Summary Report

Learning by Doing

Benthic Macroinvertebrate Biomonitoring

2020

Prepared for:

Grand County
Learning by Doing Stakeholder Group

Prepared by:

David E. Rees
Timberline Aquatics, Inc.
4219 Table Mountain Place, Suite A
Fort Collins, Colorado 80526

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Introduction

The practice of biomonitoring or the bioassessment of benthic macroinvertebrate communities is currently a well-accepted approach for the evaluation of aquatic environments (Plafkin et al. 1989, Barbour et al. 1999, Paul et al. 2005, Hawkins 2006, USEPA 2011, Hauer and Lamberti 2017, Merritt et al. 2019). The biomonitoring of aquatic life in streams allows for a scientific assessment of aquatic conditions that cannot be achieved through other types (chemical, physical, etc.) of monitoring programs (Ward et al. 2002, Hauer and Resh 2017, Cummins et al. 2019, Mazor et al. 2019). Evolution and ecological processes have resulted in benthic macroinvertebrate communities with specific adaptations and sensitivities to their surrounding environment (Huryn and Wallace 2019). Therefore, aquatic macroinvertebrate communities are sensitive to a wide range of environmental disturbances or pollution, and community composition reflects the physical and chemical conditions that occur within a stream and associated watershed over time. Consequently, benthic macroinvertebrate communities can be monitored using specific sampling methodologies in order to assess the ecological integrity of aquatic systems. Biomonitoring programs are often used in conjunction with physical and/or chemical monitoring to assess aquatic conditions in rivers and streams (Cummins et al. 2019, Mazor et al. 2019).

Sustained biomonitoring programs are essential when assessing long-term influences such as human population growth, urban development, and changes in land-use practices on aquatic environments (Rosenberg and Resh 1993, Likens and Lambert 1998, Voelz et al. 2005). Because of the unique physical and behavioral attributes of benthic macroinvertebrates, the spatial and temporal scale of biomonitoring studies can be adjusted to address the influence of various stressors at specific locations (Mazor et al. 2019). Most macroinvertebrate taxa have a relatively long aquatic life-stage and limited mobility (Huryn and Wallace 2019). 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 macroinvertebrate community response to perturbations provides assessment and management opportunities that can range from local sources of pollution to watershed scale disturbances (Rosenberg and Resh 1993, Ward et al. 2002, Mazor et al. 2019).

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 interactions among disturbances can make identification of the predominant source of stress difficult (Carlisle and Clements 1999, Johnson et al. 2013, Mazor et al. 2019). However, some insight into the source and spatial distribution of stressors can be obtained through the evaluation of benthic macroinvertebrate community structure and function (USEPA 2011, Mazor et al. 2019).

The Grand County Learning By Doing (LBD) biomonitoring study was designed to monitor and assess 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 segments of the Fraser River, Vasquez Creek, 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 that 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.

Study Area

In the fall of 2020, benthic macroinvertebrate data from three biomonitoring studies (Learning By Doing, Denver Water, and Northern Water) were shared to assist in the evaluation of aquatic life in the Upper Colorado River Basin in Grand County. The Learning By Doing (LBD) study area 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 Ranch Creek. Approximately 4.2 km downstream, site FR-12.4 was sampled downstream from Crooked and Ranch Creeks. 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 Learning By Doing biomonitoring study also included three sites on the Colorado River. Site CR-9.1 (located upstream from the CR39 Bridge), site CR-7.4 (downstream from Troublesome Creek), and 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). Several additional sites were sampled as part of the Denver Water and Northern Water biomonitoring studies and results from these sites were used to provide supplementary information within the Learning By Doing study area.

For the Denver Water biomonitoring study, benthic macroinvertebrates were collected from three sampling locations on the Fraser River and one study site on Vasquez Creek during the fall of 2020 (Table 1, Figure 1). All of these sites were selected in order to monitor aquatic macroinvertebrate communities at locations that historically produced low MMI scores. The most upstream study site on the Fraser River (FR-23.2) was established immediately upstream

from the Winter Park Sanitation District (Figures 1 and 2). Historical sampling events (prior to 2018) had suggested that this sampling location was 'impaired' for aquatic life use. Site VC-WP was located on Vasquez Creek immediately upstream from its confluence with the Fraser River within the Town of Winter Park (Figure 2). This site had also generated MMI v3 scores (in 2010 and 2011) that resulted in an 'impairment' designation. Downstream from the confluence of the Fraser River and Vasquez Creek, sites FR-20 and FR-14 were used to assess potential influences from a variety of sources, including runoff from roads and urbanized areas, water diversions, elevated stream temperatures, and habitat improvement projects. These sites were located downstream from Rendezvous Bridge (FR-20) and downstream from the bridge on County Road 83 near Tabernash (FR-14) (Table 2).

Study sites for the Northern Water Conservancy District (Northern Water) in 2020 included seven locations on the Colorado River (Table 1, Figure 3). Four of these sampling sites have been routinely sampled as part of the Windy Gap Firming Project (WGFP) for the last five years. These study sites included: site CR-WGU (immediately upstream from Windy Gap Reservoir), site CR-WGD (approximately 1.7 km downstream from Windy Gap Reservoir at River Mile 28.7), and sites CR-HSPP and CR-WFU, both located farther downstream on the Colorado River (River Miles 22.9 and 16.7, respectively). These four study sites have been consistently monitored for the last five years to assess the influence of Windy Gap Reservoir on benthic macroinvertebrates.

The three new study sites on the Colorado River were established and sampled for Northern Water in the fall of 2020 in a river segment downstream from the confluence with the Williams Fork to specifically assess the effects of a future habitat improvement project (Habitat Project) (Figure 3). The most upstream of the three new sampling locations was site CR-bWF which was established downstream from the confluence of the Williams Fork and Colorado River, and upstream from any construction associated with the Habitat Project. This site will be used to provide reference information for the Habitat Project. Farther downstream, site CR-R3 was located near a wing deflector in Reach 3 of the habitat improvement area, and site CR-R4 was established in a riffle near the lower boundary of the proposed habitat improvements (Table 1, Figure 3). A comparison of consistently calculated metric values was used to assess macroinvertebrate community health among all sampling locations on the Colorado River.

Objective

The main objective for the LBD Benthic Macroinvertebrate Bioassessment Study in Grand County, Colorado was to provide an overall evaluation of the health of benthic macroinvertebrate communities at each study site in the project area and to identify locations and stream segments with potential anthropogenic perturbations.

Table 1. GPS coordinates and elevations of sample sites for the Learning By Doing, Denver Water, and Northern Water biomonitoring studies in the Upper Colorado River Basin during September of 2020.

	Monitoring Project	Location	Latitude	Longitude
FR-25.1	Learning By Doing	Fraser River above UP Moffat Tunnel	39.8775	-105.7535
FR-23.2 (abvWPSD)	Denver Water	Fraser River above Winter Park Sanitation District	39.89445	-105.76821
VC-WP	Denver Water	Vasquez Creek at Winter Park	39.9203	-105.78498
FR-20 (Rendezvous)	Denver Water	Fraser River at Rendezvous Bridge	39.93412	-105.7896
FR-15	Learning By Doing	Fraser River above Fraser Flats Restoration	39.981338	-105.824946
FR-14 (CR83)	Denver Water	Fraser River at Tabernash below bridge on CR83	39.99053	-105.8299
FR-12.4	Learning By Doing	Fraser River below Crooked and Ranch Creeks	40.011	-105.852417
RC-1.1	Learning By Doing	Ranch Creek below Meadow Creek	39.99912	-105.82746
WF-5.5(mod)	Learning By Doing	Williams Fork above Williams Fork Reservoir	39.994792	-106.17362
WF-2(mod)	Learning By Doing	Williams Fork below Williams Fork Reservoir	40.04308	-106.19832
WF-0.5	Learning By Doing	Williams Fork at Colorado confluence	40.0561	-106.1825
CR-WGU	Northern Water	Colorado River upstream of Windy Gap Reservoir	40.10045	-105.97248
CR-WGD	Northern Water	Colorado River downstream of Windy Gap Reservoir	40.10830	-106.00356
CR-22.1 (HSPP)	Northern Water	Colorado River near Hot Sulphur Springs	40.07394	-106.10959
CR-WFU	Northern Water	Colorado River upstream of Williams Fork	40.04689	-106.14299
CR-bWF(ref)	Northern Water	Colorado River below Williams Fork	40.06262	-106.18113
CR-R3	Northern Water	Colorado River at Habitat Project Reach 3	40.063	-106.1986
CR-R4	Northern Water	Colorado River at Habitat Project Reach 4	40.0623	-106.20423
CR-9.1	Learning By Doing	Colorado River at CR39 Bridge - KB Ditch	40.05377	-106.28945
CR-7.4	Learning By Doing	Colorado River below Troublesome Creek	40.0509	-106.3112
CR-1.7	Learning By Doing	Colorado River above Blue River	40.0465	-106.373

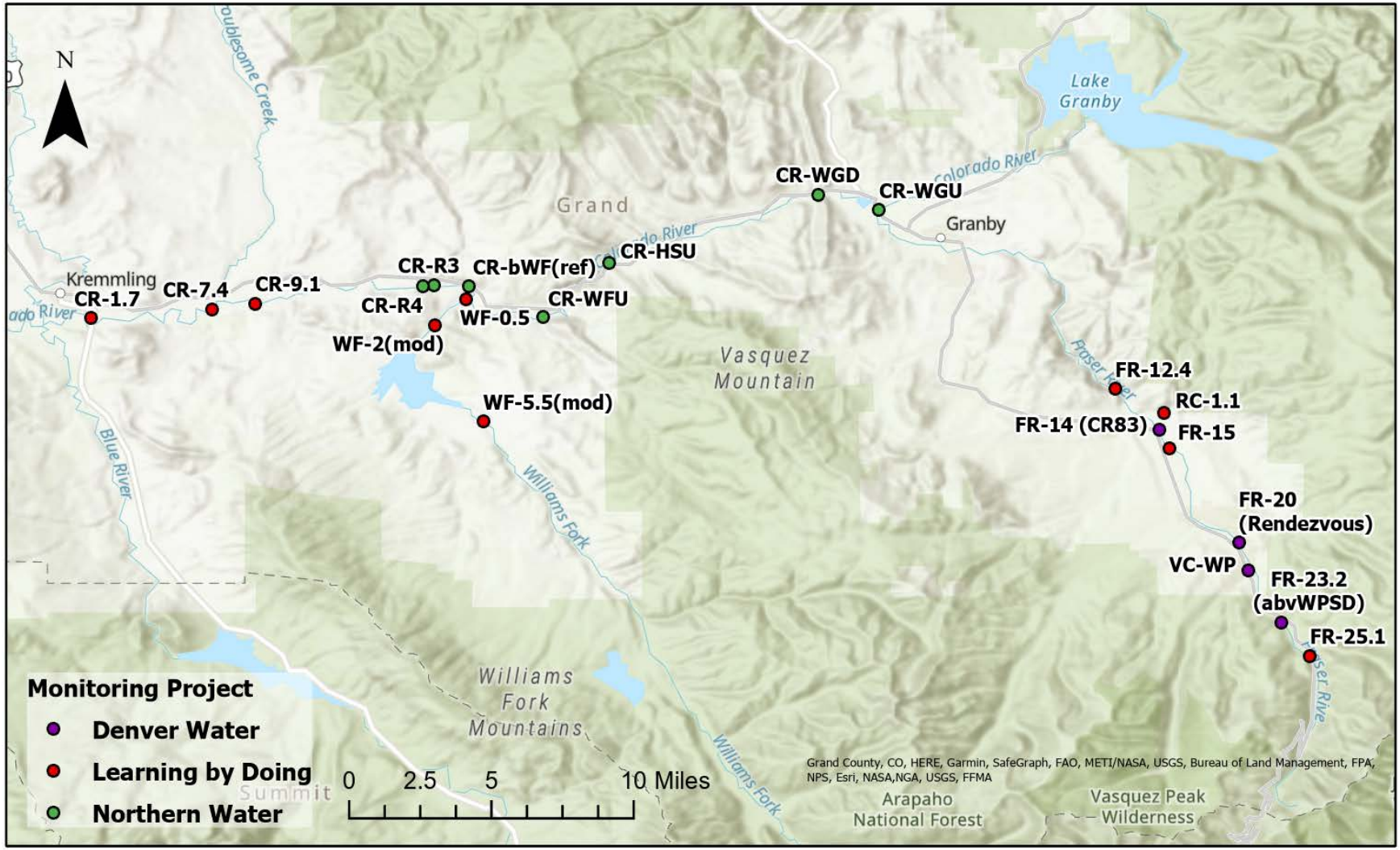

Figure 1. Map of study sites used for the Learning By Doing, Denver Water, and Northern Water biomonitoring studies in 2020.

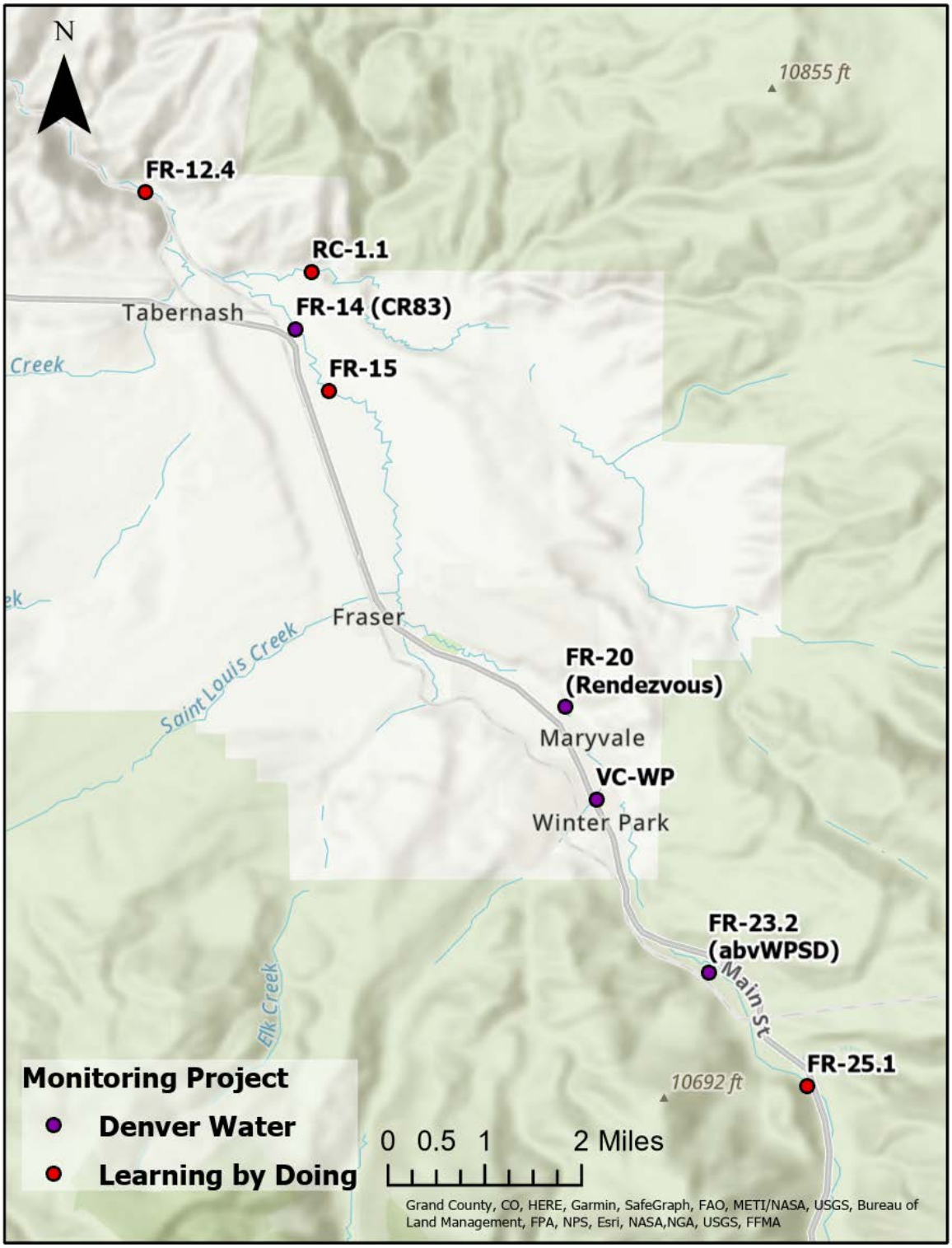

Figure 2. Map of study sites in the Fraser River Drainage used for the Learning By Doing and Denver Water biomonitoring studies in 2020.

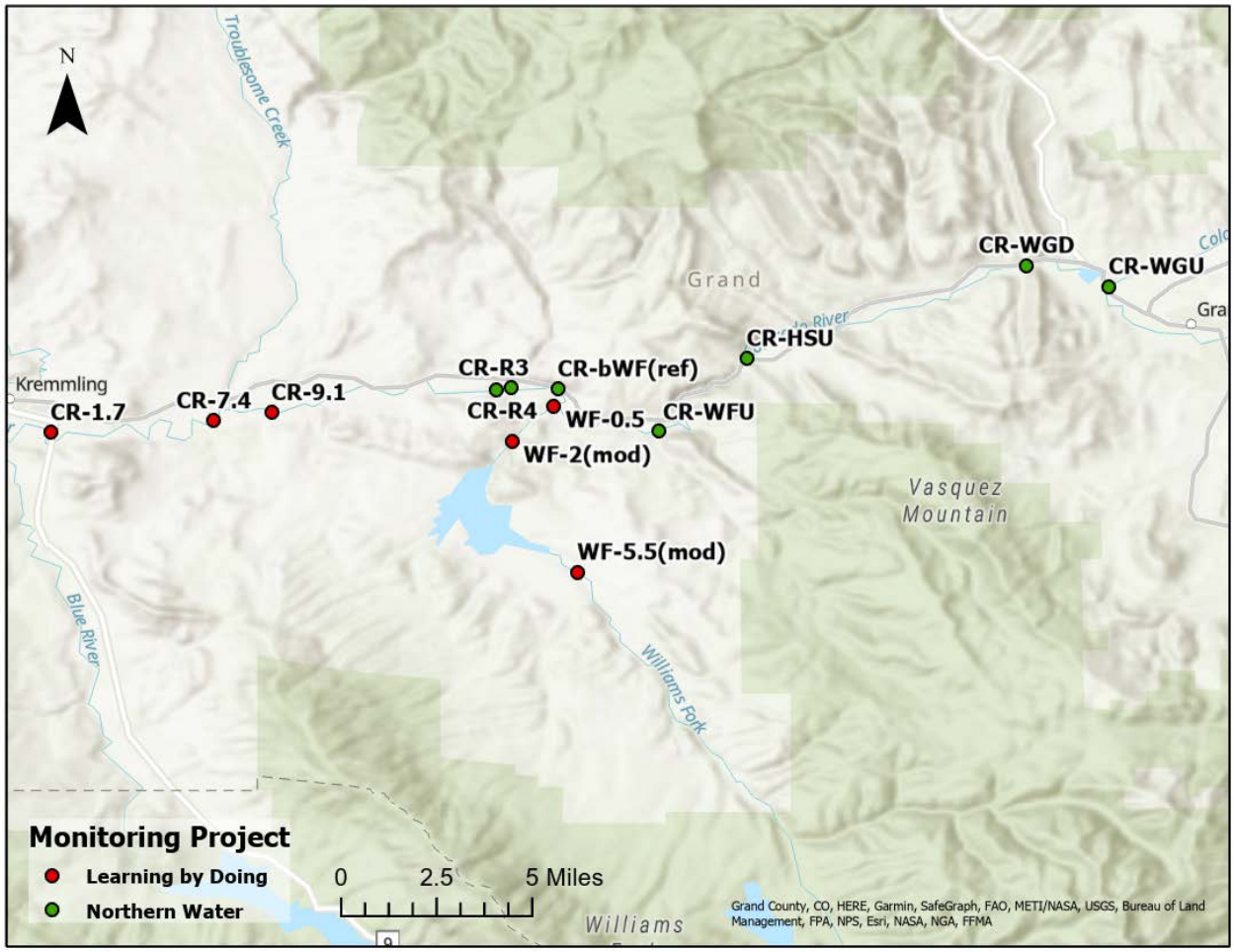

Figure 3. Map of study sites on the Colorado River and Williams Fork used for the Learning By Doing and Northern Water biomonitoring studies in 2020.

Methods

Three (3) replicate, quantitative Hess bottom samples (Jackson et al. 2019) were taken from similar riffle habitat (based on substrate type, depth, and velocity) at each study site. Dates for sampling in 2020 ranged from 16-18 September. Substrate within each sample was thoroughly agitated and individual rocks were scrubbed by hand to dislodge benthic organisms. All macroinvertebrates were stored in 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., Fort Collins, Colorado 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. All benthic macroinvertebrate samples were processed according to the guidelines 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* (CDPHE, 2017 and 2019). In addition to the Multi-Metric Index (MMI v4), 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.

All benthic macroinvertebrates collected from the Fraser River, Vasquez Creek, Ranch Creek, the Colorado River, and Williams Fork 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. (2019). 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. 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 for accuracy at Colorado State University. 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 LBD 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 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 (CDPHE, 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 auxiliary 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 individual metrics were applied in the analysis of macroinvertebrate data from the LBD, Denver Water, and Northern Water study areas 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/m^2 found at each study site. The Density metric provides an opportunity to measure and compare standing crop among sites. 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 Taxa 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 at each site. *Pteronarcys californica* is a large species of stonefly that requires specific aquatic conditions to complete its relatively long life-cycle (Kowalski and Richer 2020). Therefore, this species is known to be sensitive to a variety of anthropogenic disturbances. Additionally, *Pteronarcys californica* is an important part of the aquatic food-web that typically 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 mayfly 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, which could be indicative of increased stress.

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 (Order: Trichoptera). 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*, *Ceratopsyche morosa* group, *Cheumatopsyche* sp., *Hydropsyche cockerelli*, and *Hydropsyche oslari*) were found in this study area during 2020.

Percent Tolerant Taxa: The Percent Tolerant Taxa metric value 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 (Vannote et al. 1980, Ward et al. 2002). Scrapers and shredders are often considered sensitive to disturbance because they are specialized feeders (Barbour et al. 1999). Consequently, most feeding groups (including the sensitive groups) are expected to be well-represented in healthy streams. Much of the value from this type of analysis comes from comparisons among sites within a specific study area. Changes in the proportion of functional feeding groups can provide insight into various types of stress in river systems (Ward et al. 2002).

Results/Discussion

Benthic Macroinvertebrate Sampling – Fall 2020

Biomonitoring studies were conducted by Grand County Learning By Doing (LBD), Denver Water, and Northern Water in the Upper Colorado River Basin during September of 2020. Data and results were shared to provide a more comprehensive evaluation of macroinvertebrate community structure and function in streams that included the Fraser River, Vasquez Creek, Ranch Creek, the Colorado River, and Williams Fork. After samples were collected using the quantitative (Hess) sampling methodology, and transported to the lab at Timberline Aquatics, Inc., all specimens were sorted, identified, and enumerated (Appendix A, B, and C). 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 2-13). Results provided by select metrics (MMI v4, Diversity, HBI, EPT, and % EPT-excluding Baetidae) were also used to illustrate changes (or similarities) in community parameters among study sites (Figures 4-18). Functional Feeding Group analysis evaluated aquatic communities based on ecological function rather than taxonomic structure (Tables 11-13, Figures 19-21). In general, results from the fall of 2020 demonstrated considerable variability in the structure, function, and overall health of benthic macroinvertebrate communities throughout the study area; however, results from the MMI v4 indicated that most sampling locations met 'attainment' criteria for aquatic life use.

Results from the MMI v4

Fraser River Study Area

A comprehensive assessment of aquatic life in the Fraser River study area was made possible by combining the results of biomonitoring studies conducted by LBD and Denver Water. These studies included a total of six study sites on the Fraser River and two sites on select tributaries during the fall of 2020 (Table 2). The MMI v4 was used to provide an overall assessment of benthic macroinvertebrate community health and determine the status (attainment vs. impairment) of aquatic life use (WQCD 2019). Study sites on the Fraser River were distributed between two Biotypes in the State of Colorado (Biotypes 1 and 2), requiring different component metrics to calculate MMI v4 scores (Table 2). Site FR-25.1 was located in the mountains (Biotype 2), whereas the remaining study sites were in the "transitional zone" (Biotype 1) between the mountains and plains (WQCD 2019). Despite evidence of variability among individual (component) metric scores, all sites in the Fraser River study area produced MMI v4 scores that were above the impairment threshold for their respective biotypes (Table 2). On the Fraser River, MMI v4 scores ranged from a low of 44.7 at site FR-23.2 (abv WPSD) to a high of 75.8 at site FR-14 (Table 2, Figure 4). The MMI v4 score for site FR-23.2 was slightly below the attainment threshold, but auxiliary metrics (Diversity and HBI) indicated that this site was still in 'attainment' for aquatic life use. Between sites FR-23.2 and FR-14, the MMI v4 showed

consistent improvements in macroinvertebrate community structure in a downstream direction during the fall of 2020 (and during most previous sampling events) (Figure 4). Much of the improvement detected by the MMI v4 appeared to be associated with an increase in the relative abundance of individuals representing sensitive taxa (EPT Taxa) and specialized taxa (Clinger Taxa). On Vasquez Creek and Ranch Creek (tributaries of the Fraser River), the MMI v4 generated scores of 72.1 and 72.3 (respectively), indicating robust and healthy macroinvertebrate communities at both of these locations (Table 2). Auxiliary metrics (Diversity and HBI) were indicative of adequate community balance with relatively low proportions of nutrient-tolerant macroinvertebrates at study sites on the Fraser River (and associated tributaries) in the fall of 2020 (Figures 5 and 6). All study sites in the Fraser River study area were determined to be in 'attainment' for aquatic life use during September of 2020 (Table 3).

Colorado River Study Area

The study area on the Colorado River consisted of three study sites sampled as part of the LBD biomonitoring program, and seven sampling locations that were used in biomonitoring studies conducted by Northern Water in the fall of 2020. The health of benthic macroinvertebrate communities was assessed using the MMI v4 in a reach that spanned approximately 30 river-miles (upstream from Windy Gap Reservoir down to the confluence with the Blue River). Scores generated by the MMI v4 ranged from 37.2 at site CR-WGU to 83.5 at site CR-7.4 in September of 2020 (Table 4, Figure 7).

The MMI v4 score for site CR-WGU (37.2) was in the 'Grey Zone' (between the attainment and impairment thresholds), a condition that usually requires the use of auxiliary metrics to determine if the site is in 'attainment' or 'impaired'. Results from the auxiliary metrics suggested that this site should be considered in 'attainment' for aquatic life use; however, since the MMI v4 score in September of 2020 (37.2) represented a rapid decline of more than 22 points compared to MMI v4 scores from previous sampling events (Figure 7), site CR-WGU was determined to be 'impaired' during the fall of 2020 (Tables 4 and 5).

All other study sites on the Colorado River produced MMI v4 scores that exceeded the attainment threshold and were indicative of relatively healthy aquatic conditions, despite a slight decline in the health of the aquatic community that was observed at the most downstream study site (CR-1.7) (Table 4, Figure 7). Component metrics that detected healthy aquatic conditions throughout the Colorado River study area included EPT Taxa, % Intolerant Taxa, and Clinger Taxa metrics. A review of values produced by auxiliary metrics showed that there was good community balance at all sampling locations (Figure 8), and the proportion of nutrient-tolerant taxa remained relatively low, except at the most upstream and downstream study sites (Figure 9). Overall, results from the MMI v4 and component metrics suggested that macroinvertebrate communities were generally healthy in the Colorado River study area, and sites that exhibited increased stress (CR-WGU and CR-1.7) were likely influenced by habitat limitations (possibly due to low stable flows, excessive algal growth, etc.), rather than traditional pollutants.

Table 2. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Fraser River study area during September of 2020. All metric scores are based on the MMI v4 subsampling process. DW = Denver Water; LBD = Learning By Doing.

Metric	Station ID							
Biotype	**Biotype 2**	**Biotype 1**						
Monitoring Project	**LBD**	**Denver Water (DW)**			**LBD**	**DW**	**LBD**	
	FR-25.1	**FR-23.2 (abvWPSD)**	**VC-WP**	**FR-20 (Rendezvous)**	**FR-15**	**FR-14 (CR83)**	**FR-12.4**	**RC-1.1**
EPT Taxa	81.6	54.2	91.3	66.7	54.2	70.8	75.0	70.8
% EPT, no Baetidae	32.5	12.3	20.1	17.2	100.0	99.0	100.0	92.9
Clinger Taxa	70.0	43.3	89.2	67.3	52.9	76.9	67.3	67.3
Total Taxa	92.9	--	--	--	--	--	--	--
Intolerant Taxa	100.0	--	--	--	--	--	--	--
% Increasers, Mountains	26.4	--	--	--	--	--	--	--
Predator Taxa	92.3	--	--	--	--	--	--	--
% Scraper individuals	33.9	--	--	--	--	--	--	--
% Non-Insect individuals	--	38.4	47.6	54.9	96.2	96.6	95.8	80.0
% Coleoptera individuals	--	19.8	74.7	18.0	10.4	13.8	17.7	20.5
% Intolerant Taxa	--	78.9	90.7	82.0	64.4	79.3	84.3	77.1
% Increasers, Mid-Elev.	--	32.0	70.7	66.9	97.4	98.6	97.2	91.0
Predator/Shredder taxa	--	78.6	92.9	85.7	71.4	71.4	64.3	78.6
MMI	**66.2**	**44.7**	**72.1**	**57.3**	**68.4**	**75.8**	**75.2**	**72.3**
	Auxiliary Metrics							
Diversity	3.82	3.80	3.86	3.35	2.40	3.62	3.46	3.80
HBI	4.53	4.82	3.59	3.84	1.93	2.54	2.13	2.47
Sediment Region	SR1	SR2						
TIV	5.44	5.73	5.99	5.99	3.93	4.53	--	4.69

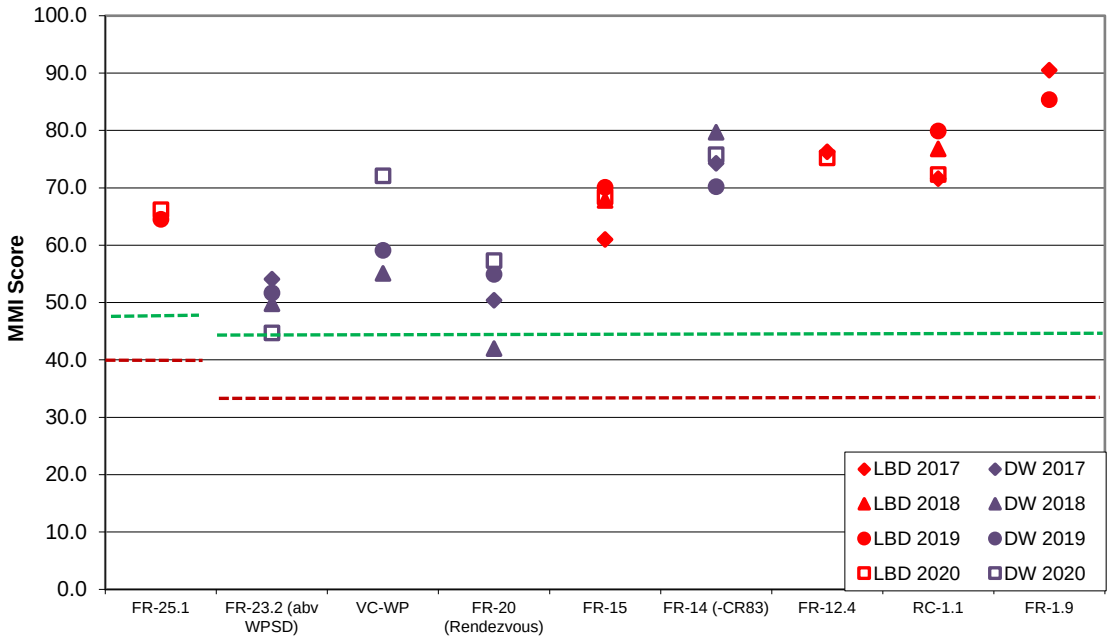

Figure 4. MMI v4 scores for the Fraser River study area from fall 2017 - fall 2020. All scores are based on the MMI v4 subsampling process. The green line indicates the attainment threshold and the red line indicates the impairment threshold. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

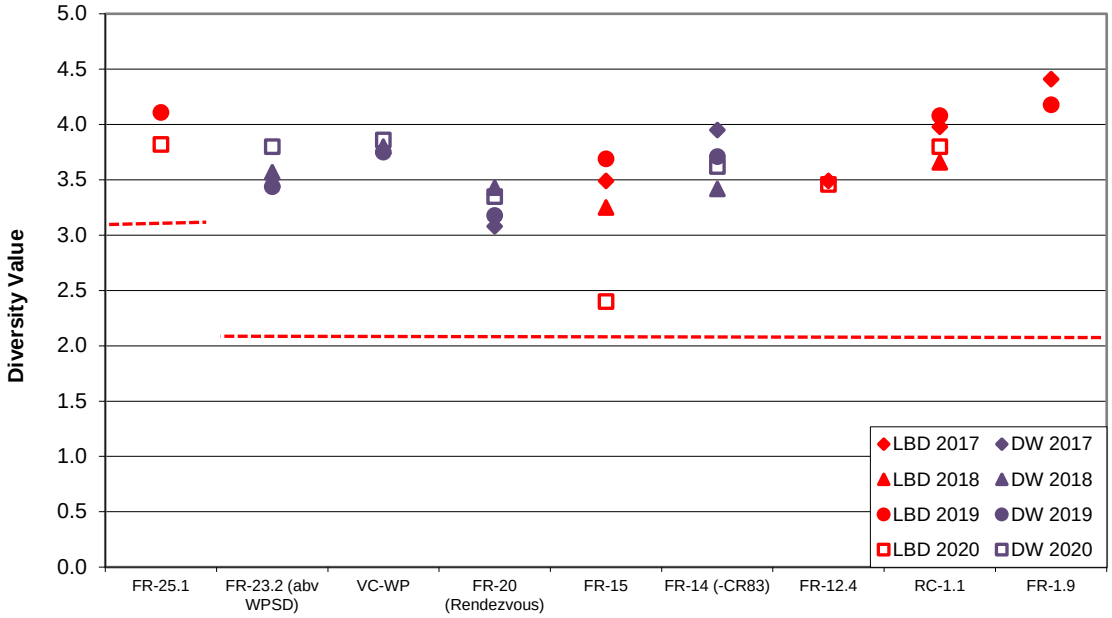

Figure 5. Diversity values in the Fraser River study area from fall 2017 - fall 2020. The red line indicates the impairment threshold for Biotypes 2 and 1. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

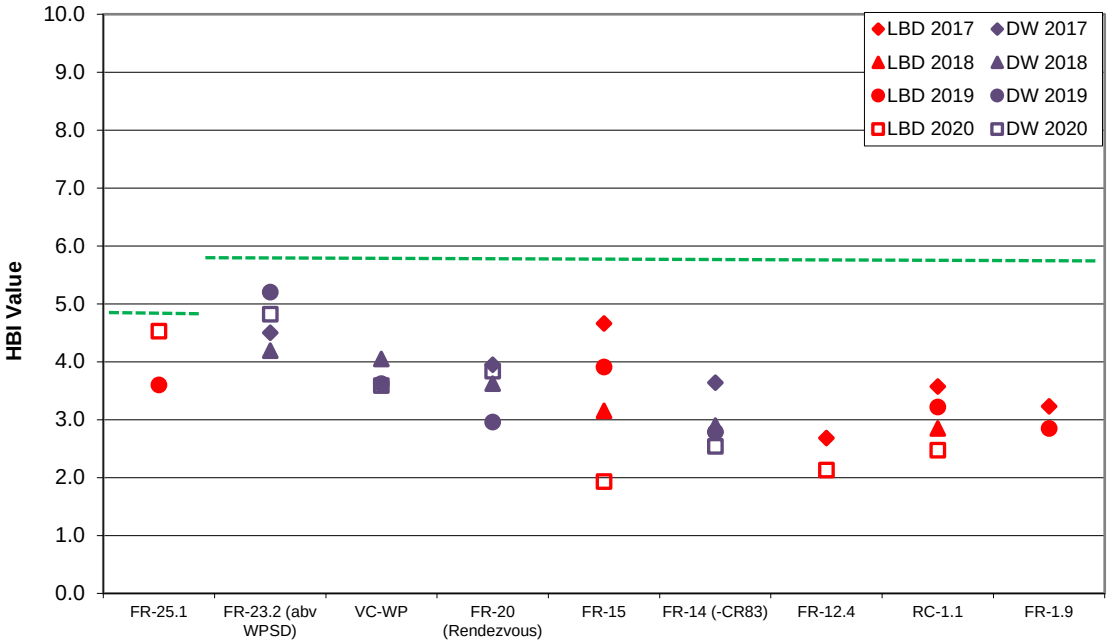

Figure 6. HBI values in the Fraser River study area from fall 2017 - fall 2020. Exceeding the green line indicates impairment for Biotypes 2 and 1. Results from Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

Table 3. Aquatic life use designations based on MMI v4 scores for sites in the Fraser River study area during September of 2020. DW = Denver Water; LBD = Learning By Doing.

Aquatic Life Designations		
Site	**Project**	Quantitative (Hess) Samples
FR-25.1	**LBD**	Attainment
FR-23.2 (abvWPSD)	**DW**	Attainment
VC-WP	**DW**	Attainment
FR-20 (Rendezvous)	**DW**	Attainment
FR-15	**LBD**	Attainment
FR-14 (CR83)	**DW**	Attainment
FR-12.4	**LBD**	Attainment
RC-1.1	**LBD**	Attainment

Table 4. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Colorado River study area during September of 2020. All metric scores are based on the MMI v4 subsampling process.

Metric	Station ID									
Monitoring Project	**Northern Water (NW)**							**LBD**		
	CR-WGU	**CR-WGD**	**CR-HSPP**	**CR-WFU**	**CR-bWF**	**CR-R3**	**CR-R4**	**CR-9.1**	**CR-7.4**	**CR-1.7**
EPT Taxa	62.5	75.0	58.3	75.0	75.0	75.0	66.7	89.0	100.0	71.1
% Non-Insect individuals	38.5	95.4	94.6	76.4	61.3	91.0	73.0	59.6	92.2	76.7
% EPT, no Baetidae	25.4	91.3	63.0	85.4	80.5	100.0	76.2	75.1	60.6	32.7
% Coleoptera individuals	5.0	8.3	6.0	12.6	8.5	1.6	7.0	32.8	50.6	21.6
% Intolerant Taxa	56.0	63.8	67.8	87.8	79.6	84.6	74.0	74.2	100.0	70.9
% Increasers, Mid-Elev.	0.0	94.7	91.8	98.6	94.5	97.4	97.2	68.4	93.4	58.4
Clinger Taxa	67.3	81.7	62.5	76.9	81.7	72.1	76.9	92.6	100.0	73.6
Predator/Shredder taxa	42.9	42.9	50.0	64.3	64.3	50.0	42.9	57.1	71.4	64.3
MMI	**37.2**	**69.1**	**61.7**	**72.1**	**68.2**	**71.5**	**64.2**	**68.6**	**83.5**	**58.7**
	Auxiliary Metrics									
Diversity	3.98	3.40	3.62	3.62	3.74	3.21	3.68	4.29	4.29	3.54
HBI	5.68	2.83	3.67	2.24	2.19	1.73	2.64	2.86	3.36	4.97
Sediment Region		SR2		SR2						
TIV	--	5.16	--	4.00	--	--	--	--	--	--

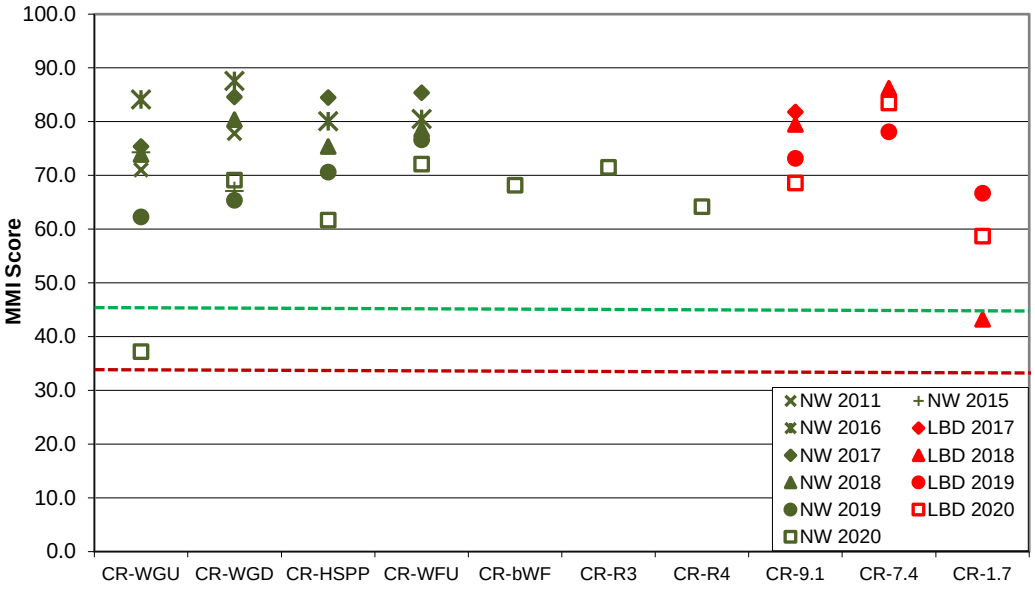

Figure 7. MMI v4 scores for the Colorado River study area from fall 2017 - fall 2020. All scores are based on the MMI v4 subsampling process. The green line indicates the attainment threshold and the red line indicates the impairment threshold. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

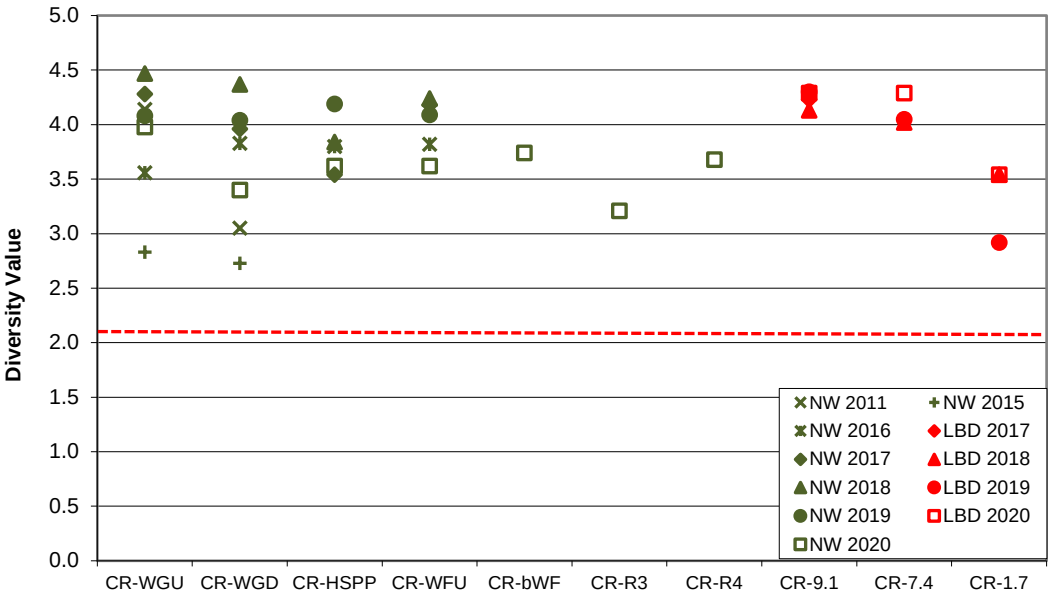

Figure 8. Diversity values in the Colorado River study area from fall 2017 - fall 2020. The red line indicates the impairment threshold for Biotype 1. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

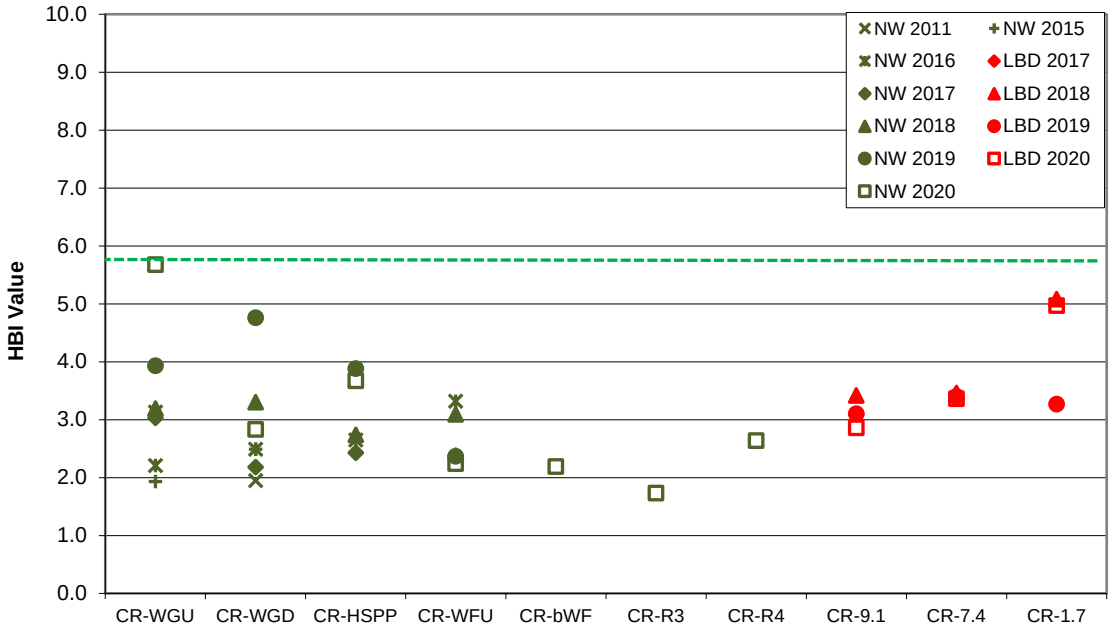

Figure 9. HBI values in the Colorado River study area from fall 2017 - fall 2020. Exceeding the green line indicates impairment for Biotype 1. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

Table 5. Aquatic life use designations based on MMI v4 scores for sites in the Colorado River study area during September of 2020. NW = Northern Water; LBD = Learning By Doing.

Aquatic Life Designations		
Site	**Project**	Quantitative (Hess) Samples
CR-WGU	**NW**	Impairment
CR-WGD	**NW**	Attainment
CR-HSPP	**NW**	Attainment
CR-WFU	**NW**	Attainment
CR-bWF	**NW**	Attainment
CR-R3	**NW**	Attainment
CR-R4	**NW**	Attainment
CR-9.1	**LBD**	Attainment
CR-7.4	**LBD**	Attainment
CR-1.7	**LBD**	Attainment

Williams Fork Study Area

Three study sites on the Williams Fork (all monitored by LBD) were sampled in the fall of 2020 to assess the influence of Williams Fork Reservoir and recent habitat restoration work that has been conducted both upstream and downstream of this impoundment. The MMI v4 generated scores that continued to surpass the attainment threshold (Tables 6 and 7, Figure 10); although, scores for sites WF-2 (mod) and WF-0.5 were relatively low compared to most study sites on the Fraser and Colorado rivers. The MMI v4 score for the most upstream sampling location, site WF-5.5 (mod), was the highest among sites on the Williams Fork (Table 6); however, this score (66.0) was considerably lower than the MMI v4 score of 80.0 that was observed in 2019 (Figure 10; Appendix D: Table 3). The recent habitat enhancement project upstream from site WF-5.5 (mod) should have a positive influence on the benthic macroinvertebrate community at this location, so the relatively low score in the fall of 2020 may have been at the lower range of what could be considered natural variability.

Downstream from Williams Fork Reservoir, sites WF-2 (mod) and WF-0.5 produced MMI v4 scores that were above the attainment threshold, but also appeared to demonstrate low levels of stress (Table 6, Figure 10). Several component metrics (EPT Taxa, % EPT Individuals-no Baetidae, and Predator/Shredder Taxa) detected impacts to sensitive and specialized taxa (Table 6), and both auxiliary metrics showed evidence of minor stress at these two sites (Figures 11 and 12). It is likely that alterations from the natural flow and temperature regime imposed by reservoir operations were responsible (at least in part) for the decline in richness and abundance of sensitive taxa downstream from the reservoir. Impacts to benthic macroinvertebrate communities downstream from deep-release reservoirs have been well-documented (Ward 1976, 1982, Baxter 1977, Ward and Stanford 1979, 1983, Ellis and Jones 2013, White et al. 2016, Krajenbrink et al. 2019). However, negative impacts are often alleviated with distance downstream from the impoundment. The fact that sites WF-2 (mod) and WF-0.5 were both able to produce MMI v4 scores above the 'attainment' threshold was somewhat unexpected, given the close proximity to Williams Fork Reservoir. Part of the intention for habitat enhancements in this segment of the Williams Fork is to eventually improve the health of aquatic life (resulting in improved MMI v4 scores) during future sampling events.

In summary, results from the MMI v4 indicated that most sites in the Fraser River, Colorado River, and Williams Fork study areas were in 'attainment' for aquatic life use during the 2020 biomonitoring season (Tables 3, 5, and 7). These results were generally supported by MMI v4 scores from previous sampling events (Figures 4, 7, and 10; Appendix D: Tables D1-D3). The one exception to the 'attainment' designations in 2020 occurred at site CR-WGU, where a 23.4-point drop in the MMI v4 score since 2019 resulted in an 'impairment' designation. Although the score of 37.2 (from 2020) was in the 'grey zone' and auxiliary metrics indicated that this site should be in 'attainment', the recent decline in the MMI v4 score (compare to five previous years of biomonitoring) should be a cause for concern. It is possible that site CR-WGU (along with several other sampling locations on the Colorado River) was temporarily impacted by the unusually

dry and warm ambient conditions (and relatively low and stable flows) that preceded this sampling event. Continued biomonitoring efforts will be necessary to help determine the persistence of the results observed during 2020, and to help in the understanding of how ambient conditions may influence aquatic communities throughout the study area.

Table 6. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Williams Fork study area during September of 2020. All metric scores are based on the MMI v4 subsampling process.

Metric	Station ID		
Monitoring Project	**Learning By Doing (LBD)**		
	WF-5.5 (mod)	**WF-2 (mod)**	**WF-0.5**
EPT Taxa	58.3	41.6	44.6
% EPT, no Baetidae	59.1	6.1	8.4
Clinger Taxa	57.7	48.1	45.4
% Non-Insect individuals	95.8	88.6	93.6
% Coleoptera individuals	15.0	0.0	0.8
% Intolerant Taxa	71.7	89.5	99.0
% Increasers, Mid-Elev.	98.6	98.6	100.0
Predator/Shredder taxa	71.4	50.0	28.6
MMI	**66.0**	**52.8**	**52.5**
	Auxiliary Metrics		
Diversity	3.78	2.89	2.26
HBI	3.61	5.43	5.05
Sediment Region			
TIV	--	--	--

Table 7. Aquatic life use designations based on MMI v4 scores for sites in the Williams Fork study area during September of 2020. LBD = Learning By Doing study sites.

Aquatic Life Designations		
Site	**Project**	Quantitative (Hess) Samples
WF-5.5 (mod)	**LBD**	Attainment
WF-2 (mod)	**LBD**	Attainment
WF-0.5	**LBD**	Attainment

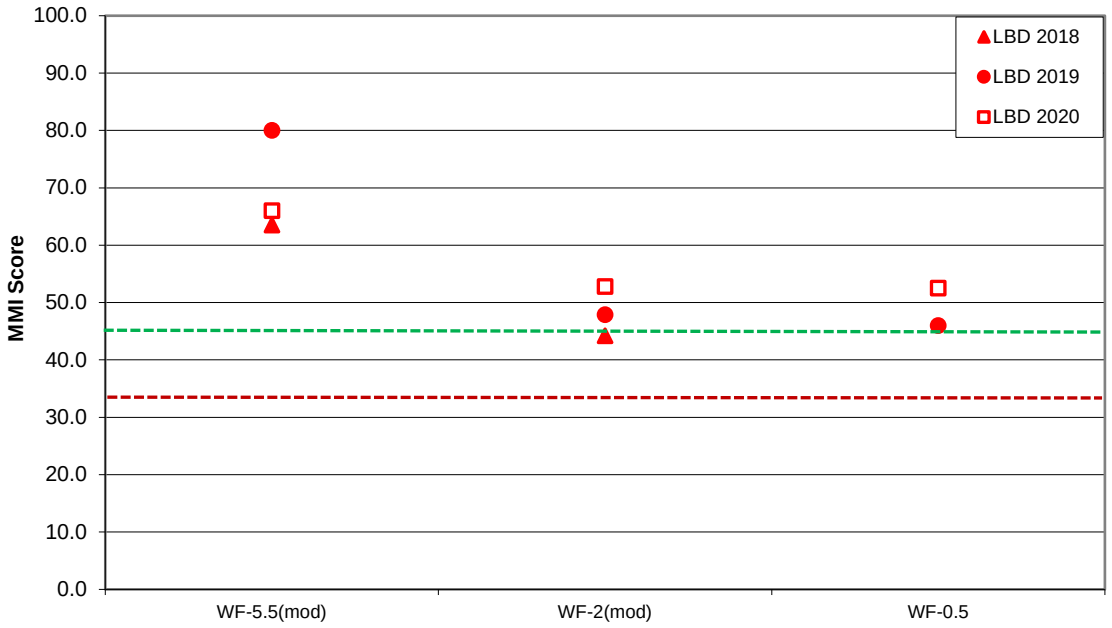

Figure 10. MMI v4 scores for the Williams Fork study area from fall 2018 - fall 2020. All scores are based on the MMI v4 subsampling process. The green line indicates the attainment threshold and the red line indicates the impairment threshold.

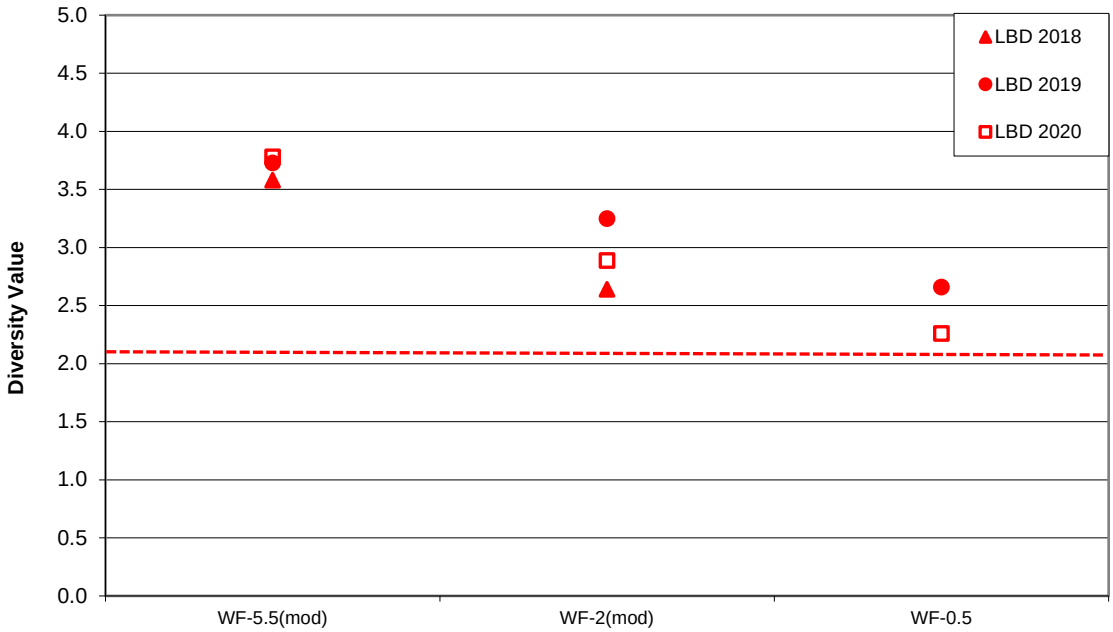

Figure 11. Diversity values in the Williams Fork study area from fall 2018 - fall 2020. The red line indicates the impairment threshold for Biotype 1.

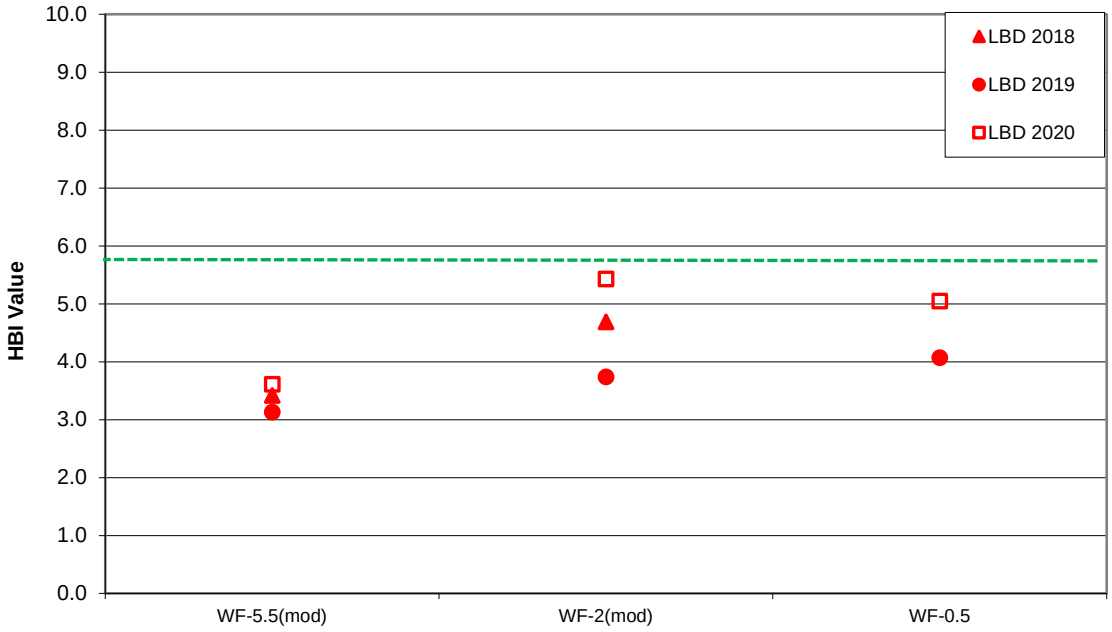

Figure 12. HBI values in the Williams Fork study area from fall 2018 - fall 2020. Exceeding the green line indicates impairment for Biotype 1.

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 (LBD) study area to further evaluate benthic macroinvertebrate community health during the fall of 2020 (Tables 8-10). Although the individual metrics had the ability to detect changes in macroinvertebrate community structure among sites, the factors influencing these changes were not easily identifiable. Benthic macroinvertebrate communities in this study area were likely influenced by regulated flows, water temperature, runoff from roads and developed areas, periphyton dynamics, substrate composition, and an assortment of other physical and biological parameters. Overall, most sites in the Fraser, Colorado, and Williams Fork study areas could be characterized as supporting high proportions of sensitive taxa (when compared to tolerant taxa), and most sites in all three study areas supported relative healthy benthic macroinvertebrate communities. It is worthy to note that the keystone aquatic insect species of the Colorado River Basin, the giant stonefly *Pteronarcys californica* (Kowalski and Richer 2020), was collected at only two sites on the Colorado River during the fall of 2020. 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 detailed description of macroinvertebrate community health during the fall of 2020.

Fraser River Study Area

The Fraser River study area consisted of eight study sites (six on the Fraser River and two on tributaries) that were sampled as part of biomonitoring studies conducted by LBD and Denver Water (Figure 2). Important individual metrics such as Taxa Richness, EPT Taxa, and % Intolerant Taxa clearly indicated that study sites on the Fraser River, Vasquez Creek, and Ranch Creek supported benthic macroinvertebrate communities with relatively high proportions of sensitive taxa in the fall (September) of 2020 (Table 8). The EPT Taxa metric, which includes the most sensitive of all aquatic insects, generated values that ranged from a low of 15 at FR-23.2 (abv WPSD) to a high of 26 at site VC-WP (Table 8, Figure 13). Two other important metrics (% EPT-excluding Baetidae and % Hydropsychidae) showed evidence of general improvements in the proportion of sensitive individuals in the downstream portion of the Fraser River. Spatial improvements in the % EPT-excluding Baetidae metric have been fairly consistent from 2017 to 2020; however, greater variability has been observed at site FR-15 (Figure 14). Additionally, two study sites on the Fraser River (FR-15 and FR-12.4) supported exceptional densities of macroinvertebrates in September of 2020 (Table 8). At FR-15, the widespread western North American mayfly, *Ephemerella dorothea infrequens* (the Pale Morning Dun), composed 65% of total density, whereas at site FR-12.4, three taxa, *E. dorothea infrequens* (28%) and two caddisflies, *Lepidostoma* sp. (15%) and *Hydropsyche cockerelli* (10%) composed 53% of the total macroinvertebrate density (Appendix A; Tables A2-A3). A complete review of individual metric values from previous sampling events (2017, 2018, and 2019) can be found in Appendix D; Tables D4-D6.

Colorado River Study Area

A total of ten study sites on the Colorado River were sampled in September of 2020 in a combined effort between LBD and Northern Water (Table 1, Figure 3). A review of the additional individual metrics indicated that most study sites supported taxa-rich communities with high proportions of sensitive individuals (Table 9). Although two metrics (% EPT-excluding Baetidae and % Chironomidae) suggested that site CR-WGU was more stressed than other sites in the study area, most other individual metrics (including Taxa Richness, % Tolerant Taxa, and % Intolerant Taxa) indicated that all ten sites supported relatively healthy macroinvertebrate communities in 2020 (Table 9). When metric results from 2020 were compared to results from previous sampling events, the EPT Taxa values were substantially lower at sites CR-WGU and CR-HSU, and Percent EPT-excluding Baetidae values also demonstrated an unusual decline at site CR-WGU (Figure 15 and 16, respectively). Otherwise, values from 2020 were similar at sites where comparable data was available (Figures 15 and 16). Although *Pteronarcys californica* was only collected at sites CR-WFU and CR-R3 during the fall of 2020, all study sites on the Colorado River were populated with a variety of other sensitive and specialized taxa (Table 9, Appendix A: A8-A10; Appendix B: B1-B7). The Density metric provided supporting evidence of adequate habitat and exceptional productivity in much of the Colorado River study area (Table 9).

Table 8. Additional individual metrics and comparative values for benthic macroinvertebrate samples collected from the Fraser River study area during September of 2020. All additional metric values are based on full count (quantitative) Hess samples. LBD = Learning By Doing study sites; DW = Denver Water study sites.

Metric	FR-25.1	FR-23.2 (abvWPSD)	VC-WP	FR-20 (Rendezvous)	FR-15	FR-14 (CR83)	FR-12.4	RC-1.1
Biomonitoring Project	**LBD**	**Denver Water (DW)**			**LBD**	**DW**	**LBD**	
Density (#/m^2)	1,848	3,654	2,032	8,681	28,703	7,896	14,088	2,329
Taxa Richness	43	31	44	41	47	42	52	37
EPT Taxa	23	15	26	21	19	21	25	18
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	0	0
% EPT-excluding Baetidae	28.33%	10.22%	14.23%	13.77%	78.30%	72.01%	76.52%	66.00%
% Chironomidae	6.13%	22.68%	19.04%	40.79%	11.73%	13.87%	8.16%	15.58%
% Hydropsychidae	6.25%	0.00%	5.13%	13.25%	55.37%	46.35%	38.15%	5.02%
% Tolerant Taxa	11.63%	19.35%	11.36%	9.76%	17.02%	14.29%	23.08%	21.62%
% Intolerant Taxa	53.49%	48.39%	54.55%	48.78%	31.91%	45.24%	44.23%	43.24%

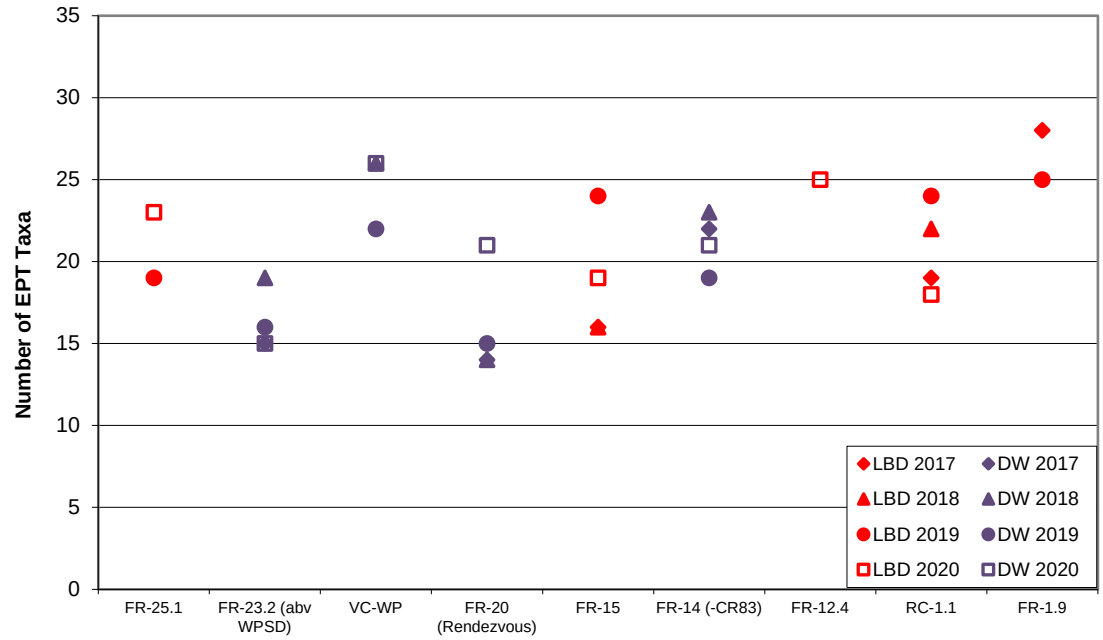

Figure 13. EPT Taxa values in the Fraser River study area from fall 2017 to fall 2020. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

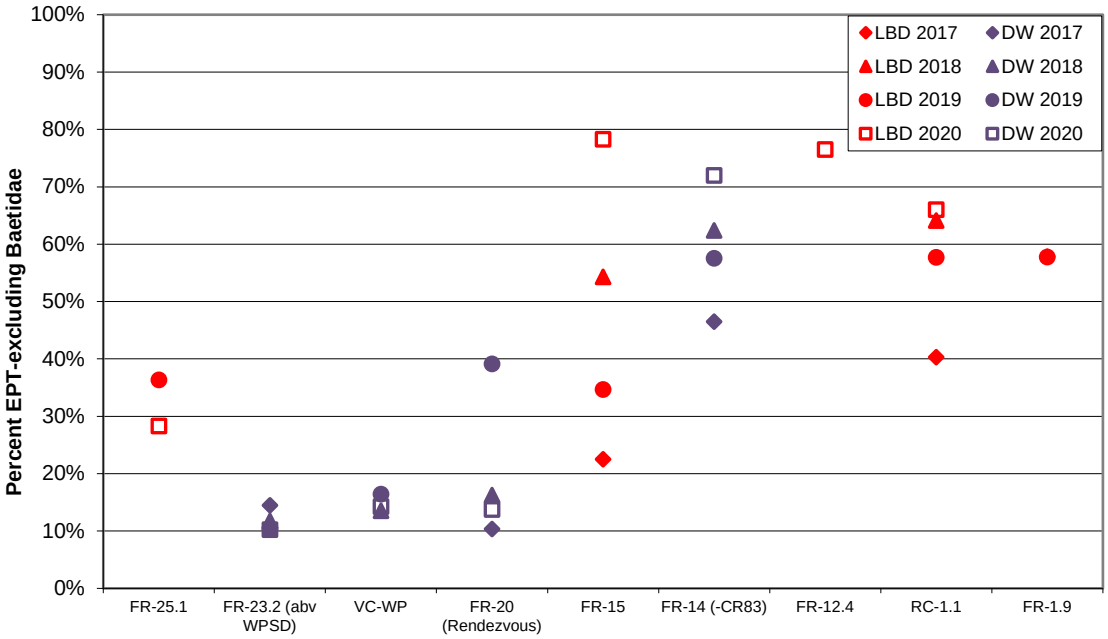

Figure 14. Percent EPT-excluding Baetidae values in the Fraser River study area from fall 2017 to fall 2020. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

Table 9. Additional individual metrics and comparative values for benthic macroinvertebrate samples collected from the Colorado River study area during September of 2020. All additional metric values are based on full count (quantitative) Hess samples. LBD = Learning By Doing study sites; NW=Northern Water study sites.

Metric	CR-WGU	CR-WGD	CR-HSPP	CR-WFU	CR-bWF	CR-R3	CR-R4	CR-9.1	CR-7.4	CR-1.7
Monitoring Project	**Northern Water (NW)**							**LBD**		
Density (#/m^2)	3,405	22,873	8,781	5,919	13,775	10,829	18,499	9,386	10,326	6,808
Taxa Richness	45	58	41	40	59	45	45	53	55	45
EPT Taxa	18	25	18	25	27	24	22	28	29	21
Density of *Pteronarcys californica* (#/m^2)	0	0	0	43	0	4	0	0	0	0
% EPT-excluding Baetidae	19.68%	68.42%	48.36%	67.72%	58.84%	81.89%	54.73%	52.63%	46.56%	24.14%
% Chironomidae	40.73%	8.90%	20.60%	1.90%	7.36%	4.37%	3.59%	8.32%	11.92%	14.16%
% Hydropsychidae	60.84%	53.18%	45.25%	21.25%	13.10%	14.35%	18.70%	14.16%	24.59%	47.88%
% Tolerant Taxa	26.67%	24.14%	21.95%	15.00%	20.34%	20.00%	22.22%	18.87%	18.18%	24.44%
% Intolerant Taxa	33.33%	32.76%	39.02%	50.00%	37.29%	42.22%	40.00%	37.74%	40.00%	31.11%

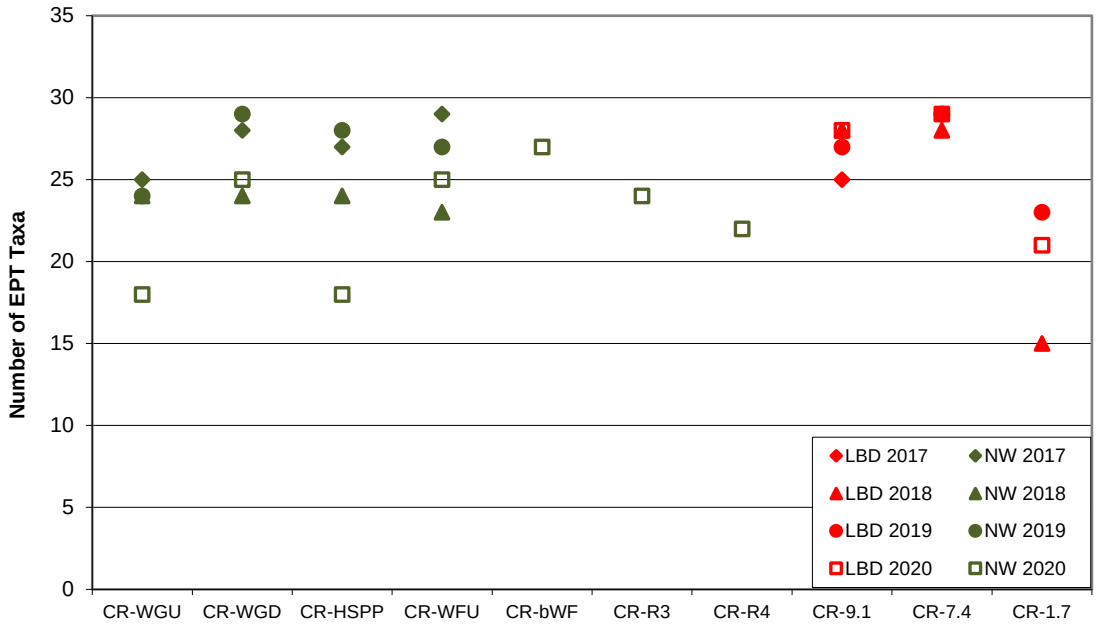

Figure 15. EPT Taxa values in the Colorado River study area from fall 2017 to fall 2020. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

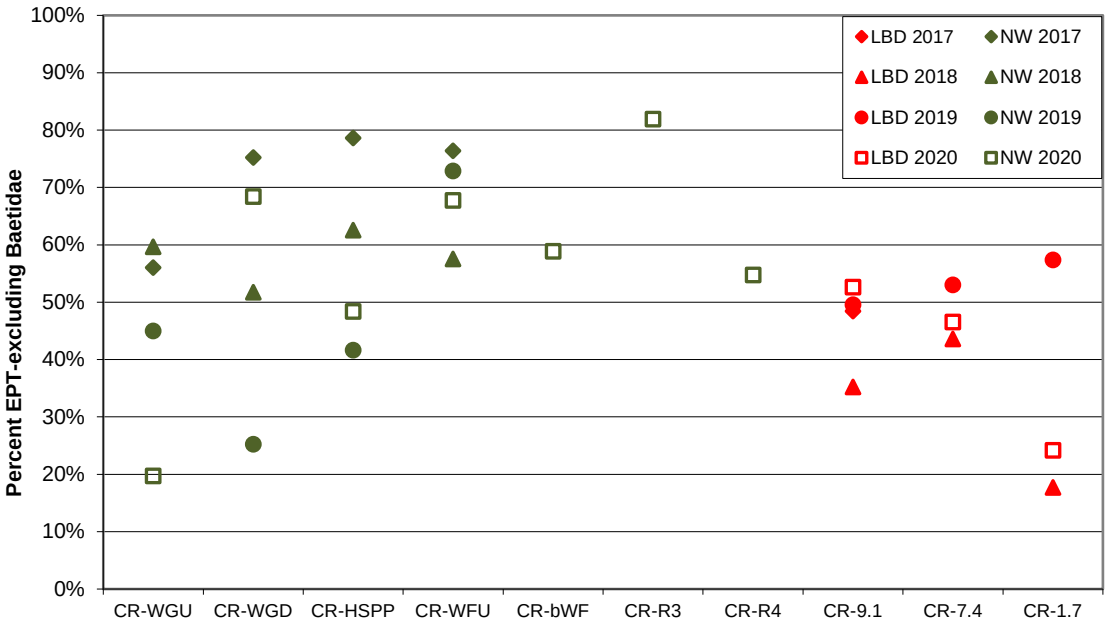

Figure 16. Percent EPT-excluding Baetidae values in the Colorado River study area from fall 2017 to fall 2020. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

Williams Fork Study Area

A review of the results provided by additional metrics in the Williams Fork study area showed considerable variability among the three sites sampled as part of the LBD biomonitoring study in September of 2020 (Table 10, Figures 17 and 18). 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 sites WF-2 (mod) and WF-0.5 (Table 10). At site WF-5.5 (mod), the Taxa Richness, EPT Taxa, and % EPT-excluding Baetidae metrics detected a variety of taxa (including sensitive taxa) with high proportions of sensitive individuals (Table 10). However, downstream from the reservoir at site WF-2 (mod), there was a reduction in Taxa Richness, and the Percent EPT-excluding Baetidae metric indicated that only 2.91% of the community was sensitive to perturbations (Table 10, Figure 18). Farther downstream (at site WF-0.5), the richness of taxa (including sensitive taxa) continued to decline; however, there was a slight increase in the proportion of sensitive taxa (Table 10). Collectively, these results suggest that study sites downstream from Williams Fork Reservoir continue to be influenced by the altered temperature and flow regime caused by reservoir releases; however, recent habitat enhancement projects should eventually assist in the recovery of benthic macroinvertebrate communities in the lower portion of the Williams Fork study area.

Table 10. Additional individual metrics and comparative values for benthic macroinvertebrate samples collected from the Williams Fork study area during September of 2020. All additional metric values are based on full count (quantitative) Hess samples.

Metric	WF-5.5 (mod)	WF-2 (mod)	WF-0.5
Monitoring Project	**Learning By Doing (LBD)**		
Density (#/m^2)	7,099	14,133	10,366
Taxa Richness	47	36	28
EPT Taxa	21	18	14
Density of *Pteronarcys californica* (#/m^2)	0	0	0
% EPT-excluding Baetidae	38.26%	2.91%	4.79%
% Chironomidae	20.63%	47.87%	10.63%
% Hydropsychidae	24.43%	20.00%	5.88%
% Tolerant Taxa	14.89%	16.67%	14.29%
% Intolerant Taxa	38.30%	38.89%	46.43%

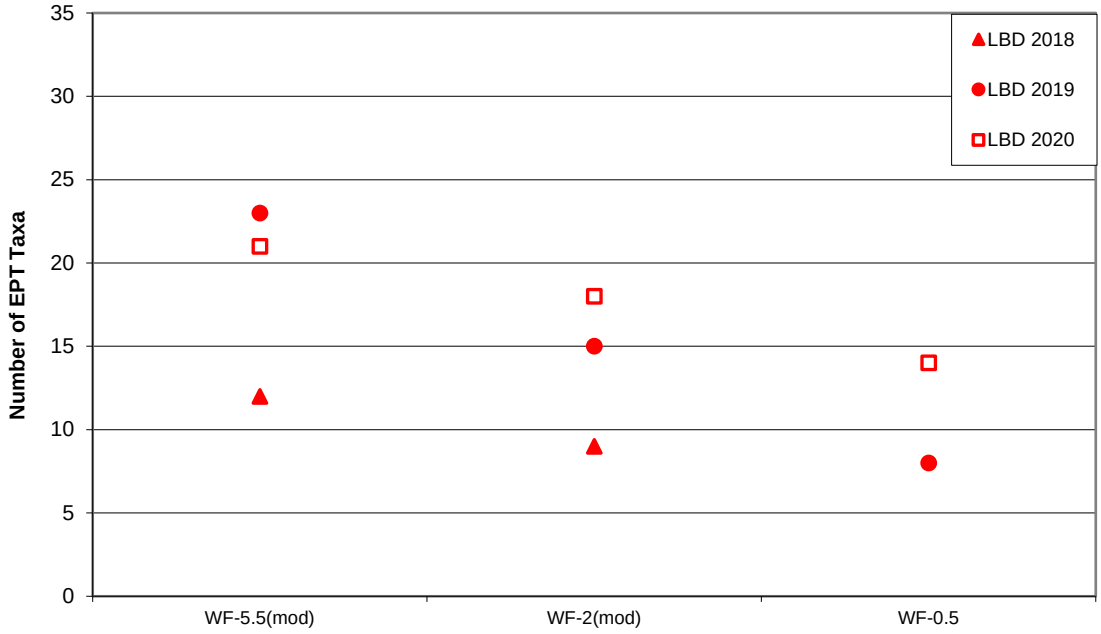

Figure 17. EPT Taxa values in the Williams Fork study area from fall 2018 to fall 2020. Site WF-0.5 was not sampled in 2018.

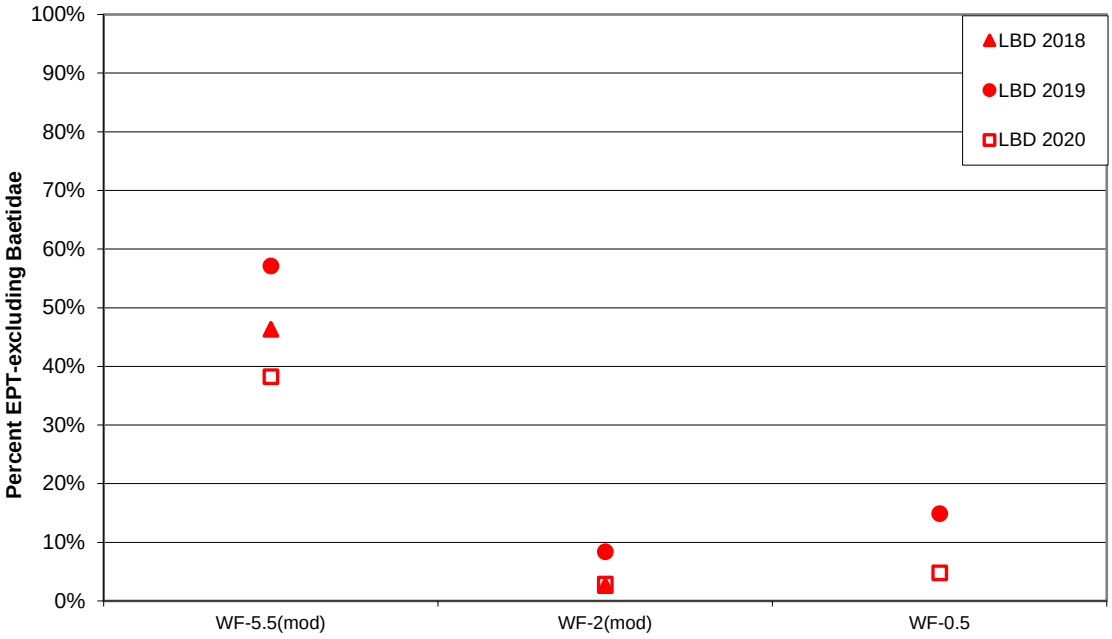

Figure 18. Percent EPT-excluding Baetidae values in the Williams Fork study area from fall 2018 to fall 2020. Site WF-0.5 was not sampled in 2018.

Results from Functional Feeding Groups

Fraser River Study Area

Analysis of functional feeding groups provided additional insight into the ecological balance of macroinvertebrate communities in the Fraser River study area during September of 2020 (Table 11, Figure 19). 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 (Ward et al. 2002). During the fall of 2020, collector-gatherers were the most abundant feeding group at all sites in the Fraser River study area except at sites FR-25.1 and RC-1.1 (Table 11). The greater proportional dominance of collector-gatherers (>50%) observed at sites FR-23.2, VC-WP, FR-20, and FR-15 may have been an indication of minor stress at these locations. The relative abundance of feeding groups that are considered sensitive and/or specialized (shredders and scrapers) varied between sites; however, the proportions of these groups generally increased in the downstream segments of the study area (Table 11, Figure 19). Results from functional feeding group analysis in the Fraser River study area generally supported the results from the MMI v4 and other metrics that detected an increase in stress at site FR-23.2 followed by gradual improvements in macroinvertebrate community health in a downstream direction.

Table 11. Relative abundance of functional feeding groups in the Fraser River study area during the fall of 2020. LBD=Learning By Doing study sites; DW=Denver Water study sites.

Site	Project	Functional Feeding Group					
		Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
FR-25.1	**LBD**	28.96%	36.15%	1.48%	14.16%	18.60%	0.63%
FR-23.2 (abvWPSD)	**DW**	66.56%	1.49%	0.11%	2.88%	24.60%	4.37%
VC-WP	**DW**	61.92%	1.35%	1.73%	5.00%	13.46%	16.54%
FR-20 (Rendezvous)	**DW**	66.23%	11.05%	0.94%	1.83%	11.18%	8.77%
FR-15	**LBD**	79.04%	9.62%	0.77%	8.74%	1.77%	0.05%
FR-14 (CR83)	**DW**	33.45%	30.55%	2.21%	29.56%	4.23%	0.00%
FR-12.4	**LBD**	46.10%	16.45%	19.40%	13.81%	3.25%	0.99%
RC-1.1	**LBD**	27.14%	8.21%	43.38%	11.56%	9.55%	0.17%

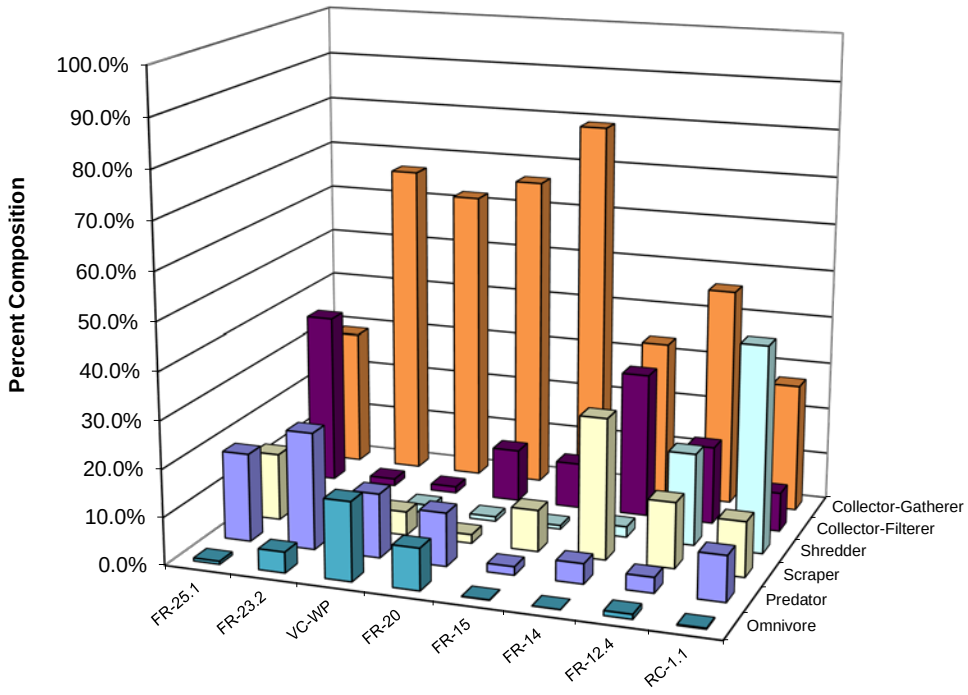

Figure 19. Functional feeding group composition for study sites in the Fraser River study area during the fall of 2020.

Colorado River Study Area

An evaluation of functional feeding groups in the Colorado River study area provided a summary of the changes in ecological function that occurred from upstream to downstream during September of 2020 (Table 12; Figure 20). Despite notable changes in the proportion of various feeding groups, none of the study sites generated results suggesting that there was substantial impairment to ecological function. The most upstream sampling location (CR-WGU) supported the least balanced macroinvertebrate community, where collector-gatherers constituted more than 70% of the community and the combination of the most specialized groups (shredders and scrapers) represented less than 10% of the community (Figure 20). Despite evidence of increased stress at site CR-WGU, representatives from all major feeding groups were found at this location. While the proportion of collector-gatherers generally declined in a downstream direction, the relative abundance of collector-filterers, shredders, and scrapers generally improved (Table 12, Figure 20). The change in balance among feeding groups that was observed in the downstream portion of the Colorado River study area could probably be attributed to (at least in part) a return to more normal stream conditions with distance downstream from the influence of reservoirs. Previous studies have identified how food resources for benthic macroinvertebrates recover and improve with distance downstream from reservoirs in the Colorado River (Rader and Ward 1988). Overall, results from functional feeding group analysis in the Colorado River study area supported the results from other metrics used in this study by detecting evidence of elevated stress at site CR-WGU, followed by improvement in community function in a downstream direction.

Table 12. Relative abundance of functional feeding groups in the Colorado River study area during the fall of 2020. NW=Northern Water; LBD=Learning By Doing.

Site	Project	Functional Feeding Group					
		Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
CR-WGU	NW	72.77%	14.99%	3.43%	6.06%	2.63%	0.11%
CR-WGD	NW	60.31%	32.14%	1.36%	4.19%	2.00%	0.00%
CR-HSPP	NW	52.21%	25.95%	2.21%	18.21%	1.06%	0.35%
CR-WFU	NW	44.03%	8.92%	2.62%	34.78%	1.25%	8.40%
CR-bWF	NW	23.06%	33.27%	13.15%	14.19%	1.73%	14.61%
CR-R3	NW	48.40%	27.68%	8.78%	10.76%	1.47%	2.90%
CR-R4	NW	31.08%	30.99%	11.85%	12.14%	1.05%	12.90%
CR-9.1	LBD	20.07%	22.88%	12.37%	29.62%	3.93%	11.13%
CR-7.4	LBD	32.49%	17.83%	19.59%	25.54%	2.90%	1.65%
CR-1.7	LBD	40.24%	39.73%	6.68%	10.96%	2.23%	0.17%

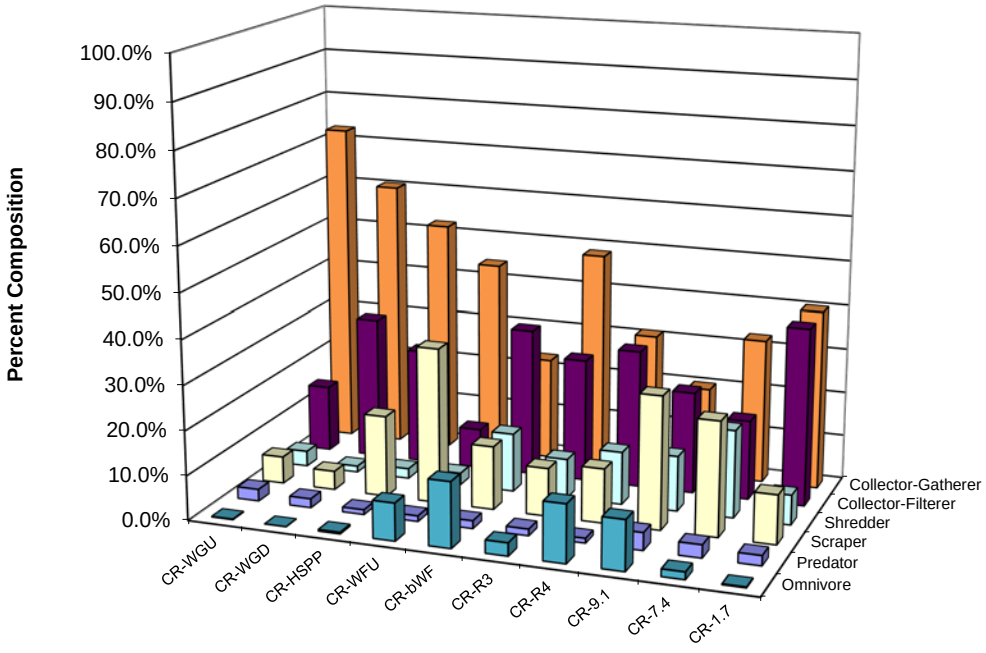

Figure 20. Functional feeding group composition for study sites in the Colorado River study area during the fall of 2020.

Williams Fork Study Area

A review of functional feeding groups at study sites on the Williams Fork clearly demonstrated how a deep-release reservoir can influence food resources for benthic macroinvertebrates. Upstream from the reservoir at site WF-5.5 (mod) collector-gatherers and collector-filterers were most abundant, while sensitive groups were also adequately represented (Table 13, Figure 21). Immediately downstream from the reservoir at site WF-2 (mod) there was a substantial reduction in collector-filterers and the most sensitive feeding groups (shredders and scrapers) were nearly absent (Table 13). This response was expected due to 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. Remarkably, macroinvertebrate community function appeared to be returning to a more normal condition a short distance farther downstream at site WF-0.5 (Table 13, Figure 21). At site WF-0.5, the proportion of collector-filterers increased substantially, although the relative abundance of shredders and scrapers remained relatively low. Overall, results from the functional feeding group analysis supported the results from other metrics used in this study by detecting increased stress downstream from Williams Fork Reservoir, while adequate community function was observed throughout the study area.

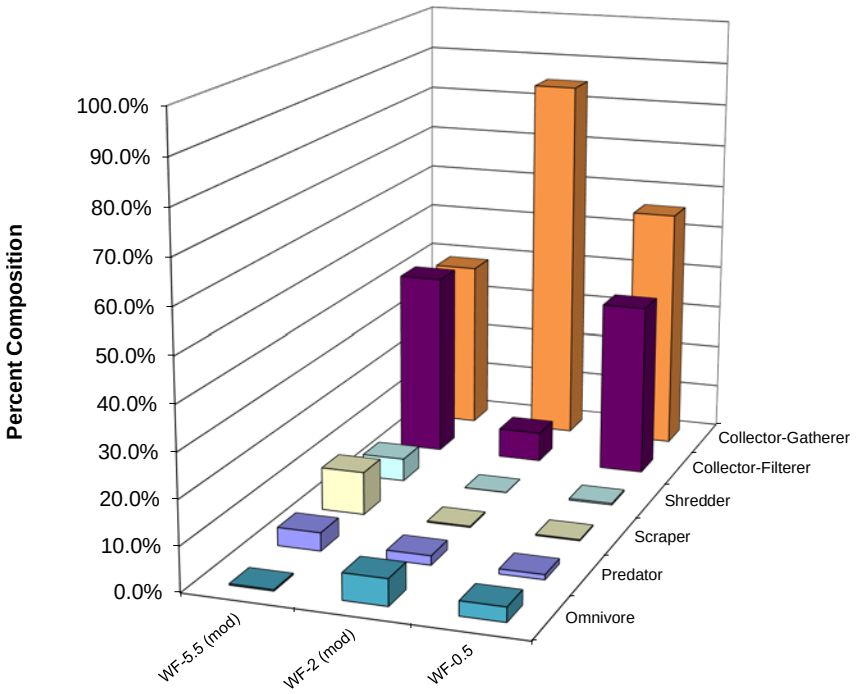

Figure 21. Functional feeding group composition for study sites in the Williams Fork study area during the fall of 2020.

Table 13. Relative abundance of functional feeding groups in the Williams Fork study area during the fall of 2020. LBD=Learning By Doing.

Site	Project	Functional Feeding Group					
		Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
WF-5.5 (mod)	**LBD**	38.81%	41.87%	5.20%	9.74%	4.11%	0.27%
WF-2 (mod)	**LBD**	84.96%	6.75%	0.03%	0.25%	2.09%	5.93%
WF-0.5	**LBD**	55.80%	39.26%	0.34%	0.22%	1.12%	3.26%

Conclusions

Overall, the benthic macroinvertebrate communities in the study areas (which included portions of the Fraser, Colorado, and Williams Fork drainages) appeared to be relatively healthy in September of 2020. While all sampling locations were able to support functioning benthic macroinvertebrate communities with relatively high proportions of sensitive taxa, minor to moderate shifts in benthic macroinvertebrate community structure and function led to the interpretation of increased stress at several sampling locations. Results from the MMI v4 and additional individual metrics indicated that all study sites were in attainment for aquatic life use in 2020; however, the rapid decline in the MMI v4 score (since 2019) at site CR-WGU resulted the only 'impairment' designation in this study area. Other sites that generated low MMI v4 scores (or showed signs of increased stress based on other analysis tools) included site FR-23.2 (abv WPSD) on the Fraser River, and sites WF-2 (mod) and WF-0.5 on the Williams Fork. Many of the study sites on the Colorado River also appeared to be slightly more stressed in 2020 when compared to previous sampling events. With the exception of site FR-23.2 (abv WPSD), most of the study sites that showed signs of minor increases in stress were found in stream segments that were likely influenced by regulated flows and/or reservoir operations. It is possible that deviations from the natural temperature and flow regime combined with unusually dry and warm conditions in the months prior to sampling in 2020 resulted in some minor (but consistent) impacts to the aquatic communities. Lenat and Barbour (1994) suggested that when the proportion of sensitive to tolerant taxa remains relatively stable but other metrics detect minor stress, the observed changes in macroinvertebrate community structure and function may be related to habitat adequacy (or hydrology) rather than water quality. While the MMI v4 and individual metrics were able to detect increases in stress at several sampling locations in 2020, the high proportion of sensitive taxa at these sites resulted in MMI v4 scores that were above the 'impairment' threshold. Future biomonitoring studies will provide an opportunity to assess any changes in influences from anthropogenic activities, and provide a continued assessment of habitat improvement projects that have occurred (or will occur) in this study area.

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Appendix A

Learning By Doing
Benthic Macroinvertebrate Data – Fall 2020

Table A1. Macroinvertebrate data collected from site FR-25.1 on 16 Sept. 2020.

Fraser River						
FR-25.1		Sample				
16 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.	1	2			3	12
Acentrella sp.	4	4			8	31
Baetis flavistriga	1	5	3		9	35
Baetis (*tricaudatus*)	13	36	11		60	233
Diphetor hageni						
Attenella margarita						
Drunella doddsii	2	5	3		10	39
Drunella grandis						
Ephemerella dorothea infrequens						
Serratella tibialis						
Cinygmula sp.	2		1		3	12
Epeorus sp.						
Epeorus deceptivus	1	5	1		7	28
Heptagenia sp.						
Rhithrogena sp.		3	2		5	20
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata		1			1	4
Chloroperlidae	1				1	4
Sweltsa sp.	1	2	1		4	16
Paraleuctra sp.	1				1	4
Zapada oregonensis group	2	2			4	16
Claassenia sabulosa						
Perlodidae	3	4	2		9	35
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva						
Megarcys signata	1	2			3	12
Skwala americana						
Pteronarcella badia						
Taenionema sp.	3	10	6		19	74
Trichoptera (caddisflies)						
Brachycentrus americanus						
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.	1				1	4
Protoptila sp.						
Arctopsyche grandis	3		1		4	16
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Ochrotrichia sp.						
Lepidostoma sp.		1			1	4
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea	2	1	2		5	20
Rhyacophila coloradensis	1	6	1		8	31
Rhyacophila sibirica group	15	4	5		24	93
Oligophlebodes sp.	3	12	6		21	82

Table A1.cont. Macroinvertebrate data collected from site FR-25.1 on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	2	3			5	20
Diamesa sp.	1				1	4
Eukiefferiella sp.	3	8	3		14	55
Lopescladius sp.						
Micropsectra/Tanytarsus sp.			1		1	4
Microtendipes sp.						
Pagastia sp.	1	4			5	20
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.		1			1	4
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.		2			2	8
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae	2	1			3	12
Chelifera/Neoplasta sp.	2	1	2		5	20
Hemerodromia sp.						
Wiedemannia sp.						
Pericoma sp.			1		1	4
Simulium sp.		154	13		167	648
Antocha sp.						
Dicranota sp.	1				1	4
Hexatoma sp.	1				1	4
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.	5	4	3		12	47
Narpus concolor						
Optioservus sp.			1		1	4
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.	1				1	4
Protzia sp.						
Sperchon sp.	3	6	1		10	39
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Physa sp.						
Gyraulus sp.						
Polycelis coronata		2	1		3	12
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae	2	11	2		15	59
Lumbricidae						
Naididae						
Tubificidae w/out hair chaetae						
Nematoda		12	1		13	51
Totals	**85**	**314**	**74**		**473**	**1848**

Table A2. Macroinvertebrate data collected from site FR-15 on 16 Sept. 2020.

Fraser River						
FR-15		Sample				
16 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.			1		1	4
Baetis flavistriga						
Baetis (*tricaudatus*)	62	67	27		156	605
Diphetor hageni	1	1	1		3	12
Attenella margarita						
Drunella doddsii						
Drunella grandis	20	27	39		86	334
Ephemerella dorothea infrequens	663	1390	2758		4811	18648
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.						
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.		1			1	4
Tricorythodes explicatus						
Paraleptophlebia sp.	4	7	7		18	70
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae		2	12		14	55
Sweltsa sp.	1		1		2	8
Paraleuctra sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva	1	3	8		12	47
Megarcys signata						
Skwala americana			3		3	12
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	11	14	14		39	152
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.	77	110	94		281	1090
Protoptila sp.						
Arctopsyche grandis	14	29	36		79	307
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	58	152	142		352	1365
Hydropsyche oslari	15	5	18		38	148
Ochrotrichia sp.		2	1		3	12
Lepidostoma sp.	4	10	40		54	210
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea			1		1	4
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A2. cont. Macroinvertebrate data collected from site FR-15 on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	4	10	4		18	70
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	163	138	254		555	2152
Diamesa sp.			1		1	4
Eukiefferiella sp.	40	58	32		130	504
Lopescladius sp.						
Micropsectra/Tanytarsus sp.		1	1		2	8
Microtendipes sp.	1	2	14		17	66
Pagastia sp.	20	28	23		71	276
Parametriocnemus sp.			2		2	8
Polypedilum sp.						
Potthastia sp.		3	3		6	24
Rheocricotopus sp.						
Sublettea sp.			2		2	8
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group		1	3		4	16
Tvetenia sp.	14	18	28		60	233
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	3	3	5		11	43
Hemerodromia sp.						
Wiedemannia sp.		1	2		3	12
Pericoma sp.						
Simulium sp.	76	74	35		185	718
Antocha sp.	1	1			2	8
Dicranota sp.						
Hexatoma sp.						
Tipula sp.	1		2		3	12
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.	6		3		9	35
Narpus concolor						
Optioservus sp.	58	94	127		279	1082
Zaitzevia parvula		1	1		2	8
Miscellaneous						
Atractides sp.						
Hygrobates sp.	1				1	4
Lebertia sp.	1	1	16		18	70
Protzia sp.						
Sperchon sp.	5	12	20		37	144
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	1	3			4	16
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae			2		2	8
Lumbricidae		1	1		2	8
Naididae	4	2	7		13	51
Tubificidae w/out hair chaetae						
Nematoda	2	3	2		7	28
Totals	**1332**	**2275**	**3793**		**7400**	**28703**

Table A3. Macroinvertebrate data collected from site FR-12.4 on 18 Sept. 2020.

Fraser River						
FR-12.4		Sample				
18 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	1	1	1		3	12
Baetis flavistriga						
Baetis (*tricaudatus*)	35	94	88		217	842
Diphetor hageni			2		2	8
Attenella margarita						
Drunella doddsii						
Drunella grandis	16	16	7		39	152
Ephemerella dorothea infrequens	264	275	481		1020	3954
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.	45	63	95		203	787
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	19	40	108		167	648
Plecoptera (stoneflies)						
Paracapnia angulata			2		2	8
Chloroperlidae	1	2	7		10	39
Sweltsa sp.	6	2	4		12	47
Paraleuctra sp.						
Zapada oregonensis group						
Claassenia sabulosa			1		1	4
Perlodidae						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva		7	2		9	35
Megarcys signata						
Skwala americana	2	3	1		6	24
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	8	44	9		61	237
Brachycentrus occidentalis	3				3	12
Micrasema bactro		1			1	4
Culoptila sp.	2	9			11	43
Glossosoma sp.	4		4		8	31
Protoptila sp.	9	10	4		23	90
Arctopsyche grandis	1	6	2		9	35
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	95	185	96		376	1458
Hydropsyche oslari	38	42	34		114	442
Ochrotrichia sp.	5	1			6	24
Lepidostoma sp.	222	165	304		691	2679
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida	2	2	1		5	20
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A3.cont. Macroinvertebrate data collected from site FR-12.4 on 18 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	1	3	3		7	28
Cricotopus/Orthocladius sp.	15	9	80		104	404
Diamesa sp.						
Eukiefferiella sp.	17	15	30		62	241
Lopescladius sp.						
Micropsectra/Tanytarsus sp.	1	2	1		4	16
Microtendipes sp.	6	4	5		15	59
Pagastia sp.	4	4	3		11	43
Parametriocnemus sp.						
Polypedilum sp.		2	1		3	12
Potthastia sp.						
Rheocricotopus sp.						
Sublettea sp.	7		9		16	62
Synorthocladius sp.	3	1	11		15	59
Thienemanniella sp.						
Thienemannimyia group		3	6		9	35
Tvetenia sp.	6	24	20		50	194
Other Diptera (true flies)						
Atherix pachypus	1	5	16		22	86
Ceratopogoninae						
Chelifera/Neoplasta sp.	1		3		4	16
Hemerodromia sp.						
Wiedemannia sp.						
Pericoma sp.						
Simulium sp.	1				1	4
Antocha sp.		1	3		4	16
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	74	59	81		214	830
Zaitzevia parvula			1		1	4
Miscellaneous						
Atractides sp.		1			1	4
Hygrobates sp.		1	1		2	8
Lebertia sp.	1	1			2	8
Protzia sp.	4	2	1		7	28
Sperchon sp.	11	9	13		33	128
Torrenticola sp.						
Pisidium sp.	1	1			2	8
Caecidotea sp.		1			1	4
Ferrissia sp.						
Physa sp.		3			3	12
Gyraulus sp.						
Polycelis coronata	7	20	9		36	140
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae						
Lumbricidae			1		1	4
Naididae						
Tubificidae w/out hair chaetae						
Nematoda						
Totals	**939**	**1139**	**1551**		**3629**	**14088**

Table A4. Macroinvertebrate data collected from site RC-1.1 on 16 Sept. 2020.

Ranch Creek						
RC-1.1		Sample				
16 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	1	1	2		4	16
Diphetor hageni						
Attenella margarita						
Drunella doddsii						
Drunella grandis	4	7	11		22	86
Ephemerella dorothea infrequens	56	25	31		112	435
Serratella tibialis						
Cinygmula sp.		1	1		2	8
Epeorus sp.		3			3	12
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.		4	4		8	31
Plecoptera (stoneflies)						
Paracapnia angulata		2			2	8
Chloroperlidae						
Sweltsa sp.		2	2		4	16
Paraleuctra sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae						
Perlodidae (*Cultus* sp.)			1		1	4
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana		1			1	4
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	20	7	9		36	140
Brachycentrus occidentalis						
Micrasema bactro	14	6	9		29	113
Culoptila sp.						
Glossosoma sp.	1	1			2	8
Protoptila sp.			1		1	4
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	2		3		5	20
Hydropsyche oslari	2	2	3		7	28
Ochrotrichia sp.						
Lepidostoma sp.	49	76	33		158	613
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea	1				1	4
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A4. cont. Macroinvertebrate data collected from site RC-1.1 on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	53	10	7		70	272
Cricotopus/Orthocladius sp.	3		1		4	16
Diamesa sp.		1			1	4
Eukiefferiella sp.	4		2		6	24
Lopescladius sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.	1				1	4
Pagastia sp.	6		1		7	28
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.			1		1	4
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	3				3	12
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	2	1			3	12
Hemerodromia sp.						
Wiedemannia sp.						
Pericoma sp.						
Simulium sp.						
Antocha sp.	1	1			2	8
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	12	6	20		38	148
Zaitzevia parvula	6	1	6		13	51
Miscellaneous						
Atractides sp.						
Hygrobates sp.		4			4	16
Lebertia sp.	2	5	3		10	39
Protzia sp.	4	1	5		10	39
Sperchon sp.	19	1	3		23	90
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Physa sp.						
Gyraulus sp.		1			1	4
Polycelis coronata		1			1	4
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae	1				1	4
Lumbricidae						
Naididae						
Tubificidae w/out hair chaetae						
Nematoda						
Totals	**267**	**171**	**159**		**597**	**2329**

Table A5. Macroinvertebrate data collected from WF-5.5(mod) on 16 Sept. 2020.

Williams Fork						
WF-5.5(mod)		Sample				
16 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	3	7	8		18	70
Baetis flavistriga	2	1	1		4	16
Baetis (*tricaudatus*)	74	56	40		170	659
Diphetor hageni	5	1			6	24
Attenella margarita						
Drunella doddsii						
Drunella grandis	4	5	2		11	43
Ephemerella dorothea infrequens	11	4	5		20	78
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.						
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.			2		2	8
Tricorythodes explicatus						
Paraleptophlebia sp.	64	14	9		87	338
Plecoptera (stoneflies)						
Paracapnia angulata	1	1			2	8
Chloroperlidae	1				1	4
Sweltsa sp.						
Paraleuctra sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae						
Perlodidae (*Cultus* sp.)	1				1	4
Isoperla sp.						
Isoperla fulva		2			2	8
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	117	63	155		335	1299
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.			1		1	4
Protoptila sp.	1				1	4
Arctopsyche grandis	3		2		5	20
Cheumatopsyche sp.						
Hydropsyche sp.	44	30	38		112	435
Hydropsyche cockerelli						
Hydropsyche oslari	4	7	12		23	90
Ochrotrichia sp.						
Lepidostoma sp.	47	13	26		86	334
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea	2	4	1		7	28
Rhyacophila coloradensis	3				3	12
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A5. cont. Macroinvertebrate data collected from site WF-5.5(mod) on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	2	7	2		11	43
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	84	38	64		186	721
Diamesa sp.						
Eukiefferiella sp.	49	40	27		116	450
Lopescladius sp.						
Micropsectra/Tanytarsus sp.			1		1	4
Microtendipes sp.						
Pagastia sp.	15	11	16		42	163
Parametriocnemus sp.		1			1	4
Polypedilum sp.		2	5		7	28
Potthastia sp.			1		1	4
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.		1	1		2	8
Thienemannimyia group	1				1	4
Tvetenia sp.	5	1	3		9	35
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	12	4	7		23	90
Hemerodromia sp.						
Wiedemannia sp.						
Pericoma sp.	3				3	12
Simulium sp.	54	138	98		290	1124
Antocha sp.		1	2		3	12
Dicranota sp.	4	1			5	20
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor	4				4	16
Optioservus sp.	114	23	26		163	632
Zaitzevia parvula	15	1	1		17	66
Miscellaneous						
Atractides sp.						
Hygrobates sp.			2		2	8
Lebertia sp.	4		1		5	20
Protzia sp.						
Sperchon sp.	7	1	1		9	35
Torrenticola sp.	2				2	8
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	4	1			5	20
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae						
Lumbricidae	18	1			19	74
Naididae						
Tubificidae w/out hair chaetae						
Nematoda	2	1			3	12
Totals	**786**	**481**	**560**		**1827**	**7099**

Table A6. Macroinvertebrate data collected from site WF-2(mod) on 16 Sept. 2020.

Williams Fork						
WF-2(mod)		Sample				
16 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.		1			1	4
Baetis flavistriga	3				3	12
Baetis (*tricaudatus*)	471	502	344		1317	5105
Diphetor hageni						
Attenella margarita		1			1	4
Drunella doddsii						
Drunella grandis	3	1	2		6	24
Ephemerella dorothea infrequens	6	6	5		17	66
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.		1	1		2	8
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus			3		3	12
Paraleptophlebia sp.	1	4			5	20
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.	1				1	4
Paraleuctra sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Isoperla sp.	8	11	2		21	82
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	1	4	3		8	31
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis	3	3	1		7	28
Cheumatopsyche sp.						
Hydropsyche sp.	2				2	8
Hydropsyche cockerelli		1			1	4
Hydropsyche oslari						
Ochrotrichia sp.						
Lepidostoma sp.			1		1	4
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea	5	4	7		16	62
Rhyacophila coloradensis	5	6	4		15	59
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A6. cont. Macroinvertebrate data collected from site WF-2(mod) on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	178	131	217		526	2039
Diamesa sp.						
Eukiefferiella sp.	288	141	419		848	3287
Lopescladius sp.						
Micropsectra/Tanytarsus sp.	9	4	1		14	55
Microtendipes sp.						
Pagastia sp.	85	41	90		216	838
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.		1			1	4
Rheocricotopus sp.			6		6	24
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group		1			1	4
Tvetenia sp.	38	58	36		132	512
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Wiedemannia sp.						
Pericoma sp.						
Simulium sp.	63	108	57		228	884
Antocha sp.			2		2	8
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	1				1	4
Zaitzevia parvula		1			1	4
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.	1				1	4
Protzia sp.						
Sperchon sp.	6	7	1		14	55
Torrenticola sp.		1			1	4
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	70	96	50		216	838
Crangonyx sp.						
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae	2				2	8
Tubificidae w/out hair chaetae						
Nematoda	2	2	2		6	24
Totals	**1252**	**1137**	**1254**		**3643**	**14133**

Table A7. Macroinvertebrate data collected from site WF-0.5 on 16 Sept. 2020.

Williams Fork						
WF-0.5		Sample				
16 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	2	19	10		31	121
Baetis flavistriga						
Baetis (*tricaudatus*)	396	241	501		1138	4411
Diphetor hageni						
Attenella margarita	8	8	5		21	82
Drunella doddsii						
Drunella grandis	1		2		3	12
Ephemerella dorothea infrequens	2	1	5		8	31
Serratella tibialis			3		3	12
Cinygmula sp.						
Epeorus sp.	1	1			2	8
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	2				2	8
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Paraleuctra sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Isoperla sp.	7	5	9		21	82
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	10	15	27		52	202
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis	3		1		4	16
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Ochrotrichia sp.						
Lepidostoma sp.	6	1	1		8	31
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea			1		1	4
Rhyacophila coloradensis		1	2		3	12
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A7. cont. Macroinvertebrate data collected from site WF-0.5 on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	1				1	4
Cricotopus/Orthocladius sp.	6	7	26		39	152
Diamesa sp.						
Eukiefferiella sp.	14	12	64		90	349
Lopescladius sp.						
Micropsectra/Tanytarsus sp.	16	14	22		52	202
Microtendipes sp.						
Pagastia sp.	16	36	40		92	357
Parametriocnemus sp.	1	1			2	8
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	6		2		8	31
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Wiedemannia sp.						
Pericoma sp.						
Simulium sp.	455	69	469		993	3849
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.		1			1	4
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.			1		1	4
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.						
Sperchon sp.						
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	20	28	39		87	338
Crangonyx sp.	1	2			3	12
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae		1	1		2	8
Tubificidae w/out hair chaetae						
Nematoda	1	1	2		4	16
Totals	**975**	**464**	**1233**		**2672**	**10366**

Table A8. Macroinvertebrate data collected from site CR-9.1 on 17 Sept. 2020.

Colorado River						
CR-9.1		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.			1		1	4
Baetis flavistriga						
Baetis (*tricaudatus*)	33	37	55		125	485
Diphetor hageni	1				1	4
Attenella margarita						
Drunella doddsii						
Drunella grandis	2	1	2		5	20
Ephemerella dorothea infrequens	35	57	68		160	621
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.	32	5	3		40	155
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.		1	4		5	20
Tricorythodes explicatus	3				3	12
Paraleptophlebia sp.	19	1	9		29	113
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae	6	3	1		10	39
Sweltsa sp.						
Paraleuctra sp.						
Zapada oregonensis group						
Claassenia sabulosa		2	1		3	12
Perlodidae						
Perlodidae (*Cultus* sp.)	6	12	7		25	97
Isoperla sp.						
Isoperla fulva	2		1		3	12
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	43	106	237		386	1497
Brachycentrus occidentalis	1	1			2	8
Micrasema bactro						
Culoptila sp.	3	7	5		15	59
Glossosoma sp.	7	72	42		121	469
Protoptila sp.	76	34	12		122	473
Arctopsyche grandis		2			2	8
Cheumatopsyche sp.	4	3	4		11	43
Hydropsyche sp.		3	1		4	16
Hydropsyche cockerelli	14	14	15		43	167
Hydropsyche oslari	4	36	40		80	311
Ochrotrichia sp.						
Lepidostoma sp.	80	78	36		194	752
Ceraclea sp.	2	1			3	12
Oecetis sp.		2			2	8
Psychomyia flavida	1		1		2	8
Rhyacophila brunnea			2		2	8
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A8. cont. Macroinvertebrate data collected from site CR-9.1 on 17 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.			2		2	8
Cricotopus nostocicola	12	54	37		103	400
Cricotopus/Orthocladius sp.	2	6	2		10	39
Diamesa sp.						
Eukiefferiella sp.	1	4	8		13	51
Lopescladius sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	4	17	22		43	167
Parametriocnemus sp.						
Polypedilum sp.			2		2	8
Potthastia sp.						
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.		1			1	4
Thienemannimyia group	3				3	12
Tvetenia sp.		12	12		24	93
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	1	3	3		7	28
Hemerodromia sp.		1			1	4
Wiedemannia sp.						
Pericoma sp.						
Simulium sp.	1	8	15		24	93
Antocha sp.		1	2		3	12
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	49	132	71		252	977
Zaitzevia parvula	1	20	16		37	144
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.	2				2	8
Protzia sp.	13	8			21	82
Sperchon sp.		10	4		14	55
Torrenticola sp.						
Pisidium sp.	1				1	4
Caecidotea sp.	18				18	70
Ferrissia sp.		3			3	12
Physa sp.	125	12	16		153	593
Gyraulus sp.						
Polycelis coronata	146	61	62		269	1042
Crangonyx sp.	1	2			3	12
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae						
Tubificidae w/out hair chaetae	2	7			9	35
Nematoda						
Totals	**756**	**840**	**821**		**2417**	**9386**

Table A9. Macroinvertebrate data collected from site CR-7.4 on 17 Sept. 2020.

Colorado River						
CR-7.4		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.			3		3	12
Baetis flavistriga						
Baetis (*tricaudatus*)	98	84	120		302	1171
Diphetor hageni		2			2	8
Attenella margarita		1			1	4
Drunella doddsii						
Drunella grandis	1	1	9		11	43
Ephemerella dorothea infrequens	70	86	87		243	942
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.	20	9	6		35	136
Epeorus deceptivus						
Heptagenia sp.						
Rhithrogena sp.	20	12	8		40	155
Tricorythodes explicatus	1	3	1		5	20
Paraleptophlebia sp.	18	17	13		48	186
Plecoptera (stoneflies)						
Paracapnia angulata		1	1		2	8
Chloroperlidae	1	3	5		9	35
Sweltsa sp.						
Paraleuctra sp.						
Zapada oregonensis group						
Claassenia sabulosa	4	3	6		13	51
Perlodidae						
Perlodidae (*Cultus* sp.)	10	5	4		19	74
Isoperla sp.	2	1	1		4	16
Isoperla fulva						
Megarcys signata						
Skwala americana			2		2	8
Pteronarcella badia	3	1	5		9	35
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	5	8	15		28	109
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.	11	12	4		27	105
Glossosoma sp.	50	15	30		95	369
Protoptila sp.	8	11	42		61	237
Arctopsyche grandis		2			2	8
Cheumatopsyche sp.	2	3	3		8	31
Hydropsyche sp.	21	7	5		33	128
Hydropsyche cockerelli	41	21	57		119	462
Hydropsyche oslari	19	7	8		34	132
Ochrotrichia sp.						
Lepidostoma sp.	88	182	118		388	1504
Ceraclea sp.		1			1	4
Oecetis sp.						
Psychomyia flavida			1		1	4
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A9. cont. Macroinvertebrate data collected from site CR-7.4 on 17 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	2		2		4	16
Cricotopus nostocicola	42	17	54		113	438
Cricotopus/Orthocladius sp.	13	5	20		38	148
Diamesa sp.						
Eukiefferiella sp.	13	8	20		41	159
Lopescladius sp.	1				1	4
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.			5		5	20
Parametriocnemus sp.						
Polypedilum sp.	2	6			8	31
Potthastia sp.						
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.	4				4	16
Thienemannimyia group	1	2			3	12
Tvetenia sp.	35	31	34		100	388
Other Diptera (true flies)						
Atherix pachypus		1			1	4
Ceratopogoninae						
Chelifera/Neoplasta sp.	2	1	2		5	20
Hemerodromia sp.						
Wiedemannia sp.						
Pericoma sp.						
Simulium sp.	189	13	47		249	966
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus	1				1	4
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	69	86	243		398	1543
Zaitzevia parvula	8	12	19		39	152
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.	1	4			5	20
Sperchon sp.	3	1	8		12	47
Torrenticola sp.						
Pisidium sp.	1				1	4
Caecidotea sp.		8	7		15	59
Ferrissia sp.						
Physa sp.	4	6	2		12	47
Gyraulus sp.						
Polycelis coronata	7	22	15		44	171
Crangonyx sp.		1			1	4
Erpobdellidae						
Enchytraeidae	1		6		7	28
Lumbricidae		2	3		5	20
Naididae	1		1		2	8
Tubificidae w/out hair chaetae						
Nematoda						
Totals	**893**	**724**	**1042**		**2659**	**10326**

Table A10. Macroinvertebrate data collected from site CR-1.7 on 17 Sept. 2020.

Colorado River						
CR-1.7		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	34	77	39		150	582
Diphetor hageni		1			1	4
Attenella margarita		1			1	4
Drunella doddsii						
Drunella grandis		2	1		3	12
Ephemerella dorothea infrequens	29	53	29		111	431
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.	6	9	20		35	136
Epeorus deceptivus						
Heptagenia sp.	2	2	1		5	20
Rhithrogena sp.	6	3	14		23	90
Tricorythodes explicatus		1	5		6	24
Paraleptophlebia sp.	5	8	6		19	74
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Paraleuctra sp.						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae						
Perlodidae (*Cultus* sp.)	4	2			6	24
Isoperla sp.	4	7	2		13	51
Isoperla fulva			1		1	4
Megarcys signata						
Skwala americana						
Pteronarcella badia	6	26	3		35	136
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	1	2			3	12
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.			3		3	12
Glossosoma sp.						
Protoptila sp.						
Arctopsyche grandis						
Cheumatopsyche sp.		6	8		14	55
Hydropsyche sp.	10	11	1		22	86
Hydropsyche cockerelli	15	16	2		33	128
Hydropsyche oslari	4	2	4		10	39
Ochrotrichia sp.						
Lepidostoma sp.	5	25	50		80	311
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table A10. cont. Macroinvertebrate data collected from CR-1.7 on 17 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	1	1			2	8
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	26	55	56		137	531
Diamesa sp.						
Eukiefferiella sp.	1		2		3	12
Lopescladius sp.						
Micropsectra/Tanytarsus sp.		1			1	4
Microtendipes sp.						
Pagastia sp.		1	2		3	12
Parametriocnemus sp.	1	1	1		3	12
Polypedilum sp.			1		1	4
Potthastia sp.						
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	28	55	15		98	380
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Wiedemannia sp.						
Pericoma sp.						
Simulium sp.	95	386	132		613	2376
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus	1				1	4
Oreodytes sp.	3				3	12
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	18	59	44		121	469
Zaitzevia parvula	2	1	3		6	24
Miscellaneous						
Atractides sp.			1		1	4
Hygrobates sp.			5		5	20
Lebertia sp.			1		1	4
Protzia sp.						
Sperchon sp.		1	2		3	12
Torrenticola sp.						
Pisidium sp.			1		1	4
Caecidotea sp.	4	34	50		88	342
Ferrissia sp.						
Physa sp.		1	1		2	8
Gyraulus sp.						
Polycelis coronata		3			3	12
Crangonyx sp.			1		1	4
Erpobdellidae	2	1	1		4	16
Enchytraeidae						
Lumbricidae						
Naididae	20	23	34		77	299
Tubificidae w/out hair chaetae						
Nematoda						
Totals	**333**	**877**	**542**		**1752**	**6808**

Appendix B
Northern Water
Benthic Macroinvertebrate Data – Fall 2020

Table B1: Macroinvertebrate data collected from site CR-WGU on 17 Sept. 2020.

Colorado River						
CR-WGU		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera						
Acentrella turbida			3		3	12
Baetis (*tricaudatus*)	10	14	62		86	334
Diphetor hageni						
Drunella grandis		2	1		3	12
Ephemerella dorothea infrequens		4	3		7	28
Serratella micheneri						
Epeorus sp.						
Rhithrogena sp.						
Tricorythodes explicatus		1	1		2	8
Paraleptophlebia sp.			2		2	8
Plecoptera						
Paracapnia angulata		2	1		3	12
Chloroperlidae	1	6			7	28
Sweltsa sp.						
Zapada cinctipes						
Claassenia sabulosa			2		2	8
Hesperoperla pacifica						
Perlodidae (*Cultus* sp.)			2		2	8
Isoperla sp.			1		1	4
Isoperla fulva						
Skwala americana						
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	4	2	4		10	39
Brachycentrus occidentalis	1	1	10		12	47
Culoptila sp.						
Glossosoma sp.	1	17	1		19	74
Protoptila sp.						
Arctopsyche grandis	1		15		16	62
Ceratopsyche morosa						
Cheumatopsyche sp.			2		2	8
Hydropsyche (cockerelli)		3	66		69	268
Hydropsyche oslari						
Hydroptila sp.						
Lepidostoma sp.	3	7	5		15	59
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						

Table B1 cont.: Macroinvertebrate data collected from site CR-WGU on 17 Sept. 2020.

Diptera						
Chironomidae						
Cardiocladius sp.						
Cricotopus nostocicola	2	4	6		12	47
Cricotopus/Orthocladius sp.	18	4	84		106	411
Eukiefferiella sp.	7	3	72		82	318
Micropsectra/Tanytarsus sp.			4		4	16
Microtendipes sp.	2	13			15	59
Nanocladius sp.						
Pagastia sp.	2	3	2		7	28
Parametriocnemus sp.	1	2	2		5	20
Polypedilum sp.						
Potthastia sp.			3		3	12
Rheocricotopus sp.		3	1		4	16
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group		1	1		2	8
Tvetenia sp.	9	2	105		116	450
Other Diptera						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	1		4		5	20
Clinocera sp.						
Hemerodromia sp.						
Wiedemannia sp.						
Simulium sp.	1		5		6	24
Antocha sp.	1		1		2	8
Tipula sp.						
Coleoptera						
Optioservus sp.	2	1	16		19	74
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Lebertia sp.						
Protzia sp.						
Sperchon sp.						
Caecidotea sp.	27	25	121		173	671
Polycelis coronata			1		1	4
Lymnaeidae		3			3	12
Physa sp.		8			8	31
Gyraulus sp.			1		1	4
Pisidium sp.		1			1	4
Crangonyx sp.			1		1	4
Erpobdellidae			1		1	4
Lumbricidae		3	2		5	20
Naididae						
Tubificidae with hair chaetae	2	2	4		8	31
Tubificidae w/o hair chaetae	18	2			20	78
Nematoda			3		3	12
Totals	**114**	**139**	**621**		**874**	**3,405**

Table B2: Macroinvertebrate data collected from site CR-WGD on 17 Sept. 2020.

Colorado River						
CR-WGD		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera						
Acentrella turbida						
Baetis (*tricaudatus*)	379	330	306		1015	3,935
Diphetor hageni	1		2		3	12
Drunella grandis						
Ephemerella dorothea infrequens	640	484	731		1855	7,190
Serratella micheneri						
Epeorus sp.	5	4	1		10	39
Rhithrogena sp.						
Tricorythodes explicatus	2	3	5		10	39
Paraleptophlebia sp.	8	40	51		99	384
Plecoptera						
Paracapnia angulata			1		1	4
Chloroperlidae		1	1		2	8
Sweltsa sp.						
Zapada cinctipes						
Claassenia sabulosa		5	3		8	31
Hesperoperla pacifica						
Perlodidae (*Cultus* sp.)	3	4	3		10	39
Isoperla sp.	5	8	13		26	101
Isoperla fulva						
Skwala americana	1				1	4
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	395	157	252		804	3,117
Brachycentrus occidentalis						
Culoptila sp.	18	6	3		27	105
Glossosoma sp.						
Protoptila sp.	3	29	1		33	128
Arctopsyche grandis	9	14	10		33	128
Ceratopsyche morosa	1	3	1		5	20
Cheumatopsyche sp.		4			4	16
Hydropsyche (cockerelli)	91	183	200		474	1,838
Hydropsyche oslari	195	144	215		554	2,148
Hydroptila sp.	4	5	2		11	43
Lepidostoma sp.	21	22	13		56	218
Ceraclea sp.		2			2	8
Oecetis sp.						
Psychomyia flavida	1	5			6	24
Rhyacophila brunnea						
Rhyacophila coloradensis	1	2			3	12

Table B2 cont.: Macroinvertebrate data collected from site CR-WGD on 17 Sept. 2020.

Diptera						
Chironomidae						
Cardiocladius sp.						
Cricotopus nostocicola	10	7	5		22	86
Cricotopus/Orthocladius sp.	40	14	20		74	287
Eukiefferiella sp.	75	38	52		165	640
Micropsectra/Tanytarsus sp.	2		1		3	12
Microtendipes sp.		1	1		2	8
Nanocladius sp.		1			1	4
Pagastia sp.	16	10	8		34	132
Parametriocnemus sp.	1	4			5	20
Polypedilum sp.						
Potthastia sp.	1	1			2	8
Rheocricotopus sp.		1	1		2	8
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.	1				1	4
Thienemannimyia group	1	8	4		13	51
Tvetenia sp.	76	64	61		201	780
Other Diptera						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	8	11	5		24	93
Clinocera sp.	1				1	4
Hemerodromia sp.						
Wiedemannia sp.		1			1	4
Simulium sp.	2	8	8		18	70
Antocha sp.	6	2	3		11	43
Tipula sp.		1			1	4
Coleoptera						
Optioservus sp.	41	58	66		165	640
Zaitzevia parvula	1	1	3		5	20
Miscellaneous						
Atractides sp.		1			1	4
Lebertia sp.	1	3	2		6	24
Protzia sp.	2	5	6		13	51
Sperchon sp.	6	2	1		9	35
Caecidotea sp.	4	7	8		19	74
Polycelis coronata						
Lymnaeidae						
Physa sp.		1			1	4
Gyraulus sp.						
Pisidium sp.	1				1	4
Crangonyx sp.		1	1		2	8
Erpobdellidae						
Lumbricidae		3	18		21	82
Naididae	1		1		2	8
Tubificidae with hair chaetae		9			9	35
Tubificidae w/o hair chaetae	1	3	5		9	35
Nematoda						
Totals	**2081**	**1721**	**2094**		**5896**	**22,873**

Table B3: Macroinvertebrate data collected from site CR-HSPP on 17 Sept. 2020.

Colorado River						
CR-HSPP		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera						
Acentrella turbida	2	1			3	12
Baetis (*tricaudatus*)	72	89	202		363	1,407
Diphetor hageni						
Drunella grandis			1		1	4
Ephemerella dorothea infrequens	53	49	214		316	1,225
Serratella micheneri						
Epeorus sp.	3	3	3		9	35
Rhithrogena sp.	1				1	4
Tricorythodes explicatus						
Paraleptophlebia sp.			3		3	12
Plecoptera						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Claassenia sabulosa			4		4	16
Hesperoperla pacifica						
Perlodidae (*Cultus* sp.)	1		1		2	8
Isoperla sp.						
Isoperla fulva						
Skwala americana						
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	5	4	12		21	82
Brachycentrus occidentalis		1			1	4
Culoptila sp.	195	60	85		340	1,318
Glossosoma sp.			1		1	4
Protoptila sp.						
Arctopsyche grandis		6	15		21	82
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche (cockerelli)	52	77	173		302	1,171
Hydropsyche oslari	1	9	10		20	78
Hydroptila sp.	1	1	2		4	16
Lepidostoma sp.	14	1	33		48	186
Ceraclea sp.						
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						

Table B3 cont.: Macroinvertebrate data collected from site CR-HSPP on 17 Sept. 2020.

Diptera						
Chironomidae						
Cardiocladius sp.		3	5		8	31
Cricotopus nostocicola	1	1			2	8
Cricotopus/Orthocladius sp.	20	55	68		143	555
Eukiefferiella sp.	25	38	49		112	435
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Nanocladius sp.						
Pagastia sp.			1		1	4
Parametriocnemus sp.			6		6	24
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.			4		4	16
Sublettea sp.						
Synorthocladius sp.	1				1	4
Thienemanniella sp.						
Thienemannimyia group		1	1		2	8
Tvetenia sp.	40	32	115		187	725
Other Diptera						
Atherix pachypus			4		4	16
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Clinocera sp.						
Hemerodromia sp.			1		1	4
Wiedemannia sp.						
Simulium sp.	1	20	201		222	861
Antocha sp.						
Tipula sp.						
Coleoptera						
Optioservus sp.	15	2	35		52	202
Zaitzevia parvula	4	1	9		14	55
Miscellaneous						
Atractides sp.						
Lebertia sp.						
Protzia sp.						
Sperchon sp.		1	2		3	12
Caecidotea sp.	2		1		3	12
Polycelis coronata	5		3		8	31
Lymnaeidae						
Physa sp.	1				1	4
Gyraulus sp.	2		1		3	12
Pisidium sp.						
Crangonyx sp.						
Erpobdellidae						
Lumbricidae			5		5	20
Naididae	2		17		19	74
Tubificidae with hair chaetae						
Tubificidae w/o hair chaetae	1				1	4
Nematoda						
Totals	**520**	**455**	**1287**		**2262**	**8,781**

Table B4: Macroinvertebrate data collected from site CR-WFU on 17 Sept. 2020.

Colorado River						
CR-WFU		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera						
Acentrella turbida	2	4	17		23	90
Baetis (*tricaudatus*)	57	70	85		212	822
Diphetor hageni						
Drunella grandis						
Ephemerella dorothea infrequens	44	113	219		376	1,458
Serratella micheneri						
Epeorus sp.	20	23	31		74	287
Rhithrogena sp.			1		1	4
Tricorythodes explicatus						
Paraleptophlebia sp.	1	4	9		14	55
Plecoptera						
Paracapnia angulata		1	1		2	8
Chloroperlidae		1			1	4
Sweltsa sp.						
Zapada cinctipes		1			1	4
Claassenia sabulosa						
Hesperoperla pacifica						
Perlodidae (*Cultus* sp.)	1	1	2		4	16
Isoperla sp.		1			1	4
Isoperla fulva						
Skwala americana			1		1	4
Pteronarcys californica	3	1	7		11	43
Trichoptera						
Brachycentrus americanus						
Brachycentrus occidentalis						
Culoptila sp.	30	157	82		269	1,043
Glossosoma sp.	6	46	22		74	287
Protoptila sp.	5	38	12		55	214
Arctopsyche grandis			1		1	4
Ceratopsyche morosa						
Cheumatopsyche sp.		1			1	4
Hydropsyche (cockerelli)	12	32	29		73	283
Hydropsyche oslari	10	11	20		41	159
Hydroptila sp.						
Lepidostoma sp.	6	11	9		26	101
Ceraclea sp.		1			1	4
Oecetis sp.		3			3	12
Psychomyia flavida			1		1	4
Rhyacophila brunnea						
Rhyacophila coloradensis		1			1	4

Table B4 cont.: Macroinvertebrate data collected from site CR-WFU on 17 Sept. 2020.

Diptera						
Chironomidae						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	3	1			4	16
Eukiefferiella sp.	5	3	11		19	74
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Nanocladius sp.						
Pagastia sp.						
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.		3	3		6	24
Other Diptera						
Atherix pachypus			1		1	4
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Clinocera sp.						
Hemerodromia sp.	1		1		2	8
Wiedemannia sp.						
Simulium sp.	6	6	8		20	78
Antocha sp.	1				1	4
Tipula sp.						
Coleoptera						
Optioservus sp.	8	21	28		57	221
Zaitzevia parvula	4	3	4		11	43
Miscellaneous						
Atractides sp.						
Lebertia sp.						
Protzia sp.		1			1	4
Sperchon sp.	1		3		4	16
Caecidotea sp.	1				1	4
Polycelis coronata	33	45	50		128	497
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Pisidium sp.						
Crangonyx sp.		1			1	4
Erpobdellidae						
Lumbricidae						
Naididae						
Tubificidae with hair chaetae						
Tubificidae w/o hair chaetae		1			1	4
Nematoda						
Totals	**260**	**606**	**658**		**1524**	**5,919**

Table B5: Macroinvertebrate data collected from site CR-bWF on 17 Sept. 2020.

Colorado River						
CR-bWF (ref)		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera						
Acentrella turbida	1		2		3	12
Baetis (*tricaudatus*)	117	92	129		338	1,311
Diphetor hageni		3			3	12
Drunella grandis	3		7		10	39
Ephemerella dorothea infrequens	43	35	71		149	578
Serratella micheneri						
Epeorus sp.	24	18	2		44	171
Rhithrogena sp.	1				1	4
Tricorythodes explicatus						
Paraleptophlebia sp.	2	7	7		16	62
Plecoptera						
Paracapnia angulata						
Chloroperlidae			2		2	8
Sweltsa sp.			1		1	4
Zapada cinctipes						
Claassenia sabulosa						
Hesperoperla pacifica			1		1	4
Perlodidae (*Cultus* sp.)	1		2		3	12
Isoperla sp.						
Isoperla fulva	3				3	12
Skwala americana	1	1	1		3	12
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	785	5	29		819	3,175
Brachycentrus occidentalis						
Culoptila sp.	28	136	55		219	849
Glossosoma sp.	2	14	15		31	121
Protoptila sp.	34	36	32		102	396
Arctopsyche grandis	3		1		4	16
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche (cockerelli)	62	2	6		70	272
Hydropsyche oslari	131	19	21		171	663
Hydroptila sp.	1				1	4
Lepidostoma sp.	194	167	61		422	1,636
Ceraclea sp.		2	1		3	12
Oecetis sp.	7	3	1		11	43
Psychomyia flavida						
Rhyacophila brunnea			15		15	59
Rhyacophila coloradensis	2				2	8

Table B5 cont.: Macroinvertebrate data collected from site CR-bWF on 17 Sept. 2020.

Diptera						
Chironomidae						
Cardiocladius sp.			1		1	4
Cricotopus nostocicola	16	10	20		46	179
Cricotopus/Orthocladius sp.	27	9	28		64	249
Eukiefferiella sp.	29	10	18		57	221
Micropsectra/Tanytarsus sp.						
Microtendipes sp.	4	1			5	20
Nanocladius sp.			1		1	4
Pagastia sp.	32	9	22		63	245
Parametriocnemus sp.	2	5	1		8	31
Polypedilum sp.	1	1			2	8
Potthastia sp.		1			1	4
Rheocricotopus sp.		1			1	4
Sublettea sp.			2		2	8
Synorthocladius sp.						
Thienemanniella sp.	1				1	4
Thienemannimyia group						
Tvetenia sp.	6	4	1		11	43
Other Diptera						
Atherix pachypus						
Ceratopogoninae	1		1		2	8
Chelifera/Neoplasta sp.	3				3	12
Clinocera sp.						
Hemerodromia sp.			1		1	4
Wiedemannia sp.						
Simulium sp.	33	7	52		92	257
Antocha sp.	14	1	5		20	78
Tipula sp.						
Coleoptera						
Optioservus sp.	28	9	59		96	373
Zaitzevia parvula	1	4	13		18	70
Miscellaneous						
Atractides sp.		2			2	8
Lebertia sp.						
Protzia sp.		1	5		6	24
Sperchon sp.		1	3		4	16
Caecidotea sp.	31	8	20		59	229
Polycelis coronata	197	154	171		522	2,024
Lymnaeidae						
Physa sp.		1	2		3	12
Gyraulus sp.						
Pisidium sp.	17	6	3		26	101
Crangonyx sp.			5		5	20
Erpobdellidae	2				2	8
Lumbricidae						
Naididae		2			2	8
Tubificidae with hair chaetae						
Tubificidae w/o hair chaetae	1				1	4
Nematoda						
Totals	**1891**	**787**	**896**		**3574**	**13,775**

Table B6: Macroinvertebrate data collected from site CR-R3 on 17 Sept. 2020.

Colorado River						
CR-R3		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera						
Acentrella turbida	2	1			3	12
Baetis (*tricaudatus*)	55	51	75		181	702
Diphetor hageni	1				1	4
Drunella grandis	6	2	5		13	51
Ephemerella dorothea infrequens	329	335	359		1023	3,966
Serratella micheneri						
Epeorus sp.	4	10			14	55
Rhithrogena sp.		7	5		12	47
Tricorythodes explicatus	4	2	2		8	31
Paraleptophlebia sp.	3	5	1		9	35
Plecoptera						
Paracapnia angulata						
Chloroperlidae	2	2			4	16
Sweltsa sp.						
Zapada cinctipes						
Claassenia sabulosa		2	1		3	12
Hesperoperla pacifica						
Perlodidae (*Cultus* sp.)	1		3		4	16
Isoperla sp.	1				1	4
Isoperla fulva		2	2		4	16
Skwala americana	1		2		3	12
Pteronarcys californica			1		1	4
Trichoptera						
Brachycentrus americanus	198	105	238		541	2,097
Brachycentrus occidentalis						
Culoptila sp.	7	6	1		14	55
Glossosoma sp.	23	163	20		206	799
Protoptila sp.		5			5	20
Arctopsyche grandis						
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche (cockerelli)	9	14	10		33	128
Hydropsyche oslari	34	36	67		137	531
Hydroptila sp.						
Lepidostoma sp.	63	132	36		231	896
Ceraclea sp.	8	7	3		18	70
Oecetis sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						

Table B6 cont.: Macroinvertebrate data collected from site CR-R3 on 17 Sept. 2020.

Diptera						
Chironomidae						
Cardiocladius sp.						
Cricotopus nostocicola		8	3		11	43
Cricotopus/Orthocladius sp.	10	1	2		13	51
Eukiefferiella sp.	1	1	5		7	28
Micropsectra/Tanytarsus sp.						
Microtendipes sp.	5	2			7	28
Nanocladius sp.						
Pagastia sp.	18	23	22		63	245
Parametriocnemus sp.						
Polypedilum sp.		2			2	8
Potthastia sp.						
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group	3		1		4	16
Tvetenia sp.		6	9		15	59
Other Diptera						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.			1		1	4
Clinocera sp.						
Hemerodromia sp.						
Wiedemannia sp.						
Simulium sp.	33		19		52	202
Antocha sp.	1	1			2	8
Tipula sp.						
Coleoptera						
Optioservus sp.	6	16	12		34	132
Zaitzevia parvula			1		1	4
Miscellaneous						
Atractides sp.		2	1		3	12
Lebertia sp.	1	2			3	12
Protzia sp.		5	2		7	28
Sperchon sp.	2	1	1		4	16
Caecidotea sp.	5	1			6	24
Polycelis coronata	9	40	32		81	314
Lymnaeidae						
Physa sp.	1		1		2	8
Gyraulus sp.						
Pisidium sp.		2			2	8
Crangonyx sp.						
Erpobdellidae						
Lumbricidae						
Naididae						
Tubificidae with hair chaetae						
Tubificidae w/o hair chaetae						
Nematoda						
Totals	**846**	**1000**	**943**		**2789**	**10,829**

Table B7: Macroinvertebrate data collected from site CR-R4 on 17 Sept. 2020.

Colorado River						
CR-R4		Sample				
17 Sept. 2020	1	2	3		Total	Total/m²
Ephemeroptera						
Acentrella turbida						
Baetis (*tricaudatus*)	80	119	90		289	1,121
Diphetor hageni	2		2		4	16
Drunella grandis	16	13	9		38	148
Ephemerella dorothea infrequens	279	434	240		953	3,694
Serratella micheneri	1				1	4
Epeorus sp.	9	2	1		12	47
Rhithrogena sp.	8	2	3		13	51
Tricorythodes explicatus						
Paraleptophlebia sp.	12	1	16		29	113
Plecoptera						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Claassenia sabulosa						
Hesperoperla pacifica	1				1	4
Perlodidae (*Cultus* sp.)	3		1		4	16
Isoperla sp.						
Isoperla fulva	4	7	6		17	66
Skwala americana			2		2	8
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	101	129	40		270	1,047
Brachycentrus occidentalis						
Culoptila sp.	13	6	6		25	97
Glossosoma sp.	234	67	52		353	1,369
Protoptila sp.	18		4		22	86
Arctopsyche grandis		1			1	4
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche (cockerelli)	28	20	9		57	221
Hydropsyche oslari	89	107	34		230	892
Hydroptila sp.						
Lepidostoma sp.	253	147	140		540	2,093
Ceraclea sp.	22	10	9		41	159
Oecetis sp.			1		1	4
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						

Table B7 cont.: Macroinvertebrate data collected from site CR-R4 on 17 Sept. 2020.

Diptera						
Chironomidae						
Cardiocladius sp.		2	1		3	12
Cricotopus nostocicola	7	13	5		25	97
Cricotopus/Orthocladius sp.	6	7	3		16	62
Eukiefferiella sp.	1	3	2		6	24
Micropsectra/Tanytarsus sp.						
Microtendipes sp.	1		1		2	8
Nanocladius sp.						
Pagastia sp.	31	48	13		92	357
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.			1		1	4
Rheocricotopus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group	2				2	8
Tvetenia sp.	5	15	4		24	93
Other Diptera						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Clinocera sp.						
Hemerodromia sp.						
Wiedemannia sp.						
Simulium sp.	279	534	95		908	3,520
Antocha sp.		1			1	4
Tipula sp.						
Coleoptera						
Optioservus sp.	34	26	53		113	438
Zaitzevia parvula	5	2	5		12	47
Miscellaneous						
Atractides sp.	4	1			5	20
Lebertia sp.						
Protzia sp.	1	1	1		3	12
Sperchon sp.		2	6		8	31
Caecidotea sp.	2	2	7		11	43
Polycelis coronata	234	190	191		615	2,384
Lymnaeidae						
Physa sp.	3				3	12
Gyraulus sp.						
Pisidium sp.	6		4		10	39
Crangonyx sp.	1				1	4
Erpobdellidae						
Lumbricidae						
Naididae			1		1	4
Tubificidae with hair chaetae						
Tubificidae w/o hair chaetae						
Nematoda	1	3			4	16
Totals	**1796**	**1915**	**1058**		**4769**	**18,499**

Appendix C

Denver Water
Benthic Macroinvertebrate Data – Fall 2020

Table C1: Macroinvertebrate data collected from site FR-abvWPSD on 16 Sept. 2020.

Fraser River						
FR-abvWPSD		Sample				
16 Sept. 2020	1	2	3		Total	Mean # /m²
Ephemeroptera (mayflies)						
Acentrella turbida	7	10	13		30	117
Baetis flavistriga	19	11	50		80	311
Baetis (*tricaudatus*)	47	44	71		162	628
Diphetor hageni						
Drunella coloradensis	1	1	2		4	16
Drunella doddsii		5	7		12	47
Drunella grandis						
Ephemerella dorothea infrequens			2		2	8
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.						
Epeorus deceptivus		1	2		3	12
Epeorus longimanus						
Rhithrogena sp.	1				1	4
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Suwallia sp.						
Sweltsa sp.		5	41		46	179
Malenka sp.						
Prostoia besametsa			1		1	4
Zapada cinctipes						
Zapada oregonensis group						
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)						
Diura knowltoni						
Isoperla sp.						
Isoperla fulva						
Megarcys signata			2		2	8
Skwala americana						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	2	3	8		13	51
Brachycentrus occidentalis						
Glossosoma sp.						
Arctopsyche grandis						
Hydropsyche cockerelli						
Ochrotrichia sp.						
Lepidostoma sp.						
Rhyacophila sp.						
Rhyacophila brunnea						
Rhyacophila coloradensis	1	1			2	8
Rhyacophila sibirica group	1	1	1		3	12
Oligophlebodes sp.	1	1	5		7	28

Table C1 cont.: Macroinvertebrate data collected from site FR-abvWPSD on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Brillia sp.						
Cardiocladius sp.						
Cricotopus/Orthocladius sp.	30	60	74		164	636
Diamesa sp.		2	2		4	16
Eukiefferiella sp.	4	1	1		6	24
Micropsectra/Tanytarsus sp.		1	2		3	12
Microtendipes sp.						
Pagastia sp.	7	2	4		13	51
Polypedilum sp.						
Potthastia sp.						
Pseudorthocladius sp.						
Rheocricotopus sp.			1		1	4
Stempellinella sp.						
Synorthocladius sp.	2	4	16		22	86
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.						
Other Diptera (true flies)						
Ceratopogoninae	4	6	9		19	74
Deuterophlebia coloradensis						
Chelifera/Neoplasta sp.						
Clinocera sp.						
Pericoma sp.						
Simulium sp.	1				1	4
Antocha sp.						
Dicranota sp.						
Coleoptera (beetles)						
Heterlimnius sp.	14	17	39		70	272
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Lebertia sp.	15	19	53		87	338
Protzia sp.						
Sperchon sp.	18	20	33		71	276
Polycelis coronata	5	26	10		41	159
Enchytraeidae	12	25	2		39	152
Lumbricidae						
Naididae	5	15	9		29	113
Tubificidae w/out hair chaetae						
Nematoda		1			1	4
Totals	**197**	**282**	**460**		**939**	**3654**

Table C2: Macroinvertebrate data collected from site VC-WP on 16 Sept. 2020.

Vasquez Creek						
VC-WP		Sample				
16 Sept. 2020	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Acentrella turbida	1	2	7		10	39
Baetis flavistriga	3	6	5		14	55
Baetis (*tricaudatus*)	4	7	19		30	117
Diphetor hageni		1			1	4
Drunella coloradensis						
Drunella doddsii		1			1	4
Drunella grandis		1	1		2	8
Ephemerella dorothea infrequens	1				1	4
Serratella tibialis		3			3	12
Cinygmula sp.	2	2	1		5	20
Epeorus sp.						
Epeorus deceptivus	2				2	8
Epeorus longimanus						
Rhithrogena sp.						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata	1				1	4
Chloroperlidae						
Suwallia sp.						
Sweltsa sp.		3	2		5	20
Malenka sp.						
Prostoia besametsa			1		1	4
Zapada cinctipes						
Zapada oregonensis group		4	1		5	20
Hesperoperla pacifica						
Perlodidae	1	1	1		3	12
Perlodidae (*Cultus* sp.)						
Diura knowltoni		2			2	8
Isoperla sp.	1				1	4
Isoperla fulva						
Megarcys signata						
Skwala americana						
Taenionema sp.		1	2		3	12
Trichoptera (caddisflies)						
Brachycentrus americanus		3	1		4	16
Brachycentrus occidentalis						
Glossosoma sp.	1				1	4
Arctopsyche grandis	1		1		2	8
Hydropsyche cockerelli						
Ochrotrichia sp.			8		8	31
Lepidostoma sp.	1				1	4
Rhyacophila sp.						
Rhyacophila brunnea	1	1	1		3	12
Rhyacophila coloradensis						
Rhyacophila sibirica group	1	1	8		10	39
Oligophlebodes sp.	4	1	5		10	39

Table C2 cont.: Macroinvertebrate data collected from site VC-WP on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Brillia sp.		1			1	4
Cardiocladius sp.						
Cricotopus/Orthocladius sp.	3	5	37		45	175
Diamesa sp.						
Eukiefferiella sp.	2		19		21	82
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	2		21		23	90
Polypedilum sp.						
Potthastia sp.						
Pseudorthocladius sp.						
Rheocricotopus sp.		1			1	4
Stempellinella sp.						
Synorthocladius sp.	1	1	1		3	12
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.		2	3		5	20
Other Diptera (true flies)						
Ceratopogoninae	2		1		3	12
Deuterophlebia coloradensis						
Chelifera/Neoplasta sp.						
Clinocera sp.						
Pericoma sp.	1	1			2	8
Simulium sp.	1				1	4
Antocha sp.			3		3	12
Dicranota sp.			1		1	4
Coleoptera (beetles)						
Heterlimnius sp.	20	39	83		142	551
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Lebertia sp.	5	5	27		37	144
Protzia sp.						
Sperchon sp.	1	3	3		7	28
Polycelis coronata	41	21	24		86	334
Enchytraeidae	2	1	3		6	24
Lumbricidae						
Naididae			4		4	16
Tubificidae w/out hair chaetae						
Nematoda						
Totals	**106**	**120**	**294**		**520**	**2032**

Table C3: Macroinvertebrate data collected from site FR-Rendezvous on 16 Sept. 2020.

Fraser River						
FR-Rendezvous		Sample				
16 Sept. 2020	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Acentrella turbida	4	2	2		8	31
Baetis flavistriga	4		4		8	31
Baetis (*tricaudatus*)	45	120	105		270	1047
Diphetor hageni						
Drunella coloradensis						
Drunella doddsii	3	5	2		10	39
Drunella grandis			2		2	8
Ephemerella dorothea infrequens	3	11	5		19	74
Serratella tibialis						
Cinygmula sp.			1		1	4
Epeorus sp.						
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Suwallia sp.						
Sweltsa sp.		1	1		2	8
Malenka sp.						
Prostoia besametsa	3	2	1		6	24
Zapada cinctipes		4	3		7	28
Zapada oregonensis group	1	6			7	28
Hesperoperla pacifica						
Perlodidae	2		1		3	12
Perlodidae (*Cultus* sp.)		1			1	4
Diura knowltoni						
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana						
Taenionema sp.		1			1	4
Trichoptera (caddisflies)						
Brachycentrus americanus	74	52	59		185	718
Brachycentrus occidentalis						
Glossosoma sp.	2		9		11	43
Arctopsyche grandis	27	3	3		33	128
Hydropsyche cockerelli						
Ochrotrichia sp.	1		1		2	8
Lepidostoma sp.						
Rhyacophila sp.						
Rhyacophila brunnea		1			1	4
Rhyacophila coloradensis			1		1	4
Rhyacophila sibirica group						
Oligophlebodes sp.	3	6	7		16	62

Table C3 cont.: Macroinvertebrate data collected from site FR-Rendezvous on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Brillia sp.						
Cardiocladius sp.	8		1		9	35
Cricotopus/Orthocladius sp.	384	139	263		786	3047
Diamesa sp.		1	2		3	12
Eukiefferiella sp.	31	8	13		52	202
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	10	9	28		47	183
Polypedilum sp.		1			1	4
Potthastia sp.		1			1	4
Pseudorthocladius sp.						
Rheocricotopus sp.						
Stempellinella sp.						
Synorthocladius sp.		1			1	4
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	5	3	4		12	47
Other Diptera (true flies)						
Ceratopogoninae	1	1	3		5	20
Deuterophlebia coloradensis						
Chelifera/Neoplasta sp.			2		2	8
Clinocera sp.						
Pericoma sp.	6	28	14		48	186
Simulium sp.	2	3	24		29	113
Antocha sp.	3	3	4		10	39
Dicranota sp.						
Coleoptera (beetles)						
Heterlimnius sp.	24	68	121		213	826
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Lebertia sp.	57	61	55		173	671
Protzia sp.						
Sperchon sp.	16	15	15		46	179
Polycelis coronata	63	73	60		196	760
Enchytraeidae						
Lumbricidae						
Naididae		1			1	4
Tubificidae w/out hair chaetae						
Nematoda	3	2	2		7	28
Totals	**785**	**633**	**818**		**2236**	**8681**

Table C4: Macroinvertebrate data collected from site FR-CR83 on 16 Sept. 2020.

Fraser River						
FR-CR83		Sample				
16 Sept. 2020	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Acentrella turbida		1	1		2	8
Baetis flavistriga						
Baetis (*tricaudatus*)	26	12	32		70	272
Diphetor hageni						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	6	6	25		37	144
Ephemerella dorothea infrequens	91	48	169		308	1194
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.		1	1		2	8
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.						
Paraleptophlebia sp.	7	2	5		14	55
Plecoptera (stoneflies)						
Paracapnia angulata	1	1			2	8
Chloroperlidae	1	8	3		12	47
Suwallia sp.						
Sweltsa sp.	3	3			6	24
Malenka sp.						
Prostoia besametsa						
Zapada cinctipes						
Zapada oregonensis group						
Hesperoperla pacifica						
Perlodidae						
Perlodidae (*Cultus* sp.)	1	2	1		4	16
Diura knowltoni						
Isoperla sp.						
Isoperla fulva	1	1	5		7	28
Megarcys signata						
Skwala americana	1	1	2		4	16
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	26	18	37		81	314
Brachycentrus occidentalis	4	2	1		7	28
Glossosoma sp.	154	165	114		433	1679
Arctopsyche grandis	4	1	30		35	136
Hydropsyche cockerelli	105	85	270		460	1783
Ochrotrichia sp.	2		2		4	16
Lepidostoma sp.	10	6	27		43	167
Rhyacophila sp.						
Rhyacophila brunnea			1		1	4
Rhyacophila coloradensis		1	3		4	16
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table C4 cont.: Macroinvertebrate data collected from site FR-CR83 on 16 Sept. 2020.

Diptera (true flies)						
Chironomidae (chironomids)						
Brillia sp.						
Cardiocladius sp.		1	3		4	16
Cricotopus/Orthocladius sp.	40	17	72		129	500
Diamesa sp.						
Eukiefferiella sp.	19	23	27		69	268
Micropsectra/Tanytarsus sp.	5		4		9	35
Microtendipes sp.	3		1		4	16
Pagastia sp.	11	6	18		35	136
Polypedilum sp.						
Potthastia sp.	1		1		2	8
Pseudorthocladius sp.						
Rheocricotopus sp.						
Stempellinella sp.						
Synorthocladius sp.	1				1	4
Thienemanniella sp.						
Thienemannimyia group	2				2	8
Tvetenia sp.	10	3	14		27	105
Other Diptera (true flies)						
Ceratopogoninae						
Deuterophlebia coloradensis						
Chelifera/Neoplasta sp.		2	3		5	20
Clinocera sp.			2		2	8
Pericoma sp.						
Simulium sp.	17	3	14		34	132
Antocha sp.	2	1	4		7	28
Dicranota sp.						
Coleoptera (beetles)						
Heterlimnius sp.						
Optioservus sp.	53	24	52		129	500
Zaitzevia parvula		1			1	4
Miscellaneous						
Lebertia sp.	2				2	8
Protzia sp.	1				1	4
Sperchon sp.	10	4	14		28	109
Polycelis coronata						
Enchytraeidae						
Lumbricidae						
Naididae	2				2	8
Tubificidae w/out hair chaetae						
Nematoda	2	2			4	16
Totals	**624**	**451**	**958**		**2033**	**7896**

Appendix D

Learning By Doing
Historical MMI v4 and Individual Metric Results – 2017, 2018 & 2019

Table D1. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during the fall of 2017. All metric scores are based on the 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 D2. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during the fall of 2018. All metric scores are based on the 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 D3. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during the fall of 2019. All metric scores are based on the 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	--	--	--	--	--	--

Table D4. Additional individual metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in the fall of 2017. All additional metric values are 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 D5. Additional individual metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in the fall of 2018. All additional metric values are 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%

Table D6. Additional individual metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in the fall of 2019. All additional metric values are based on full count 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%

Appendix E

Northern Water (WGFP) and Denver Water
Metric Results from the fall of 2019

Table E1. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected from Northern Water sampling sites on the Colorado River on 19 September 2019. All metric scores are based on the MMI v4 subsampling process. Scores indicating 'impairment' would be provided in red.

Metric	Station ID			
	CR-WGU	CR-WGD	CR-HSPP	CR-WFU
EPT Taxa	87.5	87.5	87.5	87.5
% Non-Insect Individuals	75.9	82.4	80.7	83.9
% EPT Individuals-no Baetidae	61.4	36.1	60.2	92.5
% Coleoptera Individuals	17.1	12.9	31.0	20.2
% Intolerant Taxa	60.0	62.5	65.6	75.3
% Increaser Individuals (Mid-Elevation)	60.0	74.3	75.7	92.5
Clinger Taxa	86.5	81.7	100.0	96.2
Predator/Shredder Taxa	50.0	85.7	64.3	64.3
MMI	**62.3**	**65.4**	**70.6**	**76.6**
	Auxiliary Metrics			
Diversity	4.08	4.04	4.19	4.09
HBI	3.93	4.76	3.88	2.37
TIV (Sediment Region 2)	--	6.65	--	4.22

Table E2: Additional metrics and comparative values for macroinvertebrate samples collected from Northern Water sampling sites on the Colorado River on 19 September 2019. All metrics are based on full count Hess samples.

Metric	CR-WGU	CR-WGD	CR-HSPP	CR-WFU
EPT	24	29	28	27
Evenness	0.739	0.679	0.715	0.729
DAT	37.0	41.7	35.2	29.8
Insect Taxa	38	48	44	40
Total Taxa	48	61	54	48
Percent Shredders and Scrapers	12.73%	10.06%	31.43%	42.10%
Density of *Pteronarcys californica* (#/m^2)	0	12	4	47
Percent EPT-excluding Baetidae	44.96%	25.23%	41.64%	72.84%
Density (mean #/m^2)	8,190	14,872	7,252	4,981
Percent Chironomidae	24.28%	53.06%	14.97%	3.74%
Percent Hydropsychidae	24.04%	35.21%	35.74%	24.48%
Percent Tolerant Taxa	22.92%	26.23%	24.07%	20.83%
Percent Intolerant Taxa	35.42%	36.07%	37.04%	43.75%

Table E3. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Denver Water study area (Fraser River and Vasquez Creek) during September 2019. MMI v4 scores indicating 'impairment' would be provided in red.

Metric	Station ID (Biotype 1)			
	FR-abvWPSD	VC-WP	FR-Rendezvous	FR-CR83
EPT Taxa	50.0	78.3	45.8	50.0
% Non-Insect Individuals	68.5	28.8	65.5	93.1
% EPT Individuals-no Baetidae	13.9	23.1	55.5	79.2
% Coleoptera Individuals	20.5	51.3	24.8	39.3
% Intolerant Taxa	78.1	93.0	69.4	71.0
% Increasers Mid-Elevation	75.2	45.1	80.1	93.0
Clinger Taxa	43.3	74.4	48.1	57.7
Predator/Shredder Taxa	64.3	78.6	50.0	78.6
MMI v4	**51.7**	**59.1**	**54.9**	**70.2**
	Auxiliary Metrics			
Diversity	3.44	3.75	3.18	3.71
HBI	5.20	3.62	2.96	2.79
TIV (Sediment Region 2)	5.72	5.53	6.62	5.02

Table E4. Additional metrics and comparative values for macroinvertebrate samples collected from the Denver Water study area (Fraser River and Vasquez Creek) in September 2019. All additional metric values are based on full count Hess samples.

	FR-abvWPSD	VC-WP	FR-Rendezvous	FR-CR83
Density (#/m^2)	2,736	2,690	5,663	4,698
Taxa Richness	27	34	32	42
EPT	16	22	15	19
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0
Percent EPT-excluding Baetidae	10.48%	16.43%	39.15%	57.51%
Percent Chironomidae	28.75%	16.57%	28.95%	19.97%
Evenness	0.731	0.751	0.621	0.688
DAT Index	16.4	22.0	17.9	24.8
Percent Hydropsychidae	28.57%	27.08%	1.99%	49.84%
Percent Tolerant Taxa	14.81%	11.76%	15.63%	14.29%
Percent Intolerant Taxa	55.56%	58.82%	43.75%	40.48%

Appendix F
Learning By Doing, Northern Water (WGFP) and Denver Water
Additional Metric Figures

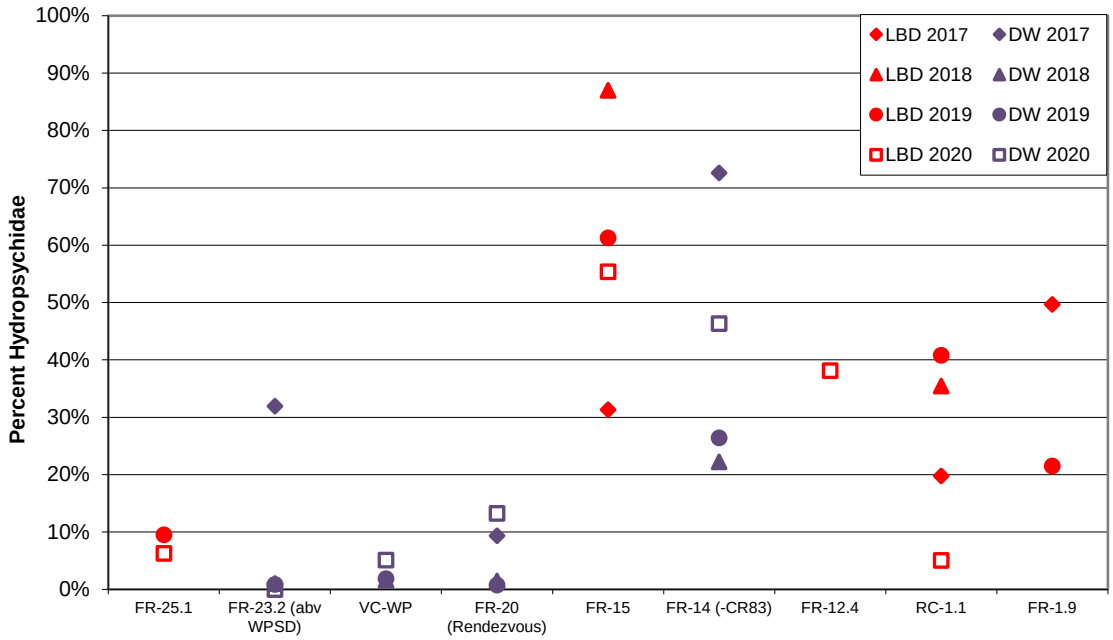

Figure F1. Percent Hydropsychidae values from study sites in the Fraser River study area from fall 2017 to fall 2020.

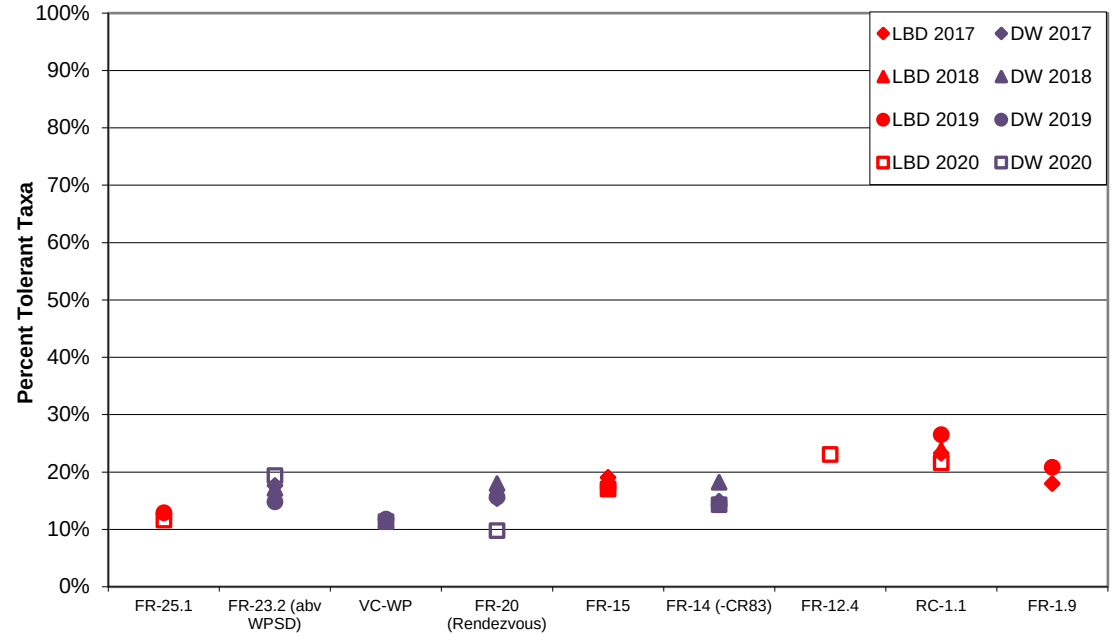

Figure F2. Percent Tolerant Taxa values from the Fraser River study area from fall 2017 to fall 2020.

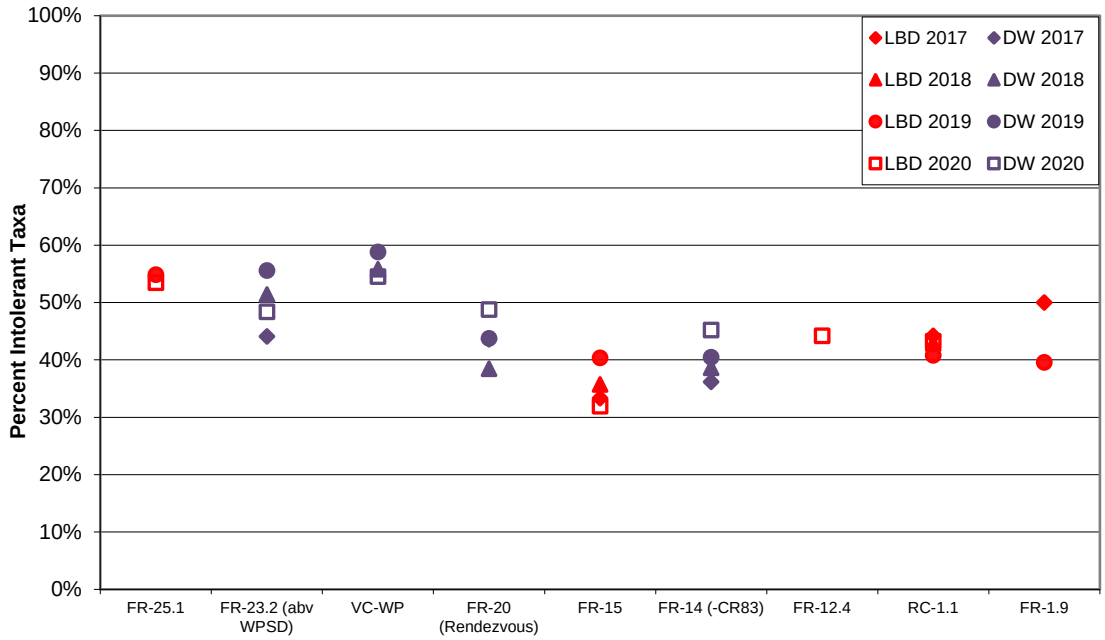

Figure F3. Percent Intolerant Taxa values from study sites in the Fraser River study area from fall 2017 to fall 2020.

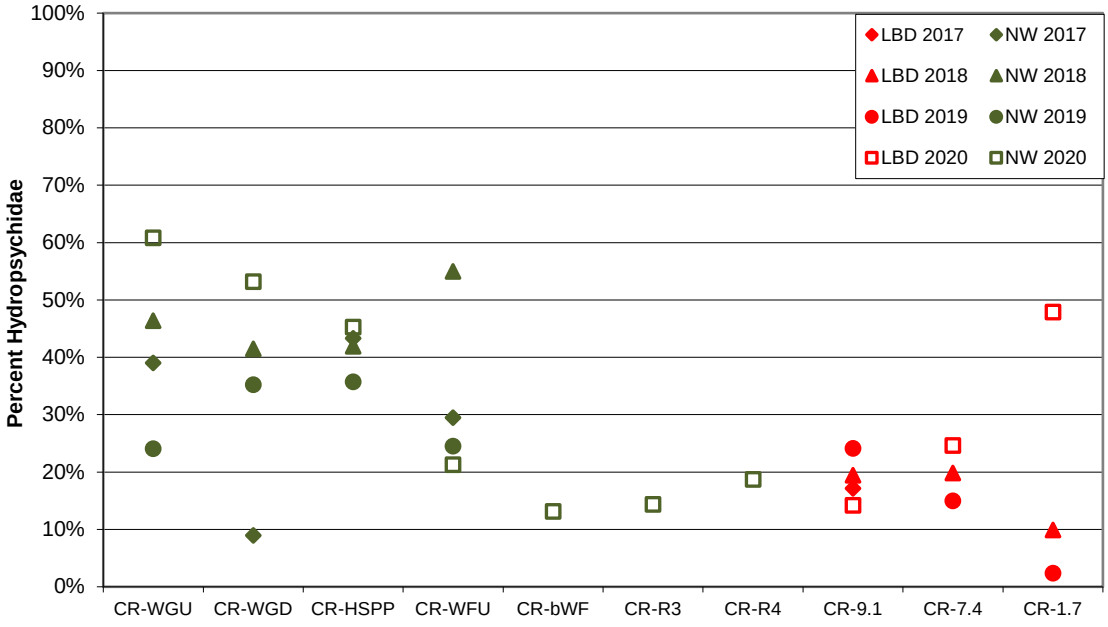

Figure F4. Percent Hydropsychidae values from study sites in the Colorado River study area from fall 2017 to fall 2020.

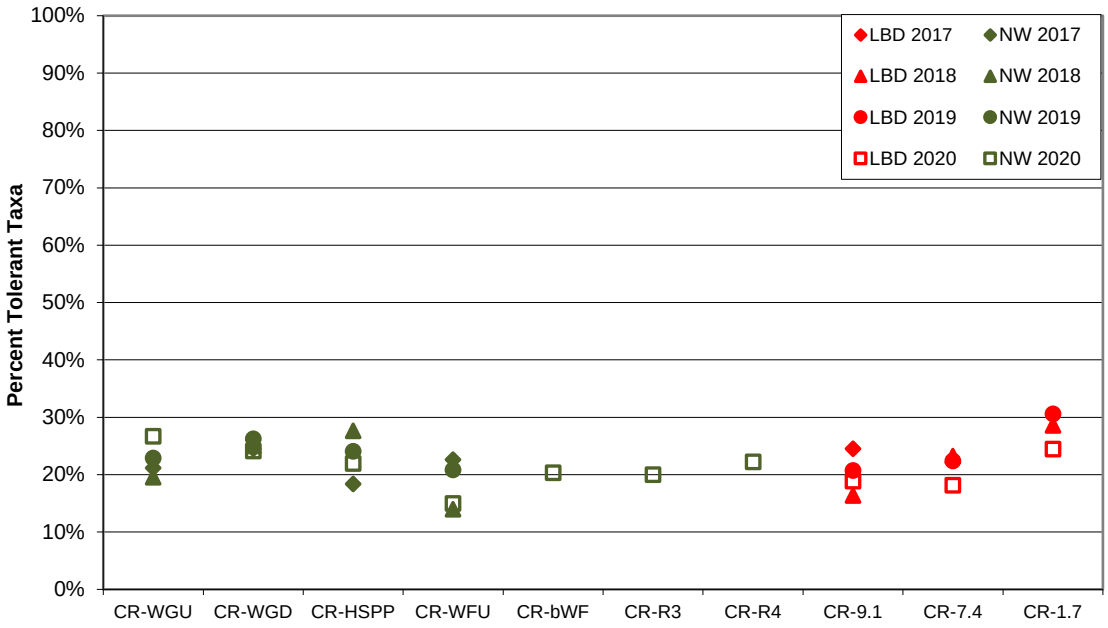

Figure F5. Percent Tolerant Taxa values from study sites in the Colorado River study area from fall 2017 to fall 2020.

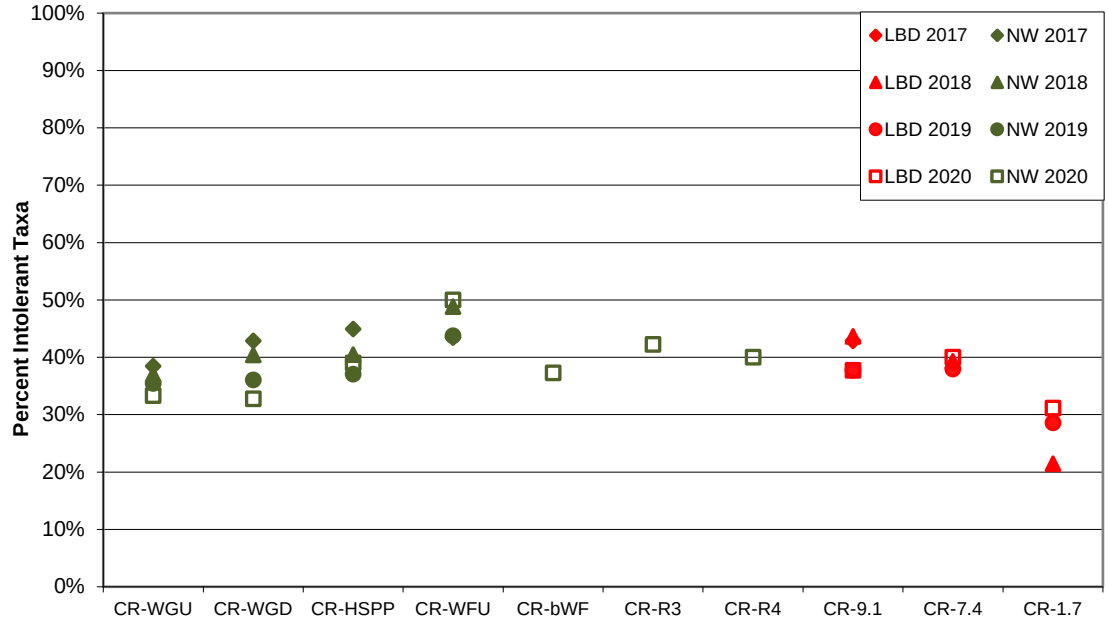

Figure F6. Percent Intolerant Taxa values from study sites in the Colorado River study area from fall 2017 to fall 2020.

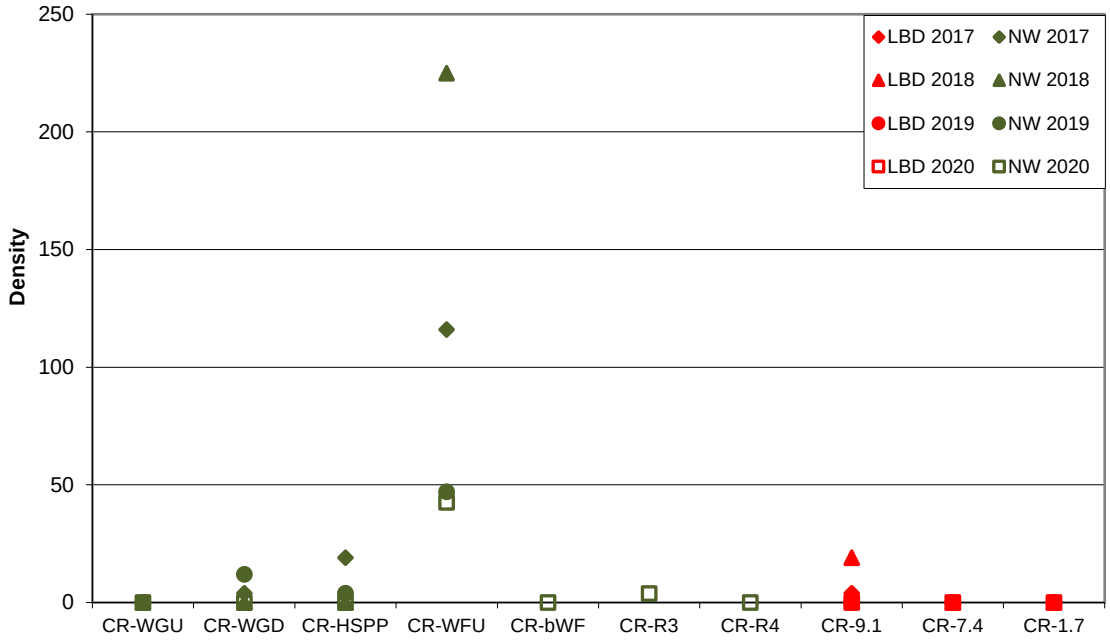

Figure F7. Density of *Pteronarcys californica* in the Colorado River study area from fall 2017 to fall 2020.

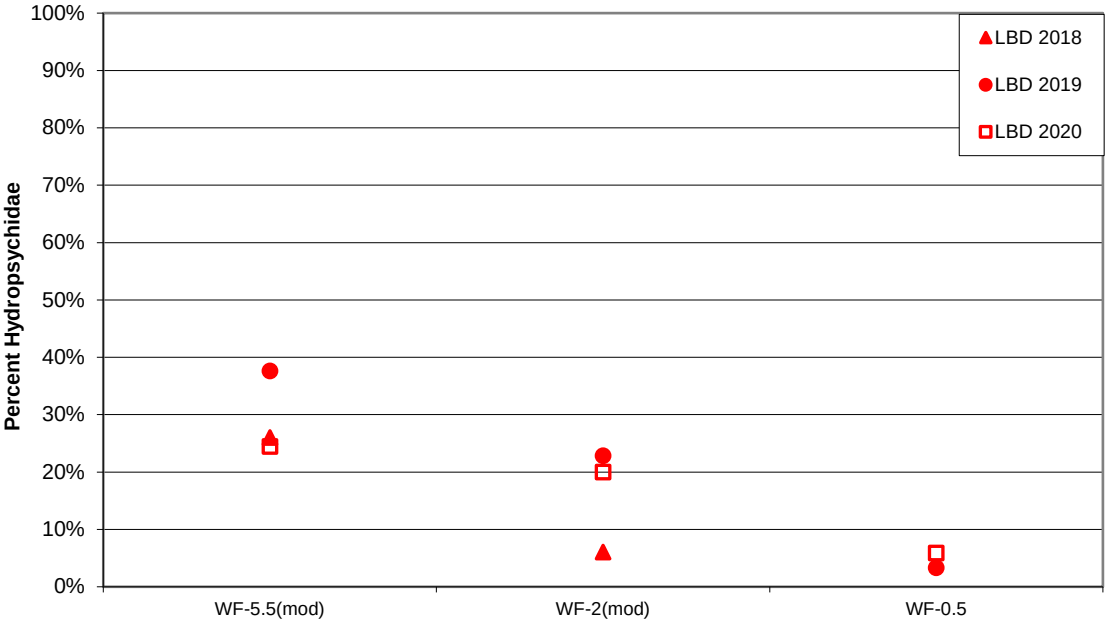

Figure F8. Percent Hydropsychidae values from study sites in the Williams Fork study area from fall 2018 to fall 2020.

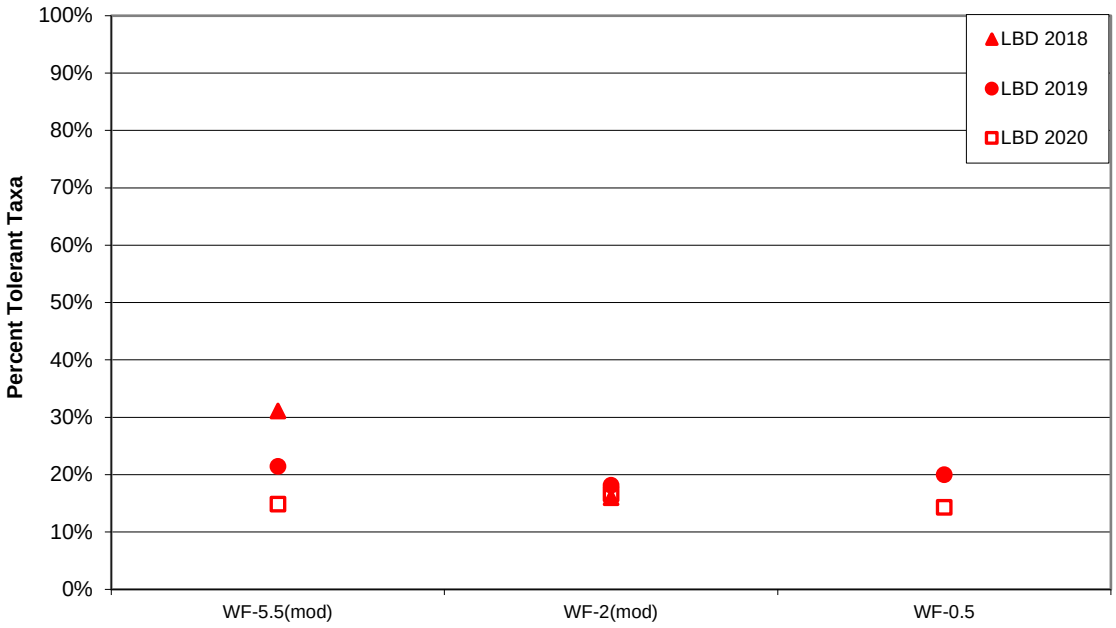

Figure F9. Percent Tolerant Taxa values from study sites in the Williams Fork study area from fall 2018 to fall 2020.

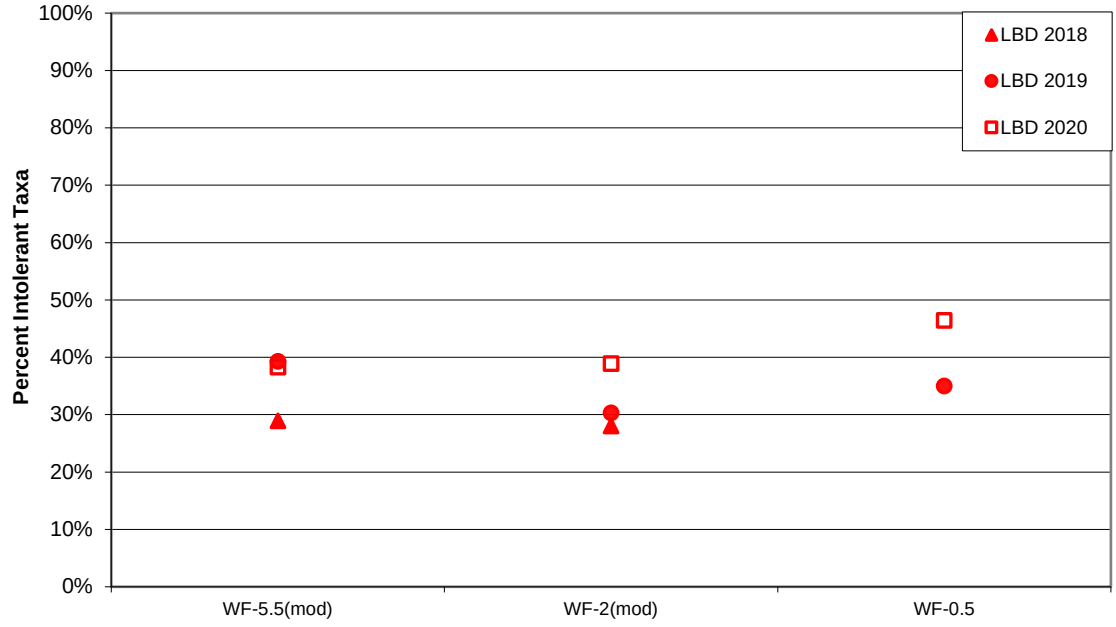

Figure F10. Percent Intolerant Taxa values from study sites in the Williams Fork study area from fall 2018 to fall 2020.

Timberline Aquatics, Inc.
4219 Table Mountain Place, Suite A
Fort Collins, Colorado 80526