinvertebrate samples were processed by Christopher Burtch. Project taxonomy was performed by Cole Ecological, Inc. 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 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 conditions 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 2013a). Owing primarily to differing geographic foci and a lack of coordination among entities, each of these efforts has 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 2013a).

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 2013a). This plan recommends sampling from the lower mainstem Clackamas River and its major tributaries once every year (or every other year, 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. CRWP has focused their monitoring efforts on the lower mainstem Clackamas River. CRWP sampled the lower mainstem Clackamas River in each of the first three years of monitoring (2013-2015) following implementation of the plan (Cole 2016, Cole 2014, Cole 2013b). After a two-year break in the effort, CRWP

sampled the lower mainstem again in 2018 (Cole and Burtch 2019) and 2019. The main objective of this fifth year of monitoring in the mainstem Clackamas River was to determine whether conditions have remained similar to those measured from 2013 to 2018. This report describes the methods, results, and conclusions for this fifth year of monitoring macroinvertebrate communities in 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. Since 2014, the uppermost site has 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 each year monitoring year since to bracket this large tributary system.

Rock Creek enters the Clackamas River at RM 6.4. A sample site was established 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 from 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.

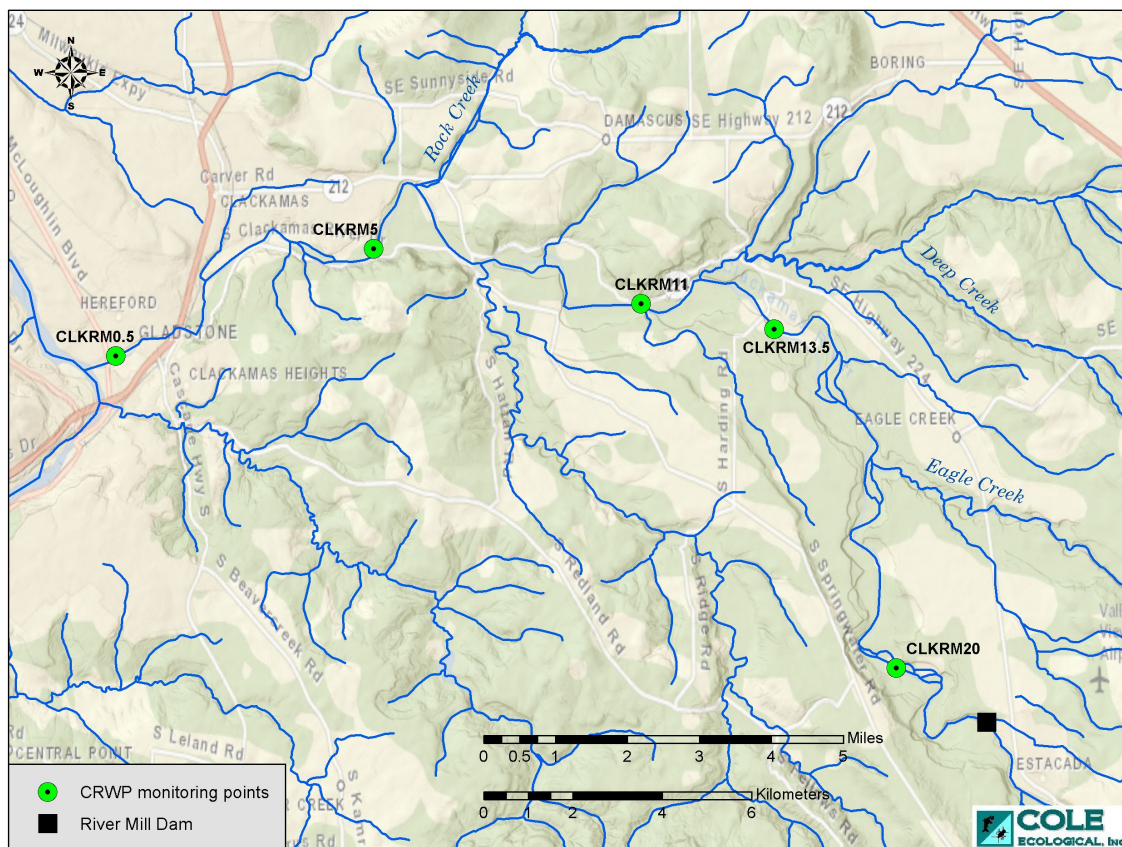


Figure 1. 2013-2015 and 2018-2019 lower Clackamas River macroinvertebrate sample sites.

## FIELD DATA COLLECTION

For the fifth year of sampling, macroinvertebrates were sampled from these five sites on the lower Clackamas River on September 24, 2019. Macroinvertebrate sample collection, physical habitat assessment, and water quality sampling were performed 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 from 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 and 2018-2019.

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 directly downriver of PODs	USGS @ Gladstone nr mouth (1999)
CLKRM5	East side of Sah-Hah-Lee Golf Course	45.395961	-122.5252	20	Monitor WQ directly 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  $\mu$ m 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  $\mu$ m 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**

Preserved samples were sorted to remove a 500-organism subsample 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 2 macroinvertebrate assessments by the Pacific Northwest Aquatic Monitoring Partnership (2015).

### **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 and 2018-2019.

Metric	Scoring Criteria		
	5	3	1
<b>POSITIVE METRICS</b>			
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
<b>NEGATIVE METRICS</b>			
Modified HBI <sup>1</sup>	<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

<sup>1</sup> 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 largely having been 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 report. Source coding for calculating these metrics was provided by Bob Wisseman of Aquatic Biology Associates (B. Wisseman, personal communication). Chironomidae were identified to genus or species-group levels for these analyses. These metrics were analyzed in the same manner as described above for the DEQ metric set.

## RESULTS

Clackamas River streamflows during the 2019 sampling event (September 24, 2019) were near seasonal base flows, as determined from data obtained from USGS gage station 14211010 on the Clackamas River near Oregon City. A wet-weather event brought discharge up to 1,800 cfs on September 18, 2019, but such flows would not be expected to disrupt the benthic community or affect the September 24<sup>th</sup> sampling (Figure 2). Provisional USGS water quality data collected at this gage station suggest that neither

late-summer temperature nor dissolved oxygen conditions notably differed between 2019 and the previous four monitoring years (Figure 3).

Rapid habitat scores from the five sites in 2019 ranged from 159 to 187 (on scale of 10 to 200). Habitat conditions most similar across reaches were those related to substrate composition, sediment deposition, and substrate embeddedness (Table 4). Substrate conditions were generally similar among the five sites and appeared largely unchanged relative to those observed during any of the earlier sampling periods between 2013 and 2018. Riffle bed materials were dominated by cobble substrate at all sites (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). Rapid habitat scores relating to riparian conditions were more variable among the five sites, as riparian conditions generally decreased in a downriver direction (Table 4). Overall, physical habitat conditions have remained similar since 2013, when monitoring was initiated. No significant changes in habitat conditions between 2013 and 2019 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 once again similar among the five reaches in 2019. Dissolved oxygen concentrations approached or exceeded complete saturation, and specific conductance ranged narrowly (between 62 and 66  $\mu\text{S}/\text{cm}$ ) across all sites (Table 4).

DEQ macroinvertebrate multimetric (MM) scores calculated from the 2019 data indicate that community conditions were similar among the reaches, as mean total MM scores ranged between 28 and 41 on a scale of 10 to 50 (Table 5 and Figure 5). Across the five sites, 2019 MM scores averaged 33.8, versus 34.0 in 2018, 31.2 in 2015, 32.8 in 2014 and 30.8 in 2013, suggesting similar lower-river-wide benthic ecological conditions across the five years.

Between 2013 and 2019, mean MM scores have ranged by three points at CLKRM5.0, by seven points at CLKRM20, by eight points at CLKRM0.5, and by nine points at CLKRM11 and CLKRM13.5. As in 2015, the 2018 MM score data suggest a general longitudinal decrease in macroinvertebrate community conditions in a downriver direction (Figure 5). While this potential trend was not evident in the first two years of sampling, it was evident in 2015, 2018, and 2019. Over the seven-year sampling period, no sites have shown any strong evidence of trends in increasing or decreasing conditions. MM scores appear to have potentially slightly decreased over time at the lowest site, CLKRM0.5, while potentially increased during the same period at CLKRM11 and CLKRM13.5 (Table 5, Figures 5 & 6). However, none of these ranges are strongly

suggestive of a change in condition at any of the sites beyond what might be expected to result from normal year-to-year variability.

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 2019 (Table 5). The mean MM score was slightly higher at CLKRM5.0 than at CLKRM0.5 (32 versus 28) in 2019, while mean the MM score at CLKRM11 was seven points higher than at CLKRM13.5 (Table 5), suggesting similar overall community conditions between sites within each pair.

Total MM scores between 2013 and 2018 have consistently been higher than those measured in 2003 by Metro (Table 5; Cole 2004). MM scores at CLKRM5 have increased from 24 in 2003 to an average of 30.2 since 2013. MM scores at CLKMR11 have increased at from 28 in 2003 to 35.2 since 2013. MM scores at CLKRM13.5 were very similar between 2003 (28) and 2013-14 (30 and 29), but the 2015-2019 scores of 35, 38, and 34 are higher than the 2003 score. As the 2003 data are from only one year and are single (rather than replicate) samples, their accuracy is less certain than that of the more recent data. Nevertheless, conditions are clearly at least as favorable as they were in 2004, and potentially slightly improved.

With only a few exceptions, individual DEQ metrics were also generally similar from 2013 to 2019 at each site (Table 5; Figures 5 and 7). As in 2015 and 2018 (but not 2013 or 2014), several metrics appeared to exhibit upstream-downstream trends in values, although these were not pronounced, and may not necessarily reflect real gradients in community conditions or composition. Taxa richness of caddisflies in particular, but also of stoneflies and mayflies, appears to exhibit some longitudinal gradients (Figure 5). These upstream-downstream trends have become more evident in the last couple of years of sampling, and appear to reflect real gradients in community composition and/or relative abundance. Importantly, these apparent trends are likely related primarily to inter-annual differences in the relative abundance of EPT taxa: Most all of these EPT taxa likely occur throughout the lower river, only in varying abundance from year to year and across sites. Nevertheless, any notable and persistent changes in community structure that result in decreased EPT richness measures would be a cause for further investigation.

Table 3. Supplemental metric set used to further assess the condition of macroinvertebrate communities in the Clackamas River, Oregon, fall 2019 (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 24, 2019.

Site Code	CLKRM0.5	CLKRM5	CLKRM11	CLKRM13.5	CLKRM20
Date	9/24/2019	9/24/2019	9/24/2019	9/24/2019	9/24/2019
<b>Water Quality</b>					
WQ Time	1506	1347	1157	1106	935
DO (% Sat)	111.2	111.9	105.6	103	103
DO (mg/L)	11.02	11.3	10.81	10.59	10.71
Cond (µS/cm)	53	53	50	49	50
Spec Con (µS/cm)	64	66	63	62	65
Temp (°C)	15.85	14.95	14.3	14.06	13.62
<b>Substrate in Area Sampled</b>					
Sand	5	5	2	0	0
Fine Gravel	10	5	5	5	5
Coarse Gravel	30	10	25	30	10
Cobble	55	70	60	55	60
Boulder	0	10	10	10	20
Embeddedness	10	10	5	10	5
Sample Depth (cm)	15-25	20-30	20-30	20-30	20-35
<b>Rapid Habitat Assessment (RHA) Scores</b>					
Epifaunal Substrate/Cover	15	17	18	18	18
Embeddedness	17	18	18	18	19
Velocity/Depth Regimes	18	18	19	19	20
Sediment Deposition	17	18	18	18	19
Channel Flow Status	16	18	18	17	18
Channel Alteration	13	18	19	18	18
Frequency/Quality of Riffles	13	19	18	16	20
Bank Stability	19	16	15	16	18
Protective Vegetation	16	16	18	17	18
Riparian Zone Width	15	12	17	20	19
RHA Total Score	<b>159</b>	<b>170</b>	<b>178</b>	<b>177</b>	<b>187</b>

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 longitudinal trends in most attributes examined (Table 6 and Figure 8). However, as was the case with in 2015 and 2018, the 2019 PGE metrics total richness and EPT richness exhibited apparent upstream-downstream trends. Total richness once again exhibited some variation among sites, ranging from 37.5 taxa at CLKRM0.5 to 51 taxa at CLKRM13.5 in 2019. Similarly, EPT richness increased from 14.5 taxa at CLKRM0.5 to 21.5 at CLKRM13.5 and CLKRM20 (and 23 at CLKRM11). Among the other PGE study metrics, 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 between 2013 and 2018 (Table 6 and Figure 8). Tolerant taxa richness and percent tolerant organisms were once again variable among sites (Figure 8).

Collector-gatherer and collector-filterer organisms (Table 3) once again dominated benthic communities across all sites in 2019 (Figure 9). As in previous years, both metrics exhibited moderate variation among sites, suggesting that these metrics are not as suitable as select others for detecting changes in benthic community conditions in the river.

2013-2019 PGE metric results were generally similar to those measured in 1999 and 2000 at the four sites where older data were available. Collectively, the 2013-2019 suggest that community richness is higher at these sites than in 1999/2000 (Table 7; Figure 10). However, with only one year of prior data and the results derived from single (not replicated) samples, inter-annual variability and sampling error are potentially responsible for these apparent differences.

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, 2015, 2018, and 2019. 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					2018					2019				
DEQ Metric		0.5	5	11	13.5	20	0.5	5	11	13.5	20	0.5	5	11	13.5	20	0.5	5	11	13.5	20	0.5	5	11	13.5	20
<b>Richness</b>	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	25.0	35.0	39.5	36.0	42.5	27.0	30.0	38.0	36.5	37.0
	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	1.4	0.0	2.1	1.4	0.7	4.2	1.4	1.4	0.7	2.8
<b>Mayfly Richness</b>	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	3.5	6.0	8.0	5.0	6.0	8.0	10.0	10.5	11.0	11.0
	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	0.7	0.0	0.0	1.4	0.0	0.0	1.4	0.7	0.0	0.0
<b>Stonefly Richness</b>	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	2.0	3.5	2.5	6.0	3.5	1.5	2.0	4.0	3.5	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	0.0	0.7	0.7	0.0	0.7	0.7	0.0	0.0	0.7	0.7
<b>Caddisfly Richness</b>	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	4.0	7.0	10.0	8.5	12.5	5.0	6.0	9.0	7.0	8.0
	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	0.0	0.0	1.4	0.7	2.1	0.0	0.0	1.4	1.4	0.0
<b>Number Sensitive Taxa</b>	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	1.5	0.5	0.0	1.5	0.0	1.0	1.5	1.0	1.0	1.5
	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	0.7	0.7	0.0	0.7	0.0	0.0	0.7	0.0	0.0	0.7
<b># Sed Sensitive Taxa</b>	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	1.0	1.0	2.5	1.0	3.0	1.0	1.0	2.5	0.0	1.0
	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	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.7	0.0	0.0
<b>Modified HBI1</b>	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	4.8	4.2	3.9	3.2	4.1	4.9	3.9	3.8	4.2	4.1
	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	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.5	0.0
<b>% Tolerant Taxa</b>	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	36.8	42.2	44.1	28.0	42.7	39.3	45.3	36.1	14.1	36.8
	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	2.2	7.6	1.0	4.7	4.6	5.0	1.2	6.4	1.9	10.8
<b>% Sed Tolerant Taxa</b>	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	2.5	1.8	1.6	0.9	2.4	5.0	1.4	2.0	2.6	2.7
	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	1.2	1.5	0.4	0.2	0.4	1.8	0.1	0.1	0.5	1.8
<b>% Dominant</b>	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	21.2	25.0	20.9	21.9	20.9	26.1	24.6	16.4	22.7	20.3
	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	2.8	5.9	1.3	6.6	5.9	2.1	1.7	1.2	2.7	5.8
<b>TOTAL SCORE</b>		Mean	32.0	31.0	32.0	29.0	30.0	35.0	31.0	34.0	29.0	35.0	32.0	35.0	33.0	33.0	29.0	29.0	37.0	38.0	37.0	28.0	32.0	41.0	34.0	34.0
		StDev	0.0	1.4	0.0	1.4	2.8	1.4	1.4	2.8	1.4	1.4	1.4	2.8	4.2	1.4	1.4	1.4	1.4	0.0	1.4	0.0	0.0	1.4	2.8	0.0
<b>Metro 2003 Total Score</b>			24.0	28.0	28.0			24.0	28.0	28.0			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, 2015, 2018, and 2019. Metrics source: PGE 2004.

PGE Metric		2013					2014					2015					2018					2019				
		0.5	5	11	13.5	20	0.5	5	11	13.5	20	0.5	5	11	13.5	20	0.5	5	11	13.5	20	0.5	5	11	13.5	20
<b>Richness</b>	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	36.0	45.0	50.0	47.5	51.5	37.5	39.5	48.5	51.0	47.5
	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	4.2	0.0	2.8	4.9	0.7	4.9	0.7	0.7	1.4	0.7
<b>EPT Richness</b>	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	9.5	16.5	20.5	19.5	22.0	14.5	18.0	23.5	21.5	21.5
	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	0.7	0.7	0.7	2.1	1.4	0.7	1.4	0.7	0.7	0.7
<b>CTI</b>	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	6.6	6.3	6.4	6.0	6.5	6.7	6.3	6.2	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	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.3	0.0
<b>Dom (3)</b>	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	40.5	49.4	50.5	43.6	45.9	39.6	53.0	34.9	37.0	39.0
	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	0.8	8.5	5.7	1.6	7.2	3.4	0.2	5.2	4.4	9.8
<b>Percent Intolerant</b>	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	0.3	0.8	0.3	0.8	1.0	0.4	0.2	0.5	0.1	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	0.4	0.9	0.5	0.4	0.1	0.0	0.3	0.4	0.1	0.4
<b>Percent Tolerant</b>	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	49.0	36.2	38.3	31.7	42.4	57.0	38.3	36.6	51.3	46.5
	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	2.0	1.0	1.6	8.0	3.0	3.3	0.1	4.7	13.5	1.0
<b>Intolerant Richness</b>	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	1.0	1.5	0.5	2.0	1.0	1.0	0.5	1.0	0.5	1.5
	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	1.4	0.7	0.7	0.0	0.0	0.0	0.7	0.0	0.7	0.7
<b>Tolerant Richness</b>	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	13.5	18.5	18.5	15.0	22.0	16.5	15.5	19.0	23.5	23.0
	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	0.7	0.7	4.9	2.8	1.4	2.1	2.1	2.8	0.7	2.8
<b>% Collector-Filterer</b>	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	48.1	34.3	36.8	22.0	33.6	35.2	42.7	29.4	10.5	26.0
	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	1.5	8.9	3.7	5.6	7.7	4.0	0.5	2.3	6.9	9.7
<b>% Collector-Gatherer</b>	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	33.4	34.8	28.1	25.1	30.8	29.2	19.6	17.8	17.5	19.1
	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	0.6	4.0	0.8	2.2	4.6	3.9	0.8	0.0	1.3	3.9
<b>% Shredder</b>	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	0.2	1.0	6.7	22.4	0.8	0.2	0.8	1.0	2.0	4.6
	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	0.0	1.2	4.0	6.7	0.3	0.0	1.1	0.2	0.7	5.4
<b>% Predator</b>	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	3.5	6.8	10.3	11.4	9.6	1.8	6.4	5.6	2.9	4.1
	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	0.1	0.0	0.5	0.2	0.3	0.1	2.1	0.4	0.5	1.1
<b>% Scraper</b>	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	12.8	19.8	17.4	16.6	22.1	5.8	14.7	15.8	9.1	9.3
	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	0.9	4.6	0.1	3.1	1.5	1.1	1.0	4.4	5.4	0.3

Table 7. Comparison of PGE metrics calculated from 2013-2015, 2018, and 2019 Clackamas River samples to samples collected in 1999 (USGS) and 2000 (PGE 2004) from the same locales (grey-highlighted rows). Source of 1999 and 2000 data: PGE 2004.

Year	Richness	EPT Richness	CTI	Dom (3)	Percent Intolerant	Percent Tolerant	Intolerant Richness	Tolerant Richness	% Collector-Filterer	% Collector-Gatherer	% Shredder	% Predator	% Scraper
<b>CLKRM0.5</b>													
<b>1999</b>	27.0	13.0	6.4	66.0	0.4	41.3	1.0	9.0	47.0	25.0	1.0	11.2	15.0
<b>2013</b>	36.5	17.5	6.2	49.6	0.5	33.0	1.0	13.5	27.4	40.3	0.9	5.8	20.1
<b>2014</b>	42.5	18.5	6.2	38.1	0.3	31.0	0.5	15.5	17.8	50.1	2.0	11.5	8.9
<b>2015</b>	34.0	14.0	6.7	51.5	0.4	54.4	1.0	10.5	36.8	40.9	0.2	3.7	9.9
<b>2018</b>	51.5	22.0	6.5	45.9	1.0	42.4	1.0	22.0	33.6	30.8	0.8	9.6	22.1
<b>2019</b>	37.5	14.5	6.7	39.6	0.4	57.0	1.0	16.5	35.2	29.2	0.2	1.8	5.8
<b>CLKRM11</b>													
<b>2000</b>	36.0	21.0	6.1	51.0	0.0	22.0	0.0	11.0	26.0	29.0	3.3	11.0	25.0
<b>2013</b>	40.0	18.5	6.0	55.4	0.3	26.2	1.5	13.0	25.8	21.7	3.4	10.2	15.4
<b>2014</b>	40.5	20.0	5.8	61.7	0.1	13.7	0.5	11.0	25.3	19.4	31.7	8.0	6.2
<b>2015</b>	39.5	20.5	6.5	55.5	0.0	38.2	0.0	13.5	43.0	20.7	4.2	10.5	13.7
<b>2018</b>	51.5	22.0	6.5	45.9	1.0	42.4	1.0	22.0	33.6	30.8	0.8	9.6	22.1
<b>2019</b>	48.5	23.5	6.2	34.9	0.5	36.6	1.0	19.0	29.4	17.8	1.0	5.6	15.8
<b>CLKRM13.5</b>													
<b>2000</b>	31.0	20.0	6.2	79.0	0.0	18.0	0.0	8.0	42.0	16.0	3.5	16.0	21.0
<b>2013</b>	34.0	17.0	6.3	62.2	0.2	32.6	1.0	9.5	35.8	17.5	2.3	10.4	9.6
<b>2014</b>	39.0	16.0	6.0	60.2	0.1	17.4	0.5	10.5	31.1	21.0	23.9	9.9	4.4
<b>2015</b>	48.0	21.0	6.2	36.4	0.2	33.9	0.5	18.0	19.3	30.4	15.3	12.1	13.5
<b>2018</b>	51.5	22.0	6.5	45.9	1.0	42.4	1.0	22.0	33.6	30.8	0.8	9.6	22.1
<b>2019</b>	51.0	21.5	6.2	37.0	0.1	51.3	0.5	23.5	10.5	17.5	2.0	2.9	9.1
<b>CLKRM20</b>													
<b>1999</b>	35.0	16.0	6.1	77.0	0.5	10.0	1.0	8.0	50.2	20.0	0.3	21.0	6.0
<b>2013</b>	41.0	19.5	6.7	52.2	1.1	48.4	0.5	15.0	41.1	24.2	1.3	9.9	14.3
<b>2014</b>	52.0	21.5	6.1	34.9	1.0	20.0	1.0	17.5	18.4	34.2	7.3	15.0	10.1
<b>2015</b>	43.5	21.0	6.6	38.3	0.4	40.5	0.5	15.5	27.8	32.9	0.9	9.9	19.6
<b>2018</b>	51.5	22.0	6.5	45.9	1.0	42.4	1.0	22.0	33.6	30.8	0.8	9.6	22.1
<b>2019</b>	47.5	21.5	6.6	39.0	0.4	46.5	1.5	23.0	26.0	19.1	4.6	4.1	9.3

## DISCUSSION

Results of the 2019 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. For the second consecutive year, these results suggest that some longitudinal gradients in community composition do occur and that these gradients potentially result in a slightly lower biological condition in the lowest segments of the river. In some years under this monitoring program, mayfly, stonefly and/or caddisfly richness have not shown any longitudinal trends, while in more recent years EPT richness has been lower in the lower river sections. These compositional changes have also affected overall multimetric scores and have resulted in subtle, yet evident, longitudinal trends in multimetric scores in the last three sampling years.

Ambient environmental conditions have largely remained unchanged between 2013-2019 within this 20-mile length of river. Observations of physical habitat conditions and limited water quality measurements made during this study from 2013 through 2019 have not identified any notable 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 across a longer length of the Clackamas River 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).

This study once again 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 these early years of monitoring benefit from utilizing this larger number of metrics from both sources, future monitoring of the river can eventually focus on a smaller set based on the results of these early years of monitoring and also based on the 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 assessing longer-term changes and trends in benthic macroinvertebrate community conditions 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 compare variation across metrics, the 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 to assess the relative precision of each metric. The signal-to-noise ratio (SNR) was also calculated to evaluate the relative strength of each metric at exhibiting *discernable* changes in values. SNR was calculated by dividing the mean by the standard deviation. In each year since 2015, the coefficient of variation (CV) and the signal-to-noise ratio (SNR) have been calculated for each of these core metrics. These most recent values from the 2013-2019 data are presented in Table 8.

Across the six metrics for which CV and SNR were calculated, the Community Tolerance Index (CTI) once again 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 is 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.

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 several recent years suggest that these results are 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 “downside” temporal variability than would the other sites. This larger variability towards lower 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.

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 2013-2019.

<b>Metric</b>	<b>Source</b>	<b>CV</b>	<b>SNR</b>
CTI	PGE 2004	3.8	<b>27.9</b>
DEQ MM Score	DEQ	9.4	<b>11.3</b>
EPT Richness	PGE 2004	14.2	<b>9.1</b>
Total Richness	PGE 2004	12.7	<b>8.1</b>
Percent Tolerant	PGE 2004	30.0	3.5
Tolerant Richness	PGE 2004	33.4	3.0

Following the 2015 sampling round, the first three years of data were used to develop a statistically based approach for assessing potential changes in biological condition at each site (Cole 2016). This approach compares the most recent (2019) values to the range of baseline values (2013-2015) 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 first 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. Within-site variation over the first three years was quantified 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. With normally distributed data (will still 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 of 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 examine the 2019 data for a change-of-condition 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 differs among sites using this approach (Table 9). Sites with larger “natural” variability, such as CLKRM0.5, currently have lower threshold values to indicate a change. 2019 mean multimetric scores ranged from 28 to 41, and were consistently higher than the threshold scores that would indicate a significant change in value (Table 9).



If such changes are detected in the future, 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.

<b>Site</b>	<b>2013- 2015 Mean</b>	<b>SD</b>	<b>2 SD</b>	<b>Mean -2 SD</b>	<b>2019 Mean</b>
CLKRM0.5	31.3	3.7	7.5	<b>23.8</b>	<b>28.0</b>
CLKRM5.0	30.3	1.5	3.0	<b>27.3</b>	<b>32.0</b>
CLKRM11	32.6	2.1	4.1	<b>28.5</b>	<b>41.0</b>
CLKRM13.5	31.0	3.7	7.5	<b>23.5*</b>	<b>34.0</b>
CLKRM20	32.6	2.7	5.5	<b>27.1</b>	<b>34.0</b>
OVERALL MEAN	31.6	2.9	5.5	<b>26.0</b>	<b>33.8</b>

The data collected in this study represent the most comprehensive assessment to date of macroinvertebrate communities in the lower Clackamas River. Their utility will only be fully 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 assist with detecting and understanding 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

- This fifth year of CRWP macroinvertebrate monitoring in the lower Clackamas River suggests that community conditions remain generally similar between river miles 0 and 20, but some longitudinal gradients/changes community composition do occur. 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.
- Community conditions measured in 2019 were generally similar to the range of conditions measured from 2013 to 2018. While temporal variability in community metrics continues to be higher at some sample sites than at others, this 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 2019). While several richness metrics indicated a potential difference in community conditions at CLKRM0.5 between 2013-2014 and 2015-2019, these differences likely reflect the natural variability in conditions in the lower river and do not necessarily suggest a decline in condition in response to increasing anthropogenic disturbance. Accordingly, these 2013-2019 data are considered to represent natural variability in these conditions over the range of environmental conditions that have occurred during this period.
- These five years of macroinvertebrate community data 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.
- Continued annual or biannual replicated sampling in the lower Clackamas River is recommended. 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.
- Continue testing the selected metrics for changes in condition and for further characterization of variability as additional data are amassed. Continue to focus analyses on the set of core metrics and multimetric indexes identified and examined in this report.

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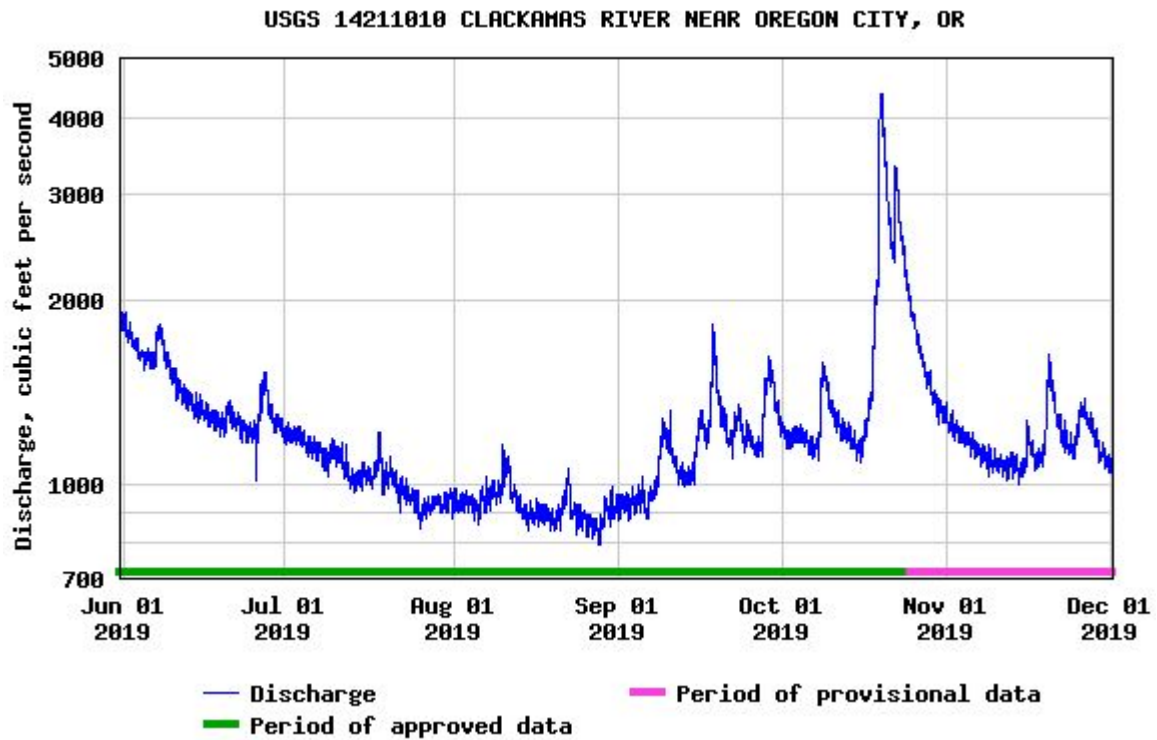


Figure 2. Summer 2019 Clackamas River discharge as measured at USGS gage station 14211010 near Oregon City. Data collected after October 22, 2019 are provisional.

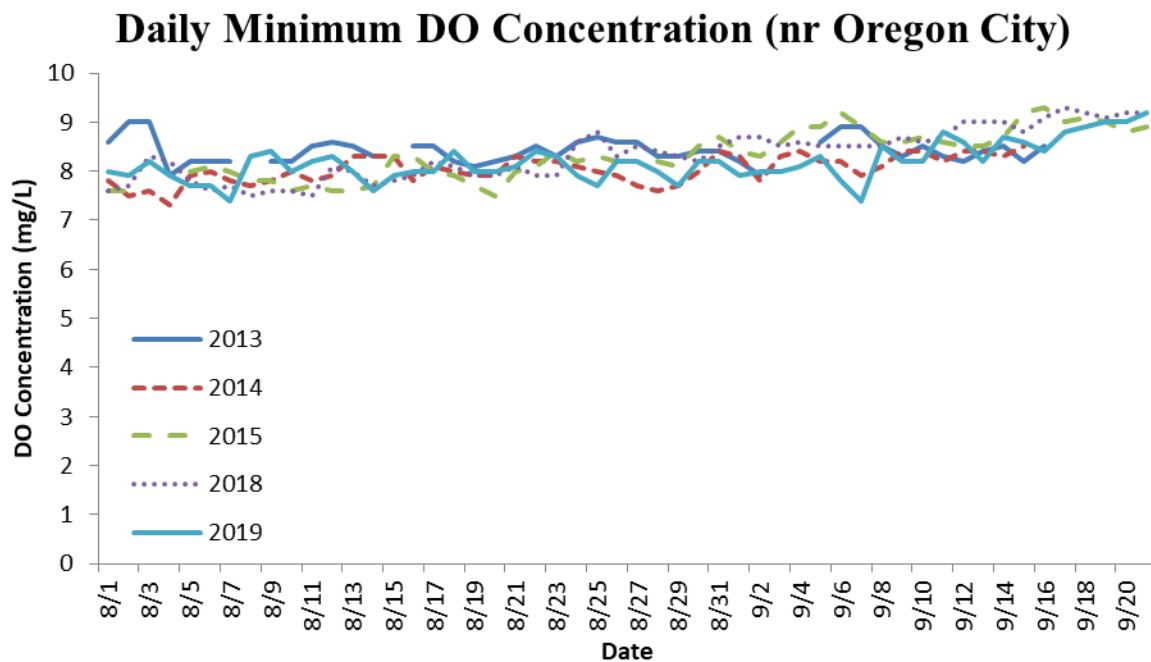
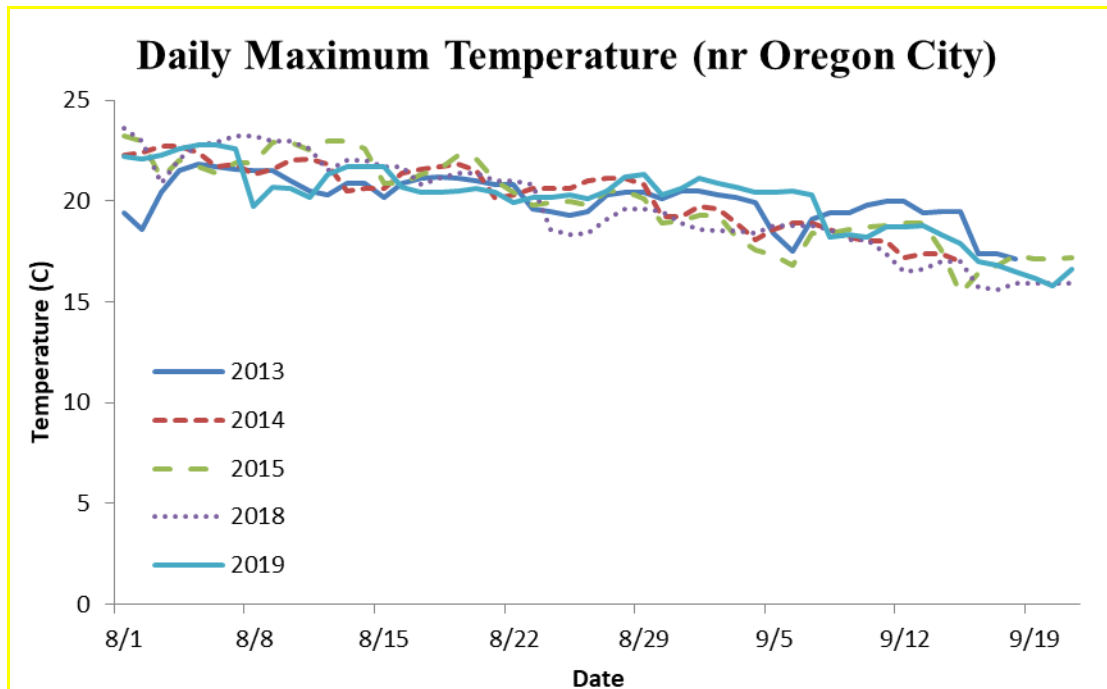


Figure 3. Clackamas River daily maximum water temperatures and daily minimum dissolved oxygen concentrations measured at USGS gage station 14211010, August 1 through September 20, 2013-2015, 2018, and 2019.

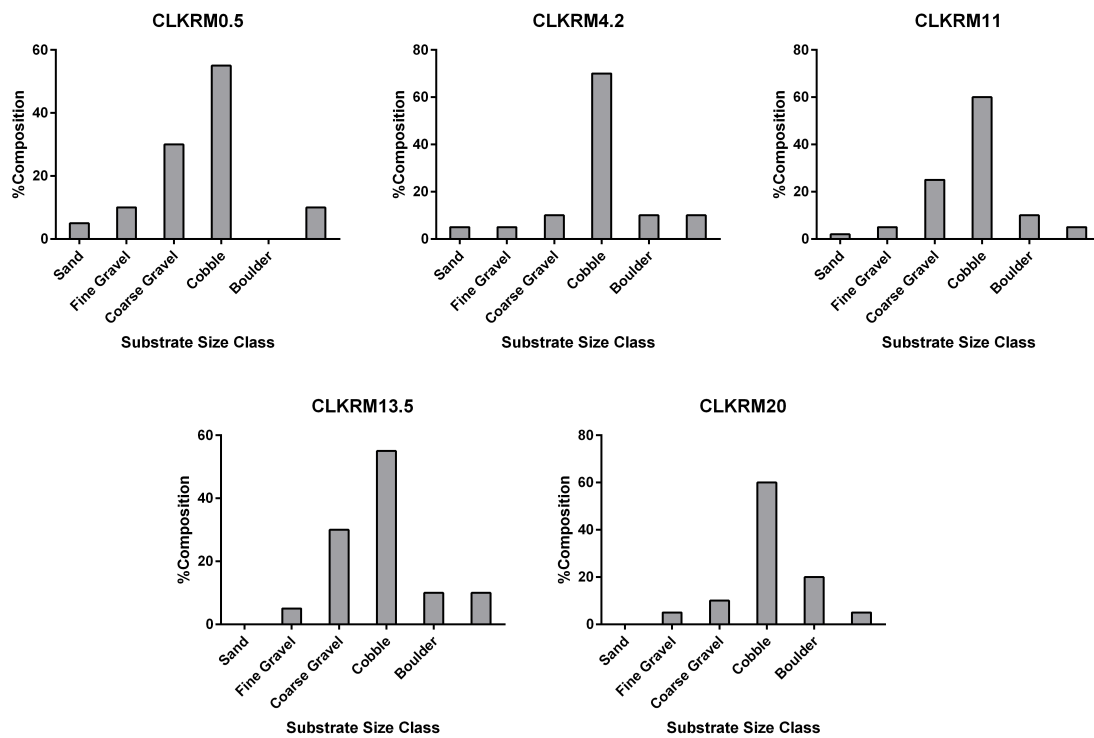


Figure 4. Substrate composition at six Clackamas River macroinvertebrate samples sites, September 2019.

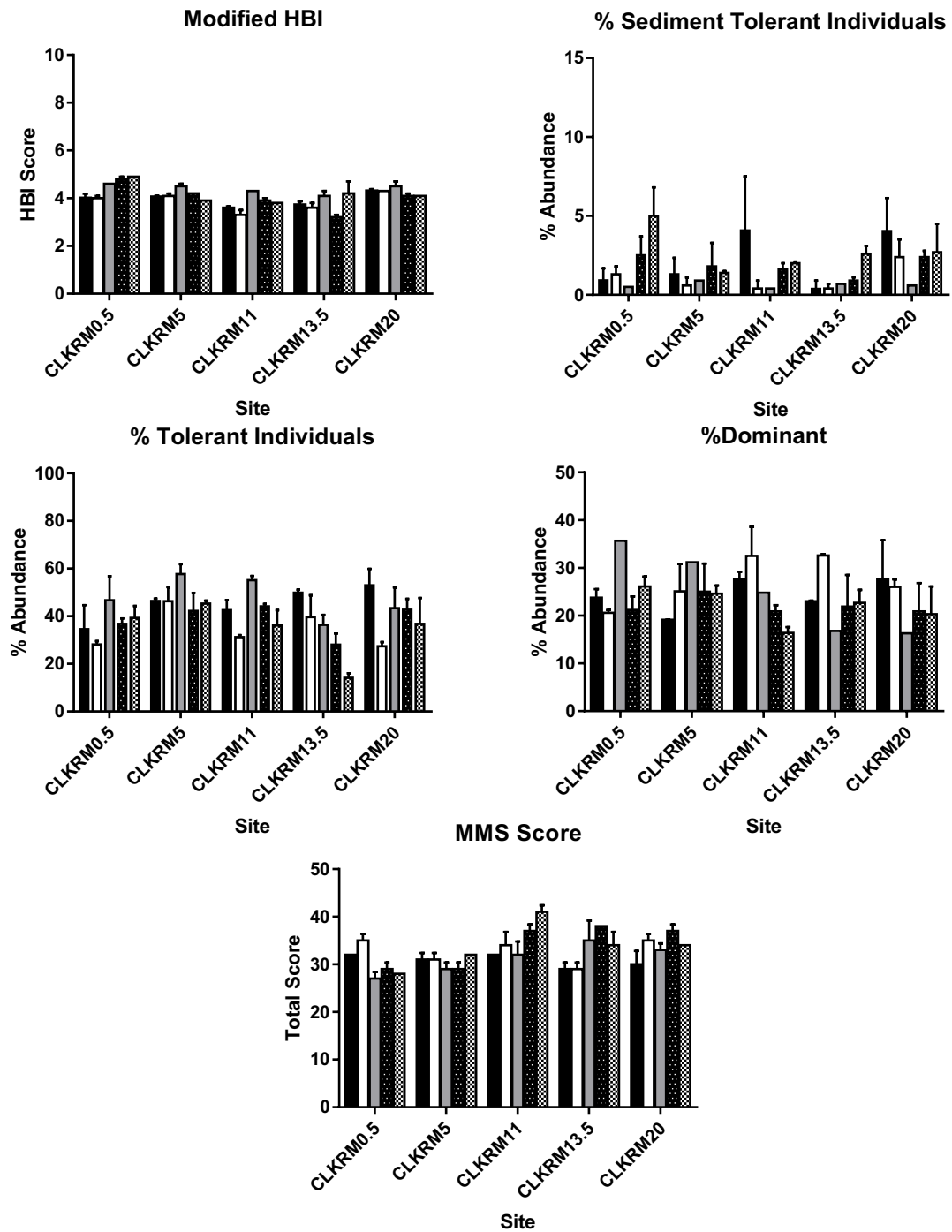


Figure 5. Mean (+SD) macroinvertebrate community metric scores and total multimetric scores (MMS) calculated from duplicate samples collected from the lower Clackamas River in September 2013 (black bars), 2014 (white bars), 2015 (grey bars), 2018 (black/white speckled bars), and 2019 (black/white checkered bars).



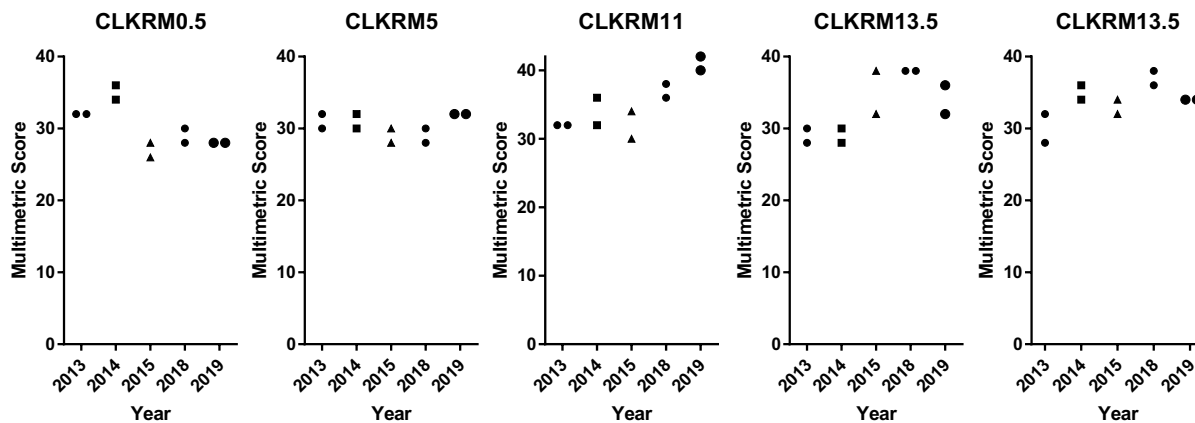


Figure 6. Macroinvertebrate multimetric scores (y axis) calculated from individual duplicate macroinvertebrate samples collected from five locations in the lower Clackamas River in 2013, 2014, 2015, 2018, and 2019. Each graph represents a single sample site.

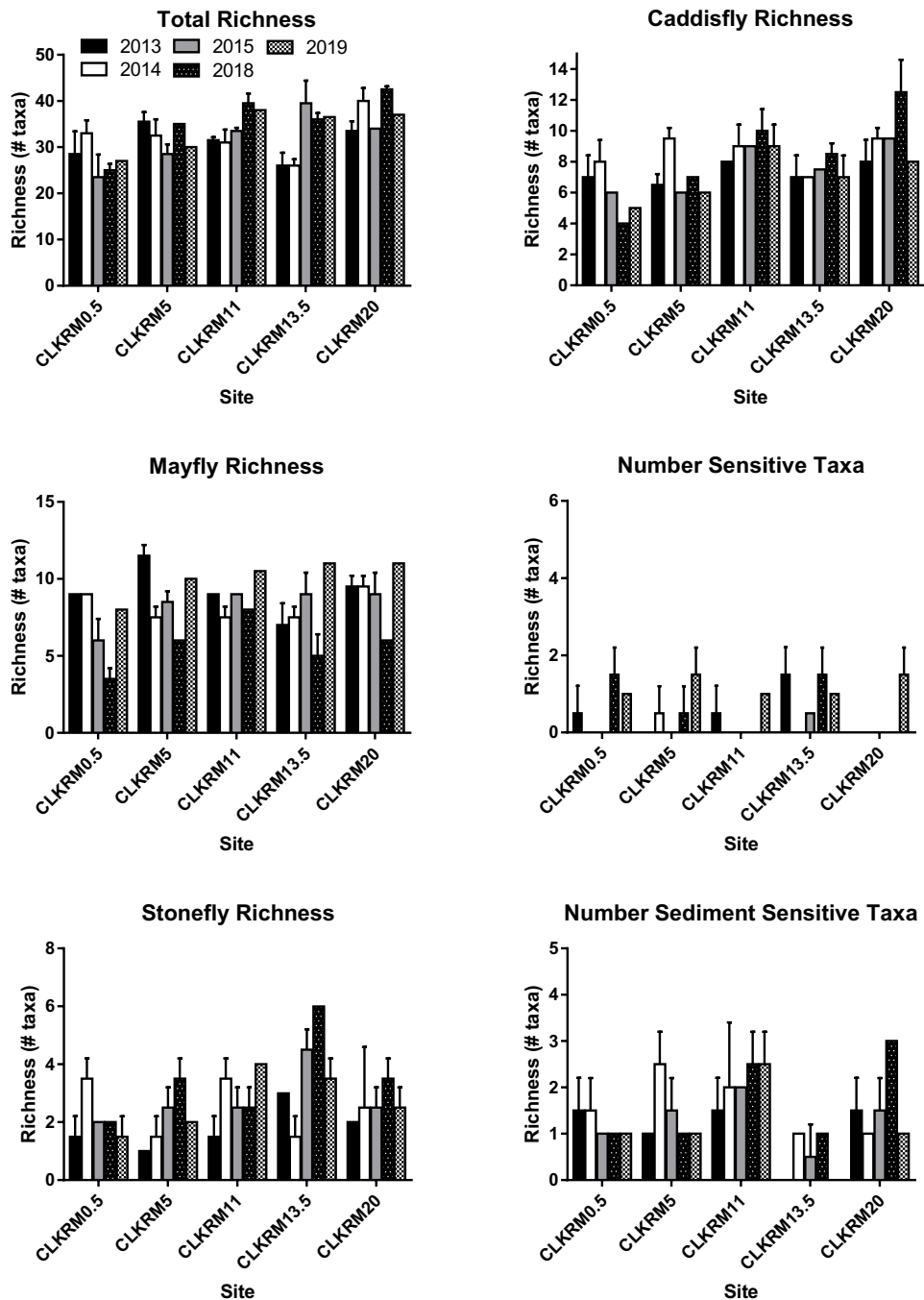


Figure 7. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013 (black bars), 2014 (white bars), 2015 (grey bars), 2018 (black/white speckled bars) and 2019 (black/white checkered bars).

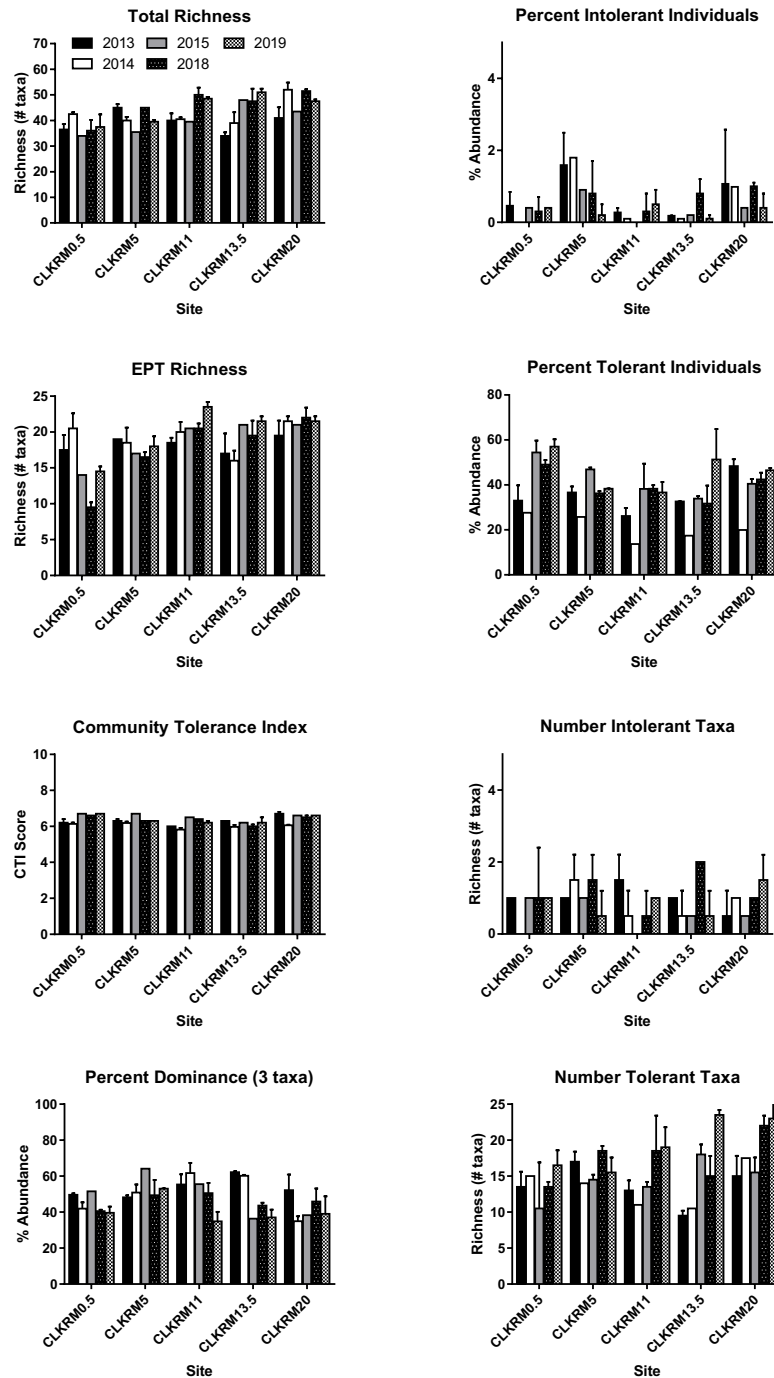


Figure 8. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013 (black bars), 2014 (white bars), 2015 (grey bars), 2018 (black/white speckled bars), and 2019 (black/white checkered bars). Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

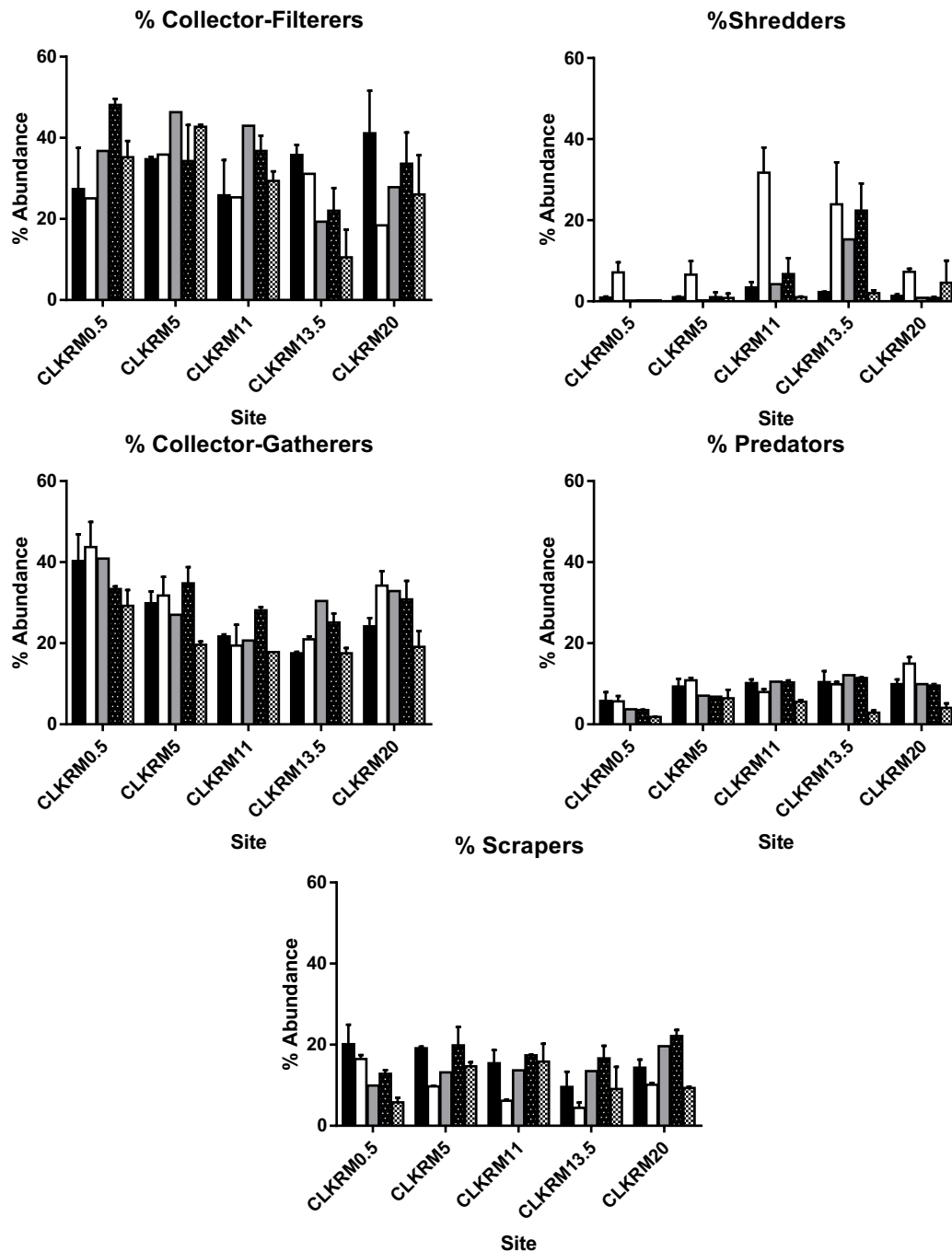


Figure 9. Mean (+SD) abundance of macroinvertebrate functional feeding groups calculated from duplicate samples collected from the lower Clackamas River in September 2013 (black bars), 2014 (white bars), 2015 (grey bars), 2018 (black/white speckled bars), and 2019 (black/white checkered bars). Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

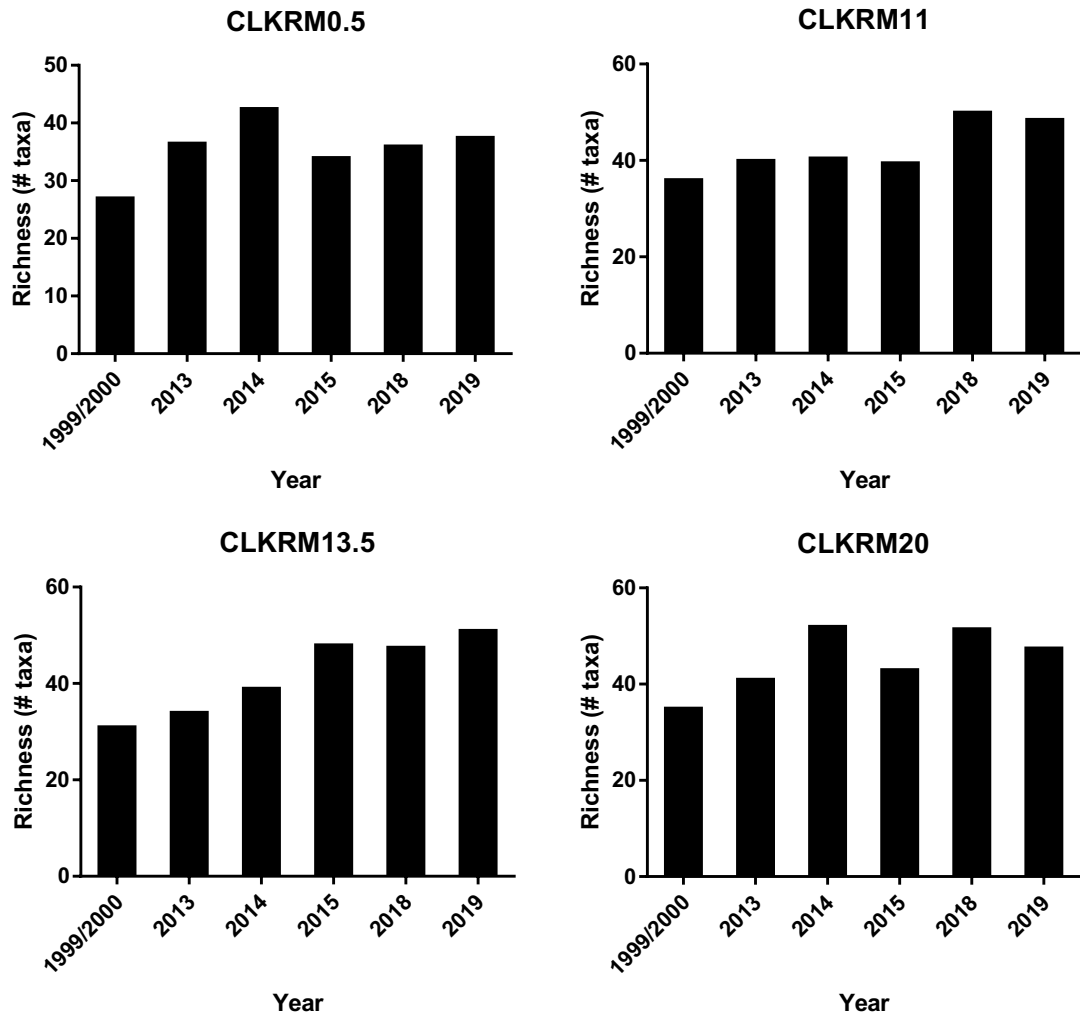
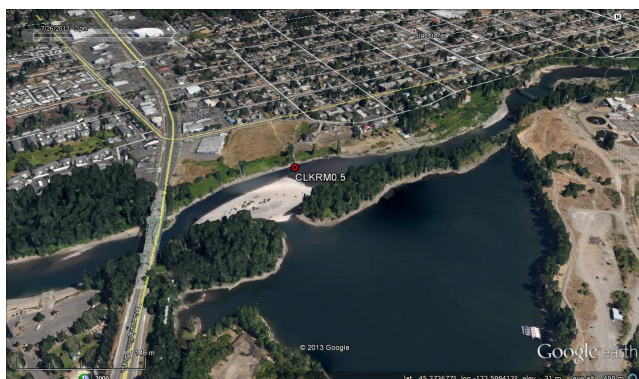


Figure 10. Mean total taxa richness calculated from macroinvertebrate samples collected from the Clackamas River in 1999/2000, 2013-2015, 2018, and 2019.

## APPENDIX A.

### Location maps and 2019 site photos



CLKRM0.5



CLKRM5



CLKRM11







CLKRM13.5



CLKRM20

