Summary Report

Learning by Doing

Benthic Macroinvertebrate Biomonitoring

2019

Prepared for:

Grand County
Learning by Doing Stakeholder Group

Prepared by:

David E. Rees and Elise S. Grape
Timberline Aquatics, Inc.
4219 Table Mountain Place, Suite A
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Introduction

In recent years, the biological monitoring (biomonitoring) of benthic macroinvertebrate communities has been identified as a valuable tool for the evaluation of aquatic environments (Plafkin et al. 1989, Barbour et al. 1999, Paul et al. 2005). The monitoring of aquatic life in streams provides opportunities to evaluate aquatic conditions in ways that cannot be achieved through other types of monitoring programs (Ward et al. 2002). Evolution and ecological processes have resulted in benthic macroinvertebrate communities with specific adaptations and sensitivities to their surrounding environment. Aquatic macroinvertebrate communities are considered sensitive to a wide range of environmental disturbances or pollution; thus, community composition reflects the physical and chemical conditions that occur within a stream and associated watershed over time. Consequently, macroinvertebrate assemblages can be monitored in order to measure the ecological integrity of aquatic systems. Biomonitoring programs are often used in conjunction with physical and/or chemical water quality monitoring to evaluate aquatic conditions.

Sustained biological monitoring is essential to understanding the effects of long-term influences such as population growth, urban development, and changes in land-use practices (Likens and Lambert 1998). The unique physical and behavioral attributes of aquatic macroinvertebrates provide an opportunity to monitor past and present influences on aquatic systems at specific locations. Most macroinvertebrate taxa have a relatively long aquatic life-stage and limited mobility. The sensitivity of each taxon in a community often varies with the type of disturbance, and this sensitivity to disturbance can exist at a structural (species/taxon) level and/or functional (trophic) level. These features result in benthic communities that inevitably respond to changes in environmental conditions. The predictability of benthic macroinvertebrates that respond to perturbations provides monitoring opportunities that range from local sources of pollution to watershed scale disturbances (Ward et al. 2002). The results from consistent sampling practices and accurate identifications can provide valuable information regarding anthropogenic influences and impacts on aquatic communities.

Because certain taxa can survive or even thrive in the presence of various contaminants, it becomes necessary to employ the use of several biotic indices (metrics) in the analysis of biological data. The wide range of stressors and potential interaction among disturbances can make identification of the predominant sources of stress difficult (Johnson et al. 2013). However, some insight into the source and spatial distribution of stressors can be obtained through the evaluation of benthic macroinvertebrate community structure and function.

This biomonitoring study was designed to monitor and evaluate the health of aquatic life in a portion of the Upper Colorado River Basin in Grand County, Colorado. The specific study area includes sampling locations on several streams including portions of the Fraser River, Ranch Creek, Williams Fork, and Colorado River (Figure 1). These streams support a variety of aquatic (and terrestrial) life; however, there are several potential

sources of anthropogenic stress ranging from impoundments (which may alter the natural temperature and flow regime) to runoff from agricultural and urbanized areas. Results from this biomonitoring study should provide a reliable measurement of the health of benthic macroinvertebrate communities at specific locations within the study area.

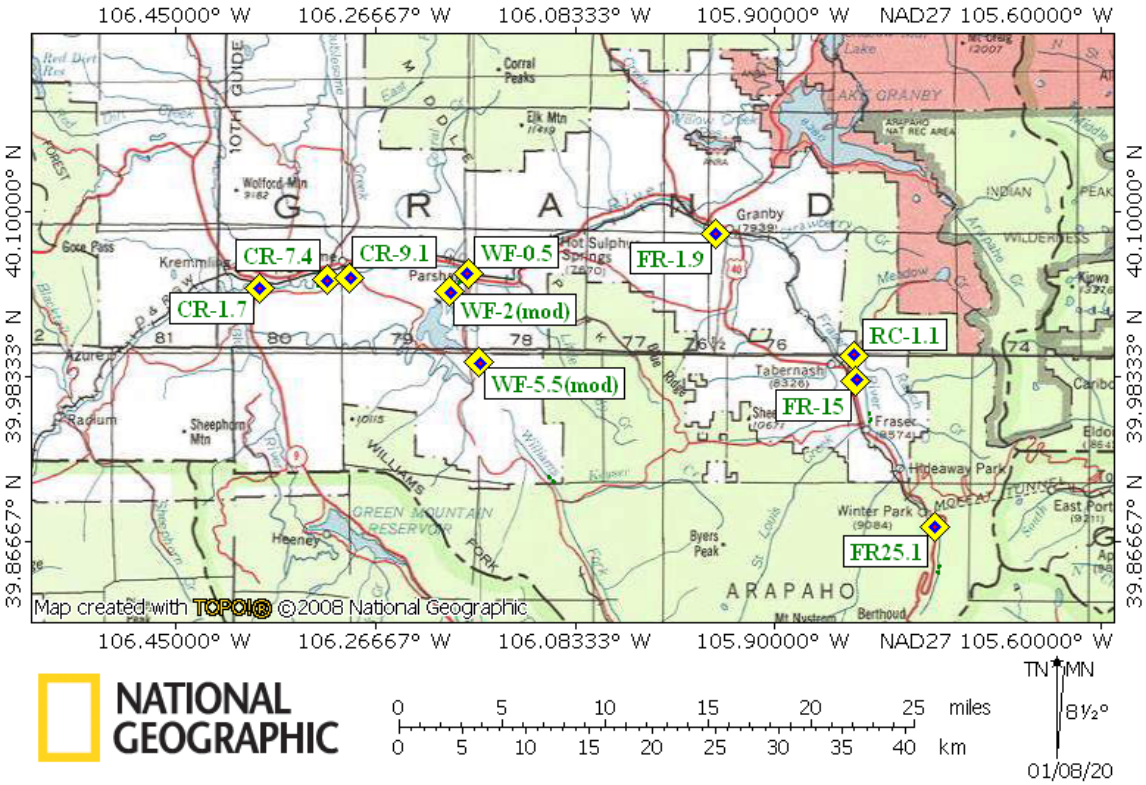

Figure 1. Map of study sites used for the Learning By Doing Biomonitoring study in 2019. This map was created with TOPO! © National Geographic Maps.

Study Area

In the fall of 2019, the Learning By Doing (LBD) study area in Grand County included ten study sites: three on the Fraser River, one on Ranch Creek, three on the Williams Fork, and three on the Colorado River (Table 1, Figure 1). On the Fraser River, the most upstream study site (FR-25.1) was located in riffle habitat upstream of Winter Park and the UP Moffat Tunnel. Farther downstream, site FR-15 was established on the Fraser River above the Fraser Flats Restoration Area and upstream from the confluence with the Ranch Creek. Approximately 23 km downstream, site FR-1.9 was sampled upstream from Windy Gap Reservoir and the Granby Sanitation District. On Ranch Creek, site RC-1.1 was located in riffle habitat upstream of its confluence with the Fraser River, but downstream from Meadow Creek. On the Williams Fork, site WF-5.5 (mod) was established upstream of the Williams Fork Reservoir at a location that could be used to evaluate the influence of a recent habitat improvement project. Approximately 1.5 km

downstream of Williams Fork Reservoir, site WF-2 (mod) was sampled to monitor the health of aquatic life as impacts from the reservoir were expected to subside in a downstream direction. Site WF-0.5 was the most downstream site on the Williams Fork, and this site was used to monitor another area of habitat improvement between Williams Fork Reservoir and the confluence with the Colorado River. The two most upstream study sites on the Colorado River included site CR-9.1 (which was located upstream from the CR39 Bridge) and site CR-7.4 (which was established downstream from Troublesome Creek). The remaining sampling location on the Colorado River (site CR-1.7) was established upstream from the confluence with the Blue River near the Town of Kremmling (Figure 1). A comparison of metric values was used to assess macroinvertebrate community health among sampling locations.

Table 1. GPS coordinates and elevations of sample sites in the Learning By Doing study area (Fraser and Colorado Rivers, Ranch Creek, and Williams Fork) sampled in fall of 2019.

	Location	Latitude	Longitude	Elevation (m)
FR-25.1	Fraser River above UP Moffat Tunnel	39.8775	-105.7535	2827
FR-15	Fraser River above Fraser Flats Restoration	39.981338	-105.824946	2580
FR-1.9	Fraser River above Granby Sanitation District	40.08526	-105.95464	2420
RC-1.1	Ranch Creek below Meadow Creek	39.99912	-105.82746	2561
WF-5.5(mod)	Williams Fork above Williams Fork Reservoir	39.994792	-106.17362	2399
WF-2(mod)	Williams Fork below Williams Fork Reservoir	40.04308	-106.19832	2325
WF-0.5	Williams Fork below WF Reservoir	40.0561	-106.1825	2296
CR-9.1	Colorado River at CR39 Bridge - KB Ditch	40.05377	-106.28945	2285
CR-7.4	Colorado River below Troublesome Creek	40.0509	-106.3112	2255
CR-1.7	Colorado River above Blue River	40.0465	-106.373	2246

Objective

The overall objective for the Benthic Macroinvertebrate Bioassessment Study in Grand County, Colorado was to provide an overall evaluation of the health of macroinvertebrate communities at each site in the Learning By Doing study area and to identify areas with potential anthropogenic perturbations.

Methods

The objective of this particular study required that three (3) replicate, quantitative Hess samples were taken from similar habitat at each study site. The Multi-Metric Index (MMI v4) and several individual biotic indices (metrics) were included in the data analysis to evaluate different aspects of macroinvertebrate community health, and account for different responses to various types of disturbances. The biomonitoring and analysis approach used for this project was intended to provide information describing local aquatic conditions, level of potential disturbances, and densities of various taxa.

Three quantitative, replicate samples were collected from each site on the Fraser River, Ranch Creek, and Colorado River on the 18th of September 2019, and replicate samples were taken from the Williams Fork on the 26th of October 2019. All samples were collected in similar (riffle) habitat at each sampling location using a Hess Sampler to provide quantitative benthic macroinvertebrate data. Substrate within each sample was thoroughly agitated and individual rocks were scrubbed by hand to dislodge benthic organisms. All macroinvertebrates were rinsed into sample jars and preserved in 80% ethanol solution. Each sample jar was labeled (with date, location, and sample ID number) on the outside and inside of each container. Samples were transported to the lab at Timberline Aquatics, Inc. where they were sorted, identified, and enumerated. The sorting and identification process was conducted for each entire sample to avoid potential problems or controversy associated with subsampling.

The sorting and identification process used in this study required that all macroinvertebrates be removed from each sample and placed into vials according to respective major taxonomic groups. As part of the quality control protocols at Timberline Aquatics, Inc., all sorted macroinvertebrate samples were checked by a qualified taxonomist, and approximately 10% of the identifications were checked by Dr. Boris Kondratieff (Professor of Entomology at Colorado State University). As an additional means of QA/QC, Dr. Kondratieff confirmed identifications in all cases where the classification of a species was difficult or questionable.

Macroinvertebrates collected from the Fraser River, Ranch Creek, Williams Fork, and Colorado River were identified to a taxonomic level consistent with the Operational Taxonomic Unit (OTU) established by the CDPHE. Specimens were identified using a variety of taxonomic keys including Ward et al. (2002) and Merritt et al. (2008). This level of identification was typically genus or species for mayflies, stoneflies, caddisflies, and many dipterans. Members of the family Chironomidae were also identified to the genus level. All macroinvertebrate data were analyzed using the MMI v4 and a variety of individual metrics. The following section provides a description of the analysis tools used in this study:

The Multi-Metric Index (MMI v4)

In 2017, the CDPHE published detailed guidelines for benthic macroinvertebrate sampling and analysis to assist in the evaluation of aquatic life in the State of Colorado (Colorado Department of Public Health and Environment 2017). These guidelines described specific protocols for the evaluation of benthic macroinvertebrate data using a Multi-Metric Index (MMI v4). This most recent version of the MMI provides a single index score based on eight equally weighted metrics. The group of metrics used in MMI v4 calculations depends on the sampling location and corresponding Biotype (Mountains, Transitional, or Plains). In the Learning By Doing study area, site FR-25.1 was located in Biotype 2 (Mountains), while all other sampling locations were located within Biotype 1 (the Transition Zone), which includes lower mountain areas in the State of Colorado. Each of the individual metrics used in the analysis produces a score that is adjusted to a scale from 1 to 100 based on the range of metric scores found at "reference sites". In Biotype 1, these metrics include: EPT Taxa, % Non-Insect Individuals, % EPT Individuals (no Baetidae), % Coleoptera Individuals, % Intolerant Taxa, % Increaser Individuals (Mid-Elevation), Clinger Taxa, and Predator/Shredder Taxa. In Biotype 2, these metrics include: EPT Taxa, % EPT Individuals (no Baetidae), Clinger Taxa, Total Taxa, Intolerant Taxa, % Increasers (Mountains), Predator Taxa, and % Scraper Individuals. A detailed description of these metrics and methods used to calculate MMI v4 scores can be found in the *Aquatic Life Use Attainment: Methodology to Determine Use Attainment for Rivers and Streams, Policy 10-1* and Appendix D in the *Section 303(d) Listing Methodology 2020 Listing Cycle* (WQCD, 2017 and 2019). Thresholds for the MMI v4 in Biotypes 1 and 2 are as follows:

Biotype	**Attainment Threshold**	**Impairment Threshold**
Transitional (Biotype 1)	45.2	33.7
Mountains (Biotype 2)	47.5	39.8

Metric scores that fall between the thresholds for attainment and impairment (the 'grey zone') require further evaluation using additional metrics in order to determine an aquatic life use designation. The additional metrics include the Shannon Diversity (Diversity) and Hilsenhoff Biotic Index (HBI). The specific thresholds for the auxiliary metrics in Biotypes 1 and 2 are listed below, followed by descriptions of each metric:

Biotype	**HBI**	**Diversity**
Transitional (Biotype 1)	5.8	2.1
Mountains (Biotype 2)	4.9	3.2

Shannon Diversity (Diversity): Diversity was used as an auxiliary metric for the MMI v4 and as an independent metric in this study to evaluate changes in macroinvertebrate community structure by providing a measure of community balance. In unpolluted waters, Diversity values typically range from near 3.0 to 4.0. In polluted waters, this value is generally less than 1.0 (Ward et al. 2002).

Hilsenhoff Biotic Index (HBI): The HBI is another auxiliary metric used for the MMI v4; however, it is also valuable as an independent metric and has been widely used and/or recommended in numerous regional biomonitoring studies (Paul et al. 2005). Most of the value from this metric lies in the detection of organic pollution, but it is also used to evaluate aquatic conditions in a variety of other circumstances. The HBI was originally developed using macroinvertebrate taxa from streams in Wisconsin; therefore, it may require regional modifications (Hilsenhoff 1988). Tolerance values for taxa occurring in this study area were taken from a list provided by the CDPHE, which was derived from a variety of regional sources. Although HBI values may naturally vary among regions, a comparison of the values produced within the same river system should provide information regarding locations impacted by nutrients and/or other aquatic disturbances. Values for the HBI range from 0.0 to 10.0, and increase as water quality decreases.

Additional metrics used in this study:

In addition to the MMI v4 and associated auxiliary metrics, several other individual metrics were applied in the analysis of macroinvertebrate data from sites in the Learning By Doing study area in order to provide a more thorough evaluation of macroinvertebrate community structure and function. The following section provides a description of each individual metric used in this study:

Density: Macroinvertebrate abundance (Density) was reported as the mean number of macroinvertebrates per m^2 found at each study site. The Density metric provides a means of measuring and comparing standing crop at each site. This metric can be useful when paired with other individual metrics used in this study.

Taxa Richness (Total Taxa): The Total Taxa metric is reported as the total number of identifiable taxa collected from each sampling location. Total Taxa has become one of the most widely used metrics to evaluate stream health, as it provides a general indication of community health and stability (Courtemanch 1996). Total Taxa values are expected to decrease with increased perturbations in the aquatic environment (Resh and Jackson 1993).

Ephemeroptera Plecoptera Trichoptera (EPT Taxa): The design of this metric is based on the assumption that the orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are generally more sensitive to pollution than other benthic macroinvertebrate orders (Lenat 1988). The EPT metric is currently an

important and widely used metric in many regions of the United States (Barbour et al. 1999). The EPT Taxa value is simply given as the total number of distinguishable taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera found at each sampling location. This number will naturally vary among river systems, but it can be an excellent indicator of disturbances within a specific drainage. The EPT value is expected to decrease in response to a variety of stressors including nutrients (Wang et al. 2007).

Density of *Pteronarcys californica*: This metric measures the abundance of *Pteronarcys californica* from three replicate, quantitative samples to provide a mean number of individuals per square meter. *Pteronarycs californica* is a large species of stonefly that requires specific aquatic conditions to complete its relatively long life-cycle. Therefore, it is known to be sensitive to a variety of anthropogenic disturbances. Additionally, this species is an important part of the aquatic food-web that requires (and processes) leaf material from a healthy riparian corridor as a food source.

Percent EPT (excluding Baetidae): As previously stated, most taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera are expected to be sensitive to environmental perturbations or pollution. However, members of the family Baetidae (Order: Ephemeroptera) tend to be more tolerant to disturbances than other EPT taxa. Therefore, the Percent EPT (excluding Baetidae) metric provides a measure of the percent composition of benthic macroinvertebrates (at each sampling location) that are expected to be highly sensitive to anthropogenic stressors or pollution. A decrease in this metric value suggests that the benthic macroinvertebrate community consists of a higher proportion of tolerant taxa.

Percent Chironomidae: Chironomidae taxa are considered fairly tolerant to environmental disturbances when compared to other aquatic insect families (Plafkin et al. 1989). The Percent Chironomidae metric relies on the assumption that the proportion of Chironomidae will increase with decreasing water quality. Streams that are undisturbed often have a relatively even distribution of Ephemeroptera, Plecoptera, Trichoptera, and Chironomidae (Mandaville 2002); while study sites degraded by metals or other pollutants are often dominated by the Chironomidae family (Barton and Metcalfe-Smith 1992). Most species of Chironomidae tend to have a relatively short life-cycle, which enables them to continually re-colonize unstable or polluted habitats (Lenat 1983).

Percent Hydropsychidae: The Percent Hydropsychidae metric was reported for each study site as the proportion of caddisflies that are in the family Hydropsychidae. Members of this family provide some insight into macroinvertebrate community structure and function because they are almost always collector-filterers and their large body size makes them an important food source for fish. These caddisflies are known to be moderately sensitive to a variety of stressors, particularly ammonia and fine sediment. Five taxa representing the family Hydropsychidae (*Arctopsyche grandis*, *Cheumatopsyche sp.*, *Hydropsyche sp.*, *Hydropsyche cockerelli*, and *Hydropsyche oslari*) were found in this study area during the fall of 2019.

Percent Tolerant Taxa: Percent Tolerant Taxa is reported as the percentage of taxa that are considered tolerant to a variety of environmental disturbances and stressors. This metric measures the relative abundance of all taxa that have tolerance values of 7 or greater.

Percent Intolerant Taxa: This metric is expressed as the percentage of taxa that are expected to be sensitive to a variety of anthropogenic disturbances and environmental stressors. Intolerant taxa include all taxa with a tolerance value of 3 or lower.

Functional Feeding Groups: Most of the previously described metrics utilize macroinvertebrate information that is related to community structure; however, macroinvertebrate taxa were also separated into functional guilds based on their method of food acquisition to provide a measurement of community function. Aquatic macroinvertebrates were categorized according to feeding strategy to determine the relative abundance of various groups. Some representation of each group usually indicates healthy aquatic conditions; however, it is common for certain groups (collector-gatherers) to be more abundant than others (Ward et al. 2002).

Results/Discussion

Benthic Macroinvertebrate Sampling – Fall 2019

Benthic macroinvertebrates were collected from study sites on the Fraser River, Ranch Creek, Williams Fork, and Colorado River in the fall of 2019 to evaluate aquatic conditions based on macroinvertebrate community structure and function. After samples were collected using the quantitative (Hess) sampling methodology, they were transported to the lab at Timberline Aquatics, Inc. where specimens were sorted, identified, and enumerated (Appendix A; Tables A1-A10). The previously described metrics and analysis tools (including the MMI v4) were applied to the macroinvertebrate data to provide a comprehensive assessment of macroinvertebrate community health in the study area (Tables 2-4). Results provided by select metrics (MMI v4, Diversity, HBI, EPT, % EPT no Baetidae) were also used to illustrate changes (or similarities) in community parameters among study sites (Figures 2-6). Functional Feeding Group analysis evaluated aquatic communities based on ecological function rather than taxonomic structure (Table 5, Figure 7). In general, results from the fall of 2019 demonstrated considerable variability in the structure, function, and health of benthic macroinvertebrate communities within the study area; however, results from the MMI v4 indicated that all sampling locations were in ‘attainment’ for aquatic life use.

Results from the MMI v4

In the fall of 2019, a comprehensive evaluation of benthic macroinvertebrate community health was provided by the MMI v4. All samples were processed according to the guidelines provided in Appendix D of the *Section 303(d) Listing Methodology 2020 Listing Cycle* (WQCD 2019). Despite evidence of variability among individual (component) metric scores, all sites in the study area produced MMI v4 scores that were above the attainment threshold for their respective biotypes (Table 2).

Study sites on the Fraser River were distributed between two Biotypes in the State of Colorado (Biotypes 1 and 2). Site FR-25.1 was located in the mountains (Biotype 2), while the remaining two study sites were in a transitional area (based on State classifications) between the mountains and plains (Biotype 1). On the Fraser River, MMI v4 scores improved in a downstream direction, ranging from 64.5 at site FR-25.1 to 85.4 at site FR-1.9. Site FR-1.9 produced the highest MMI v4 score throughout the study area in the fall of 2019 (Table 2, Figure 2). Much of the improvement detected by the MMI v4 at site FR-1.9 appeared to be associated with an increase in the relative abundance of individuals representing sensitive taxa (EPT Taxa) and specialized taxa (Clinger Taxa). On Ranch Creek (a tributary of the Fraser River), site RC-1.1 produced an MMI v4 score of 79.9, and component metrics indicated that the benthic community was also dominated by sensitive and specialized taxa with low proportions of tolerant individuals (Table 2). Diversity and HBI values were indicative of adequate community balance with relatively low proportions of nutrient-tolerant macroinvertebrates at study sites on the Fraser River and Ranch Creek in the fall of 2019 (Figures 3 and 4).

On the Williams Fork, three study sites were sampled in the fall of 2019 to monitor the influence of Williams Fork Reservoir and recent habitat restoration work that had been conducted both upstream and downstream of this impoundment. The MMI v4 generated scores that were consistently above the attainment threshold, although scores for sites WF-2 (mod) and WF-0.5 were among the lowest in the LBD study area. The most upstream sampling location on the Williams Fork, site WF-5.5 (mod), was established above the reservoir and downstream of a recent habitat enhancement project. This site produced the second highest MMI v4 score (80.0) in study area, and the highest score among sites that were sampled on the Williams Fork. Several of the component metrics for the MMI v4 that performed well at this location included the % EPT Individuals (no Baetidae), % Non-Insect Individuals, % Increasers Mid-Elevation, and Predator/Shredder Taxa metrics (Table 2). These metrics suggested that site WF-5.5 (mod) was able to support a community with high proportions of sensitive individuals and a variety of sensitive and specialized taxa. Farther downstream, the MMI v4 generated scores slightly above the attainment threshold at sites WF-2 (mod) and WF-0.5 (Figure 2). Alterations from the natural flow and temperature regime imposed by reservoir operations were likely responsible for the decline in richness and abundance of sensitive and specialized taxa at these two sampling locations. Several components of the MMI v4 that detected these types of impacts included the EPT Taxa, % EPT Individuals (no Baetidae), Clinger Taxa, % Non-Insect Individuals, and Predator/Shredder Taxa metrics.

It should be noted that habitat restoration work occurred between sites WF-2 (mod) and WF-0.5 prior to sampling in the fall of 2019, and it is unlikely that the habitat and substrate had time to stabilize prior to macroinvertebrate sampling in the fall of 2019. Benefits from these habitat enhancement projects may not be realized until future sampling events. Continued monitoring will provide an opportunity for the long-term assessment of habitat enhancements at study sites on the Williams Fork.

The health of benthic macroinvertebrate communities was assessed using the MMI v4 at three locations on the Colorado River in a reach that spanned approximately 10 river-miles (upstream from the confluence with the Blue River). Scores generated by the MMI v4 ranged from 78.1 (at site CR-7.4) to 66.7 (at site CR-1.7) in the fall of 2019 (Table 2). All sites produced MMI v4 scores that were indicative of relatively healthy aquatic conditions; however, a slight decline in the health of the aquatic community was observed at the most downstream study site (CR-1.7), where habitat improvements had recently been completed. Several component metrics used in the MMI v4 (EPT Taxa, % EPT no Baetidae, Clinger Taxa, and % Non-Insect Individuals) generated scores that remained relatively high at all study sites on the Colorado River (Table 2). These metrics were primarily influenced by high proportions of sensitive and specialized individuals such as *Ephemerella dorothea infrequens* and *Lepidostoma* sp. (Appendix A; Tables A8-A10). Component metrics that detected a slight increase in stress at site CR-1.7 included % Intolerant Taxa and % Increasers Mid Elevation. These two metrics were generally responding to an increase in the richness of tolerant taxa at the downstream study site. A review of values produced by auxiliary metrics showed that there was also a sharp decline in community balance at site CR-1.7 (Figure 3), while the proportion of nutrient-tolerant taxa remained relatively low (Figure 4). Overall, results from the MMI v4 suggested that macroinvertebrate communities were healthy at all three study sites on the Colorado River, with a slight increase in stress at site CR-1.7 that could probably be attributed to limitations in preferred habitat.

In summary, results from the MMI v4 indicated that all sites in the study area were in attainment for aquatic life use during the fall of 2019 (Table 3). These results were generally supported by MMI v4 scores from previous sampling events in this same study area (Appendix B: Tables B1 and B2). In 2019, there was a wide range in MMI v4 scores (from 85.4 at site FR-1.9 to 46.0 at site WF-0.5), and components of the MMI v4 often responded to changes in the richness of specialized taxa and proportions of sensitive individuals (Table 2). Since the % Intolerant Taxa and % Increasers Mid Elevation metrics generated relatively high scores throughout the study area, much of the change in MMI v4 scores could probably be linked to the adequacy of aquatic habitat (including deviations from the natural temperature regime) rather than water quality. Continued biomonitoring efforts will help in the evaluation of potential anthropogenic stressors and the long-term influence of habitat restoration efforts in the Learning By Doing study area.

Table 2. Individual metrics and MMI scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during fall 2019. All metric scores based on MMI v4 subsampling process.

Metric	Station ID									
	FR-25.1	**FR-15**	**FR-1.9**	**RC-1.1**	**WF-5.5 (mod)**	**WF-2 (mod)**	**WF-0.5**	**CR-9.1**	**CR-7.4**	**CR-1.7**
EPT Taxa	73.5	66.7	100.0	87.5	83.3	41.6	35.6	93.2	100.0	85.3
% EPT, no Baetidae	45.8	45.6	78.9	83.1	81.5	15.1	17.9	68.3	72.9	80.6
Clinger Taxa	70.0	62.5	96.1	76.9	76.9	52.9	35.3	92.6	100.0	84.1
Total Taxa	71.4	--	--	--	--	--	--	--	--	--
Intolerant Taxa	81.0	--	--	--	--	--	--	--	--	--
% Increasers, Mountains	41.3	--	--	--	--	--	--	--	--	--
Predator Taxa	76.9	--	--	--	--	--	--	--	--	--
% Scraper Individuals	56.2	--	--	--	--	--	--	--	--	--
% Non-Insect Individuals	--	88.3	95.8	84.5	90.1	47.0	58.9	78.1	86.0	71.8
% Coleoptera Individuals	--	53.4	58.5	34.8	41.8	1.0	0.0	25.8	33.1	33.1
% Intolerant Taxa	--	74.9	92.4	82.0	77.7	60.7	76.0	75.1	95.2	67.8
% Increasers, Mid-Elev.	--	91.1	97.2	90.5	88.6	93.4	94.5	88.2	80.1	46.7
Predator/Shredder Taxa	--	78.6	64.3	100.0	100.0	71.4	50.0	64.3	57.1	64.3
MMI	**64.5**	**70.1**	**85.4**	**79.9**	**80.0**	**47.9**	**46.0**	**73.2**	**78.1**	**66.7**
	Auxiliary Metrics									
Diversity	4.11	3.69	4.18	4.08	3.73	3.25	2.66	4.30	4.05	2.92
HBI	3.60	3.91	2.85	3.22	3.13	3.74	4.07	3.10	3.40	3.27
Sediment Region	SR1	SR2		SR2						
TIV	4.92	5.69	--	5.20	--	--	--	--	--	--

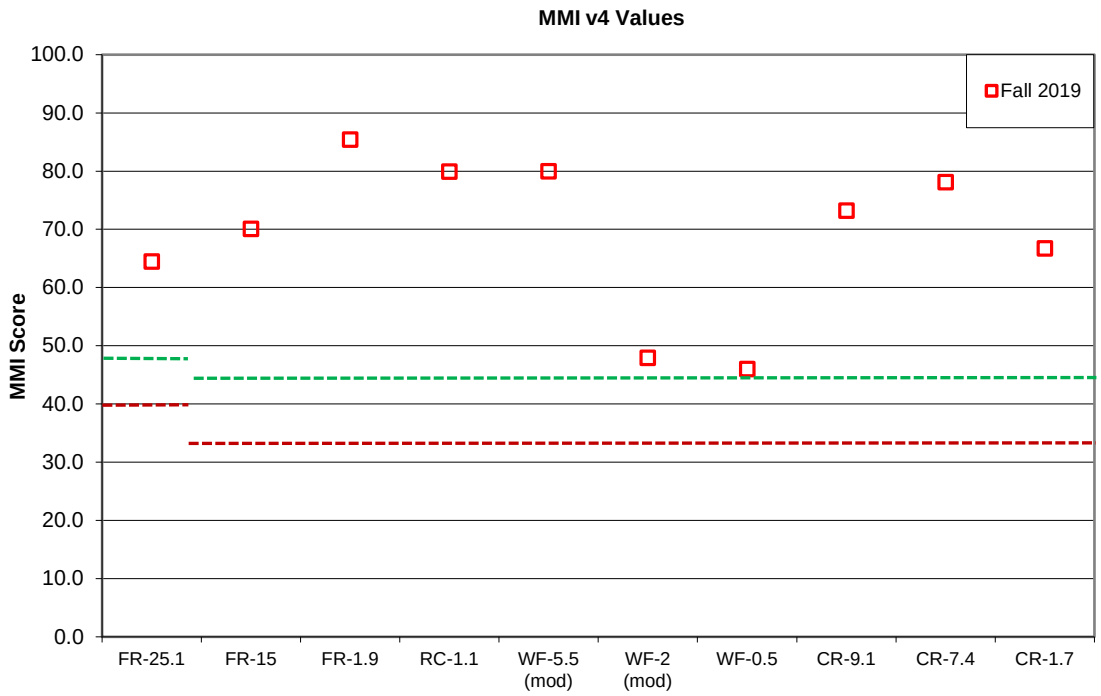

Figure 2. MMI (v4) scores from study sites in the Learning By Doing study area during fall 2019. All scores based on MMI (v4) subsampling process. The green line indicates the attainment threshold and the red line indicates the impairment threshold.

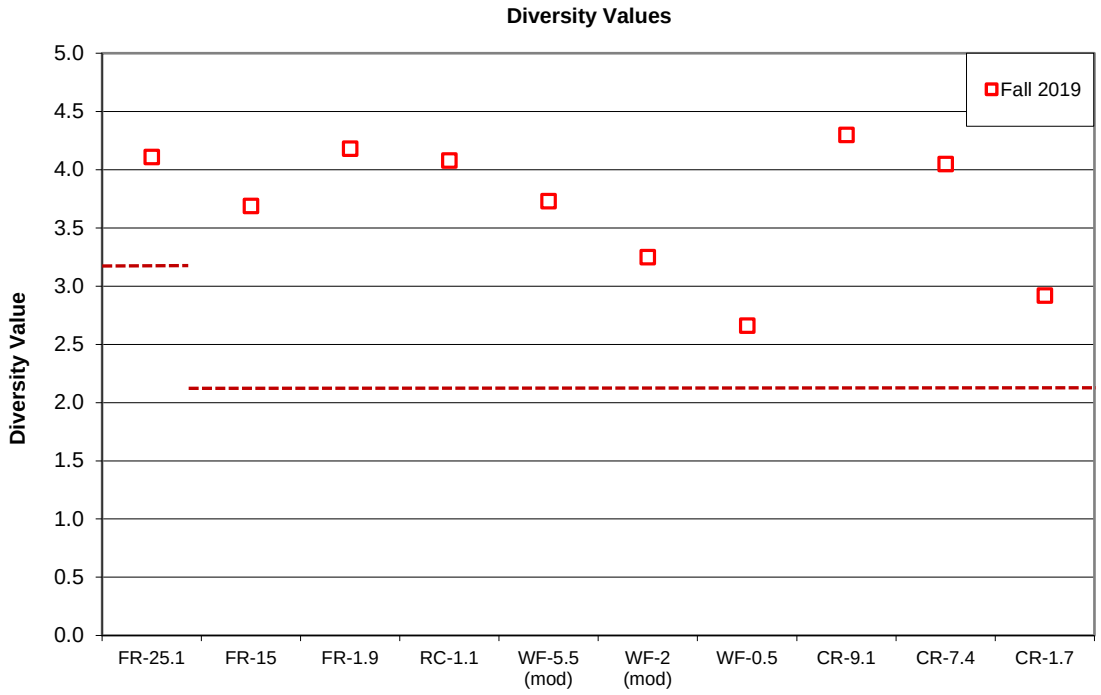

Figure 3. Diversity values from study sites in the Learning By Doing study area during fall 2019. The red line indicates the impairment threshold for Biotypes 2 and 1.

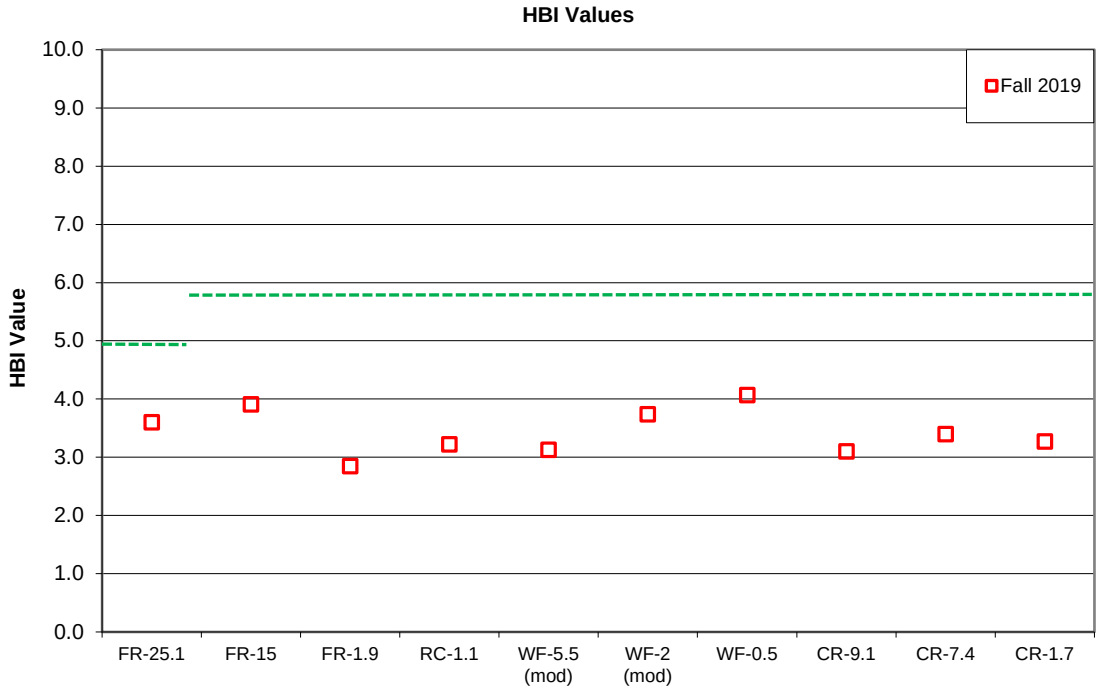

Figure 4. HBI values from study sites in the Learning By Doing study area during fall 2019. Exceeding the green line indicates impairment for Biotypes 2 and 1.

Table 3. Aquatic life designations based on MMI (v4) scores for ten sample sites in the Learning By Doing study area during fall 2019.

Aquatic Life Designations	
Site	Quantitative (Hess) Samples
FR-25.1	Attainment
FR-15	Attainment
FR-1.9	Attainment
RC-1.1	Attainment
WF-5.5(mod)	Attainment
WF-2(mod)	Attainment
WF-0.5	Attainment
CR-9.1	Attainment
CR-7.4	Attainment
CR-1.7	Attainment

Results from Additional Metrics

In addition to the MMI v4 and associated metrics, nine individual metrics were applied to macroinvertebrate data from the Learning By Doing study area to further evaluate benthic macroinvertebrate community health during the fall of 2019 (Table 4). Although the individual metrics were able to detect changes in macroinvertebrate community structure among sites, the factors influencing these changes were not always easily identifiable. Overall, most study sites could be characterized as supporting a high proportion of sensitive taxa (when compared to tolerant taxa), while the density of benthic macroinvertebrates varied throughout the study area. The stonefly *Pteronarcys californica* was not collected at any study sites during the fall of 2019; however, a variety of other sensitive taxa were present at most sampling locations. The following comparison of individual metric values among study sites provides a more detailed description of macroinvertebrate community health during the fall of 2019.

At sampling locations on the Fraser River and Ranch Creek, the additional metrics used in this study generally supported results from the MMI v4. On the Fraser River, the EPT metric produced values that increased in a downstream direction, from 19 at site FR-25.1 to 25 at site FR-1.9; however, all of these values indicated a healthy representation of sensitive taxa (Figure 5). At site FR-1.9, the % EPT (excluding Baetidae) metric produced a value of 57.78%, suggesting that more than half of the aquatic community was sensitive to general perturbations. The Percent Hydropsychidae metric indicated that this family of net-spinning caddisflies was present at all study sites on the Fraser River and dominated (61.29%) the aquatic community at site FR-15 (Table 4). At site RC-1.1 on Ranch Creek, the Taxa Richness, % EPT (excluding Baetidae), and EPT taxa metrics generated values similar to the Fraser River sites, indicating that site RC-1.1 was able to support a variety of sensitive taxa and a high proportion of sensitive individuals.

A review of results provided by individual metrics for study sites on the Williams Fork demonstrated some of the greatest variability in the study area in 2019 (Table 4). While most metrics were indicative of a healthy macroinvertebrate community at site WF-5.5 (mod), there was evidence of increased stress downstream from Williams Fork Reservoir. At site WF-5.5 (mod), the Taxa Richness and % EPT (excluding Baetidae) metric values were among the highest in the study area, indicating that this site supported a variety of taxa with high proportions of sensitive individuals (Table 4). However, downstream of the reservoir at site WF-2 (mod), several metrics detected increased stress and the Percent EPT (excluding Baetidae) metric indicated that only 8.39% of the community was sensitive to perturbations (Table 4). Farther downstream, continued declines in the Density, Taxa Richness, EPT, and Percent Hydropsychidae values at site WF-0.5 suggested that aquatic habitat had not yet stabilized (following a habitat improvement project) and macroinvertebrates at this location continued to be influenced by the effects of the impoundment. Collectively, these results suggested that macroinvertebrate communities were relatively healthy upstream of the reservoir, but downstream study sites seemed to be influenced by the altered temperature and flow regimes caused by reservoir releases.

Table 4. Additional metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in fall 2019. All additional metrics are based on full count (quantitative) Hess samples.

Metric	FR-25.1	FR-15	FR-1.9	RC-1.1	WF-5.5 (mod)	WF-2 (mod)	WF-0.5	CR-9.1	CR-7.4	CR-1.7
Density (#/m^2)	1,087	8,521	5,528	7,180	10,328	7,264	1,801	10,060	12,549	8,758
Taxa Richness	31	52	48	49	56	33	20	53	58	49
EPT Taxa	19	24	25	24	23	15	8	27	29	23
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	0	0	0	0
% EPT excluding Baetidae	36.33%	34.64%	57.78%	57.68%	57.11%	8.39%	14.90%	49.54%	53.00%	57.36%
% Chironomidae	18.71%	27.71%	7.18%	15.91%	3.46%	17.85%	6.70%	17.49%	6.47%	4.96%
% Hydropsychidae	9.52%	61.29%	21.48%	40.78%	37.60%	22.83%	3.28%	24.09%	14.98%	2.35%
% Tolerant Taxa	12.90%	17.31%	20.83%	26.53%	21.43%	18.18%	20.00%	20.75%	22.41%	30.61%
% Intolerant Taxa	54.84%	40.38%	39.58%	40.82%	39.29%	30.30%	35.00%	37.74%	37.93%	28.57%

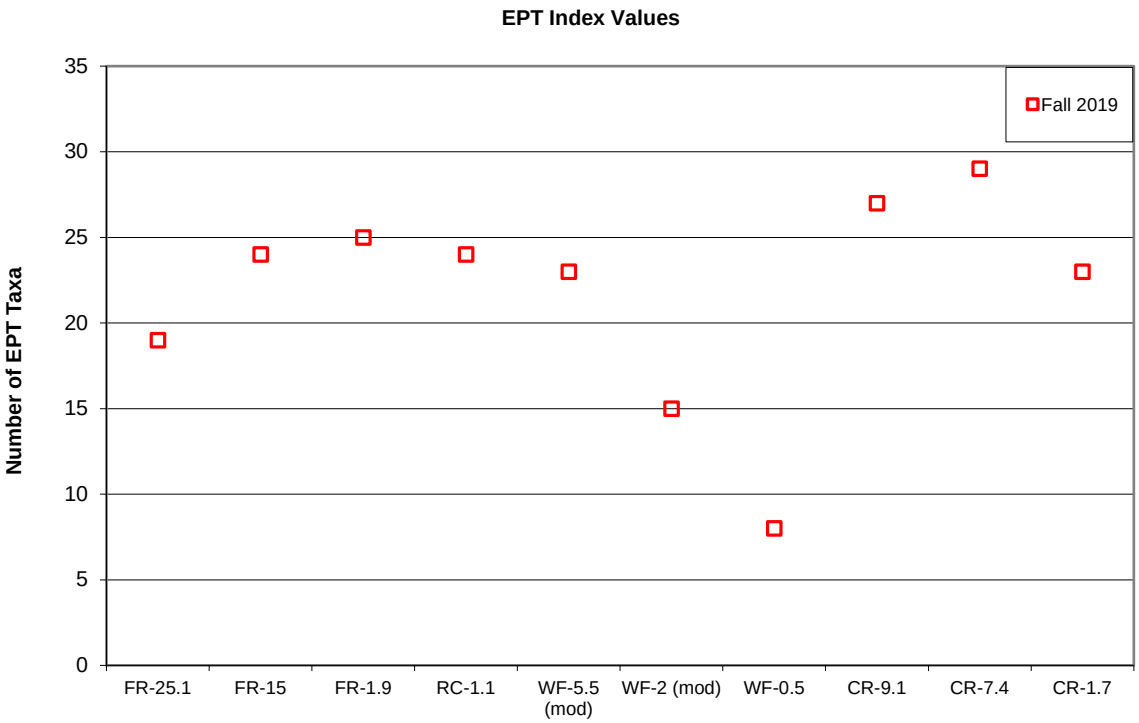

Figure 5. EPT values from study sites in the Learning By Doing study area during fall 2019.

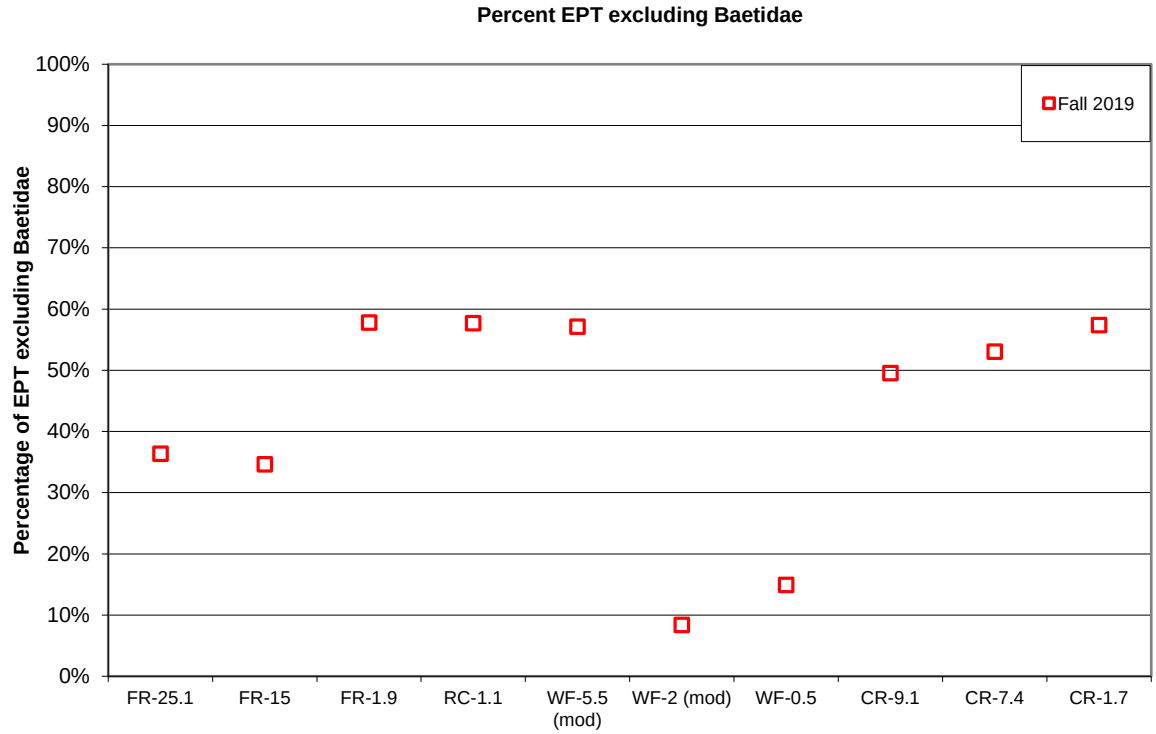

Figure 6. Percent EPT (excluding Baetidae) values from study sites in the Learning By Doing study area during fall 2019.

On the Colorado River, the additional individual metrics continued to detect healthy benthic community parameters while demonstrating some of the highest macroinvertebrate densities in the study area (Table 4). The Taxa Richness, EPT, and % EPT (excluding Baetidae) metrics all performed well relative to other sites in the study area, indicating that sampling locations on the Colorado River were able to support taxa-rich communities with high proportions of sensitive individuals. The most optimal values (in the entire study area) for the Taxa Richness and EPT metric (58 and 29, respectively) were found at site CR-7.4. The abundance (Density) of macroinvertebrates was also higher (12,549 individuals/m^2) at this site than any other sampling location (Table 4). Some of the best evidence of shifts in macroinvertebrate community structure among sites on the Colorado River was provided by the Percent Hydropsychidae metric, which declined in a downstream direction between sites CR-9.1 and CR-1.7 (Table 4). In general, most of the subtle changes in community structure in the Colorado River could probably be attributed to changes in habitat. Although the stonefly *Pteronarcys californica* was not collected during the fall of 2019, all three study sites on the Colorado River were populated with a variety of other sensitive and specialized taxa.

The reorganization of benthic macroinvertebrate taxa according to their method of food acquisition provided an opportunity to evaluate aquatic communities based on ecological function rather than taxonomic structure (Table 5, Figure 7). Healthy aquatic ecosystems typically support adequate representation from most feeding groups; however, it is common for certain groups (such as collector-gatherers) to be proportionally dominant. During the fall of 2019, all sites maintained an adequate distribution among feeding groups, without the dominance of a single trophic guild (Figure 7). While the collector-gatherer group was present at all sampling locations, the relative abundance of this group never exceeded 50.0% (Table 5). Other feeding groups that are considered sensitive and/or specialized (collector-filterers, shredders, and scrapers) were often well-represented or even dominant at certain sampling locations (Figure 7). An evaluation of the Fraser River showed that all study sites maintained good distributions among feeding groups, and although the shredder group was poorly represented upstream (sites FR-25.1 and FR-15), the scraper group maintained relatively high proportions at all sampling locations. Downstream from Williams Fork Reservoir there was a sharp decline in the most sensitive feeding groups (shredders and scrapers) at sites WF-2 (mod) and WF-0.5; however, this was expected due to potential impacts from the altered temperature and flow regime on algal communities and the absence of extensive riparian habitat (a food source for shredders) in the vicinity of the reservoir. On the Colorado River, collector-filterers decreased in a downstream direction, while shredders increased from 9.61% at site CR-9.1, to over half (50.58%) of the benthic macroinvertebrate community at site CR-1.7. This shift among feeding groups may have been caused by an increase in coarse particulate organic material (CPOM) and a decrease in fine particulate organic material (FPOM) in a downstream direction (Table 5, Figure 7). Overall, results from the functional feeding group analysis supported the results from other metrics used in this study by detecting relatively healthy aquatic communities at all study sites despite changes in community composition.

Table 5. Relative abundance of functional feeding groups during fall 2019 sampling in the Learning By Doing study area.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
FR-25.1	48.92%	9.35%	1.80%	18.35%	21.58%	0.00%
FR-15	39.65%	20.10%	0.46%	30.36%	8.71%	0.73%
FR-1.9	28.71%	26.74%	10.56%	28.22%	5.77%	0.00%
RC-1.1	28.68%	27.44%	20.83%	12.99%	10.06%	0.00%
WF-5.5(mod)	30.79%	35.04%	5.34%	21.17%	7.59%	0.08%
WF-2(mod)	49.71%	20.42%	1.71%	0.21%	6.31%	21.65%
WF-0.5	38.01%	30.02%	8.21%	0.00%	3.67%	20.09%
CR-9.1	32.90%	35.68%	9.61%	12.86%	4.05%	4.90%
CR-7.4	30.88%	21.66%	30.20%	14.73%	2.32%	0.22%
CR-1.7	27.35%	6.12%	50.58%	15.12%	0.80%	0.04%

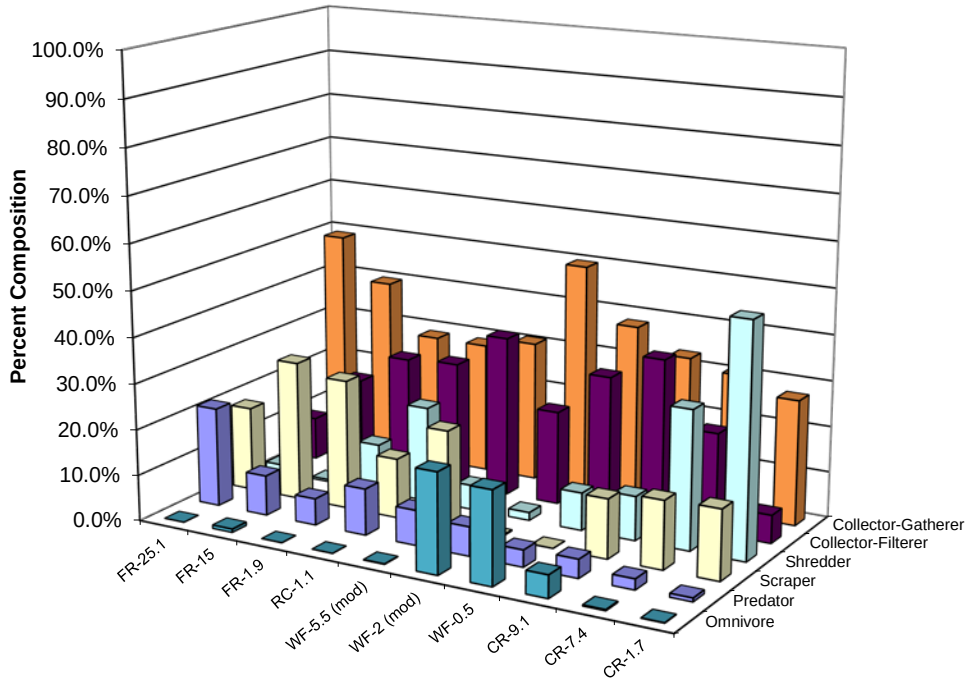

Figure 7. Functional feeding group composition for study sites in the Learning By Doing study area in fall of 2019.

Conclusions

Overall, benthic macroinvertebrate communities demonstrated minor changes in structure and function while remaining relatively healthy throughout the Learning By Doing study area. Collectively, the MMI v4 and individual metrics indicated that most sampling locations were able to support well-balanced communities with high proportions of sensitive taxa. When the proportion of sensitive to tolerant taxa remains stable and abundance of benthic macroinvertebrates increases or decreases, the observed changes in macroinvertebrate community structure are often responses to changes in habitat adequacy rather than water quality. Functional Feeding Group analysis indicated that all sites maintained adequate ecological balance and proportions of feeding groups likely fluctuated throughout the study area due to variations in the availability of preferred habitat, food resources, competition, predation, etc.

There was some evidence of increased stress detected by the MMI v4 and several individual metrics at study sites downstream of Williams Fork Reservoir. However, the variety of analysis tools used in this study suggested that while these two study sites (WF-2 (mod) and WF-0.5) were apparently stressed, they were not considered 'impaired' for aquatic life use. Habitat restoration work that occurred prior to macroinvertebrate sampling on the Williams Fork had yet to have a discernable positive influence on the applied metrics at site WF-0.5. Future biomonitoring studies would provide an opportunity to assess any changes in influences from anthropogenic activities, and provide a continued assessment of habitat improvement projects that have occurred in this study area.

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Appendix A

Benthic Macroinvertebrate Data – Fall 2019

Table A1. Macroinvertebrate data collected from site FR-25.1 on 18 Sept. 2019.

Fraser River						
FR-25.1		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	8	18	9		35	136
Baetis flavistriga		1	1		2	8
Baetis (*tricaudatus*)	12	9	4		25	97
Diphetor hageni						
Attenella margarita						
Drunella coloradensis	1				1	4
Drunella doddsii			1		1	4
Drunella grandis						
Ephemerella dorothea infrequens						
Serratella tibialis						
Cinygmula sp.	1				1	4
Epeorus sp.						
Epeorus deceptivus	4	2	1		7	28
Heptagenia sp.						
Rhithrogena sp.	3		2		5	20
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata	1				1	4
Chloroperlidae						
Sweltsa sp.	1				1	4
Zapada oregonensis group	2	1	1		4	16
Claassenia sabulosa						
Hesperoperla pacifica						
Perlodidae	12	4	5		21	82
Perlodidae (*Cultus* sp.)						
Diura knowltoni						
Isoperla sp.						
Isoperla fulva						
Megarcys signata	2	1	1		4	16
Skwala americana						
Pteronarcella badia						
Taenionema sp.	21	8	5		34	132
Trichoptera (caddisflies)						
Brachycentrus americanus						
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis		1	1		2	8
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Ochrotrichia sp.						
Lepidostoma sp.						
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea		2	3		5	20
Rhyacophila coloradensis	3	2	4		9	35
Rhyacophila sibirica group			3		3	12
Oligophlebodes sp.			2		2	8

Table A1. cont. Macroinvertebrate data collected from site FR-25.1 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	6	18	2		26	101
Diamesa sp.						
Eukiefferiella sp.	1	9	8		18	70
Limnophyes sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	1	2			3	12
Paracladopelma sp.						
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheotanytarsus sp.						
Synorthocladius sp.	1	1			2	8
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	2		1		3	12
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae	3	4			7	28
Chelifera/Neoplasta sp.						
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	8	1	15		24	93
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	10	3	8		21	82
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.			1		1	4
Protzia sp.						
Sperchon sp.		1			1	4
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Polycelis coronata						
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae			1		1	4
Nematoda		8			8	31
Totals	**103**	**96**	**79**		**278**	**1087**

Table A2. Macroinvertebrate data collected from site FR-15 on 18 Sept. 2019.

Fraser River						
FR-15		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	3	2			5	20
Baetis flavistriga						
Baetis (*tricaudatus*)	73	49	75		197	764
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	4	5	17		26	101
Ephemerella dorothea infrequens	20	10	18		48	186
Serratella tibialis		1	2		3	12
Cinygmula sp.			1		1	4
Epeorus sp.		1			1	4
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus		1			1	4
Paraleptophlebia sp.	4	2	3		9	35
Plecoptera (stoneflies)						
Paracapnia angulata	4		1		5	20
Chloroperlidae		2	2		4	16
Sweltsa sp.	5				5	20
Zapada oregonensis group			1		1	4
Claassenia sabulosa						
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)	1				1	4
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	12	3	3		18	70
Megarcys signata						
Skwala americana	4	3	10		17	66
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	6	3	9		18	70
Brachycentrus occidentalis		3	2		5	20
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.	13	46	136		195	756
Protoptila sp.						
Arctopsyche grandis	13	6	12		31	121
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	127	45	175		347	1345
Hydropsyche oslari		2			2	8
Ochrotrichia sp.		5	15		20	78
Lepidostoma sp.			2		2	8
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A2. cont. Macroinvertebrate data collected from site FR-15 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	20	6	6		32	124
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	147	73	190		410	1590
Diamesa sp.						
Eukiefferiella sp.	33	17	44		94	365
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	3	1	4		8	31
Microtendipes sp.		1	1		2	8
Pagastia sp.	6	5	17		28	109
Paracladopelma sp.						
Parametriocnemus sp.	2	1			3	12
Polypedilum sp.						
Potthastia sp.	1	2	1		4	16
Rheotanytarsus sp.		1			1	4
Synorthocladius sp.	1	1			2	8
Thienemanniella sp.						
Thienemannimyia group			2		2	8
Tvetenia sp.	10	3	9		22	86
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	1	5	3		9	35
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	10	11	14		35	136
Antocha sp.						
Dicranota sp.	1	1			2	8
Hexatoma sp.		1			1	4
Tipula sp.			2		2	8
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	3				3	12
Optioservus sp.	114	130	199		443	1718
Zaitzevia parvula						
Miscellaneous						
Atractides sp.	1		1		2	8
Hygrobates sp.			1		1	4
Lebertia sp.	7	14	12		33	128
Protzia sp.						
Sperchon sp.	11	17	23		51	198
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	7	4	5		16	62
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae		1	1		2	8
Lumbricidae	2	4			6	24
Naididae	3	2			5	20
Nematoda		12	1		13	51
Totals	**672**	**502**	**1020**		**2194**	**8521**

Table A3. Macroinvertebrate data collected from site FR-1.9 on 18 Sept. 2019.

Fraser River						
FR-1.9		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	3	6	9		18	70
Baetis flavistriga						
Baetis (*tricaudatus*)	35	36	63		134	520
Diphetor hageni			1		1	4
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	2	2	3		7	28
Ephemerella dorothea infrequens	9	22	24		55	214
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.	9	10	19		38	148
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus		1			1	4
Paraleptophlebia sp.	17	5	26		48	186
Plecoptera (stoneflies)						
Paracapnia angulata	1		4		5	20
Chloroperlidae						
Sweltsa sp.	16		6		22	86
Zapada oregonensis group						
Claassenia sabulosa	1	2	1		4	16
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)	6	2	13		21	82
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	1		6		7	28
Megarcys signata						
Skwala americana		1	2		3	12
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	74	71	95		240	931
Brachycentrus occidentalis		2			2	8
Micrasema bactro						
Culoptila sp.	4	8	9		21	82
Glossosoma sp.	16	35	22		73	283
Protoptila sp.	6	4	12		22	86
Arctopsyche grandis		3	1		4	16
Cheumatopsyche sp.		9	5		14	55
Hydropsyche sp.						
Hydropsyche cockerelli	16	5	12		33	128
Hydropsyche oslari	3	36	41		80	311
Ochrotrichia sp.						
Lepidostoma sp.	48	27	44		119	462
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida	1		1		2	8
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A3. cont. Macroinvertebrate data collected from site FR-1.9 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.			1		1	4
Cricotopus nostocicola	11	5	8		24	93
Cricotopus/Orthocladius sp.	5	4	1		10	39
Diamesa sp.	1				1	4
Eukiefferiella sp.	7	7	7		21	82
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	1		4		5	20
Microtendipes sp.						
Pagastia sp.	3	6	6		15	59
Paracladopelma sp.			1		1	4
Parametriocnemus sp.						
Polypedilum sp.	1	1			2	8
Potthastia sp.						
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	6	8	8		22	86
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	1		2		3	12
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	1	1	3		5	20
Antocha sp.						
Dicranota sp.						
Hexatoma sp.	3	1	4		8	31
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	2				2	8
Optioservus sp.	81	44	109		234	907
Zaitzevia parvula	24	12	29		65	252
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.			1		1	4
Sperchon sp.	3	1	8		12	47
Torrenticola sp.						
Pisidium sp.	1		1		2	8
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.	3	1	2		6	24
Gyraulus sp.						
Polycelis coronata						
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae	3				3	12
Lumbricidae	3				3	12
Naididae	1				1	4
Nematoda						
Totals	**429**	**378**	**614**		**1421**	**5528**

Table A4. Macroinvertebrate data collected from site RC-1.1 on 18 Sept. 2019.

Ranch Creek						
RC-1.1		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.			1		1	4
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	8	42	17		67	260
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	7	30	10		47	183
Ephemerella dorothea infrequens	45	107	40		192	745
Serratella tibialis						
Cinygmula sp.	1		2		3	12
Epeorus sp.	1	1	6		8	31
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus			1		1	4
Paraleptophlebia sp.	14	9	31		54	210
Plecoptera (stoneflies)						
Paracapnia angulata	3	1	5		9	35
Chloroperlidae						
Sweltsa sp.	3	4	2		9	35
Zapada oregonensis group						
Claassenia sabulosa	1		1		2	8
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	4	8	2		14	55
Megarcys signata						
Skwala americana	4	3	1		8	31
Pteronarcella badia		2			2	8
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	60	91	57		208	807
Brachycentrus occidentalis						
Micrasema bactro		1	1		2	8
Culoptila sp.						
Glossosoma sp.		2			2	8
Protoptila sp.						
Arctopsyche grandis	1	2	2		5	20
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	4	6			10	39
Hydropsyche oslari	54	165	58		277	1074
Ochrotrichia sp.	1				1	4
Lepidostoma sp.	67	21	118		206	799
Ceraclea sp.						
Oecetis sp.			2		2	8
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis		2	1		3	12
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A4. cont. Macroinvertebrate data collected from site RC-1.1 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	66	52	48		166	644
Cricotopus/Orthocladius sp.	3	12	2		17	66
Diamesa sp.						
Eukiefferiella sp.	9	27	7		43	167
Limnophyes sp.						
Micropsectra/Tanytarsus sp.		2			2	8
Microtendipes sp.						
Pagastia sp.	2	17	1		20	78
Paracladopelma sp.						
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheotanytarsus sp.	1		1		2	8
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	4	38	2		44	171
Other Diptera (true flies)						
Atherix pachypus		2			2	8
Ceratopogoninae			2		2	8
Chelifera/Neoplasta sp.	1				1	4
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.	1	2	2		5	20
Simulium sp.		4	1		5	20
Antocha sp.	1	2	1		4	16
Dicranota sp.						
Hexatoma sp.			1		1	4
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	56	66	54		176	683
Zaitzevia parvula	31	26	19		76	295
Miscellaneous						
Atractides sp.						
Hygrobates sp.			3		3	12
Lebertia sp.	6	18	8		32	124
Protzia sp.	13	11	20		44	171
Sperchon sp.	23	26	13		62	241
Torrenticola sp.			1		1	4
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae			1		1	4
Physa sp.			1		1	4
Gyraulus sp.			2		2	8
Polycelis coronata						
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae						
Lumbricidae		3			3	12
Naididae						
Nematoda						
Totals	**495**	**805**	**548**		**1848**	**7180**

Table A5. Macroinvertebrate data collected from site WF-5.5(mod) on 26 Oct 2019.

Williams Fork						
WF-5.5(mod)		Sample				
26 Oct. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	106	242	18		366	1419
Diphetor hageni	1	3	3		7	28
Attenella margarita						
Drunella coloradensis						
Drunella doddsii	2				2	8
Drunella grandis	17	13	11		41	159
Ephemerella dorothea infrequens	87	129	55		271	1051
Serratella tibialis						
Cinygmula sp.	5	5	7		17	66
Epeorus sp.	2		1		3	12
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	29	26	24		79	307
Plecoptera (stoneflies)						
Paracapnia angulata		1	1		2	8
Chloroperlidae						
Sweltsa sp.	2				2	8
Zapada oregonensis group						
Claassenia sabulosa		1	1		2	8
Hesperoperla pacifica	3				3	12
Perlodidae						
Perlodidae (*Cultus* sp.)	4	1	3		8	31
Diura knowltoni	1				1	4
Isoperla sp.						
Isoperla fulva	2				2	8
Megarcys signata						
Skwala americana						
Pteronarcella badia		1			1	4
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	164	254	94		512	1985
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis	4	12	3		19	74
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari	132	217	40		389	1508
Ochrotrichia sp.						
Lepidostoma sp.	31	58	46		135	524
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.		2			2	8
Psychomyia flavida						
Rhyacophila brunnea	10	9	8		27	105
Rhyacophila coloradensis			1		1	4
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A5. cont. Macroinvertebrate data collected from site WF-5.5(mod) on 26 Oct 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.		3	1		4	16
Diamesa sp.		2			2	8
Eukiefferiella sp.	4	21			25	97
Limnophyes sp.	1				1	4
Micropsectra/Tanytarsus sp.		1			1	4
Microtendipes sp.						
Pagastia sp.	1	2	1		4	16
Paracladopelma sp.						
Parametriocnemus sp.						
Polypedilum sp.		1			1	4
Potthastia sp.		4	1		5	20
Rheotanytarsus sp.		1			1	4
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group	7	17	9		33	128
Tvetenia sp.	4	11			15	59
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	2	7	4		13	51
Wiedemannia sp.			1		1	4
Lispoides aequifrons						
Pericoma sp.	7	7	4		18	70
Simulium sp.	3	5	3		11	43
Antocha sp.		2			2	8
Dicranota sp.			1		1	4
Hexatoma sp.		4	4		8	31
Tipula sp.			1		1	4
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	2	1	1		4	16
Optioservus sp.	131	276	87		494	1915
Zaitzevia parvula	2	4			6	24
Miscellaneous						
Atractides sp.						
Hygrobates sp.	3	3	2		8	31
Lebertia sp.	6	20	21		47	183
Protzia sp.	2	2	3		7	28
Sperchon sp.	13	10	13		36	140
Torrenticola sp.	1		1		2	8
Pisidium sp.						
Caecidotea sp.	1	5	2		8	31
Ferrissia sp.						
Lymnaeidae						
Physa sp.			3		3	12
Gyraulus sp.		2			2	8
Polycelis coronata			2		2	8
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae	1				1	4
Nematoda		1			1	4
Totals	**793**	**1386**	**481**		**2660**	**10328**

Table A6. Macroinvertebrate data collected from site WF-2(mod) on 26 Oct 2019.

Williams Fork						
WF-2(mod)		Sample				
26 Oct. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	217	117	200		534	2070
Diphetor hageni		1			1	4
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis						
Ephemerella dorothea infrequens	22	12	11		45	175
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.						
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus		1	1		2	8
Paraleptophlebia sp.			1		1	4
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	8	5	4		17	66
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	5	6	4		15	59
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis	11	2	5		18	70
Cheumatopsyche sp.	1		1		2	8
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari			1		1	4
Ochrotrichia sp.			1		1	4
Lepidostoma sp.	9	17	5		31	121
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.		1			1	4
Psychomyia flavida						
Rhyacophila brunnea	5	1	12		18	70
Rhyacophila coloradensis	3	1	1		5	20
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A6. cont. Macroinvertebrate data collected from site WF-2(mod) on 26 Oct 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	60	47	48		155	601
Diamesa sp.						
Eukiefferiella sp.	11	7	11		29	113
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	4	4	2		10	39
Microtendipes sp.						
Pagastia sp.	65	28	38		131	508
Paracladopelma sp.						
Parametriocnemus sp.		1			1	4
Polypedilum sp.						
Potthastia sp.	3	1	1		5	20
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	2	1			3	12
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Wiedemannia sp.	1				1	4
Lispoides aequifrons		1	1		2	8
Pericoma sp.						
Simulium sp.	197	21	128		346	1342
Antocha sp.	1		5		6	24
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.		1	3		4	16
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.	2	8			10	39
Protzia sp.						
Sperchon sp.	9	26	7		42	163
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	66	221	118		405	1570
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae	1		1		2	8
Lumbricidae						
Naididae	1		3		4	16
Nematoda	5	5	13		23	90
Totals	**709**	**536**	**626**		**1871**	**7264**

Table A7. Macroinvertebrate data collected from site WF-0.5 on 26 Oct 2019.

Williams Fork						
WF-0.5		Sample				
26 Oct. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	22	15	103		140	543
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis						
Ephemerella dorothea infrequens	1		2		3	12
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.						
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Diura knowltoni						
Isoperla sp.						
Isoperla fulva			5		5	20
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	2	2	9		13	51
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari	1		1		2	8
Ochrotrichia sp.						
Lepidostoma sp.	2		35		37	144
Ceraclea sp.						
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea		1	7		8	31
Rhyacophila coloradensis	1				1	4
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A7. cont. Macroinvertebrate data collected from site WF-0.5 on 26 Oct 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	3	2	12		17	66
Diamesa sp.						
Eukiefferiella sp.	3	1	2		6	24
Limnophyes sp.						
Micropsectra/Tanytarsus sp.		1			1	4
Microtendipes sp.						
Pagastia sp.	2		2		4	16
Paracladopelma sp.						
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.			1		1	4
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.		1	1		2	8
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	8	14	102		124	481
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.		1			1	4
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.			3		3	12
Protzia sp.						
Sperchon sp.						
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	2	11	80		93	361
Crangonyx sp.		1			1	4
Erpobdellidae						
Enchytraeidae		1			1	4
Lumbricidae						
Naididae						
Nematoda						
Totals	**47**	**51**	**365**		**463**	**1801**

Table A8. Macroinvertebrate data collected from site CR-9.1 on 18 Sept. 2019.

Colorado River						
CR-9.1		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	2	1	1		4	16
Baetis flavistriga						
Baetis (*tricaudatus*)	59	68	83		210	814
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	1	5	5		11	43
Ephemerella dorothea infrequens	20	35	49		104	404
Serratella tibialis		1			1	4
Cinygmula sp.						
Epeorus sp.	5		3		8	31
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.	3	2	2		7	28
Tricorythodes explicatus	7	10	2		19	74
Paraleptophlebia sp.	7		4		11	43
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.	1		4		5	20
Zapada oregonensis group						
Claassenia sabulosa	3	12	7		22	86
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)	9	8	25		42	163
Diura knowltoni						
Isoperla sp.	1		1		2	8
Isoperla fulva		2			2	8
Megarcys signata						
Skwala americana			1		1	4
Pteronarcella badia	1	1			2	8
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	199	143	163		505	1958
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.	29	5	18		52	202
Protoptila sp.	20	2	11		33	128
Arctopsyche grandis	1		1		2	8
Cheumatopsyche sp.	3	3			6	24
Hydropsyche sp.	27	32	11		70	272
Hydropsyche cockerelli	15	15	14		44	171
Hydropsyche oslari	40	56	34		130	504
Ochrotrichia sp.			1		1	4
Lepidostoma sp.	135	43	23		201	780
Ceraclea sp.			2		2	8
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A8. cont. Macroinvertebrate data collected from site CR-9.1 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.		9			9	35
Cricotopus nostocicola	9	22	11		42	163
Cricotopus/Orthocladius sp.	2	8	14		24	93
Diamesa sp.						
Eukiefferiella sp.	39	78	49		166	644
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	2	1			3	12
Microtendipes sp.						
Pagastia sp.	49	49	68		166	644
Paracladopelma sp.						
Parametriocnemus sp.		2			2	8
Polypedilum sp.		4			4	16
Potthastia sp.						
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.		1			1	4
Thienemannimyia group			1		1	4
Tvetenia sp.	17	17	1		35	136
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	2	4	1		7	28
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	27	103	34		164	636
Antocha sp.	1		2		3	12
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	63	74	72		209	811
Zaitzevia parvula	16	16	14		46	179
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.		1			1	4
Sperchon sp.	2	3	6		11	43
Torrenticola sp.						
Pisidium sp.	1	2			3	12
Caecidotea sp.	12	17	4		33	128
Ferrissia sp.						
Lymnaeidae						
Physa sp.	10	2			12	47
Gyraulus sp.		1			1	4
Polycelis coronata	39	44	44		127	493
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae			6		6	24
Lumbricidae		8	7		15	59
Naididae						
Nematoda		1	1		2	8
Totals	**879**	**911**	**800**		**2590**	**10060**

Table A9. Macroinvertebrate data collected from site CR-7.4 on 18 Sept. 2019.

Colorado River						
CR-7.4		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	11	14	25		50	194
Baetis flavistriga						
Baetis (*tricaudatus*)	172	77	132		381	1477
Diphetor hageni		2	3		5	20
Attenella margarita	1	2			3	12
Drunella coloradensis						
Drunella doddsii						
Drunella grandis			2		2	8
Ephemerella dorothea infrequens	35	9	22		66	256
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.	2	6	14		22	86
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.	6	2	6		14	55
Tricorythodes explicatus	37	12	28		77	299
Paraleptophlebia sp.	33	11	8		52	202
Plecoptera (stoneflies)						
Paracapnia angulata	1		1		2	8
Chloroperlidae						
Sweltsa sp.	6	4	1		11	43
Zapada oregonensis group						
Claassenia sabulosa	6	5	1		12	47
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)	10	10	5		25	97
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	4				4	16
Megarcys signata						
Skwala americana	1	1	1		3	12
Pteronarcella badia	3		2		5	20
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	85	37	88		210	814
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.		6			6	24
Glossosoma sp.	13	15			28	109
Protoptila sp.	7	2	2		11	43
Arctopsyche grandis	1				1	4
Cheumatopsyche sp.	2	1			3	12
Hydropsyche sp.	48	16	59		123	477
Hydropsyche cockerelli	12	4	11		27	105
Hydropsyche oslari	24	9	25		58	225
Ochrotrichia sp.						
Lepidostoma sp.	322	208	415		945	3663
Ceraclea sp.			1		1	4
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida	2				2	8
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A9. cont. Macroinvertebrate data collected from site CR-7.4 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	7	7	9		23	90
Cricotopus/Orthocladius sp.	2	1	10		13	51
Diamesa sp.						
Eukiefferiella sp.	36	4	33		73	283
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	1		38		39	152
Microtendipes sp.			1		1	4
Pagastia sp.	6		1		7	28
Paracladopelma sp.						
Parametriocnemus sp.	7		4		11	43
Polypedilum sp.			1		1	4
Potthastia sp.	1				1	4
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group	1				1	4
Tvetenia sp.	23	2	14		39	152
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	2				2	8
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	165	22	90		277	1074
Antocha sp.			1		1	4
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	195	74	122		391	1516
Zaitzevia parvula	19	3	6		28	109
Miscellaneous						
Atractides sp.	1				1	4
Hygrobates sp.	2				2	8
Lebertia sp.						
Protzia sp.	3				3	12
Sperchon sp.	4	3	3		10	39
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.	35	19	47		101	392
Ferrissia sp.						
Lymnaeidae						
Physa sp.		1			1	4
Gyraulus sp.		1			1	4
Polycelis coronata	4	3			7	28
Crangonyx sp.	4	3	3		10	39
Erpobdellidae						
Enchytraeidae	4				4	16
Lumbricidae	3	3			6	24
Naididae			28		28	109
Nematoda			1		1	4
Totals	**1369**	**599**	**1264**		**3232**	**12549**

Table A10. Macroinvertebrate data collected from site CR-1.7 on 18 Sept. 2019.

Colorado River						
CR-1.7		Sample				
18 Sept. 2019	1	2	3		Totals	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	4	2	1		7	28
Baetis flavistriga						
Baetis (*tricaudatus*)	28	30	55		113	438
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	4	7	11		22	86
Ephemerella dorothea infrequens	9	10	14		33	128
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.			3		3	12
Epeorus deceptivus						
Heptagenia sp.		2			2	8
Rhithrogena sp.			2		2	8
Tricorythodes explicatus		1	9		10	39
Paraleptophlebia sp.		8	15		23	90
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada oregonensis group						
Claassenia sabulosa			1		1	4
Hesperoperla pacifica						
Perlodidae			1		1	4
Perlodidae (*Cultus* sp.)		1	3		4	16
Diura knowltoni						
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcella badia			1		1	4
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	2	2	4		8	31
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.		1			1	4
Glossosoma sp.			1		1	4
Protoptila sp.		1	3		4	16
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.	2				2	8
Hydropsyche cockerelli			1		1	4
Hydropsyche oslari			25		25	97
Ochrotrichia sp.	5	5	1		11	43
Lepidostoma sp.	407	448	283		1138	4411
Ceraclea sp.			1		1	4
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A10. cont. Macroinvertebrate data collected from site CR-1.7 on 18 Sept. 2019.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	1		1		2	8
Cricotopus/Orthocladius sp.	12	11	11		34	132
Diamesa sp.						
Eukiefferiella sp.	4	2	7		13	51
Limnophyes sp.						
Micropsectra/Tanytarsus sp.	7	26	9		42	163
Microtendipes sp.						
Pagastia sp.						
Paracladopelma sp.						
Parametriocnemus sp.		1			1	4
Polypedilum sp.						
Potthastia sp.						
Rheotanytarsus sp.						
Synorthocladius sp.						
Thienemanniella sp.	1		1		2	8
Thienemannimyia group						
Tvetenia sp.	2	4	12		18	70
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Wiedemannia sp.						
Lispoides aequifrons						
Pericoma sp.						
Simulium sp.	3	10	88		101	392
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.	1				1	4
Heterlimnius sp.						
Optioservus sp.	60	61	172		293	1136
Zaitzevia parvula	1	2	9		12	47
Miscellaneous						
Atractides sp.						
Hygrobates sp.		2	1		3	12
Lebertia sp.		1	1		2	8
Protzia sp.			1		1	4
Sperchon sp.		2			2	8
Torrenticola sp.						
Pisidium sp.		1			1	4
Caecidotea sp.	31	32	59		122	473
Ferrissia sp.			1		1	4
Lymnaeidae	1				1	4
Physa sp.	1	5	2		8	31
Gyraulus sp.	1	2			3	12
Polycelis coronata	1				1	4
Crangonyx sp.	3		3		6	24
Erpobdellidae			3		3	12
Enchytraeidae	2				2	8
Lumbricidae						
Naididae	101	43	23		167	648
Nematoda						
Totals	**694**	**723**	**839**		**2256**	**8758**

Appendix B

Historical Metric Results – 2017 & 2018

Table B1. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during fall 2017. All metric scores based on MMI (v4) subsampling process.

Metric	Station ID							
	FR-23.2	**FR-20**	**FR-15**	**FR-14**	**RC-1.1**	**FR-12.4**	**FR-1.9**	**CR-9.1**
EPT taxa	50.0	45.8	58.3	62.5	66.7	75.0	100.0	93.2
% Non-Insect individuals	70.4	55.6	92.7	94.1	80.6	86.2	94.6	83.1
% EPT individuals, no Baetidae	19.6	15.0	29.1	61.7	53.5	81.3	79.4	68.1
% Coleoptera individuals	16.2	9.5	4.6	31.6	44.8	47.4	54.8	52.3
% Intolerant Taxa	76.5	82.0	71.7	72.3	71.5	72.9	100.0	89.0
% Increasers, Mid-Elevation	70.9	58.9	87.7	95.5	91.2	85.5	95.3	92.9
Clinger taxa	43.3	43.3	72.1	76.9	72.1	62.5	100.0	97.4
Predator/Shredder taxa	85.7	92.9	71.4	100.0	92.9	100.0	100.0	78.6
MMI v4	**54.1**	**50.4**	**61.0**	**74.3**	**71.6**	**76.3**	**90.5**	**81.8**
	Auxiliary Metrics							
Diversity	3.44	3.08	3.49	3.95	3.98	3.49	4.41	4.23
HBI	4.50	3.95	4.66	3.64	3.57	2.68	3.23	3.09
Sediment Region	SR2	SR2	SR2	SR2	SR2			
TIV	6.39	5.88	6.31	5.64	5.56	--	--	--

Table B2. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during fall 2018. All metric scores based on MMI (v4) subsampling process.

Metric	Station ID									
	FR-27.2	SLC-0	FR-15	RC-1.1	WF-13.1	WF-5.5 (mod)	WF-2 (mod)	CR-9.1	CR-7.4	CR-1.7
EPT Taxa	65.3	66.7	45.8	70.8	75.0	45.8	29.2	84.8	100.0	52.1
% EPT, no Baetidae	100.0	35.6	72.1	90.6	85.0	62.1	4.3	50.9	58.0	24.9
Clinger Taxa	65.0	81.7	67.3	67.3	72.1	57.7	33.7	100.0	100.0	57.8
Total Taxa	59.5	--	--	--	--	--	--	--	--	--
Intolerant Taxa	81.0	--	--	--	--	--	--	--	--	--
% Increasers, Mountains	63.9	--	--	--	--	--	--	--	--	--
Predator Taxa	61.5	--	--	--	--	--	--	--	--	--
% Scraper individuals	100.0	--	--	--	--	--	--	--	--	--
% Non-Insect individuals	--	70.4	82.2	74.3	86.5	66.6	92.3	76.7	81.7	30.4
% Coleoptera individuals	--	62.6	70.5	46.6	6.2	66.5	0.8	89.4	73.1	67.9
% Intolerant Taxa	--	65.6	62.2	76.8	94.4	43.4	51.8	79.0	94.9	55.0
% Increasers, Mid-Elev.	--	49.7	85.3	87.8	84.2	87.3	98.7	83.5	88.7	0.0
Predator/Shredder taxa	--	100.0	57.1	100.0	100.0	78.6	42.9	71.4	92.9	57.1
MMI	**74.5**	**66.5**	**67.8**	**76.8**	**75.4**	**63.5**	**44.2**	**79.5**	**86.2**	**43.2**
	Auxiliary Metrics									
Diversity	2.98	3.87	3.25	3.66	3.61	3.58	2.64	4.13	4.02	3.54
HBI	2.16	4.05	3.15	2.85	3.23	3.42	4.69	3.42	3.46	5.08
Sediment Region	SR1	SR2	SR2	SR2	SR2					
TIV	2.28	6.20	4.79	4.59	4.25	--	--	--	--	--

Table B3. Additional metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in the fall of 2017. All additional metrics based on full count Hess samples.

Metric	FR-23.2	FR-20	FR-15	FR-14	RC-1.1	FR-12.4	FR-1.9	CR-9.1
Density (#/m^2)	3,866	10,789	8,284	8,908	9,388	11,725	7,934	8,618
Taxa Richness	34	39	42	47	43	53	50	49
EPT	15	14	16	22	19	24	28	25
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	4	4
Percent EPT excluding Baetidae	14.49%	10.36%	22.50%	46.51%	40.28%	55.51%	57.79%	48.42%
Percent Chironomidae	48.99%	47.45%	48.57%	25.33%	25.89%	15.01%	11.56%	17.00%
Percent Hydropsychidae	31.91%	9.32%	31.33%	72.59%	19.77%	21.38%	49.66%	17.14%
Percent Tolerant Taxa	17.65%	15.38%	19.05%	14.89%	23.26%	20.75%	18.00%	24.49%
Percent Intolerant Taxa	44.12%	43.59%	33.33%	36.17%	44.19%	37.74%	50.00%	42.86%

Table B4. Additional metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in the fall of 2018. All additional metrics based on full count Hess samples.

Metric	FR-27.2	SLC-0	FR-15	RC-1.1	WF-13.1	WF-5.5 (mod)	WF-2 (mod)	CR-9.1	CR-7.4	CR-1.7
Density (#/m^2)	3,862	3,524	8,770	8,566	3,231	6,429	8,755	7,037	7,384	6,197
Taxa Richness	33	46	42	42	37	45	25	55	56	42
EPT	19	22	16	22	20	12	9	28	28	15
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	0	19	0	0
Percent EPT excluding Baetidae	78.85%	28.73%	54.32%	64.10%	61.93%	46.34%	2.62%	35.23%	43.58%	17.68%
Percent Chironomidae	2.01%	5.75%	6.02%	2.77%	23.25%	1.57%	74.34%	12.09%	10.16%	11.72%
Percent Hydropsychidae	0.00%	16.42%	86.99%	35.47%	47.22%	26.01%	6.06%	19.45%	19.81%	9.91%
Percent Tolerant Taxa	12.12%	15.22%	19.05%	23.81%	13.51%	31.11%	16.00%	16.36%	23.21%	28.57%
Percent Intolerant Taxa	57.58%	41.30%	35.71%	42.86%	54.05%	28.89%	28.00%	43.64%	39.29%	21.43%

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