2022 LOWER CLACKAMAS RIVER MACROINVERTEBRATE ASSESSMENT

Clackamas County, Oregon

FINAL REPORT

Prepared for

Clackamas River Water Providers

By

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EXECUTIVE SUMMARY

In recognizing the value of 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, 2019, and 2022. Each year, macroinvertebrates were sampled from five sites in the lower Clackamas River between river miles 0.5 and 20 (21.8 in 2022). 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 six years of CRWP macroinvertebrate monitoring in the lower Clackamas River suggest that community conditions are generally similar between river miles 0 and 21.8, 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 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 2022 were generally similar to the range of conditions measured from 2013 to 2019. These six years of data collectively suggest that changes have largely not occurred to macroinvertebrate community conditions in the lower Clackamas River since 2013; the only potential change indicated by these data occurs as CLKRM11, where a number of community metrics, as well as multi-metric scores, suggest improving ecological conditions. 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 ecological change is response to changing ambient environmental conditions.

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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 2022 was led by Christopher Burtch of Cole Ecological, Inc. with assistance from Kim Swan and Christine Hollenbeck from the Clackamas River Water Providers (CRWP). Macroinvertebrate samples were processed by Christopher Burtch. Project taxonomy was performed by 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 supply 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 in the lower mainstem Clackamas River where their five PODs occur. 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 (Cole and Burtch 2020). Following another two-year break in 2020 and 2021, a sixth round of sampling was performed in 2022. The main objective of this sixth year of monitoring in the mainstem Clackamas River was to determine whether conditions have remained similar to those measured from 2013 to 2019. This report describes the methods, results, and conclusions for this sixth 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. From 2014 through 2019, the uppermost site had occurred at CLKRM20 below the River Mill Dam (Figure 1). In 2022, this was relocated 1.8 miles upriver owing to access to CLKRM20 being temporarily closed as a result of a local fire. This uppermost site (listed as CLKRM20+ in this report) 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 initially 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.

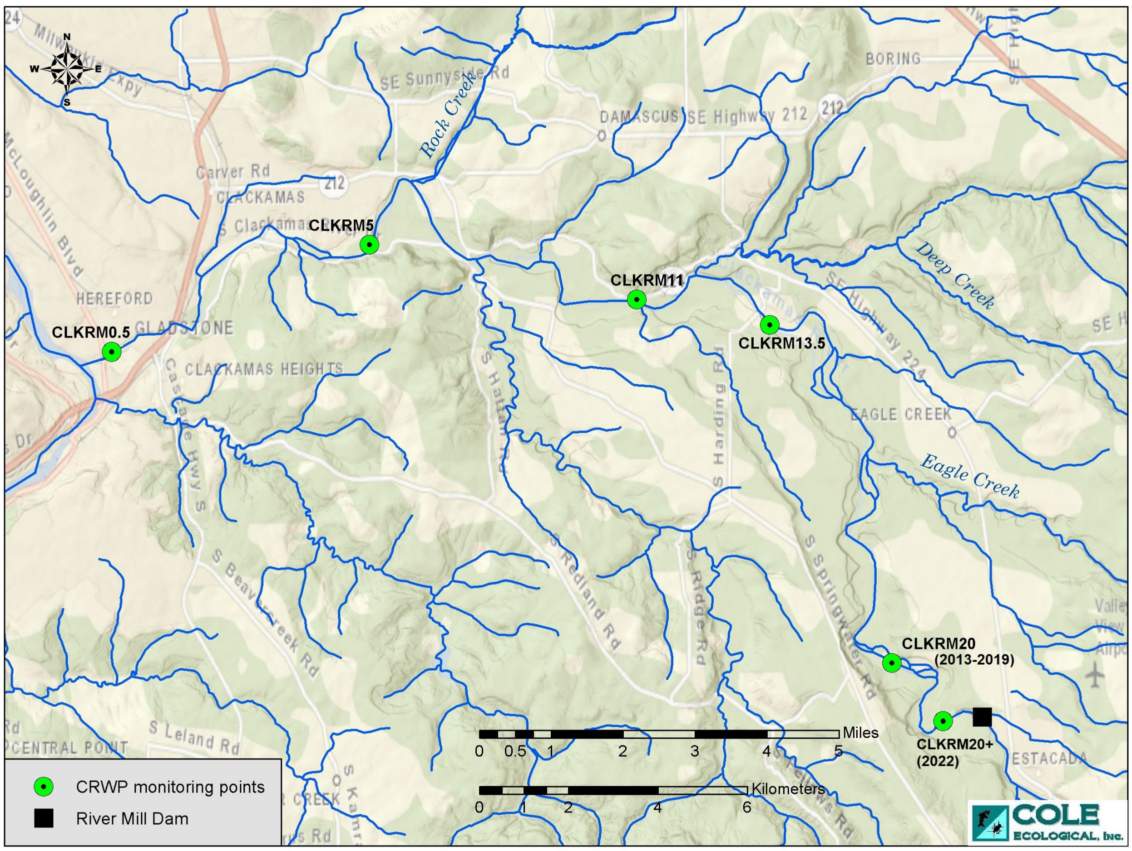

Figure 1. 2013-2015, 2018-2019, and 2022 lower Clackamas River macroinvertebrate sample sites.

FIELD DATA COLLECTION

For the sixth year of sampling, macroinvertebrates were sampled from these five sites on the lower Clackamas River on September 20, 2022. 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, 2018-2019, and 2022.

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	2013-2019 Milo McIver State Park	45.31087	-122.37666	79	DS bracket Estacada WWTP and River Mill Dam	USGS McIver Pk (1999)
CLKRM20+	2022 US Dog Creek	45.29674	-122.36516	85		

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

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, 2018-2019, and 2022.

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

RESULTS

Clackamas River streamflows during the 2022 sampling event (September 20, 2011) were near seasonal base flows, as determined from data obtained from USGS gage station 14211010 on the Clackamas River near Oregon City. No significant wet-weather events occurred in the weeks prior to 2022 macroinvertebrate sampling (Figure 2). USGS water quality data collected at this gage station suggest that neither late-summer temperature nor dissolved oxygen conditions notably differed between 2022 and the previous four monitoring years (Figure 3).

Rapid habitat scores from the five sites in 2022 ranged from 159 to 188 (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 2019. Riffle bed materials were dominated by cobble substrate at all sites (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 2022 were noted at any of the 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 2022 (Table 4).

DEQ macroinvertebrate multimetric (MM) scores calculated from the 2022 data indicate that community conditions ranged narrowly among the five reaches, as mean total MM scores ranged between 31 and 43 on a scale of 10 to 50 (Table 5 and Figure 5). Across the five sites, 2022 MM scores averaged 35.0, versus 33.8 in 2019, 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 2022, mean MM scores have ranged by four points at CLKRM5.0, by seven points at CLKRM20+, by eight points at CLKRM0.5, by nine points at CLKRM13.5, and by eleven points at CLKRM11. Generally increasing MM scores at CLKRM11 suggest that ecological conditions have potentially improved over the nine-year monitoring period (Figure 7, bottom graph). Over the nine-year sampling period, no other 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 CLKRM13.5 (Table 5, Figures 5 & 6). However, neither of the MM score ranges are strongly suggestive of a change in condition at either of those two sites beyond what might be expected to result from normal year-to-year variability.

As in prior years, the 2022 MM score data suggest a general longitudinal decrease in macroinvertebrate community conditions in a downriver direction (Figure 5). Owing to the increase in scores at CLKRM11, a longitudinal trend in condition between CLKRM20+ and CLKRM11 is not as evident in 2022, while the decrease in condition between CLKRM11 and the lowermost two sites (CLKRM0.5 and CLKRM5.0) is even more evident in the 2022 data than in past years.

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 once again exhibited similar mean total scores in 2022 (Table 5). The mean MM score was slightly higher at CLKRM5.0 than at CLKRM0.5 (33 versus 31) in 2022, while mean the MM score at CLKRM11 was nine points higher than at CLKRM13.5 (Table 5), suggesting similar overall community conditions between sites within each pair, and even slightly improved biological conditions at CLKRM11 relative to those at CLKRM13.5.

Total MM scores between 2013 and 2022 have consistently been higher than those measured in 2003 by Metro (Table 5; Cole 2004). MM scores at CLKRM5.0 have increased from 24 in 2003 to an average of 30.8 since 2013. MM scores at CLKMR11 have increased at from 28 in 2003 to 36.5 since 2013. MM scores at CLKRM13.5 were very similar between 2003 (28) and 2013-14 (30 and 29), but 2015-2022 scores have averaged 35.3. As the 2003 data are from only one year and are single samples (rather than replicates), their accuracy is less certain than that of the more recent data. Nevertheless, conditions are clearly at least as favorable as they were in 2003 and have potentially improved.

With only a few exceptions, individual DEQ metrics were also generally similar from 2013 to 2022 at each site (Table 5; Figures 5 and 7). Temporal trends in individual community metrics are evident at CLKRM11, where mayfly richness, stonefly richness, caddisfly richness, and total taxa richness each appear to increase over the nine-year monitoring period (Figure 5). As in 2015-2019 (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 became increasing evident in the 2015-2019 data, but as individual metric scores continue to strengthen at CLKRM11, the most apparent differences in ecological conditions now occur between the three upper sites and the two lower sites (see select metrics on Figures 5 and 7).

Table 3. Supplemental metric set used to further assess the condition of macroinvertebrate communities in the Clackamas River, Oregon, fall 2022 (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 20, 2022.

Site Code Date	CLKRM0.5 9/20/2022	CLKRM5 9/20/2022	CLKRM11 9/20/2022	CLKRM13.5 9/20/2022	CLKRM20+ 9/20/2022
Water Quality					
WQ Time	14:30	13:20	11:30	10:40	9:20
Cond (µS/cm)	72	71	70	69	69
Spec Con (µS/cm)	60	59	57	56	55
Temp (°C)	16.14	16.25	15.28	14.87	14.47
Substrate in Area Sampled					
Sand	5	5	5	0	5
Fine Gravel	10	5	5	5	10
Coarse Gravel	30	10	30	40	35
Cobble	55	70	50	50	50
Boulder	0	10	10	5	0
Embeddedness	10	10	5	10	5
Sample Depth (cm)	~20	~35	~30	~30	~35
Rapid Habitat Assessment (RHA) Scores					
Epifaunal Substrate/Cover	15	17	18	18	19
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	19	19	18	19
Frequency/Quality of Riffles	13	19	18	16	20
Bank Stability	19	15	17	15	17
Protective Vegetation	16	17	18	17	18
Riparian Zone Width	15	12	17	20	19
RHA Total Score	**159**	**171**	**180**	**176**	**188**

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 community attributes examined (Table 6 and Figure 8). However, as was the case in 2015-2019, the PGE metrics total richness and EPT richness exhibited apparent upstream-downstream trends. Total richness once again exhibited some variation among sites, ranging from 38 taxa at CLKRM0.5 to 54 taxa at CLKRM11 in 2022. Similarly, EPT richness increased from 15.5 taxa at CLKRM0.5 to 26 at CLKRM13.5. Among the other PGE study metrics, the Community Tolerance Index (CTI; Table 3) was similar among sites, ranging only from 6.1 to 6.7 on a scale of 0 to 10, a range similar to that exhibited between 2013 and 2019 (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 2022 (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.

2013-2022 PGE metric results were generally similar to those measured in 1999 and 2000 at the four sites where older data were available. Collectively, the 2013-2022 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 could be 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, 2019 and 2022. 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**	**13.5**	**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	32.0	31.0	32.0	29.0	30.0	35.0	31.0	34.0	29.0	35.0	27.0	29.0	32.0	35.0	33.0
	StDev	0.0	1.4	0.0	1.4	2.8	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	

		2018					2019					2022				
DEQ Metric		**0.5**	**5**	**11**	**13.5**	**20**	**0.5**	**5**	**11**	**13.5**	**20**	**0.5**	**5**	**11**	**13.5**	**20**
Richness	Mean	25.0	35.0	39.5	36.0	42.5	27.0	30.0	38.0	36.5	37.0	26.5	36.0	41.5	40.0	36.0
	StDev	1.4	0.0	2.1	1.4	0.7	4.2	1.4	1.4	0.7	2.8	0.7	0.0	2.1	4.2	1.4
Mayfly Richness	Mean	3.5	6.0	8.0	5.0	6.0	8.0	10.0	10.5	11.0	11.0	7.0	12.0	11.5	11.5	9.5
	StDev	0.7	0.0	0.0	1.4	0.0	0.0	1.4	0.7	0.0	0.0	1.4	1.4	0.7	0.7	0.7
Stonefly Richness	Mean	2.0	3.5	2.5	6.0	3.5	1.5	2.0	4.0	3.5	2.5	2.0	2.5	4.0	3.5	3.0
	StDev	0.0	0.7	0.7	0.0	0.7	0.7	0.0	0.0	0.7	0.7	1.4	0.7	1.4	2.1	0.0
Caddisfly Richness	Mean	4.0	7.0	10.0	8.5	12.5	5.0	6.0	9.0	7.0	8.0	6.5	8.0	10.5	8.0	8.0
	StDev	0.0	0.0	1.4	0.7	2.1	0.0	0.0	1.4	1.4	0.0	0.7	0.0	0.7	1.4	1.4
Number Sensitive Taxa	Mean	1.5	0.5	0.0	1.5	0.0	1.0	1.5	1.0	1.0	1.5	0.0	0.0	1.0	0.5	0.5
	StDev	0.7	0.7	0.0	0.7	0.0	0.0	0.7	0.0	0.0	0.7	0.0	0.0	1.4	0.7	0.7
# Sed Sensitive Taxa	Mean	1.0	1.0	2.5	1.0	3.0	1.0	1.0	2.5	0.0	1.0	2.0	1.5	2.5	0.0	1.5
	StDev	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.7	0.7	0.0	0.7
Modified HBI1	Mean	4.8	4.2	3.9	3.2	4.1	4.9	3.9	3.8	4.2	4.1	4.8	4.6	3.7	4.2	4.5
	StDev	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.5	0.0	0.1	0.2	0.1	0.8	0.1
% Tolerant Taxa	Mean	36.8	42.2	44.1	28.0	42.7	39.3	45.3	36.1	14.1	36.8	20.7	35.5	25.3	17.2	46.8
	StDev	2.2	7.6	1.0	4.7	4.6	5.0	1.2	6.4	1.9	10.8	0.9	0.1	2.4	1.0	10.2
% Sed Tolerant Taxa	Mean	2.5	1.8	1.6	0.9	2.4	5.0	1.4	2.0	2.6	2.7	2.7	6.2	2.5	0.9	2.4
	StDev	1.2	1.5	0.4	0.2	0.4	1.8	0.1	0.1	0.5	1.8	1.2	6.4	1.2	0.3	1.1
% Dominant	Mean	21.2	25.0	20.9	21.9	20.9	26.1	24.6	16.4	22.7	20.3	31.7	28.7	17.3	20.3	25.3
	StDev	2.8	5.9	1.3	6.6	5.9	2.1	1.7	1.2	2.7	5.8	3.7	0.4	2.8	3.4	4.6
TOTAL SCORE	Mean	29.0	29.0	37.0	38.0	37.0	28.0	32.0	41.0	34.0	34.0	31.0	33.0	43.0	34.0	34.0
	StDev	1.4	1.4	1.4	0.0	1.4	0.0	0.0	1.4	2.8	0.0	1.4	4.2	1.4	5.7	2.8
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, 2015, 2018, 2019, and 2022. Metrics source: PGE 2004.

		2013					2014					2015					2018					2019					2022				
PGE 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**	**0.5**	**5**	**11**	**13.5**	**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	36.0	45.0	50.0	47.5	51.5	37.5	39.5	48.5	51.0	47.5	38.0	47.0	54.0	51.5	49.5
	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	2.8	2.8	5.7	4.9	2.1
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	9.5	16.5	20.5	19.5	22.0	14.5	18.0	23.5	21.5	21.5	15.5	22.5	26.0	23.0	20.5
	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	0.7	0.7	0.0	2.8	2.1
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	6.6	6.3	6.4	6.0	6.5	6.7	6.3	6.2	6.2	6.6	6.1	6.3	6.1	6.5	6.7
	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	0.1	0.0	0.1	0.4	0.1
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	40.5	49.4	50.5	43.6	45.9	39.6	53.0	34.9	37.0	39.0	48.4	54.5	39.2	37.3	44.1
	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	1.8	7.7	3.3	8.1	10.0
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	0.3	0.8	0.3	0.8	1.0	0.4	0.2	0.5	0.1	0.4	0.4	1.2	1.5	0.6	0.5
	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	0.0	0.6	0.0	0.3	0.4
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	49.0	36.2	38.3	31.7	42.4	57.0	38.3	36.6	51.3	46.5	26.1	31.2	33.3	51.7	49.4
	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	0.6	3.2	7.5	18.9	4.9
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	1.0	1.5	0.5	2.0	1.0	1.0	0.5	1.0	0.5	1.5	1.0	1.0	1.5	1.5	1.0
	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	0.0	0.0	0.7	0.7	0.0
Tolerant Richness	Mean	13.5	17.0	13.0	9.5	15.0	15.5	14.0	11.0	10.5	17.5	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	14.0	18.5	20.0	23.5	21.5
	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	0.7	0.7	4.9	2.8	1.4	2.1	2.1	2.8	0.7	2.8	1.4	2.1	1.4	2.1	0.7
% 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	48.1	34.3	36.8	22.0	33.6	35.2	42.7	29.4	10.5	26.0	43.6	52.6	34.0	20.3	37.1
	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	11.5	8.1	2.9	7.3	9.1
% 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	33.4	34.8	28.1	25.1	30.8	29.2	19.6	17.8	17.5	19.1	38.9	22.0	23.7	39.7	34.7
	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	9.7	5.5	0.3	5.5	9.1
% 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	0.2	1.0	6.7	22.4	0.8	0.2	0.8	1.0	2.0	4.6	0.3	0.6	6.2	7.7	0.3
	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	0.4	0.2	4.1	8.1	0.1
% 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	3.5	6.8	10.3	11.4	9.6	1.8	6.4	5.6	2.9	4.1	4.1	5.5	6.6	3.3	8.4
	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	0.6	1.3	0.4	1.4	0.3
% 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	12.8	19.8	17.4	16.6	22.1	5.8	14.7	15.8	9.1	9.3	8.5	16.7	23.9	21.6	12.1
	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	0.1	3.7	7.4	1.2	0.4

Table 7. Comparison of PGE metrics calculated from 2013-2015, 2018, 2019, and 2022 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
						CLKRM0.5							
1999	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
2013	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
2014	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
2015	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
2018	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
2019	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
2022	38.0	15.5	6.1	48.4	0.4	26.1	1.0	14.0	43.6	38.9	0.3	4.1	8.5
						CLKRM11							
2000	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
2013	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
2014	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
2015	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
2018	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
2019	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
2022	47.0	26.0	6.1	39.2	1.5	33.3	1.5	20.0	34.0	23.7	6.2	6.6	23.9
						CLKRM13.5							
2000	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
2013	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
2014	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
2015	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
2018	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
2019	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
2022	51.5	23.0	6.5	37.3	0.6	51.7	1.5	23.5	20.3	39.7	7.7	3.3	21.6
						CLKRM20+							
1999	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
2013	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
2014	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
2015	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
2018	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
2019	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
2022	49.5	20.5	6.7	44.1	0.5	49.4	1.0	21.5	37.1	34.7	0.3	8.4	12.1

DISCUSSION

Results of the 2022 lower Clackamas River macroinvertebrate assessment once again suggest that macroinvertebrate communities inhabiting shallow riffle habitat of the lower Clackamas River presently exhibit modest variation in community conditions among lower river locations. The 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.

Ambient environmental conditions have largely remained unchanged between 2013-2022 within the lower river. Observations of physical habitat conditions and limited water quality measurements made during this study from 2013 through 2022 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 this monitoring presently benefits from utilizing this larger number of metrics from both sources, monitoring of the river can eventually focus on a smaller set based on the results of these earlier 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 2013, the coefficient of variation (CV) and the signal-to-noise ratio (SNR) have been calculated for each of these core metrics. These 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) has the lowest CV (and therefore highest SNR), while the percent tolerant and tolerant richness metrics have the highest CV and correspondingly lowest SNR. DEQ MM scores, EPT richness, and total richness each have 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. 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.

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 (2022) values to the range of values from all previous years (2013-2019) in order to determine the likelihood that the new and old values derive from the same population (signifying no change). The data collected from 2013-2019 years are considered to be representative of the "natural" variability within sites, among sites, and across years, and have been collected in the absence of any known significant disturbances. Interannual variation was quantified at each site 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, 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.

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.

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

The DEQ multimetric score was used to examine the 2022 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 less than 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 inter-annual variability, such as CLKRM0.5, currently have lower threshold values to indicate a change. 2022 mean multimetric scores ranged from 31 to 43, 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. 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, 2013-2019.

Site	2013-2015 Mean	SD	2 SD	Mean -2 SD	2022 Mean
CLKRM0.5	30.2	3.3	6.5	26.9	**31.0**
CLKRM5.0	30.4	1.3	2.7	29.1	**33.0**
CLKRM11	35.2	3.8	7.7	31.4	**43.0**
CLKRM13.5	33	3.9	7.9	29.1	**34.0**
CLKRM20	33.8	2.6	5.2	31.2	**34.0**
OVERALL MEAN	32.5	3.0	6.0	**29.5**	**33.8**

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. 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. 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 this 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 values. Sampling at least biannually 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 sixth year of CRWP macroinvertebrate monitoring in the lower Clackamas River suggests that community conditions remain generally similar across the lower river, 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 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 2022 were generally similar to the range of conditions measured from 2013 to 2019. While temporal variability in community metrics continues to be higher at some sample sites than at others, this measured variability was largely 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 2022). Among the five samples sites, potential temporal change over the nine-year monitoring period is evident only at CLKRM5.0, where several individual community metrics and MM scores show a consistent temporal trend of improving metric performance.

- Continued, regular, 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.

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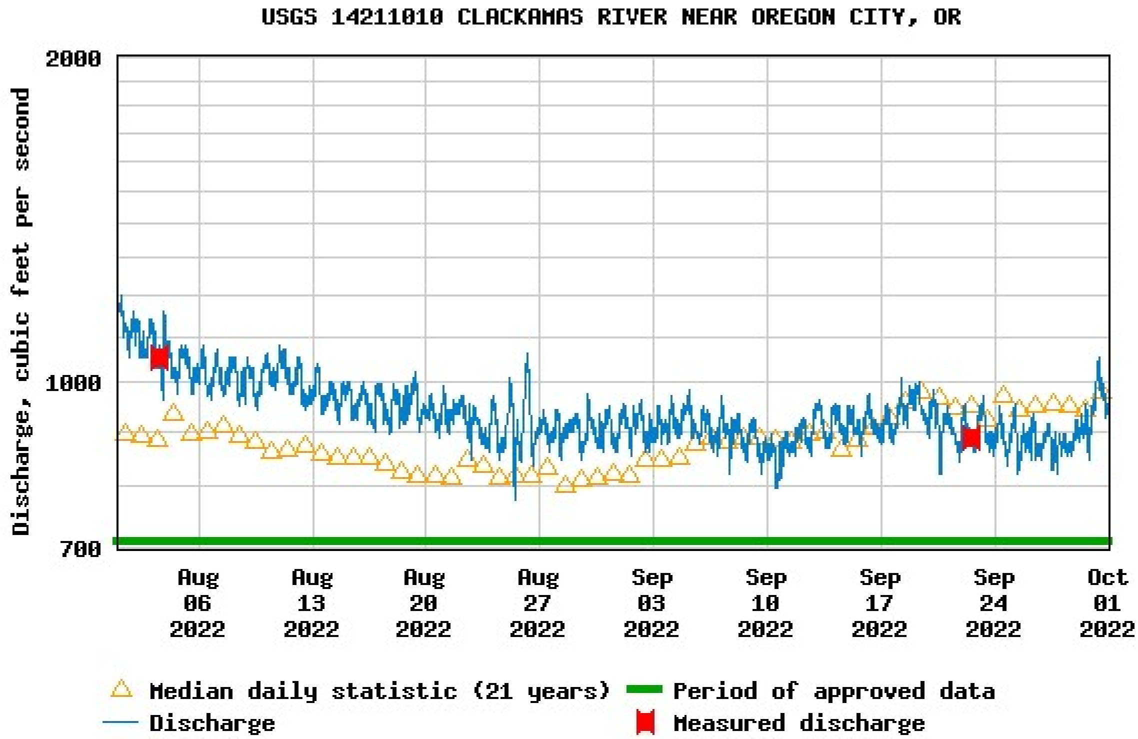
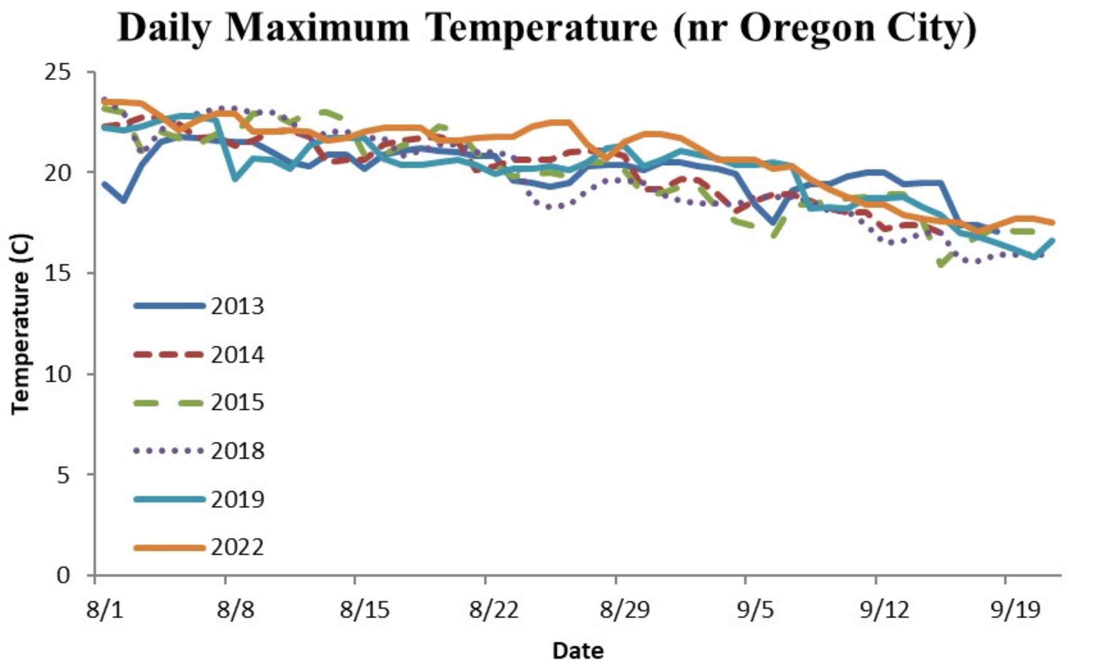


Figure 2. Summer 2022 Clackamas River discharge as measured at USGS gage station 14211010 near Oregon City.



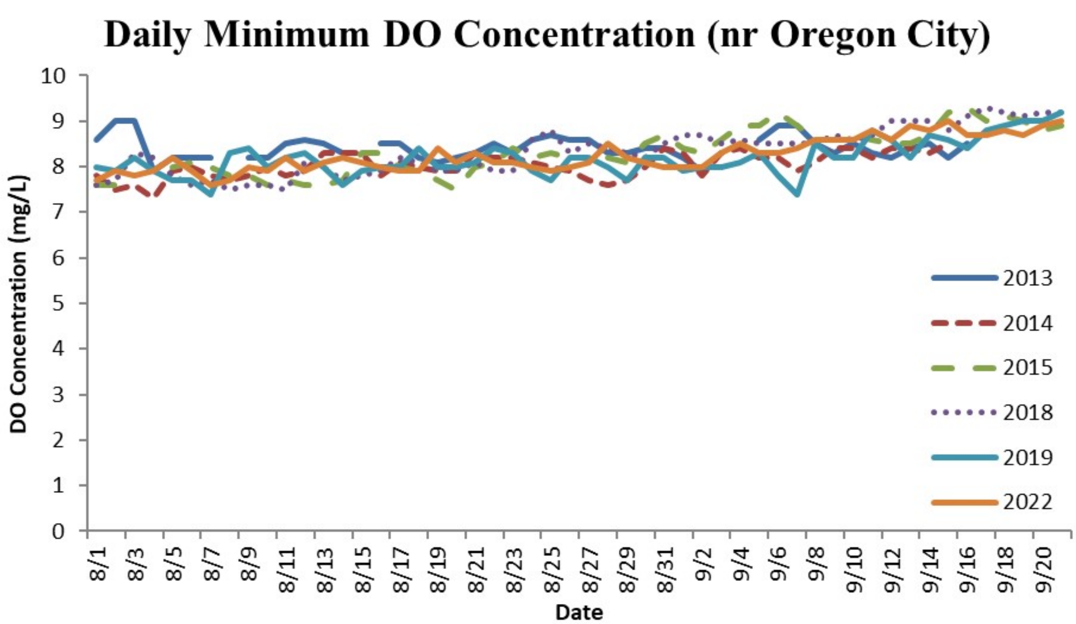


Figure 3. Clackamas River daily maximum water temperatures and daily minimum dissolved oxygen concentrations measured at USGS gage station 14211010, August 1 through September 20, 2013-2015, 2018, 2019, and 2022.

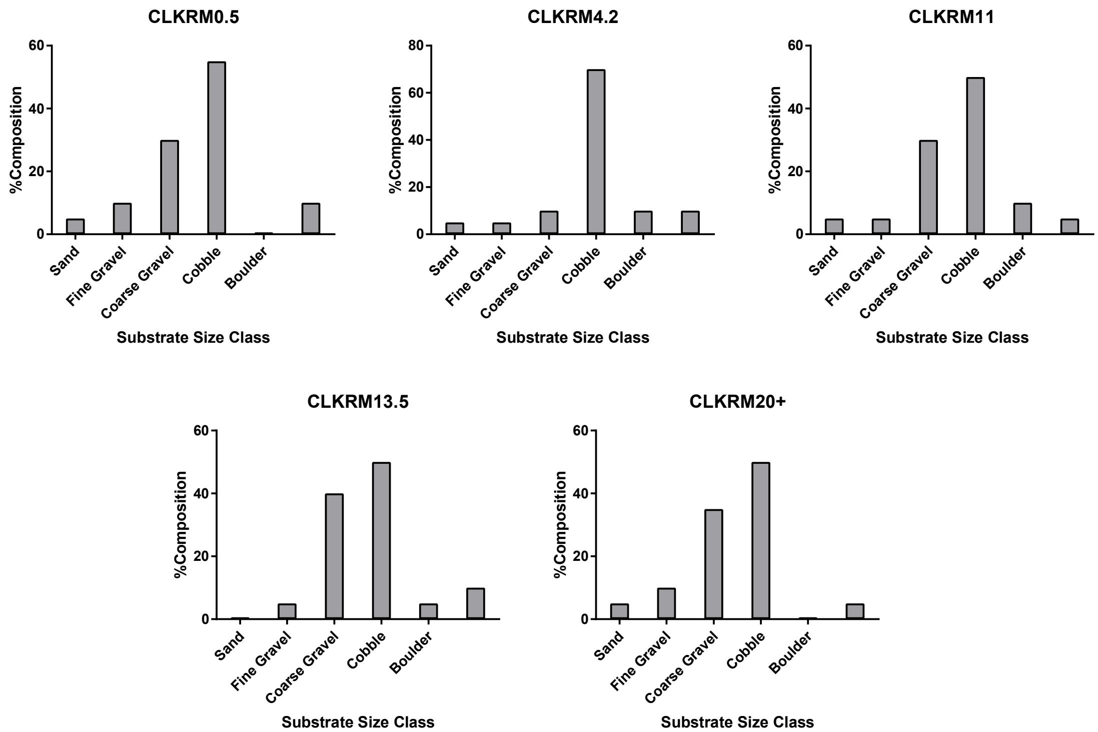


Figure 4. Substrate composition at six Clackamas River macroinvertebrate samples sites, September 2022.

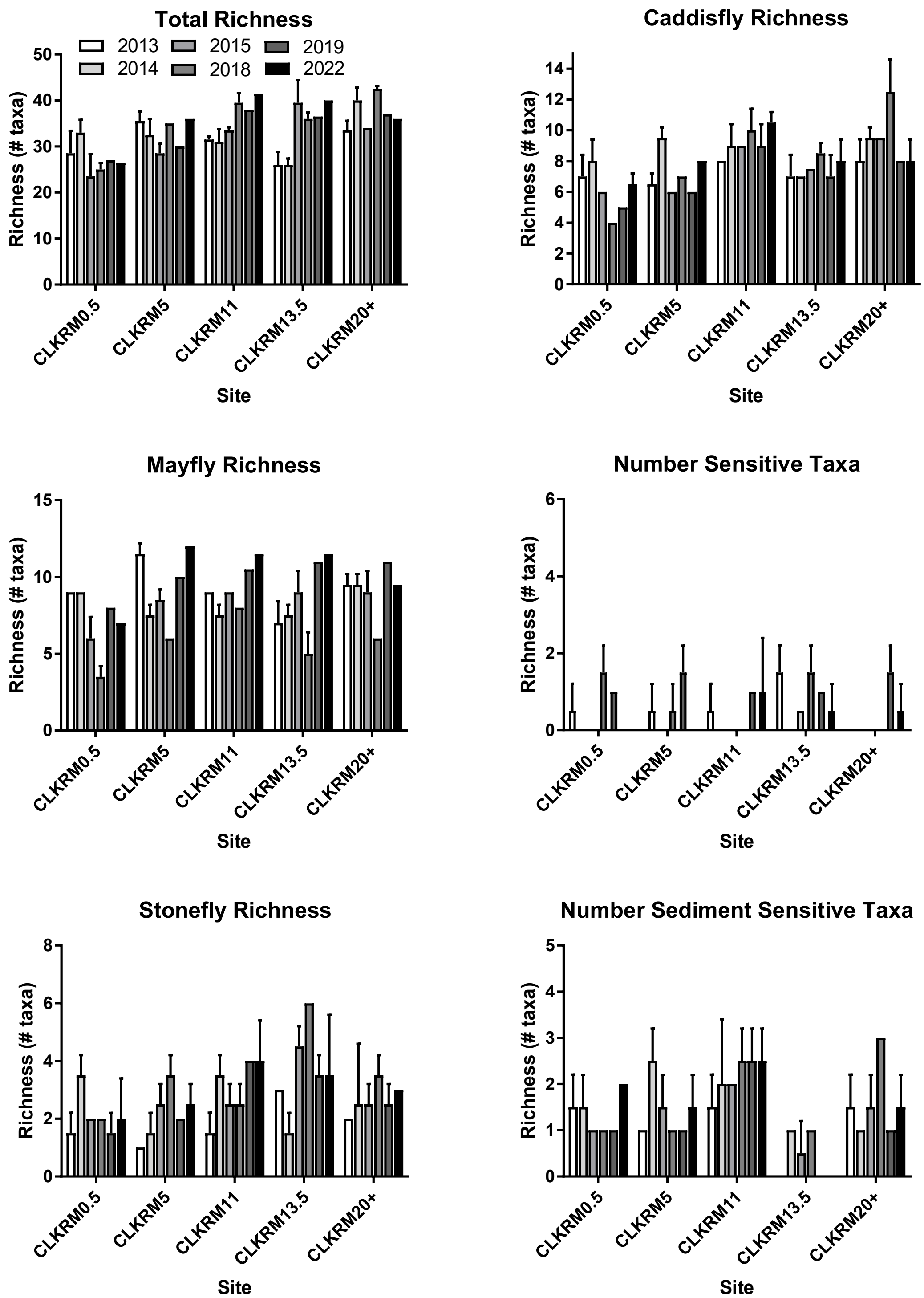


Figure 5. Mean (+SD) macroinvertebrate community metric scores and total multimetric scores (MMS) calculated from duplicate samples collected from the lower Clackamas River in September 2013, 2014, 2015, 2018, 2019 and 2022.

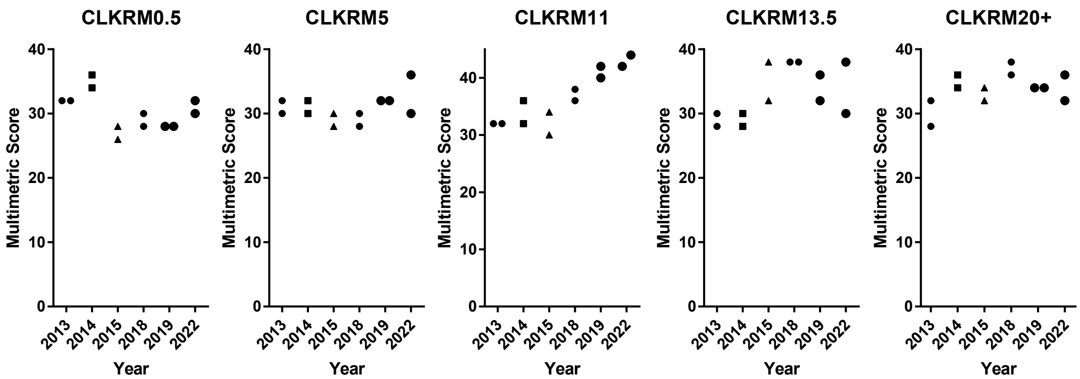


Figure 6. Macroinvertebrate multimetric scores (y axis) calculated from individual duplicate macroinvertebrate samples collected from five locations in the lower Clackamas River in 2013, 2014, 2015, 2018, 2019, and 2022. Each graph represents a single sample site.

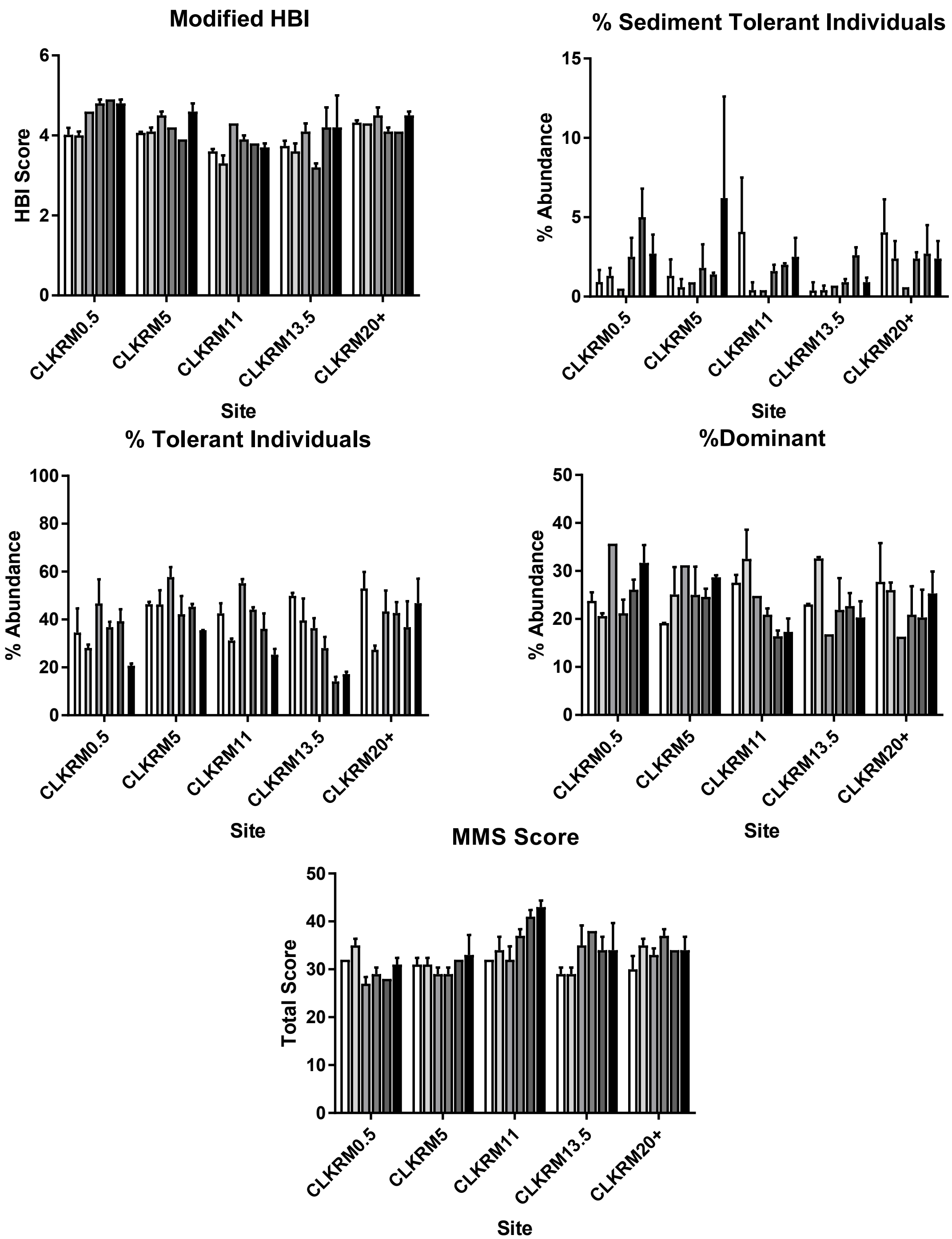


Figure 7. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013, 2014, 2015, 2018, 2019 and 2022.

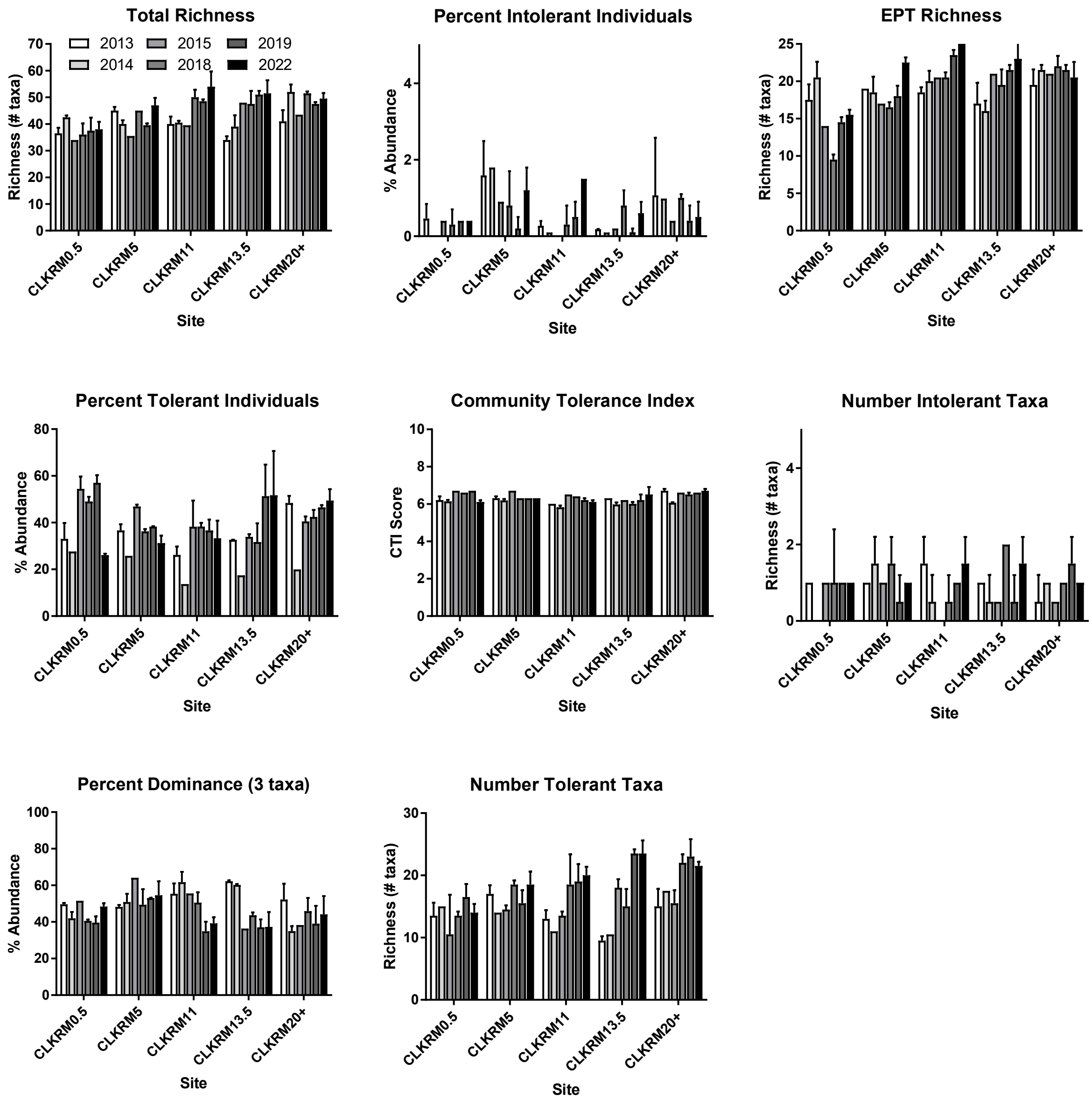


Figure 8. Mean (+SD) macroinvertebrate community metric scores calculated from duplicate samples collected from the lower Clackamas River in September 2013, 2014, 2015, 2018, 2019 and 2022. Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

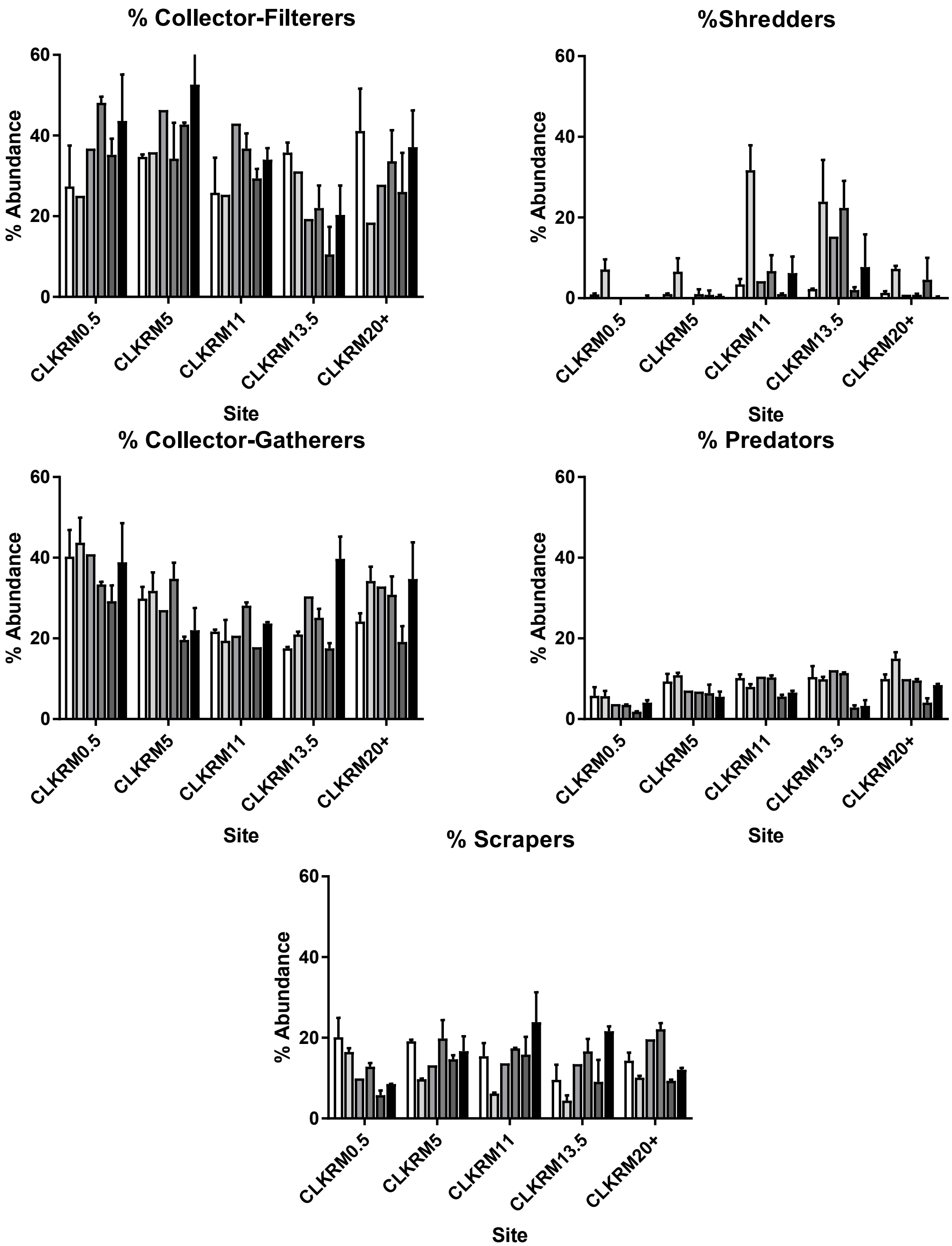


Figure 9. Mean (+SD) abundance of macroinvertebrate functional feeding groups calculated from duplicate samples collected from the lower Clackamas River in September 2013, 2014, 2015, 2018, 2019 and 2022. Metrics in this figure are the same as those used in the 2000-2001 PGE macroinvertebrate study of the Clackamas River (PGE 2004).

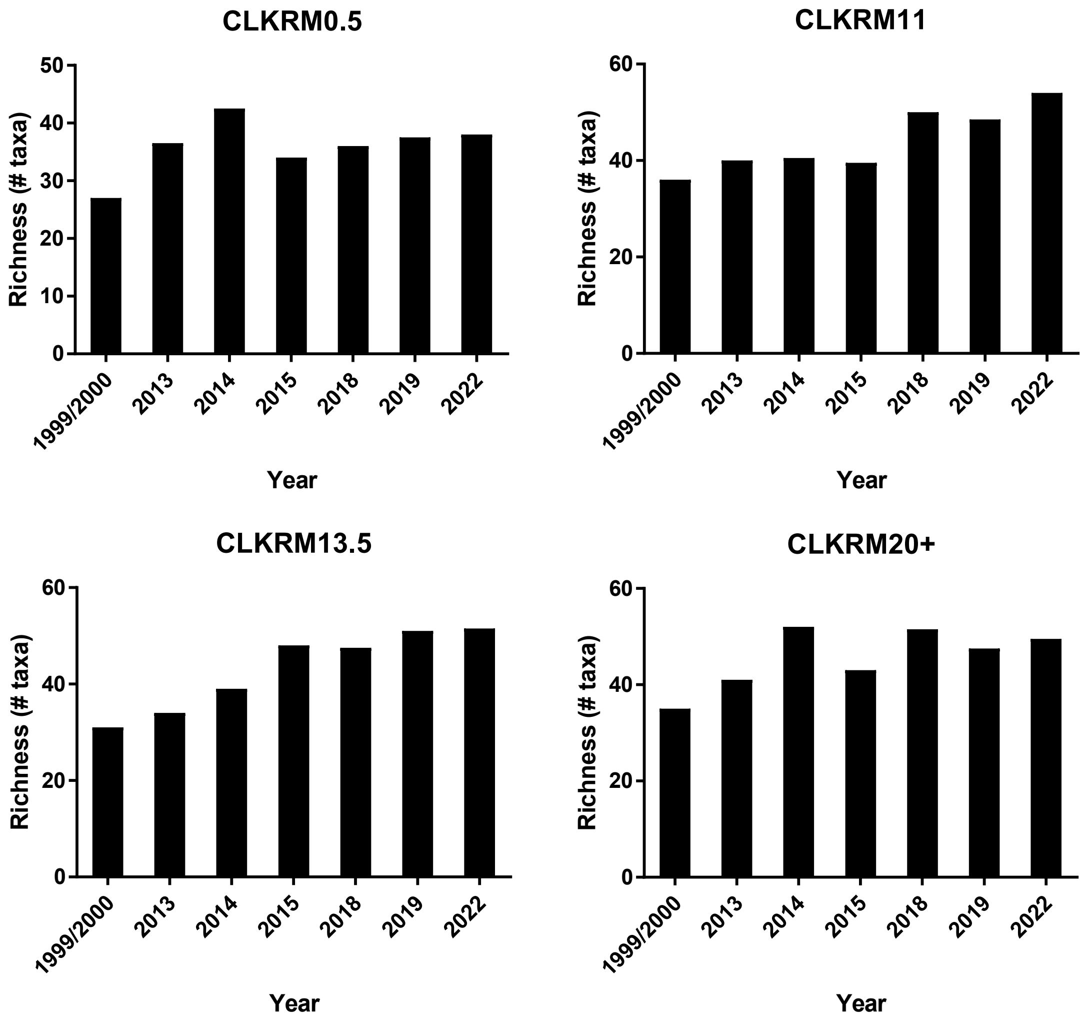


Figure 10. Mean total taxa richness calculated from macroinvertebrate samples collected from the Clackamas River in 1999/2000, 2013-2015, 2018, 2019 and 2022.

APPENDIX A.

Location maps and 2022 site photos

CLKRM0.5

CLKRM5

CLKRM11

CLKRM13.5

CLKRM20+