Summary Report

Learning by Doing

Benthic Macroinvertebrate Biomonitoring

2021

Prepared for:

Grand County
Learning by Doing Stakeholder Group

Prepared by:

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Fort Collins, Colorado 80526

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Introduction

The protection and maintenance of the biological integrity in waterways is a fundamental responsibility of our society (Karr 1991). An important component of this responsibility includes the assessment of water quality. Biomonitoring of benthic macroinvertebrate communities is often an integral part of these water quality assessment protocols (Plafkin et al. 1989, Rosenberg and Resh 1993, 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 and defendable assessment of aquatic conditions that cannot be effectively accomplished 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).

Evolutionary and ecological pressures have resulted in benthic macroinvertebrate communities with specific requirements and responses to their dynamic environments (Poff et al. 2006, Lytle et al. 2008, Huryn and Wallace 2019). The various aquatic organisms in these communities, especially aquatic insects, exhibit well-documented sensitivities to a wide range of environmental disturbances or pollution, and community composition typically reflects the physical and chemical conditions that occur within a stream and associated watershed over time (Rosenberg and Resh 1993, Carlson et al. 2013, Mazor et al. 2019). Most macroinvertebrate taxa also have a relatively long aquatic life-stage and limited mobility (Williams and Feltmate 2017, Huryn and Wallace 2019). The sensitivity of each taxon in a community often varies with the type of disturbance, and responses to disturbance can exist at a structural and/or functional level. Inevitably, these specific attributes of benthic macroinvertebrates result in aquatic communities that respond to changes in environmental conditions. Therefore, benthic macroinvertebrate communities can be monitored using specific sampling methodologies in order to assess and report on 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 (Rosenberg and Resh 1993, Cummins et al. 2019, Mazor et al. 2019).

Long-term biomonitoring programs are essential when assessing continuous large-scale influences such as human population growth, urban development, changes in land-use practices, and even climate change (Rosenberg and Resh 1993, Likens and Lambert 1998, Voelz et al. 2005, Mazor et al. 2019). Changes in biological conditions can be best elucidated by monitoring benthic macroinvertebrate community structure (species/taxon) and function (trophic) at core sampling stations over time (Rosenberg and Resh 1993, Ward et al. 2002, Mazor et al. 2019). Due to the unique physical and behavioral attributes of benthic macroinvertebrates (especially aquatic insects), the spatial and temporal scale of biomonitoring studies can also be adjusted to address the influence of various stressors in stream segments of concern (Mazor et al. 2019). 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 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 roads, agricultural areas, urbanized areas, and portions of the watershed that were recently burned in a wildfire. 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 2021, 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. A comprehensive evaluation of spatial changes in benthic macroinvertebrate community health was made possible by the coordinated efforts provided by Learning By Doing (LBD), Northern Water, and Denver Water.

Learning By Doing Cooperative Effort Area (LBD CEA) Study Sites

The LBD CEA included a total of 11 study sites: three on the Fraser River, one on Ranch Creek, four 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 Union Pacific (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. At the downstream boundary of the Fraser River study area, site FR-1.9 was located approximately 2.0 km upstream from Windy Gap Reservoir. 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 (Figure 2).

The LBD Stakeholder Group was also responsible for biomonitoring studies conducted at three sampling locations on the Colorado River and four study sites on the Williams Fork. Sampling locations on the Colorado River included: site CR-9.1 (located upstream from the CR39 Bridge), site CR-7.4 (downstream from Troublesome Creek), and the most downstream study site in the Colorado River study area (site CR-1.7) which was established upstream from the confluence with the Blue River near the Town of Kremmling (Figure 3). The LBD CEA on the Williams Fork included two sites upstream from Williams Fork Reservoir and two sites downstream from the reservoir (Figure 4). Site WF-13.1 was located downstream from Henderson Mill, and site WF-5.5 was strategically positioned immediately upstream of the reservoir at a location that would assist in the evaluation of a recent habitat improvement project. Downstream from the Williams Fork Reservoir, site WF-2.0 was located approximately 1.5 km downstream from the impoundment and site WF-0.5 was positioned near the confluence with the Colorado River

(Figure 4). The two downstream sites were used to monitor influences from habitat improvement projects and potential impacts from reservoir operations. Several sites on the Fraser and Colorado rivers 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 LBD CEA.

Denver Water Study Sites

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 2021 (Table 1; Figure 1). All of these sites were selected in order to monitor aquatic macroinvertebrate communities at locations that historically produced low MMI v3 scores. Denver Water's 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) 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 the Town of Tabernash (FR-14) (Table 1).

Northern Water Study Sites

Study sites for the Northern Water Conservancy District (Northern Water) in 2021 included four sampling locations on the Colorado River (Table 1; Figure 3). These four sites have been routinely sampled as part of the Windy Gap Firming Project (WGFP) for the last six years. In 2021, Northern Water biomonitoring sampling locations included: site CR-31 (WGU) (immediately upstream from Windy Gap Reservoir), site CR-28.7 (WGD) (approximately 1.7 km downstream from Windy Gap Reservoir at River Mile 28.7), and sites CR-22.1 (HSPP) and CR-16.7 (WFU), both located farther downstream on the Colorado River (River Miles 22.1 and 16.7, respectively). These four study sites have been consistently monitored to assess the influence of operations associated with Windy Gap Reservoir on benthic macroinvertebrate communities.

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 stream segments and specific locations affected by 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 2021.

	Monitoring Project	Location	Latitude	Longitude
FR-25.1	Learning By Doing	Fraser River above Union Pacific 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
RC-1.1	Learning By Doing	Ranch Creek below Meadow Creek	39.99912	-105.82746
FR-1.9	Learning By Doing	Fraser River above Granby Sanitation District	40.08526	-105.95464
WF-13.1	Learning By Doing	Williams Fork below Henderson Mill	39.9092	-106.1029
WF-5.5	Learning By Doing	Williams Fork above Williams Fork Reservoir	39.994792	-106.17362
WF-2.0	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-31.0 (WGU)	Northern Water	Colorado River upstream of Windy Gap Reservoir	40.10045	-105.97248
CR-28.7 (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-16.7 (WFU)	Northern Water	Colorado River upstream of Williams Fork	40.04689	-106.14299
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

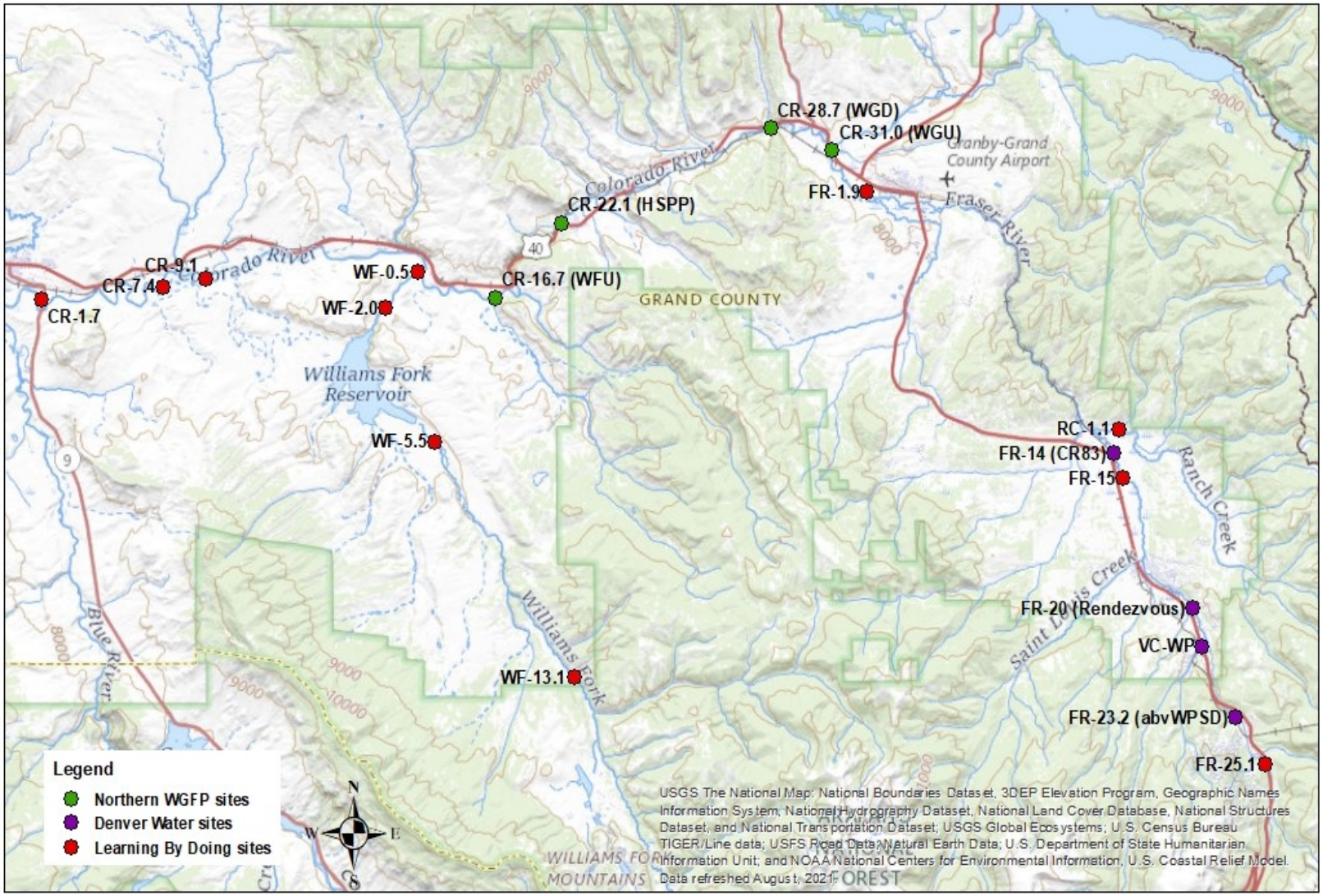

Figure 1. Map of study sites used for the Learning By Doing, Denver Water, and Northern Water biomonitoring studies in 2021.

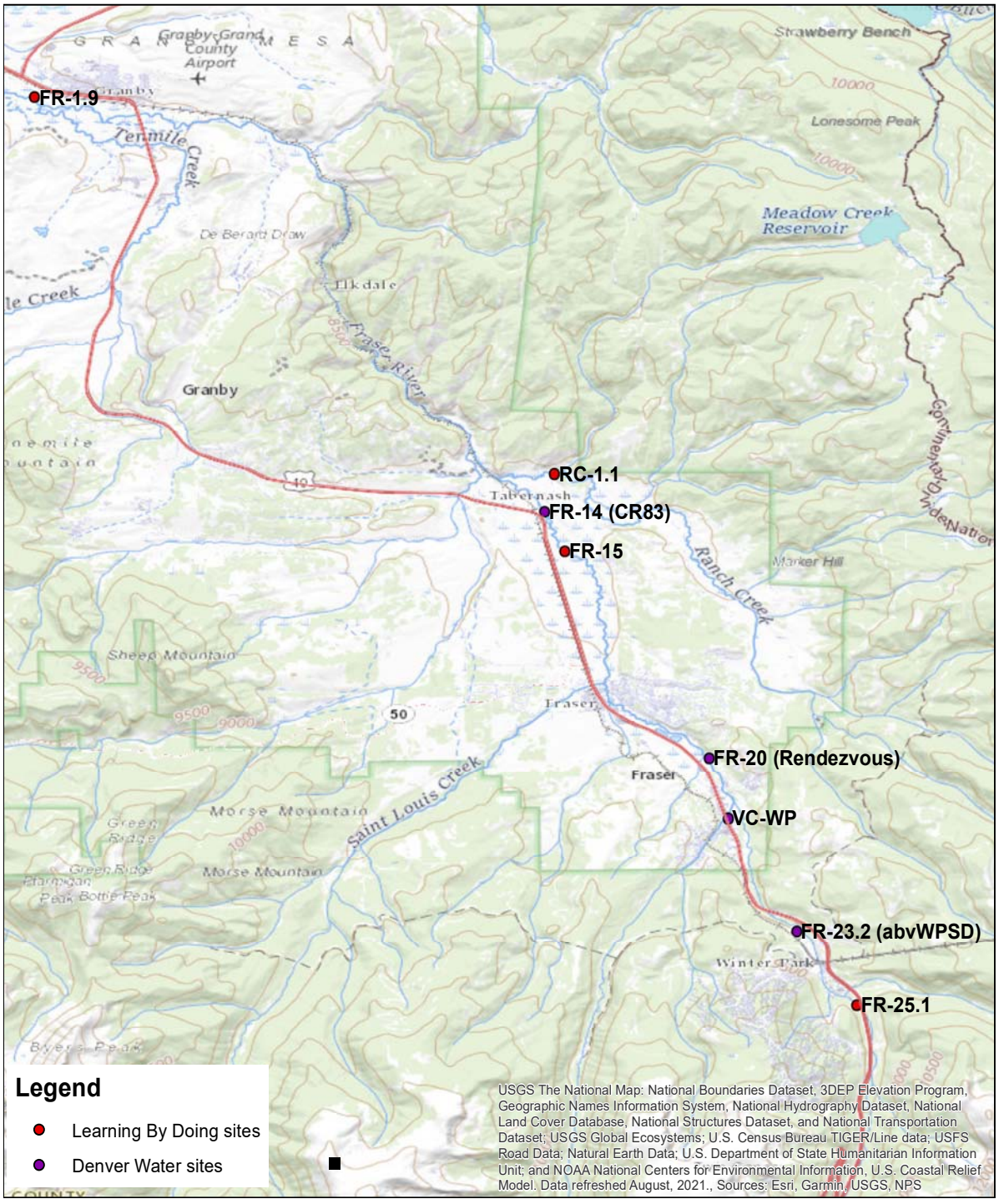

Figure 2. Map of study sites in the Fraser River Drainage used for the Learning By Doing and Denver Water biomonitoring studies in 2021.

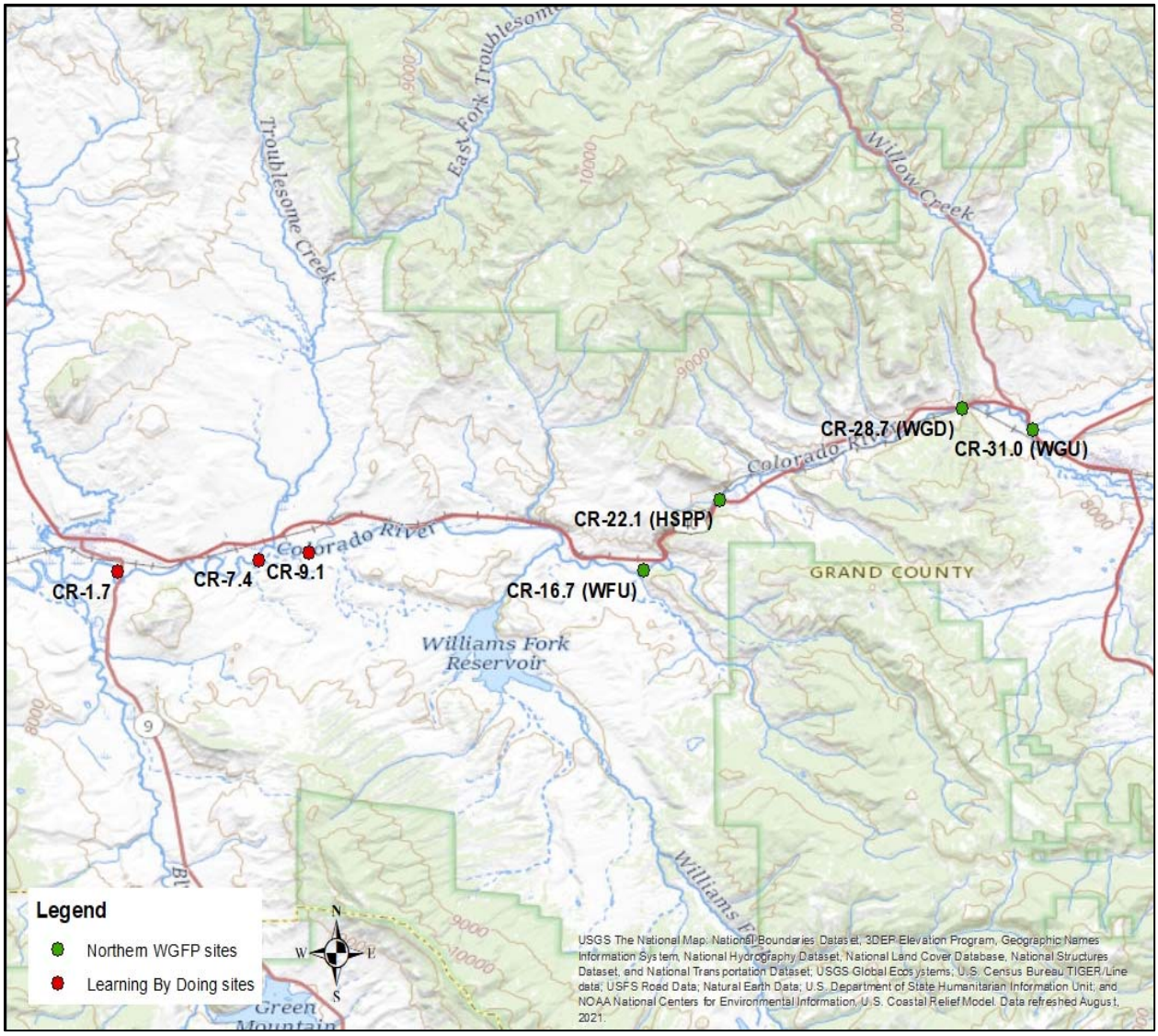

Figure 3. Map of study sites on the Colorado River used for the Learning By Doing and Northern Water biomonitoring studies in 2021.

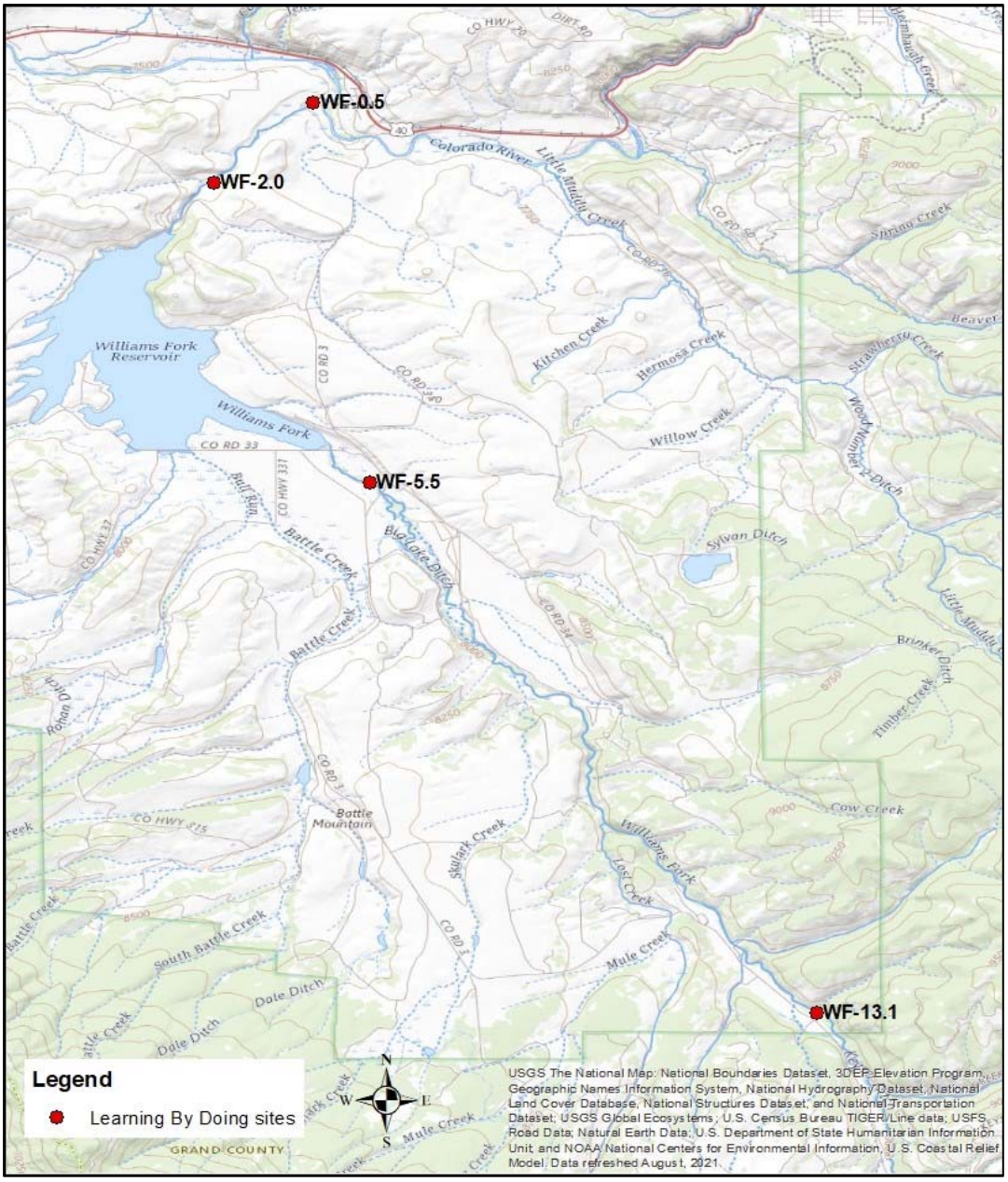

Figure 4. Map of study sites on the Williams Fork used for the Learning By Doing biomonitoring study in 2021.

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 benthic macroinvertebrate sampling ranged from 20-22 September in 2021. 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 2022). 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 to 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, 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 (the MMI v4). This most recent version of the MMI provides a single index score based on eight equally weighted metrics. The group of component metrics used in MMI v4 calculations depends on the sampling location and corresponding Biotype (Mountains, Transitional, or Plains). In the LBD CEA, site FR-25.1 was located in Biotype 2 (Mountains), while all other sampling locations were located within Biotype 1 (the Transition Zone), which includes lower mountain areas in the State of Colorado. Each of the individual metrics used in the analysis produces a score that is adjusted to a scale from 1 to 100 based on the range of metric scores found at "reference sites". In Biotype 1, these metrics include: EPT Taxa, % Non-Insect Individuals, % EPT Individuals-no Baetidae, % Coleoptera Individuals, % Intolerant Taxa, % Increaser Individuals (Mid-Elevation), Clinger Taxa,

and Predator/Shredder Taxa. In Biotype 2, these metrics include: EPT Taxa, % EPT Individuals-no Baetidae, Clinger Taxa, Total Taxa, Intolerant Taxa, % Increasers (Mountains), Predator Taxa, and % Scraper Individuals. A detailed description of these metrics and methods used to calculate MMI v4 scores can be found in the *Aquatic Life Use Attainment: Methodology to Determine Use Attainment for Rivers and Streams, Policy 10-1* and Appendix D in the *Section 303(d) Listing Methodology 2020 Listing Cycle* (CDPHE, 2017 and 2022). 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 (nutrient-enrichment), 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.

An additional means of determining 'attainment' or 'impairment' designations using the MMI v4 involves the rapid decline of scores in high scoring waters. When MMI v4 scores are available from multiple years for the same sampling location, and a large decline in scores occurs over the span of at least 12 months, a site will automatically be considered 'impaired' for aquatic life use. The requirements for an allowable decline in the MMI v4 for Biotypes 1 and 2 are as follows:

Biotype	High Scoring Water (MMI score)	Allowable MMI Decline
Transitional (Biotype 1)	>56	-22
Mountains (Biotype 2)	>62	-22

Additional metrics used in this study:

In addition to the MMI v4 and associated 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 study sites. This metric becomes more useful when paired with other individual metrics.

Taxa Richness (Total Taxa): The Taxa Richness metric was reported as the total number of identifiable taxa collected from each sampling location. Taxa Richness 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). Taxa Richness 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 Taxa 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 study site. *Pteronarcys californica* is a large species of stonefly that requires specific aquatic conditions over a relatively long period of time to complete its four-year 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.

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: Members of the family Chironomidae 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 relatively short life-cycles, which also 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. Six taxa representing the family Hydropsychidae (*Arctopsyche grandis*, *Ceratopsyche* (=*Hydropsyche*) *morosa* group, *Cheumatopsyche* sp., *Hydropsyche* sp., *Hydropsyche cockerelli*, and *Hydropsyche oslari*) were found in this study area during 2021.

Percent Tolerant Taxa: The Percent Tolerant Taxa metric value was 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 was 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. When reviewing the proportions of various feeding groups, some representation from each group usually indicates healthy aquatic conditions; however, it is common for certain groups (such as 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 (Delong and Brusven 1998, Ward et al. 2002).

Results and Discussion

Benthic Macroinvertebrate Sampling – Fall 2021

Biomonitoring studies in the Upper Colorado River Basin were conducted by Grand County Learning By Doing (LBD), Denver Water, and Northern Water at a total of 19 sampling locations during September of 2021. Data and results from all three projects were shared to provide a more thorough evaluation of macroinvertebrate community structure and function in the Fraser River, Vasquez Creek, Ranch Creek, Colorado River, and Williams Fork. After samples were collected using a quantitative (Hess) sampling methodology, they were transported to the lab at Timberline Aquatics, Inc., where 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 community structure and function within 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 5-20). Functional Feeding Group analysis was used to provide an evaluation of ecological function as opposed to taxonomic structure (Tables 11-13; Figures 21-23). In general, results from the fall of 2021 demonstrated considerable variability in the overall health of benthic macroinvertebrate communities throughout the study area. Detectable changes in macroinvertebrate community structure and function were often dependent on the stream or stream-reach, and the overall health of benthic macroinvertebrate communities appeared to be a reflection of conditions in the associated watershed that either altered, improved, or had little influence on the site-specific aquatic conditions and habitat.

Results from the MMI v4

Fraser River Study Area

The assessment of aquatic life in the Fraser River study area benefited from the additional data and results that were obtained by combining the LBD and Denver Water biomonitoring studies. These two studies included a total of six sampling locations on the Fraser River and two sites on select tributaries during the fall of 2021 (Table 2). Study sites on the Fraser River were distributed between two Biotypes in the State of Colorado (Biotypes 1 and 2), and each Biotype required a different set of 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 all located in the "transitional zone" (Biotype 1) between the mountains and plains (CDPHE 2017). The MMI v4 was used to provide an overall assessment of benthic macroinvertebrate community health and to determine the status (attainment vs. impairment) of aquatic life use (CDPHE 2022).

Despite evidence of variability among MMI v4 scores and individual (component) metric scores, all sites in the Fraser River study area produced MMI v4 scores that were above the 'attainment' threshold for their respective biotypes (Tables 2-3; Figure 5). On the Fraser River, MMI v4 scores ranged from a low of 47.0 at site FR-23.2 (abvWPSD) to a high of 90.5 at site FR-1.9 (Table 2). These scores suggested that the macroinvertebrate community at site FR-23.2 was the most stressed in this study area; however, consistent improvements in macroinvertebrate community structure occurred on the Fraser River in a downstream direction (Figure 5). Much of the improvement detected by the MMI v4 in the downstream portion of the study area appeared to be associated with an increase in sensitive taxa (EPT Taxa) and specialized taxa (Clinger Taxa). The MMI v4 scores from the fall of 2021 generally followed the pattern that was produced by mean MMI v4 scores from previous sampling events which detected gradual improvements in community structure downstream from site FR-23.2 (Figure 5).

On Vasquez Creek and Ranch Creek (tributaries of the Fraser River), the MMI v4 generated scores of 67.7 and 74.4 (respectively), indicating that macroinvertebrate communities were robust and relatively healthy at both sampling locations (Table 2). The MMI v4 and auxiliary metrics (Diversity and HBI) indicated that the study sites on these tributaries were in 'attainment' for aquatic life use and scores from 2021 were similar to the mean scores from previous sampling events (Figures 5-7).

An evaluation of auxiliary metric values from the fall of 2021 confirmed that all sites in the Fraser River study area supported benthic macroinvertebrate communities with adequate community balance (based on the Diversity metric) and relatively low proportions of nutrient-tolerant individuals (based on HBI values) (Figures 6-7). Similar to the MMI v4, HBI values tended to improve in the downstream portion of the study area; however, both auxiliary metrics generated values that remained within a range indicating relatively healthy aquatic conditions. In general, results from the MMI v4 and associated metrics indicated that all sites in the Fraser River study area were in 'attainment' for aquatic life use despite some variability in metric scores that resulted in a pattern of minor stress (at site FR-23.2) followed by recovery.

Table 2. Component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Fraser River study area during September of 2021. 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)**	**RC-1.1**	**FR-1.9**
EPT Taxa	65.3	58.3	78.3	70.8	66.7	79.2	70.8	100.0
% EPT, no Baetidae	38.4	13.4	29.2	16.1	80.3	81.2	100.0	63.8
Clinger Taxa	70.0	33.7	84.3	67.3	67.3	86.5	67.3	100.0
Total Taxa	64.3	--	--	--	--	--	--	--
Intolerant Taxa	85.7	--	--	--	--	--	--	--
% Increasers, Mountains	41.2	--	--	--	--	--	--	--
Predator Taxa	69.2	--	--	--	--	--	--	--
% Scraper Individuals	39.3	--	--	--	--	--	--	--
% Non-Insect Individuals	--	53.1	74.9	71.9	92.5	97.6	93.4	95.2
% Coleoptera Individuals	--	21.5	47.0	30.6	12.8	59.6	27.7	95.9
% Intolerant Taxa	--	75.7	88.9	87.1	82.0	72.3	79.1	100.0
% Increasers, Mid-Elev.	--	48.8	67.8	89.9	91.7	100.0	100.0	97.6
Predator/Shredder Taxa	--	71.4	71.4	78.6	64.3	71.4	57.1	71.4
MMI v4	**59.2**	**47.0**	**67.7**	**64.0**	**69.7**	**81.0**	**74.4**	**90.5**
	Auxiliary Metrics							
Diversity	3.23	3.34	3.91	3.31	3.65	3.83	3.75	3.63
HBI	4.01	4.84	4.22	3.74	2.27	2.80	2.25	3.05
Sediment Region	SR1	SR2						
TIV	4.54	6.09	6.07	6.22	4.58	4.80	4.47	--

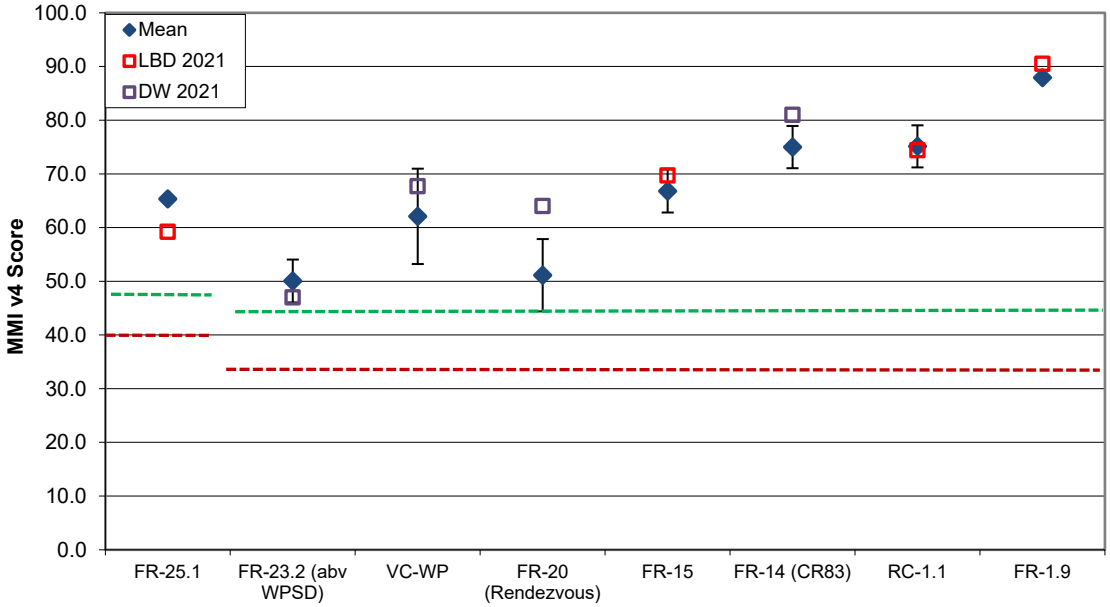

Figure 5. MMI v4 scores for the Fraser River study area from the fall of 2021 and mean MMI scores (±1 standard deviation) from previous sampling events. All scores are based on the MMI v4 subsampling process. The green line indicates the 'attainment' threshold and the red line indicates the 'impairment' threshold for Biotypes 2 and 1. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

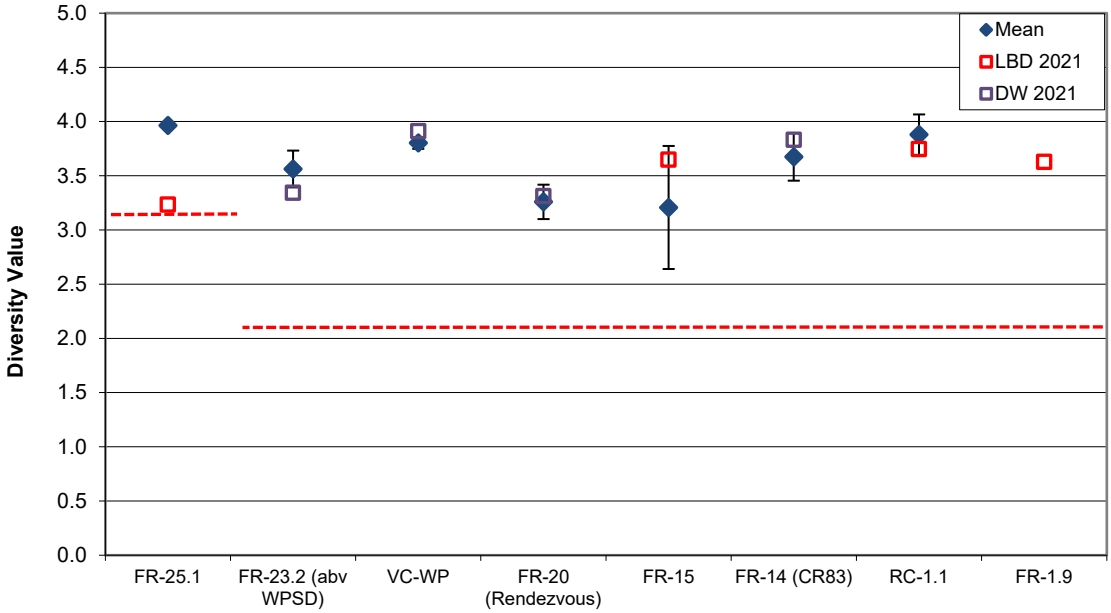

Figure 6. Diversity values in the Fraser River study area from the fall of 2021 and mean Diversity values (±1 standard deviation) from previous sampling events. The red line indicates the 'impairment' threshold for Biotypes 2 and 1. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

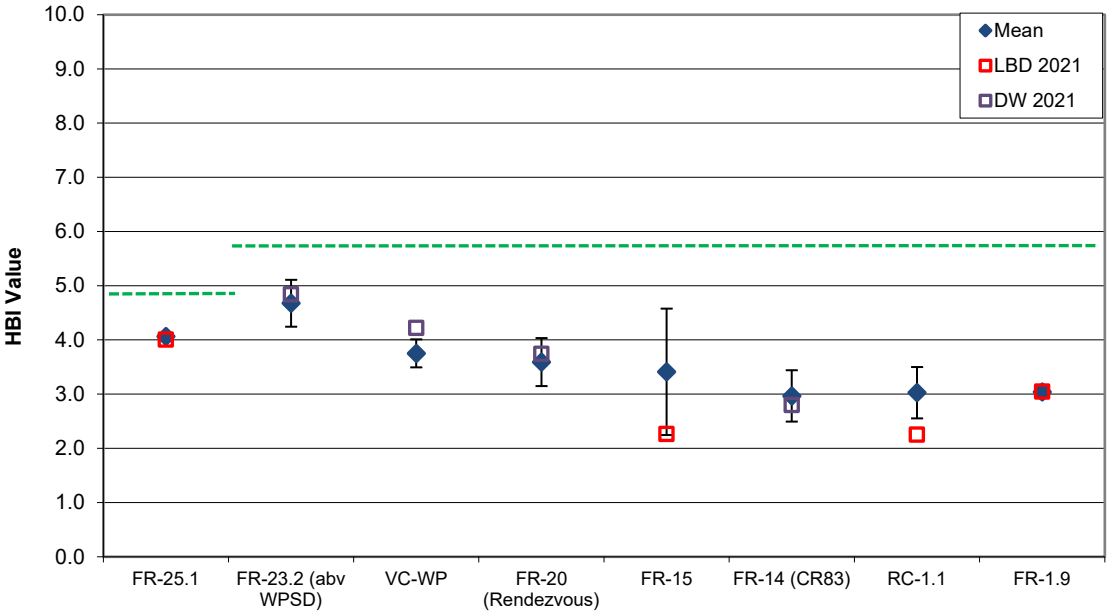

Figure 7. HBI values in the Fraser River study area from the fall of 2021 and mean HBI values (±1 standard deviation) from previous sampling events. Exceeding the green line indicates 'impairment' for Biotypes 2 and 1. Results from Denver Water (DW) sites are provided in purple and Learning By Doing (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 2021. DW = Denver Water; LBD = Learning By Doing.

Aquatic Life Use 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
RC-1.1	**LBD**	Attainment
FR-1.9	**LBD**	Attainment

Colorado River Study Area

In the fall of 2021, the study area on the Colorado River consisted of three sampling locations that were used as part of the LBD biomonitoring program and four study sites sampled as part of the Northern Water (WGFP) biomonitoring study (Table 1; Figure 3). The health of benthic macroinvertebrate communities in the Colorado River was assessed using the MMI v4 in a stream reach that spanned approximately 30 river-miles (upstream from Windy Gap Reservoir down to the confluence with the Blue River).

In 2021, MMI v4 scores varied considerably on the Colorado River, with scores ranging from 77.7 at site CR-28.7 (WGD) to 23.4 at site CR-1.7 (Table 4). Three of the seven sampling locations generated MMI v4 scores indicating 'impairment', while four of the study sites were in 'attainment' for aquatic life use (Tables 4-5; Figure 8). The MMI v4 score for site CR-1.7 (23.4) was below the 'impairment' threshold, which resulted in an 'impairment' designation for this location. Two other sites with 'impairment' designations (CR-31.0 and CR-9.1) produced MMI v4 scores that were in the 'Grey Zone' (the range of scores between the 'attainment' and 'impairment' thresholds). Typically, MMI v4 scores that fall into the 'Grey Zone' require the use of auxiliary metrics to determine an aquatic life use designation; however, both of these sites were considered 'impaired' due to a rapid decline (>22 points) in MMI v4 scores. The Northern Water study site, CR-31.0 (WGU), generated a relatively high MMI v4 score of 60.6 in 2019. In 2020, the score for this site declined to 37.2, which represented a 23.4 point drop in one year. Based on the guidelines in the *Section 303(d) Listing Methodology* (CDPHE 2022), this site will need to produce an MMI v4 score of 48.9 (an improvement at least half of the original decline) to be considered in 'attainment' for aquatic life use. In 2021, the MMI v4 score for site CR-31.0 (36.3) actually declined slightly compared to the score from 2020, and the HBI (auxiliary metric) value (6.08) exceeded the threshold (5.8) that indicates 'impairment' in Biotype 1 (Table 4). For these reasons site CR-31.0 continued to be designated as 'impaired' in 2021. Farther downstream, site CR-9.1 (an LBD CEA study site) also received an 'impairment' designation despite generating an MMI v4 score of 42.8 (Table 4). Results from the auxiliary metrics suggested that this site would typically be in 'attainment' for aquatic life use; however, similar to site CR-31.0, the 'impairment' designation for site CR-9.1 was based on a rapid decline in MMI v4 scores (from 68.6 in 2020 to 42.8 in 2021). In the future, site CR-9.1 will need to produce an MMI v4 score of at least 55.7 to be considered in 'attainment' for aquatic life use.

The remaining four study sites on the Colorado River all produced MMI v4 scores that exceeded the 'attainment' threshold. A comparison of recent MMI v4 scores (and auxiliary metric scores) to the mean values from previous sampling events showed evidence of some increasing stress at most sites in 2021 (Table 4; Figures 8-10). All study sites (with the exception of site CR-28.7) experienced at least a slight decline in MMI v4 scores, and the auxiliary metrics (Diversity and HBI) detected a recent increase in stress at site CR-31.0 and most of the downstream sampling locations. Overall, the component metrics suggested that much of the stress in the Colorado River study area could be attributed to an increase in the proportion of tolerant individuals (Table 4).

Table 4. Component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Colorado River study area during September of 2021. All metric scores are based on the MMI v4 subsampling process and all sites are located within Biotype 1.

Metric	Station ID						
Monitoring Project	**Northern Water (NW)**				**LBD**		
	CR-31.0	**CR-28.7**	**CR-22.1**	**CR-16.7**	**CR-9.1**	**CR-7.4**	**CR-1.7**
EPT Taxa	75.0	83.3	79.2	95.8	67.8	100.0	23.7
% Non-Insect Individuals	0.0	92.7	88.3	76.8	10.1	85.9	15.4
% EPT, no Baetidae	23.4	100.0	76.2	65.7	39.1	47.2	5.5
% Coleoptera Individuals	4.8	11.5	21.8	22.9	22.2	46.7	70.1
% Intolerant Taxa	64.7	89.4	56.1	76.0	74.9	68.5	16.1
% Increasers, Mid-Elev.	0.0	88.9	82.5	75.9	0.0	82.0	0.0
Clinger Taxa	72.1	91.3	86.5	100.0	77.9	84.4	21.0
Predator/Shredder Taxa	50.0	64.3	64.3	78.6	50.0	78.6	35.7
MMI v4	**36.3**	**77.7**	**69.3**	**74.0**	**42.8**	**74.2**	**23.4**
	Auxiliary Metrics						
Diversity	3.23	3.59	3.78	4.06	3.96	3.91	2.77
HBI	6.08	2.62	3.16	3.45	4.02	4.29	6.02
Sediment Region		SR2		SR2			
TIV	--	4.75	--	4.55	--	--	--

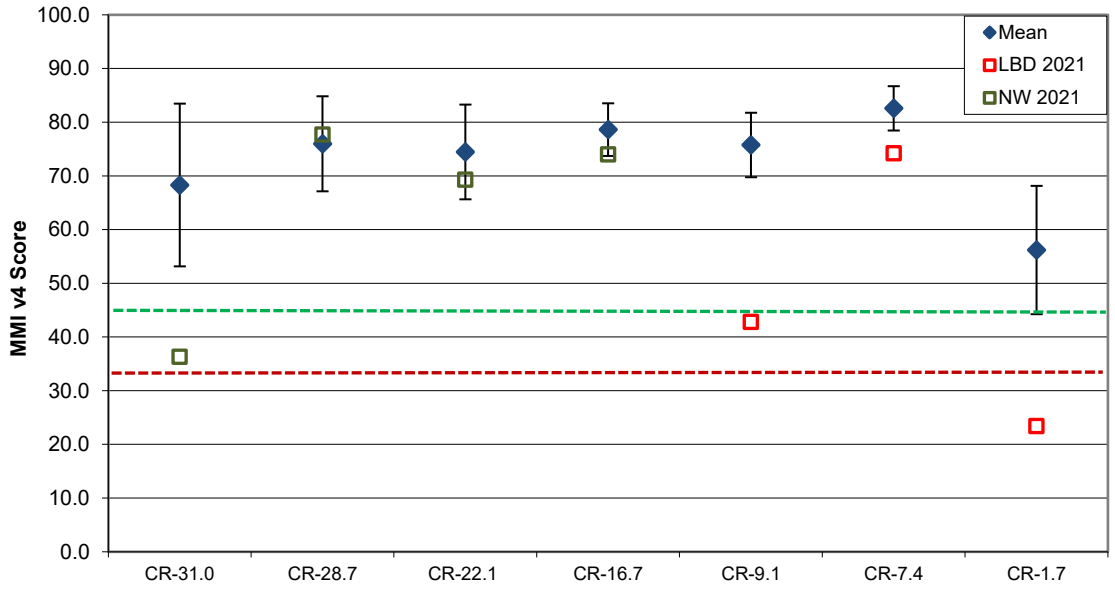

Figure 8. MMI v4 scores for the Colorado River study area from the fall of 2021 and mean MMI v4 scores (±1 standard deviation) from previous sampling events. All scores are based on the MMI v4 subsampling process. The green line indicates the 'attainment' threshold and the red line indicates the 'impairment' threshold for Biotype 1. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

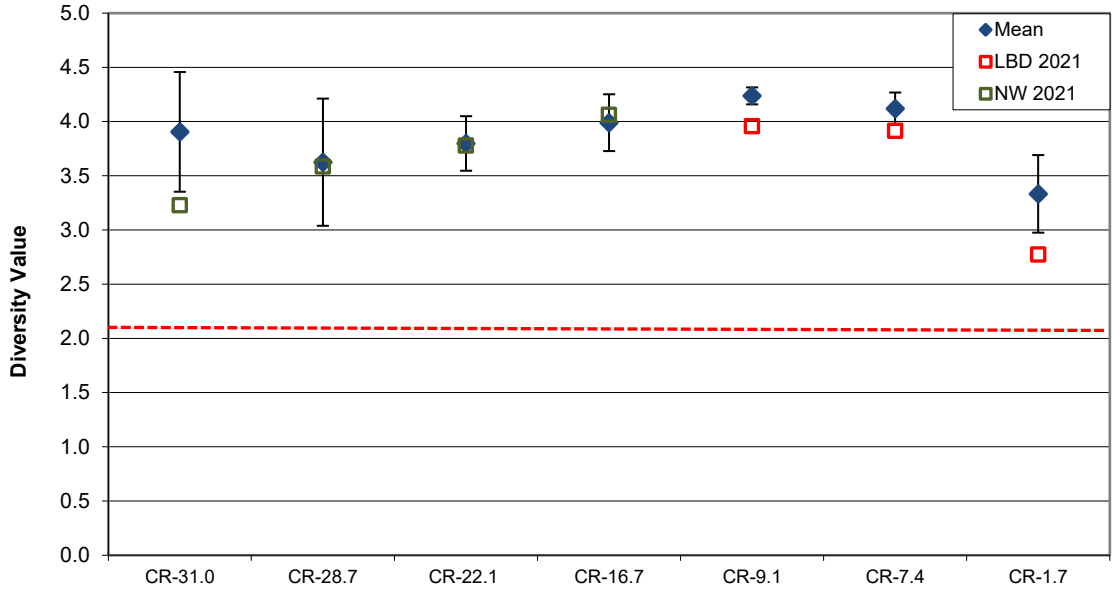

Figure 9. Diversity values for the Colorado River study area from the fall of 2021 and mean Diversity values (±1 standard deviation) from previous sampling events. The red line indicates the 'impairment' threshold for Biotype 1. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

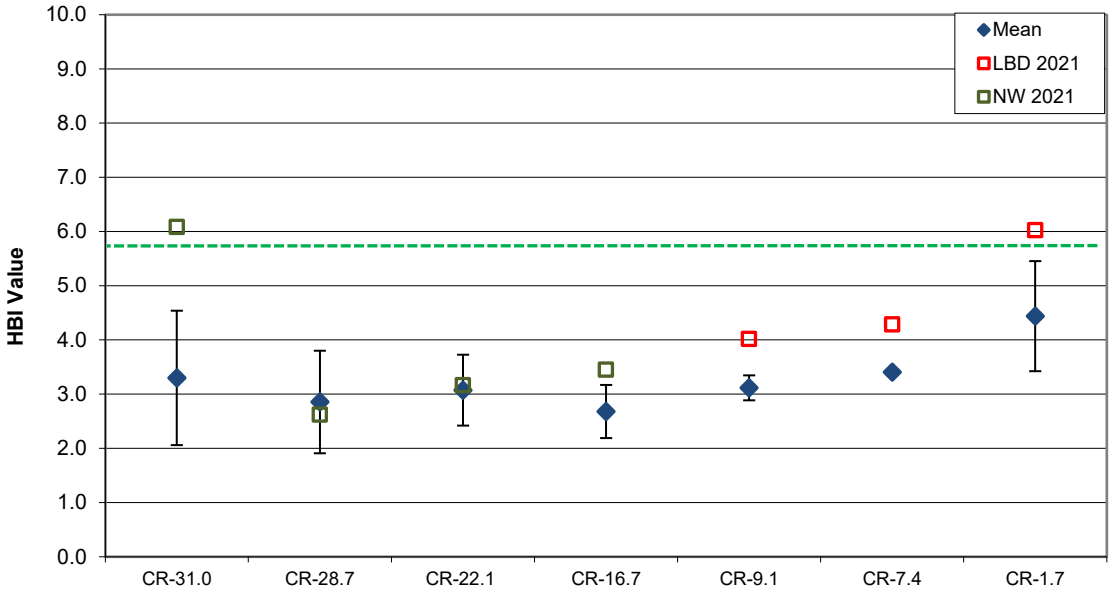

Figure 10. HBI values for the Colorado River study area from the fall of 2021 and mean HBI values (±1 standard deviation) from previous sampling events. Exceeding the green line indicates 'impairment' for Biotype 1. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are 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 2021. NW = Northern Water; LBD = Learning By Doing.

Aquatic Life Use Designations		
Site	**Project**	Quantitative (Hess) Samples
CR-31.0	**NW**	Impairment
CR-28.7	**NW**	Attainment
CR-22.1	**NW**	Attainment
CR-16.7	**NW**	Attainment
CR-9.1	**LBD**	Impairment
CR-7.4	**LBD**	Attainment
CR-1.7	**LBD**	Impairment

Williams Fork Study Area

A total of four study sites on the Williams Fork were sampled as part of the LBD biomonitoring study in the fall of 2021. These sampling locations were selected to assess the potential influences on aquatic life that included: operations of Williams Fork Reservoir, runoff from a portion of the watershed that was burned in a major wildfire, and recent habitat restoration work (both upstream and downstream from the reservoir). Overall, the MMI v4 and auxiliary metrics indicated that all four sites supported adequate benthic macroinvertebrate community structure and function; however, there was a noticeable decline in most community parameters downstream from the reservoir that was likely caused by alterations to the natural temperature and flow regime.

In the fall of 2021, the MMI v4 and auxiliary metrics generated scores resulting in 'attainment' designations for all four sampling locations in the Williams Fork study area (Tables 6 and 7; Figure 11). Scores were highest at the two sites located upstream from Williams Fork Reservoir, with site WF-13.1 producing the highest MMI v4 score (77.3) in the study area. Downstream from site WF-13.1 (and immediately upstream from Williams Fork Reservoir), site WF-5.5 also generated a relatively high MMI v4 score (71.2) which was similar to the mean value from the last three years (2018-2020) of biomonitoring (Figure 11). Downstream from Williams Fork Reservoir, sites WF-2.0 and WF-0.5 produced MMI v4 scores (44.9 and 52.7, respectively) that were above the 'attainment' threshold, but these scores appeared to be influenced by low levels of stress (Table 6; Figure 11). Most of the negative impacts downstream from the impoundment were detected by component metrics that measured the presence of sensitive and specialized taxa (EPT Taxa, Clinger Taxa, and Predator/Shredder Taxa) or the relative abundance of tolerant taxa (Percent Non-Insect Individuals) (Table 6). Both of the auxiliary metrics (Diversity and HBI) were also consistent in detecting evidence of minor stress at site WF-2.0 in the fall of 2021 (Table 6; Figures 12-13).

It is likely that alterations to the natural flow and temperature regime imposed by reservoir operations were responsible (at least in part) for a decline in the richness of sensitive and specialized taxa downstream from Williams Fork 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), and these impacts are often alleviated with distance downstream from the impoundment. The fact that sites WF-2.0 and WF-0.5 were both able to generate MMI v4 scores above the 'attainment' threshold was somewhat extraordinary, given their close proximity to the reservoir. Habitat enhancements in this segment of the Williams Fork could eventually improve the structure of aquatic communities during future sampling events.

In summary, results provided by the MMI v4 (and associated analysis tools) indicated that all sampling locations on the Fraser River and Williams Fork supported relatively healthy and stable benthic macroinvertebrate communities, while three of the seven study sites on the Colorado River showed signs of recent 'impairment' during the fall of 2021

(Tables 2, 4, and 6). All sampling locations on the Fraser River and Williams Fork produced MMI v4 scores that were above the 'attainment' threshold; however, variability in these scores suggested that there continued to be areas of stress and recovery within each drainage. When MMI v4 scores from the Fraser River and Williams Fork were compared with results from previous sampling events, the recent MMI v4 scores generally suggested that aquatic conditions had remained stable (or improved) at most of the study sites (Figures 5 and 11; Appendix D: Tables D1-D4). In contrast, MMI v4 scores from the Colorado River study area exhibited considerable variability in the fall of 2021 (Figure 8). All sites except CR-28.7 showed evidence of slight to moderate declines in benthic macroinvertebrate community health, and sites CR-31.0, CR-9.1 and CR-1.7 were determined to be 'impaired' for aquatic life use (Tables 4-5; Figure 8). A review of individual component metrics suggested that much of this decline in MMI v4 scores could be attributed to an increase in the proportion of tolerant individuals and a decrease in the relative abundance of sensitive individuals. This could be a response to a variety of stressors including nutrient-enrichment, runoff from areas impacted by recent fires, elevated water temperatures, and excessive algal growth. At this time, the exact source (or sources) of stress remains unknown; however, the recent decline in the MMI v4 scores at several locations on the Colorado River should be a reason for concern, and continued biomonitoring efforts will be necessary to help determine the persistence of these results.

Table 6. Component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Williams Fork study area during September of 2021. All metric scores are based on the MMI v4 subsampling process and all sites are located within Biotype 1.

Metric	**Station ID**			
Monitoring Project	**Learning By Doing (LBD)**			
	WF-13.1	**WF-5.5**	**WF-2.0**	**WF-0.5**
EPT Taxa	70.8	58.3	33.3	53.5
% EPT, no Baetidae	88.4	87.1	77.8	70.5
Clinger Taxa	79.7	58.4	3.4	17.9
% Non-Insect Individuals	28.5	96.2	0.8	0.0
% Coleoptera Individuals	100.0	60.9	77.7	85.5
% Intolerant Taxa	100.0	84.4	92.3	91.3
% Increasers, Mid-Elev.	72.1	52.9	38.5	45.4
Predator/Shredder Taxa	78.6	71.4	35.7	57.1
MMI v4	**77.3**	**71.2**	**44.9**	**52.7**
	Auxiliary Metrics			
Diversity	3.39	3.18	2.40	3.20
HBI	2.28	3.76	4.31	4.19
Sediment Region	SR2			
TIV	4.54	--	--	--

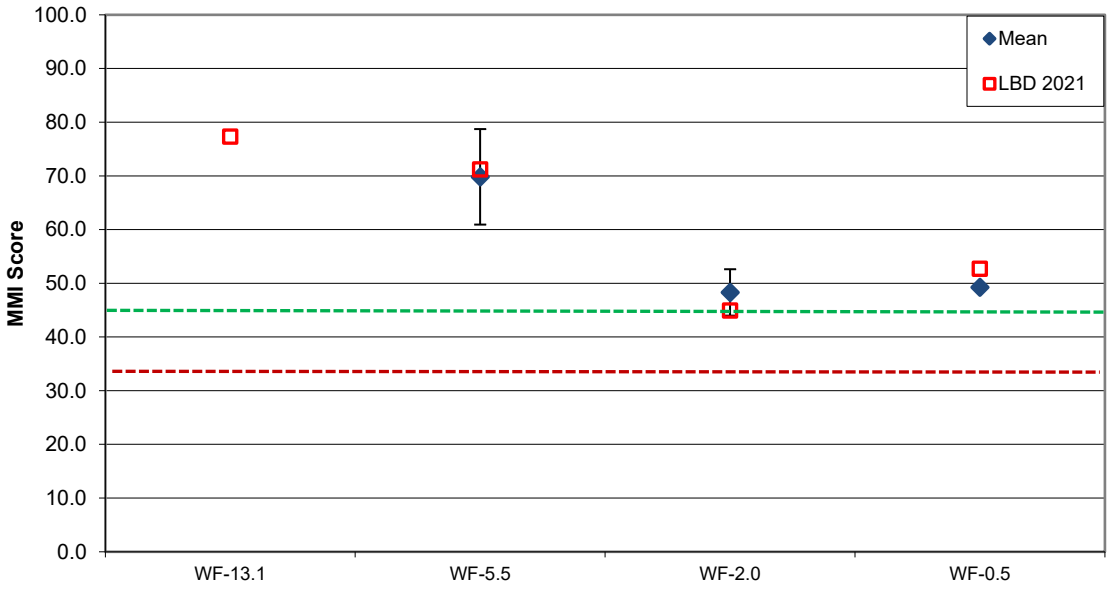

Figure 11. MMI v4 scores for the Williams Fork study area from the fall of 2021 and mean MMI scores (±1 standard deviation) from previous sampling events. All scores are based on the MMI v4 subsampling process. The green line indicates the 'attainment' threshold and the red line indicates the 'impairment' threshold for Biotype 1.

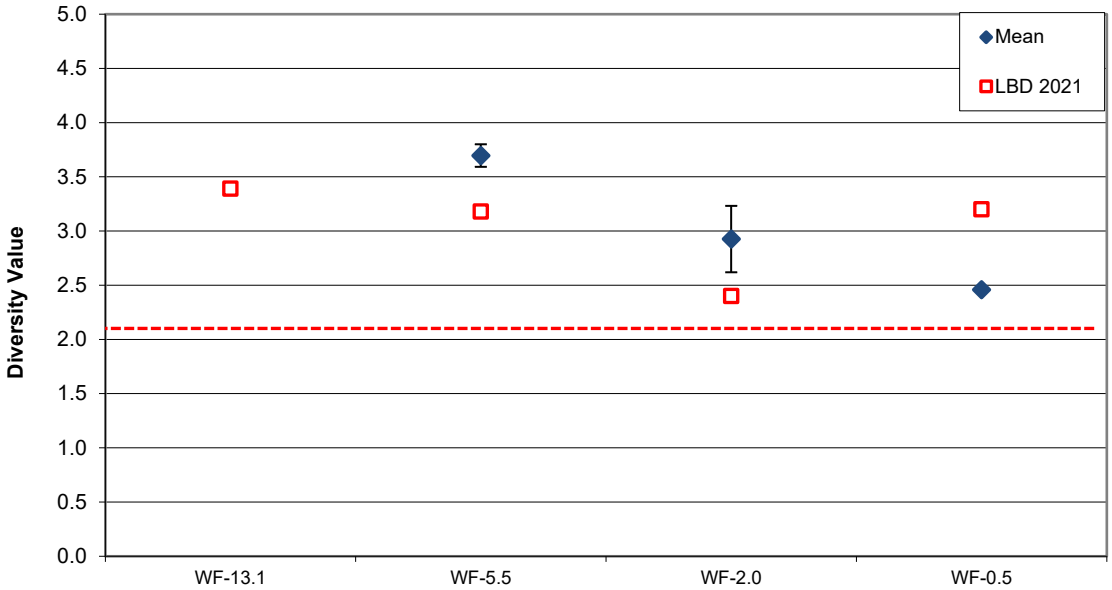

Figure 12. Diversity values for the Williams Fork study area from the fall of 2021 and mean Diversity values (±1 standard deviation) from previous sampling events. The red line indicates the 'impairment' threshold for Biotype 1.

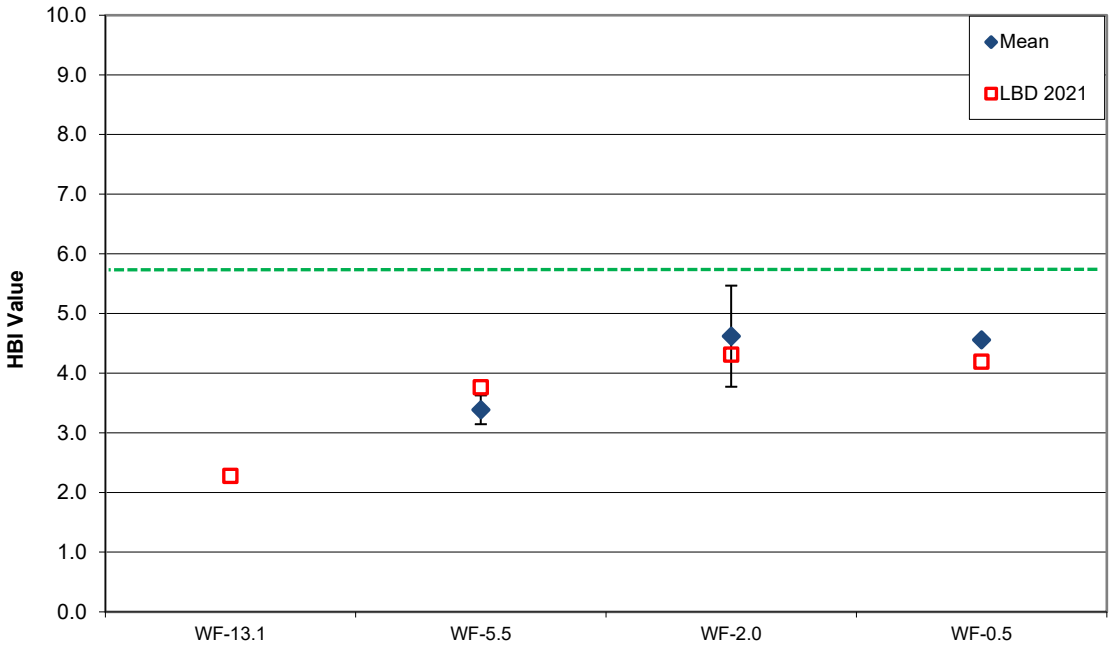

Figure 13. HBI values for the Williams Fork study area from the fall of 2021 and mean HBI values (±1 standard deviation) from previous sampling events. Exceeding the green line indicates 'impairment' for Biotype 1.

Table 7. Aquatic life use designations based on MMI v4 scores for sites in the Williams Fork study area during September of 2021. LBD = Learning By Doing study sites.

Aquatic Life Use Designations		
Site	**Project**	Quantitative (Hess) Samples
WF-13.1	**LBD**	Attainment
WF-5.5	**LBD**	Attainment
WF-2.0	**LBD**	Attainment
WF-0.5	**LBD**	Attainment

Results from Additional Metrics

In addition to the MMI v4 and associated metrics, nine individual metrics were applied to macroinvertebrate data collected from the Fraser River, Colorado River, and Williams Fork study areas to further evaluate benthic macroinvertebrate community health during the fall of 2021 (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 were likely influenced by regulated flows, water temperature, runoff from roads and developed areas, periphyton dynamics, runoff from portions of the watershed recently burned in wildfires, and possible combinations of these and other physical and biological conditions. Overall, most sites in the Fraser River, Colorado River, and Williams Fork study areas could be characterized as supporting a variety of sensitive taxa; however, the relative abundance of individuals representing these sensitive taxa (demonstrated by the % EPT-excluding Baetidae metric) varied throughout the study area (Tables 8-10). While a variety of macroinvertebrate taxa were present at all sampling locations, the proportional balance between sensitive individuals and tolerant individuals provided the greatest distinction of changes in stress during the 2021 biomonitoring season. It is also 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 in relatively low numbers at only one site on the Fraser River (FR-1.9) and two sites on the Colorado River (CR-16.7 and CR-9.1) during the fall of 2021 (Tables 8-9). The following comparison of individual metric values among study sites provides a detailed description of macroinvertebrate community health in the Fraser River, Colorado River, and Williams Fork study areas during the fall of 2021.

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 (Table 1; Figure 2). Important individual metrics such as Density (#/m^2), 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 a relatively high number of individuals, a variety of taxa, and a variety of sensitive taxa in the fall (September) of 2021 (Table 8). The EPT Taxa metric, which includes the most sensitive of all aquatic insects, generated values that ranged from a low of 19 (at sites FR-25.1 and FR-15) to a high of 26 at the downstream boundary of the study area, site FR-1.9 (Table 8; Figure 14). While all EPT Taxa values were indicative of relatively healthy macroinvertebrate communities, higher values in the downstream portion of the Fraser River study area may have been associated with improvements in habitat complexity and a larger stream size. With the exception of the study site on Vasquez Creek (VC-WP), most EPT Taxa values from 2021 were either near the mean values from previous sampling events or demonstrated recent improvements (Figure 14). Spatial changes in proportions of various macroinvertebrates in the Fraser River were clearly demonstrated by the % EPT-excluding Baetidae metric (Figure 15). Most of the

Table 8. Additional individual metrics and comparative values for benthic macroinvertebrate samples collected from the Fraser River study area during September of 2021. 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)	RC-1.1	FR-1.9
Biomonitoring Project	**LBD**	**Denver Water (DW)**			**LBD**	**DW**	**LBD**	
Density (mean #/m^2)	1,795	5,933	2,132	9,725	6,993	6,419	3,436	4,871
Taxa Richness	33	40	38	45	42	47	33	46
EPT Taxa	19	21	20	21	19	24	21	26
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	0	4
% EPT-excluding Baetidae	27.61%	8.32%	19.56%	10.10%	59.58%	59.69%	79.75%	46.77%
% Chironomidae	13.70%	29.99%	19.38%	49.60%	27.37%	11.62%	5.20%	3.43%
% Hydropsychidae	10.00%	0.00%	6.45%	12.04%	23.63%	56.90%	31.37%	33.19%
% Tolerant Taxa	12.12%	17.50%	13.16%	15.56%	14.29%	17.02%	21.21%	21.74%
% Intolerant Taxa	57.58%	50.00%	52.63%	44.44%	45.24%	40.43%	45.45%	50.00%

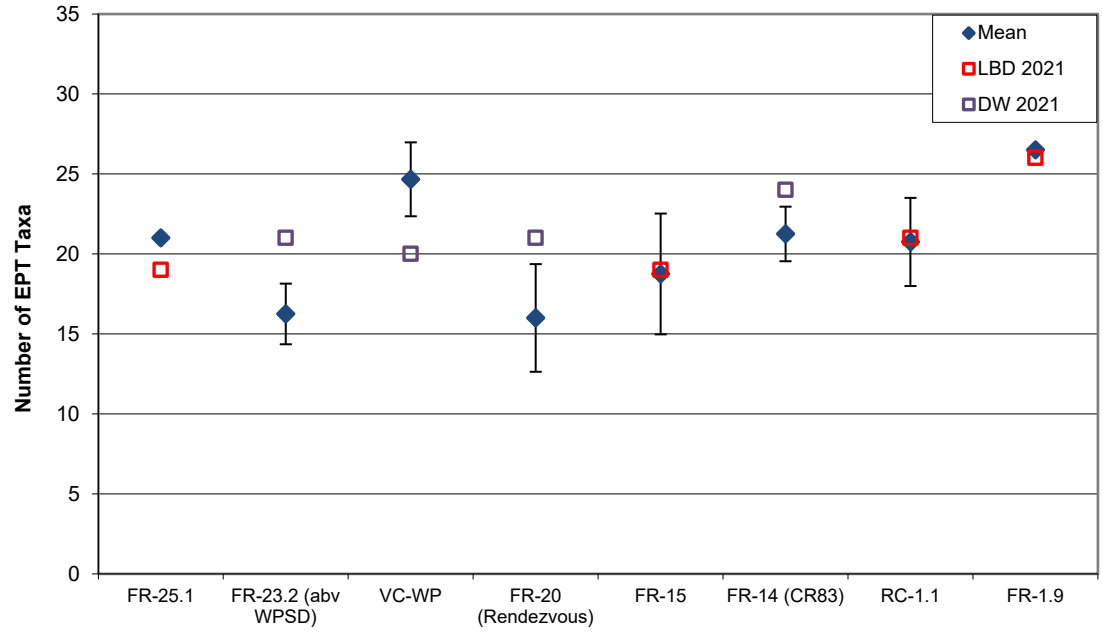

Figure 14. EPT Taxa values from the Fraser River study area during the fall of 2021 and mean values (±1 standard deviation) from previous sampling events. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

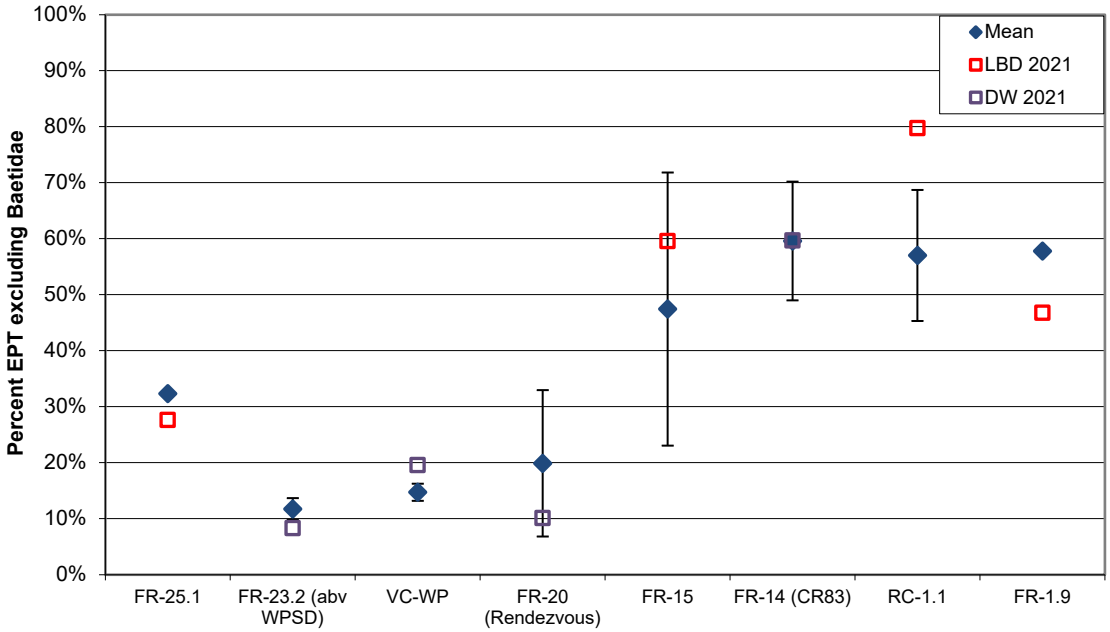

Figure 15. Percent EPT-excluding Baetidae values from the Fraser River study area during the fall of 2021 and mean values (±1 standard deviation) from previous sampling events. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

improvements in % EPT-excluding Baetidae values that were observed downstream from site FR-20 in 2021 appeared to be fairly consistent with results from previous sampling events (Figure 15). Additionally, sites FR-23.2, FR-20, FR-15 and FR-14 supported relatively high densities of macroinvertebrates in September of 2021, and Taxa Richness values were relatively high at sites FR-20, FR-15, FR-14 and FR-19 (Table 8). *Pteronarcys californica* nymphs, which are sensitive to disturbance and pollution, were only collected (in low numbers) at site FR-1.9 during the fall of 2021. A complete review of individual metric values from previous sampling events (2017, 2018, 2019, and 2020) in the LBD CEA can be found in Appendix D: Tables D5-D8.

Colorado River Study Area

A total of seven study sites on the Colorado River were sampled in September of 2021 in a combined effort between Northern Water and LBD (Table 1; Figure 3). A review of the individual metric values (Table 9) indicated that all study sites, except the LBD study site CR-1.7, supported taxa-rich communities with high densities of macroinvertebrates and relatively high numbers of sensitive taxa. Many of the individual metrics used to evaluate the health of benthic macroinvertebrate communities (Density [mean #/m^2], Taxa Richness, EPT Taxa, % Hydropsychidae, % Tolerant Taxa, and % Intolerant Taxa) indicated that negative impacts from anthropogenic stressors could not be detected upstream from site CR-1.7 (Table 9). Alternatively, individual metrics that specifically measure the relative abundance of the most sensitive individuals (and tolerant individuals) detected stress at several locations in the Colorado River study area. For example, the EPT Taxa metric, which measures the richness of sensitive aquatic insect taxa, indicated that all study sites upstream of site CR-1.7 were able to support relatively healthy aquatic communities (Figure 16), but the % EPT-excluding Baetidae metric detected a substantial decline in the proportion of the most sensitive individuals at sites CR-31.0, CR-16.7, CR-9.1, CR-7.4, and CR-1.7 in 2021 (Table 9; Figure 17). Additionally, three of these study sites (CR-31.0, CR-9.1, and CR-1.7) not only exhibited a substantial decline in the relative abundance of sensitive individuals, but they also experienced an unusual increase in the abundance of tolerant individuals, particularly the highly tolerant isopod, *Caecidotea* sp. (Appendix F: Figure F8). These specific changes in macroinvertebrate community structure were primarily responsible for the detection of increased stress in the fall of 2021 and the 'impairment' designations from the MMI v4 at sites CR-31.0, CR-9.1, and CR-1.7. When a study site supports a variety of sensitive taxa but the relative abundance of sensitive individuals is reduced, it is often an indication of stress from sources that are not highly toxic but have the ability to modify habitat (such as nutrient-enrichment, excessive algal growth, elevated water temperatures, etc.). In summary, individual metric values from the Upper Colorado River in fall (September) of 2021 indicated that all of the study sites upstream from site CR-1.7 were able to support high densities of benthic macroinvertebrates and relatively high numbers of sensitive taxa; however, several sites experienced a decline in the proportion of the most sensitive individuals, and three sites (CR-31.0, CR-9.1, and CR-1.7) exhibited a substantial increase in the relative abundance of highly tolerant individuals (Table 9).

Table 9. Additional individual metrics and comparative values for benthic macroinvertebrate samples collected from the Colorado River study area during September of 2021. 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-31.0	CR-28.7	CR-22.1	CR-16.7	CR-9.1	CR-7.4	CR-1.7
Monitoring Project	**Northern Water (NW)**				**LBD**		
Density (mean #/m^2)	10,985	10,747	8,563	7,662	11,520	8,184	2,924
Taxa Richness	53	52	55	57	47	54	30
EPT Taxa	23	24	25	31	22	27	8
Density of *Pteronarcys californica* (#/m^2)	0	0	0	31	4	0	0
% EPT-excluding Baetidae	14.00%	74.24%	55.51%	45.44%	27.26%	33.13%	3.46%
% Chironomidae	24.85%	8.89%	16.37%	10.80%	7.04%	15.99%	14.49%
% Hydropsychidae	43.95%	53.75%	35.35%	33.66%	14.88%	76.66%	0.00%
% Tolerant Taxa	26.42%	26.92%	23.64%	17.54%	19.15%	20.37%	43.33%
% Intolerant Taxa	30.19%	36.54%	32.73%	43.86%	38.30%	35.19%	6.67%

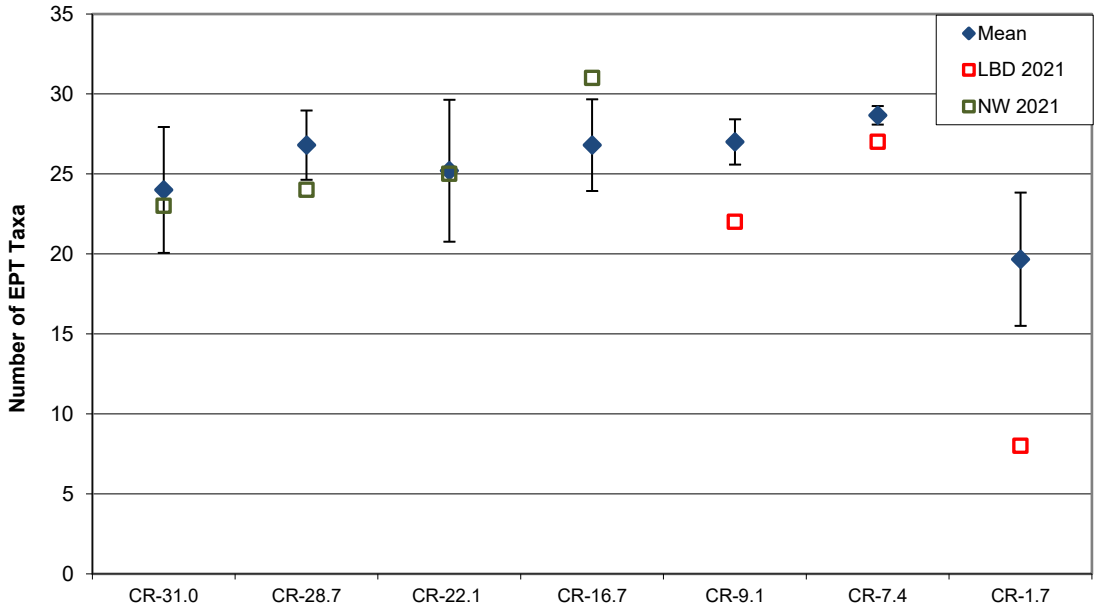

Figure 16. EPT Taxa values from the Colorado River study area during the fall of 2021 and mean values (±1 standard deviation) from previous sampling events. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

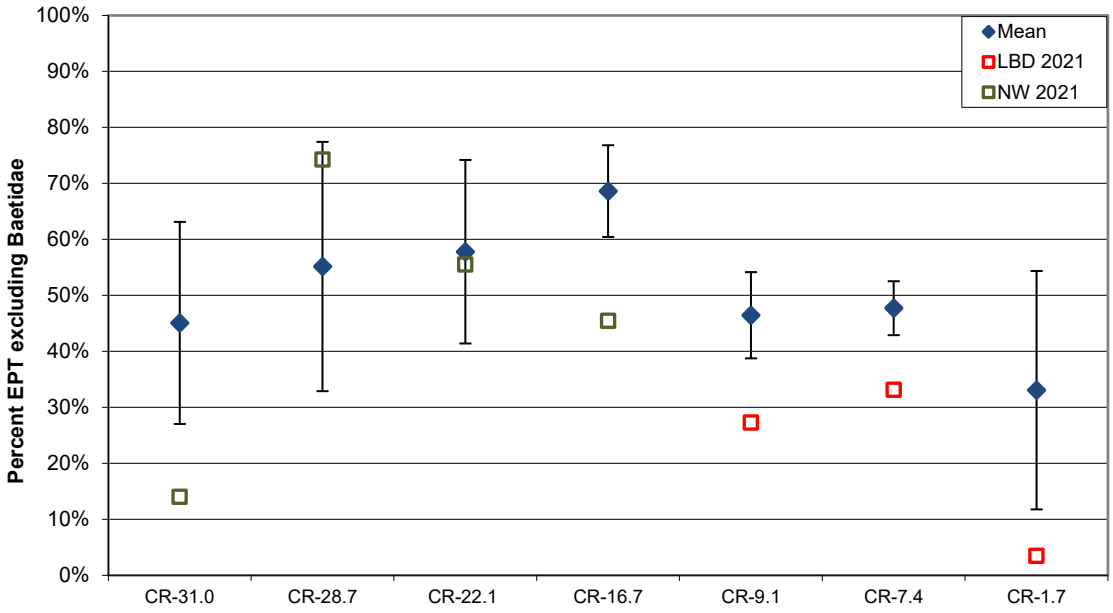

Figure 17. Percent EPT-excluding Baetidae values from the Colorado River study area during the fall of 2021 and mean values (±1 standard deviation) from previous sampling events. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

Williams Fork Study Area

A review of the results provided by individual metrics used in the Williams Fork study area showed notable variability among the four sites sampled as part of the LBD biomonitoring study in September of 2021 (Table 10; Figures 18-19). Upstream of Williams Fork Reservoir (sites WF-13.1 and WF-5.5), the EPT Taxa metric generated values that were slightly lower than most values observed at sites in the Fraser River and Colorado River study areas, while downstream from Williams Fork Reservoir, the majority of individual metrics (including the EPT Taxa metric) detected a moderate decline in macroinvertebrate community health (Table 10; Figures 18-19). Metric values for site WF-2.0 exhibited a typical response to reservoir releases (specifically the altered temperature and flow regime) that is often observed downstream from an impoundment (Ward and Stanford 1979, Ward 1982); however, farther downstream, gradual improvements in most community parameters were observed at site WF-0.5 (Table 10). It is possible that slightly lower EPT Taxa values in 2021 could have been related to runoff from portions of the watershed that were burned in the 2020 Williams Fork Fire; however, when results from 2021 were compared to results from previous sampling events, there was little change in the EPT Taxa and % EPT-excluding Baetidae values (Figures 18-19). It should be noted that recent habitat enhancement projects should eventually allow some recovery of the benthic macroinvertebrate communities in the lower portion of the Williams Fork study area. Collectively, these results suggested that most of the impacts in the Williams Fork study area continued to come from the altered temperature and flow regime associated with reservoir releases.

Table 10. Additional individual metrics and comparative values for benthic macroinvertebrate samples collected from the Williams Fork study area during September of 2021. All additional metric values are based on full count (quantitative) Hess samples.

Metric	WF-13.1	WF-5.5	WF-2.0	WF-0.5
Monitoring Project	**Learning By Doing (LBD)**			
Density (mean #/m^2)	3,539	4,211	8,597	9,909
Taxa Richness	31	41	25	28
EPT Taxa	20	16	12	14
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0
% EPT-excluding Baetidae	56.26%	41.74%	2.17%	9.79%
% Chironomidae	2.97%	2.95%	40.34%	23.61%
% Hydropsychidae	3.01%	64.18%	25.00%	0.00%
% Tolerant Taxa	3.23%	26.83%	24.00%	17.86%
% Intolerant Taxa	61.29%	29.27%	44.00%	42.86%

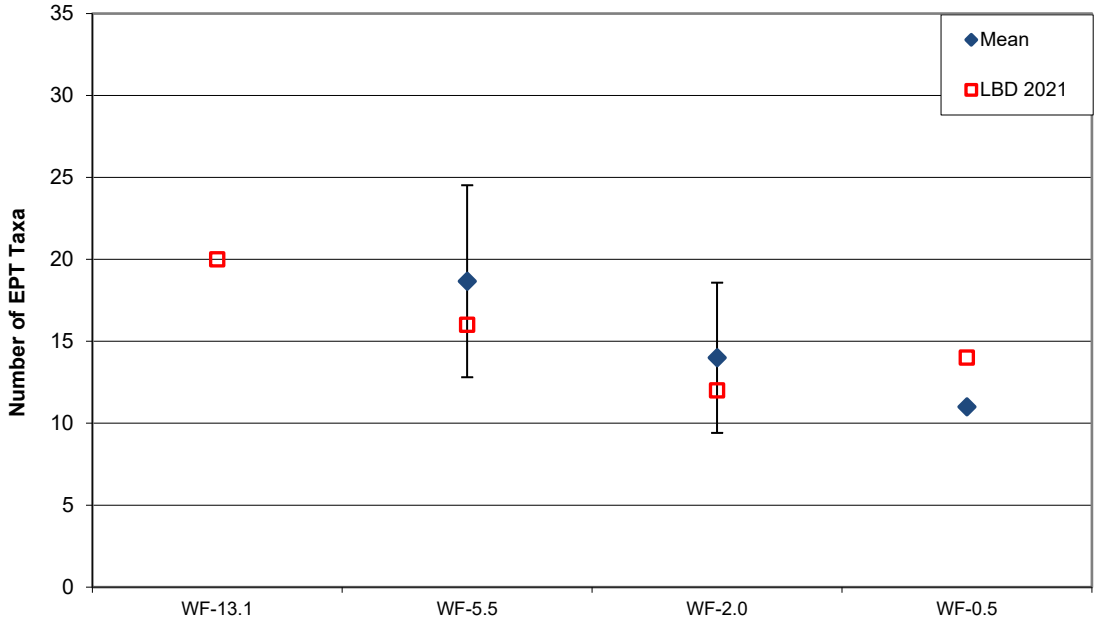

Figure 18. EPT Taxa values in the Williams Fork study area from the fall of 2021 and mean values (±1 standard deviation) from previous sampling events.

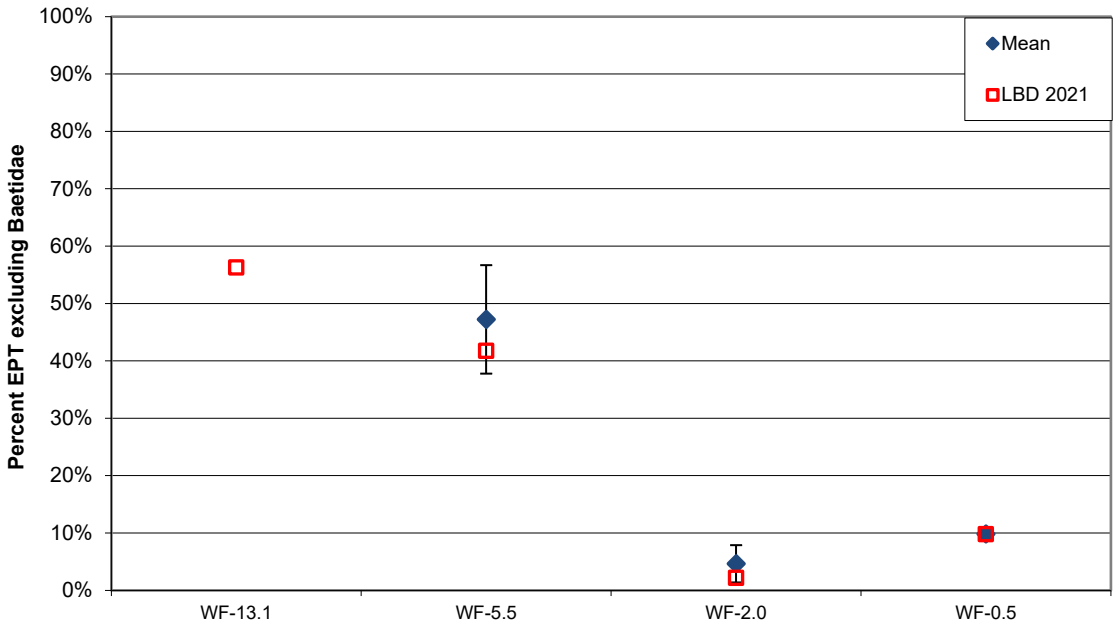

Figure 19. Percent EPT-excluding Baetidae values in the Williams Fork study area from the fall of 2021 and mean values (±1 standard deviation) from previous sampling events.

Results from Functional Feeding Group Analysis

Fraser River Study Area

An assessment of the relative percentages of various functional feeding groups provided an ecological perspective to the evaluation of macroinvertebrate communities at each sampling location in the Fraser River study area during the fall of 2021. Healthy mountain streams typically support diverse macroinvertebrate communities that exhibit a variety of feeding strategies; however, it is common for certain feeding groups (such as collector-gatherers) to be proportionally dominant (Ward et al. 2002). During the fall of 2021, there was a clear shift from sites dominated (>60%) by collector-gatherers in the upstream portion of the study area to sites with better functional balance and higher proportions of sensitive and specialized individuals in the downstream portion of the study area (Table 11; Figure 20). While it is common for collector-gatherers to be the most abundant feeding group in small mountain streams (Vannote et al. 1980, Rawer-Jost et al. 2000), negative impacts are often associated with the reduction or exclusion of sensitive/specialized feeding groups (i.e., shredders and scrapers). Therefore, the relatively high proportions of collector-gatherers (>68%) combined with reduced proportions of collector-filterers, shredders, and scrapers may have been an indication of minor to moderate stress at sites FR-25.1, FR-23.2, VC-WP, and FR-20 (Table 11). Improvements in the balance among feeding groups in the downstream portion of the study area suggested that the aquatic habitat had the ability to support greater ecological diversity (Figure 20). Overall, the results from functional feeding group analysis in the Fraser River study area supported the results from MMI v4 by suggesting that ecological function in the Fraser River improved in a downstream direction.

Table 11. Relative abundance of functional feeding groups in the Fraser River study area during the fall of 2021. 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**	68.48%	2.17%	7.17%	7.39%	13.26%	1.52%
FR-23.2 (abvWPSD)	**DW**	70.73%	1.64%	1.57%	2.82%	19.38%	3.86%
VC-WP	**DW**	69.84%	1.83%	3.11%	10.60%	11.52%	3.11%
FR-20 (Rendezvous)	**DW**	68.33%	12.86%	1.52%	1.68%	7.19%	8.43%
FR-15	**LBD**	60.08%	8.88%	7.33%	21.43%	1.89%	0.39%
FR-14 (CR83)	**DW**	28.93%	27.42%	7.99%	32.93%	2.66%	0.06%
RC-1.1	**LBD**	35.75%	17.99%	24.66%	20.14%	1.47%	0.00%
FR-1.9	**LBD**	23.46%	15.32%	2.63%	53.79%	4.71%	0.08%

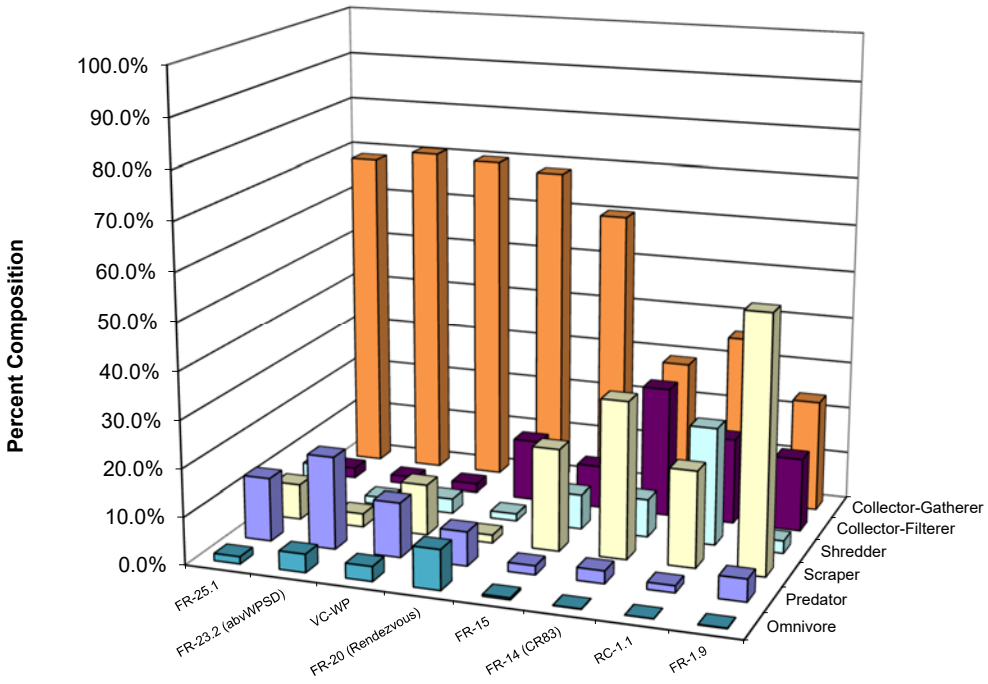

Figure 20. Functional feeding group composition for study sites in the Fraser River study area during the fall of 2021.

Colorado River Study Area

Functional feeding group analysis continued in the Colorado River study area during the fall of 2021 to provide an assessment of ecological function as well as an overall evaluation of macroinvertebrate community health. While the collector-gatherer group was the most abundant feeding group at all sites on the Colorado River, the proportional dominance of this group varied among sites (Table 12; Figure 21). Upstream from Windy Gap Reservoir, the Northern Water study site CR-31.0 (WGU) appeared to be moderately stressed based on the proportional dominance of collector-gatherers (82.54%) and the poor combined representation from shredders and scrapers (<7.0%). Downstream from Windy Gap Reservoir, the relative abundance of collector-gatherers decreased (slightly), and the proportions of collector-filterers, shredders, and scrapers tended to improve at most study sites (Table 12). In 2021, the proportion of scrapers actually showed a pattern of consistent improvements in a downstream direction in the Colorado River (Figure 21). These results generally suggested that the most optimal balance among feeding groups occurred in the downstream portion of the study area at sites CR-9.1, CR-7.4 and CR-1.7. It is important to note that the results from functional feeding group analysis conflicted with the conclusions provided by the MMI v4 and other metrics that detected moderate stress and 'impaired' aquatic conditions at sites CR-9.1 and CR-1.7. The perturbations that were responsible for low MMI v4 scores apparently had little influence on the ecological function of benthic macroinvertebrates in the downstream portion of the Colorado River study area in 2021.

Table 12. Relative abundance of functional feeding groups in the Colorado River study area during the fall of 2021. NW=Northern Water; LBD=Learning By Doing.

Site	Project	Functional Feeding Group					
		Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
CR-31.0	**NW**	82.54%	9.26%	1.91%	4.49%	1.10%	0.71%
CR-28.7	**NW**	61.09%	22.83%	1.41%	12.39%	2.28%	0.00%
CR-22.9	**NW**	66.12%	9.43%	9.39%	13.65%	1.27%	0.14%
CR-16.7	**NW**	61.71%	7.51%	6.19%	17.04%	1.27%	6.29%
CR-9.1	**LBD**	42.92%	11.32%	12.40%	17.76%	1.15%	14.45%
CR-7.4	**LBD**	41.05%	30.80%	3.94%	21.55%	1.95%	0.71%
CR-1.7	**LBD**	59.97%	7.18%	2.79%	27.53%	2.39%	0.13%

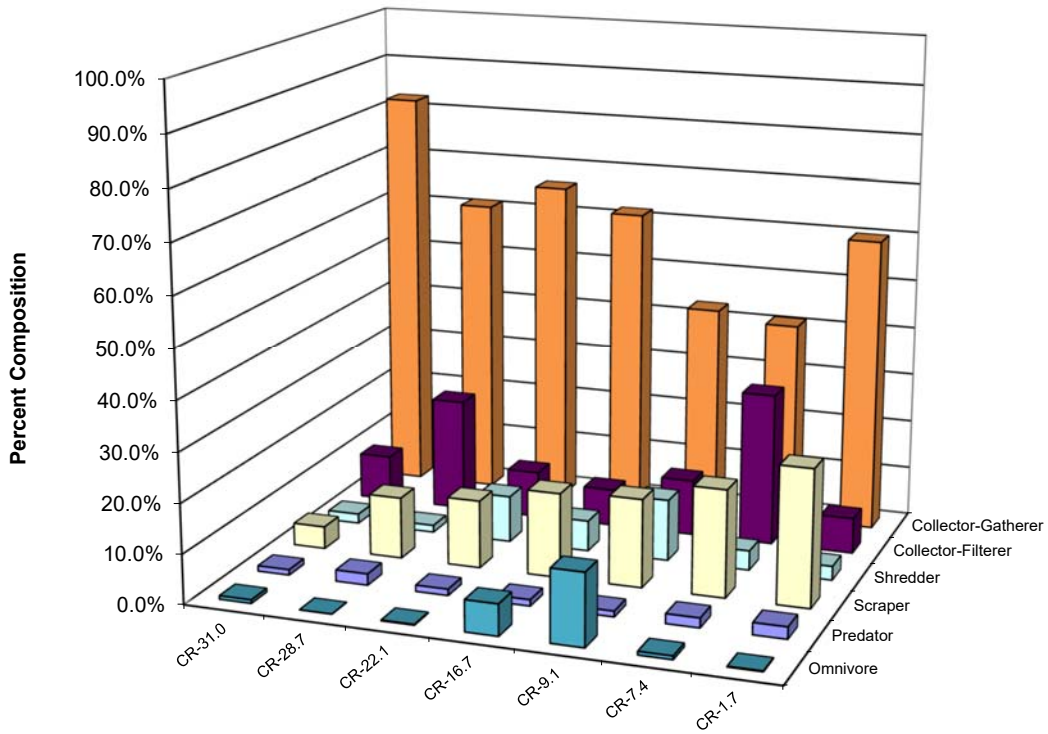

Figure 21. Functional feeding group composition for study sites in the Colorado River study area during the fall of 2021.

Williams Fork Study Area

A review of macroinvertebrate assemblages from the four study sites on the Williams Fork clearly demonstrated how a deep-release reservoir can influence food resources for benthic macroinvertebrates downstream from an impoundment. Evidence of increased stress was observed downstream from Williams Fork Reservoir at site WF-2.0, while the remaining sites in the study area produced results that were more variable, but indicative of relatively healthy aquatic conditions (Table 13; Figure 22). Upstream from the reservoir, sites WF-13.1 and WF-5.5 both supported members from all six feeding groups; however, site WF-13.1 was proportionally dominated (65.7%) by collector-gatherers. It is possible that runoff from portions of the watershed that were burned during a recent wildfire could be influencing the aquatic community this site. The most optimal balance among feeding groups was found immediately upstream from Williams Fork Reservoir at site WF-5.5. This sampling location supported the highest proportions of collector-filterers, shredders, and scrapers throughout the study area during the fall of 2021 (Table 13; Figure 22). Downstream from Williams Fork Reservoir, site WF-2.0 showed signs of minor to moderated stress, with collector-gatherers dominating (89.26%) the community and poor representation from collector-filterers, shredders, and scrapers (1.71%, 0.05%, and 1.22%, respectively). This was a fairly predictable response downstream from a deep-release reservoir where there are often impacts to macroinvertebrate life cycles, algal community structure, and reductions in riparian habitat (a food source for shredders). Farther downstream (immediately upstream from the confluence with the Colorado River), the balance of functional feeding groups appeared to return to a more optimal distribution with improved proportions of sensitive feeding groups at site WF-0.5 (Table 13; Figure 22). In general, the most optimal balance among functional feeding groups was found immediately upstream from Williams Fork Reservoir at site WF-5.5 and immediately upstream from the confluence with the Colorado River at site WF-0.5. The results from the functional feeding group analysis supported the results from other metrics used in this study by detecting increased stress immediately downstream from Williams Fork Reservoir, while a better balance in community function was observed throughout the remainder of the Williams Fork study area (Table 13; Figure 22).

Table 13. Relative abundance of functional feeding groups in the Williams Fork study area during the fall of 2021. LBD=Learning By Doing.

Site	Project	Functional Feeding Group					
		Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
WF-13.1	**LBD**	65.71%	3.52%	4.51%	8.02%	11.43%	6.81%
WF-5.5	**LBD**	14.68%	33.98%	7.20%	38.50%	4.52%	1.11%
WF-2.0	**LBD**	89.26%	1.71%	0.05%	1.22%	1.17%	6.59%
WF-0.5	**LBD**	47.30%	30.62%	2.23%	6.19%	1.14%	12.53%

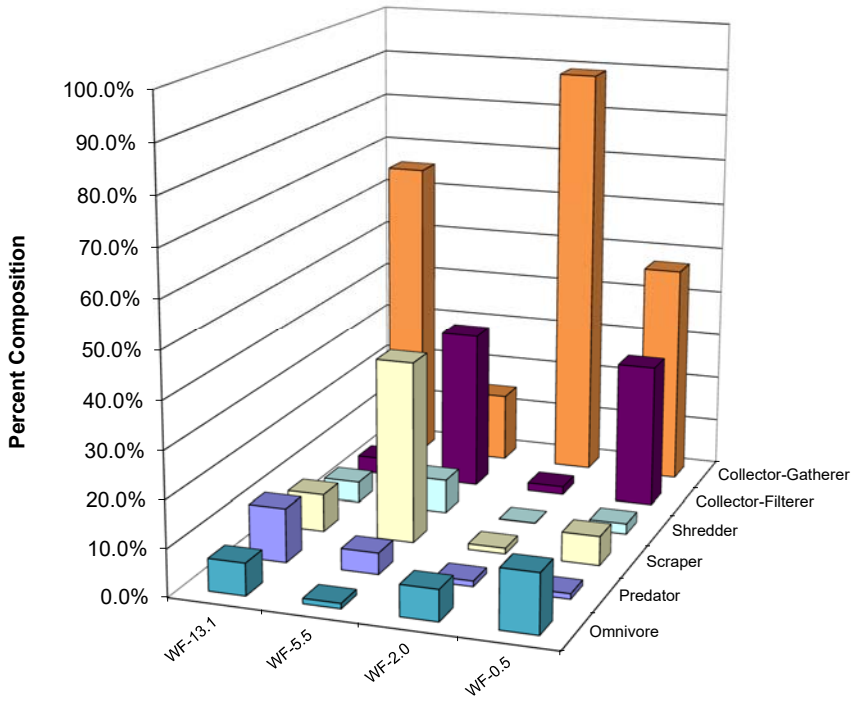

Figure 22. Functional feeding group composition for study sites in the Williams Fork study area during the fall of 2021.

Conclusions

Benthic macroinvertebrate biomonitoring studies were conducted for Denver Water, LBD, and Northern Water in three major drainages in Grand County, Colorado, during September of 2021. These three drainages included portions of the Fraser River, Colorado River, and Williams Fork, where most of the study sites have been monitored annually to assess the overall health of aquatic life and identify any potential negative impacts from anthropogenic sources. While all sampling locations in the Fraser River study area were able to support functioning benthic macroinvertebrate communities with relatively high proportions of sensitive taxa, minor to moderate stress was detected at site FR-23.2 (abvWPSD) before gradual improvements in macroinvertebrate community structure and function occurred in a downstream direction. Results from the Williams Fork showed an area of increased stress downstream from Williams Fork Reservoir; however, all study sites in the Williams Fork study area appeared to support relatively healthy macroinvertebrate communities. When metric values from both of these drainages were compared to mean values from previous sampling events, a similar pattern of stress and recovery was observed. In the Colorado River, three of the seven sites received 'impairment' designations that represented a substantial departure from previous results. Stressed macroinvertebrate communities appeared to be associated with excessive algal growth, which could have been related to nutrient-enrichment, runoff from areas impacted by recent wildfires, and/or elevated water temperatures. Future biomonitoring studies will provide an opportunity to assess the persistence of these results and monitor any changes in macroinvertebrate community structure and function.

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Appendix A

Learning By Doing
Benthic Macroinvertebrate Data – Fall 2021

Table A1. Macroinvertebrate data collected from site FR-25.1 on 20 Sept. 2021.

Fraser River						
FR-25.1		Sample				
20 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.	4	2	2		8	31
Baetis flavistriga	1				1	4
Baetis notos						
Baetis (*tricaudatus*)	63	75	78		216	838
Diphetor hageni						
Attenella margarita						
Drunella coloradensis		1			1	4
Drunella doddsii	1	1	1		3	12
Drunella grandis						
Ephemerella dorothea infrequens	7	1			8	31
Serratella sp.						
Serratella tibialis						
Epeorus sp.						
Epeorus deceptivus	3	2			5	20
Epeorus longimanus						
Rhithrogena sp.	5	2	1		8	31
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.	3	1	1		5	20
Zapada cinctipes	10	1	2		13	51
Zapada oregonensis group	7	5	4		16	62
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.	15	3	2		20	78
Isoperla fulva						
Megarcys signata	1				1	4
Skwala americana						
Pteronarcella badia						
Pteronarcys californica						
Taenionema sp.	8	4	5		17	66
Trichoptera (caddisflies)						
Allomyia sp.	3				3	12
Brachycentrus americanus						
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis	1		2		3	12
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.						
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea	7	2	3		12	47
Rhyacophila coloradensis	1	3	2		6	24
Rhyacophila sibirica group	4	2			6	24

Table A1. cont. Macroinvertebrate data collected from site FR-25.1 on 20 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	1				1	4
Cricotopus/Orthocladius sp.	9	4	5		18	70
Diamesa sp.						
Eukiefferiella sp.	22	6	7		35	136
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	2	1			3	12
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.			1		1	4
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	1	3	1		5	20
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Pericoma sp.	1				1	4
Simulium sp.	1	3	3		7	28
Antocha sp.						
Dicranota sp.			1		1	4
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.	15	1	3		19	74
Narpus concolor						
Optioservus sp.						
Zaitzevia parvula						
Haliplus sp.						
Miscellaneous						
Hygrobates sp.						
Lebertia sp.	4				4	16
Protzia sp.						
Sperchon sp.	2	2	1		5	20
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	4	3			7	28
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Glossiphonia complanata						
Lumbricidae						
Naididae						
Tubificidae						
Nematoda		1			1	4
Totals	**206**	**129**	**125**		**460**	**1795**

Table A2. Macroinvertebrate data collected from site FR-15 on 20 Sept. 2021.

Fraser River						
FR-15		Sample				
20 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.						
Baetis flavistriga						
Baetis notos						
Baetis (*tricaudatus*)	5	6	6		17	66
Diphetor hageni	16	1	2		19	74
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	6	26	9		41	159
Ephemerella dorothea infrequens	104	277	130		511	1981
Serratella sp.						
Serratella tibialis						
Epeorus sp.	2	9			11	43
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	30	7	5		42	163
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae	1	4	1		6	24
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa		1			1	4
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva	1				1	4
Megarcys signata						
Skwala americana	1	1			2	8
Pteronarcella badia		1			1	4
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus	1	7	2		10	39
Brachycentrus occidentalis		2			2	8
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.	26	163	17		206	799
Protoptila sp.		2			2	8
Helicopsyche borealis						
Arctopsyche grandis	4	25	16		45	175
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	12	15	22		49	190
Hydropsyche oslari	5	9			14	55
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	17	110	2		129	500
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						

Table A2. cont. Macroinvertebrate data collected from site FR-15 on 20 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	97	129	106		332	1287
Diamesa sp.	24	14	28		66	256
Eukiefferiella sp.	4	3	5		12	47
Micropsectra/Tanytarsus sp.	11	2			13	51
Microtendipes sp.	10	27	1		38	148
Pagastia sp.		5	4		9	35
Parametriocnemus sp.						
Polypedilum sp.		2			2	8
Potthastia sp.	1				1	4
Rheocricotopus sp.						
Synorthocladius sp.	3				3	12
Thienemanniella sp.						
Thienemannimyia group	9				9	35
Tvetenia sp.	1	3	4		8	31
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.	2				2	8
Hemerodromia sp.						
Pericoma sp.						
Simulium sp.	1		1		2	8
Antocha sp.		1	1		2	8
Dicranota sp.						
Hexatoma sp.	1				1	4
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	34	60	32		126	489
Zaitzevia parvula	1				1	4
Haliplus sp.						
Miscellaneous						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.						
Sperchon sp.	1	4	4		9	35
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	4	3			7	28
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Glossiphonia complanata						
Lumbricidae	4		2		6	24
Naididae		24			24	93
Tubificidae	16				16	62
Nematoda	1		2		3	12
Totals	**456**	**943**	**402**		**1801**	**6993**

Table A3. Macroinvertebrate data collected from site RC-1.1 on 20 Sept. 2021.

Ranch Creek						
RC-1.1		Sample				
20 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.						
Baetis flavistriga						
Baetis notos						
Baetis (*tricaudatus*)	18	12	3		33	128
Diphetor hageni	1				1	4
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	13	22	14		49	190
Ephemerella dorothea infrequens	92	71	38		201	780
Serratella sp.						
Serratella tibialis						
Epeorus sp.	33	5	14		52	202
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.			1		1	4
Tricorythodes explicatus						
Paraleptophlebia sp.	7	4	10		21	82
Plecoptera (stoneflies)						
Paracapnia angulata	1		3		4	16
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.	1				1	4
Isoperla fulva		2			2	8
Megarcys signata						
Skwala americana			1		1	4
Pteronarcella badia						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus	10	21	11		42	163
Brachycentrus occidentalis						
Micrasema bactro	6	18	4		28	109
Culoptila sp.		1	2		3	12
Glossosoma sp.		1	3		4	16
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis		2			2	8
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche sp.	2				2	8
Hydropsyche cockerelli	13	3	3		19	74
Hydropsyche oslari	48	26	20		94	365
Hydroptila sp.						
Ochrotrichia sp.			1		1	4
Lepidostoma sp.	41	45	92		178	690
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						

Table A3. cont. Macroinvertebrate data collected from site RC-1.1 on 20 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	2	1	5		8	31
Cricotopus/Orthocladius sp.	2	15			17	66
Diamesa sp.						
Eukiefferiella sp.	8	5			13	51
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.						
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	4	1	3		8	31
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Pericoma sp.						
Simulium sp.						
Antocha sp.		1	2		3	12
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	16	11	37		64	249
Zaitzevia parvula	4	4	9		17	66
Haliplus sp.						
Miscellaneous						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.						
Sperchon sp.	1	2	5		8	31
Torrenticola sp.			1		1	4
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae		1			1	4
Physa sp.						
Gyraulus sp.		2	2		4	16
Dugesia sp.						
Polycelis coronata						
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Glossiphonia complanata						
Lumbricidae		1			1	4
Naididae						
Tubificidae						
Nematoda						
Totals	**323**	**277**	**284**		**884**	**3436**

Table A4. Macroinvertebrate data collected from site FR-1.9 on 21 Sept. 2021.

Fraser River						
FR-1.9		Sample				
21 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.						
Baetis flavistriga						
Baetis notos						
Baetis (*tricaudatus*)	32	55	40		127	493
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis		2	1		3	12
Ephemerella dorothea infrequens	21	28	12		61	237
Serratella sp.						
Serratella tibialis						
Epeorus sp.	1	7			8	31
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	9	14	3		26	101
Plecoptera (stoneflies)						
Paracapnia angulata	1	1			2	8
Chloroperlidae	3	8	5		16	62
Sweltsa sp.		1			1	4
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa	4	4			8	31
Perlodidae (*Cultus* sp.)	2		2		4	16
Isoperla sp.						
Isoperla fulva	1				1	4
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Pteronarcys californica	1				1	4
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus	3	14	7		24	93
Brachycentrus occidentalis	2	7	3		12	47
Micrasema bactro						
Culoptila sp.	12	5	4		21	82
Glossosoma sp.	59	20	12		91	353
Protoptila sp.	119	11	5		135	524
Helicopsyche borealis						
Arctopsyche grandis		3	1		4	16
Ceratopsyche morosa	2	6	2		10	39
Cheumatopsyche sp.	12	12			24	93
Hydropsyche sp.	4	8	1		13	51
Hydropsyche cockerelli	16	31	8		55	214
Hydropsyche oslari	16	17	12		45	175
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	2	9	7		18	70
Oecetis sp.	2				2	8
Hesperophylax sp.						
Psychomyia flavida			1		1	4
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						

Table A4. cont. Macroinvertebrate data collected from site FR-1.9 on 21 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	6	6			12	47
Cricotopus/Orthocladius sp.		1			1	4
Diamesa sp.						
Eukiefferiella sp.	2	4	3		9	35
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.		1			1	4
Parametriocnemus sp.	1	1			2	8
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group	2				2	8
Tvetenia sp.	2	13	1		16	62
Other Diptera (true flies)						
Atherix pachypus	1				1	4
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Pericoma sp.						
Simulium sp.		3	1		4	16
Antocha sp.						
Dicranota sp.						
Hexatoma sp.	3	3	3		9	35
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	121	140	148		409	1586
Zaitzevia parvula	14	16	16		46	179
Haliplus sp.						
Miscellaneous						
Hygrobates sp.	1		2		3	12
Lebertia sp.	1	1			2	8
Protzia sp.						
Sperchon sp.	4	4	2		10	39
Torrenticola sp.						
Pisidium sp.			1		1	4
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.	2	1	3		6	24
Gyraulus sp.		1			1	4
Dugesia sp.						
Polycelis coronata		1			1	4
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Glossiphonia complanata						
Lumbricidae	3	1			4	16
Naididae						
Tubificidae						
Nematoda						
Totals	**487**	**460**	**306**		**1253**	**4871**

Table A5. Macroinvertebrate data collected from WF-13.1 on 22 Sept. 2021.

Williams Fork						
WF-13.1		Sample				
22 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.	1				1	4
Baetis flavistriga						
Baetis notos						
Baetis (*tricaudatus*)	34	49	84		167	648
Diphetor hageni		1	2		3	12
Attenella margarita						
Drunella coloradensis						
Drunella doddsii		7	12		19	74
Drunella grandis	6	3	12		21	82
Ephemerella dorothea infrequens	44	132	106		282	1093
Serratella sp.						
Serratella tibialis						
Epeorus sp.						
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.	1	8	6		15	59
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.		13	15		28	109
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa		1			1	4
Perlodidae (*Cultus* sp.)						
Isoperla sp.		4			4	16
Isoperla fulva	5	3			8	31
Megarcys signata						
Skwala americana		1			1	4
Pteronarcella badia						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus	6	11	8		25	97
Brachycentrus occidentalis						
Micrasema bactro		1			1	4
Culoptila sp.						
Glossosoma sp.		1	5		6	24
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis	1	2	1		4	16
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	8	7	25		40	155
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea	2	4	6		12	47
Rhyacophila coloradensis	2	1	4		7	28
Rhyacophila sibirica group	5	18	15		38	148

Table A5. cont. Macroinvertebrate data collected from site WF-13.1 on 22 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	2	1	1		4	16
Diamesa sp.						
Eukiefferiella sp.	2	7	1		10	39
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	3	3	7		13	51
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.						
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.			1		1	4
Hemerodromia sp.						
Pericoma sp.	6	7	14		27	105
Simulium sp.	2	1			3	12
Antocha sp.						
Dicranota sp.						
Hexatoma sp.		3	1		4	16
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.	1	48	40		89	345
Narpus concolor						
Optioservus sp.	11	1			12	47
Zaitzevia parvula			2		2	8
Haliplus sp.						
Miscellaneous						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.						
Sperchon sp.						
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	7	36	19		62	241
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Glossiphonia complanata						
Lumbricidae						
Naididae						
Tubificidae						
Nematoda						
Totals	**149**	**374**	**387**		**910**	**3539**

Table A6. Macroinvertebrate data collected from WF-5.5 on 22 Sept. 2021.

Williams Fork						
WF-5.5		Sample				
22 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.	1				1	4
Baetis flavistriga	3	2	1		6	24
Baetis notos						
Baetis (*tricaudatus*)	18	14	16		48	186
Diphetor hageni	5	1	1		7	28
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	2	4	7		13	51
Ephemerella dorothea infrequens	2	1	1		4	16
Serratella sp.						
Serratella tibialis						
Epeorus sp.						
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	8	4	4		16	62
Plecoptera (stoneflies)						
Paracapnia angulata	1		1		2	8
Chloroperlidae			1		1	4
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus	12	19	23		54	210
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis						
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche sp.	90	105	71		266	1031
Hydropsyche cockerelli						
Hydropsyche oslari			1		1	4
Hydroptila sp.						
Ochrotrichia sp.		2			2	8
Lepidostoma sp.	27	23	24		74	287
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea	5	1	3		9	35
Rhyacophila coloradensis	3	4	3		10	39
Rhyacophila sibirica group						

Table A6. cont. Macroinvertebrate data collected from site WF-5.5 on 22 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	4	2	1		7	28
Diamesa sp.						
Eukiefferiella sp.		2	2		4	16
Micropsectra/Tanytarsus sp.			1		1	4
Microtendipes sp.						
Pagastia sp.	4	4	8		16	62
Parametriocnemus sp.						
Polypedilum sp.	1				1	4
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.		1			1	4
Thienemanniella sp.						
Thienemannimyia group	1	1			2	8
Tvetenia sp.						
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.			1		1	4
Hemerodromia sp.						
Pericoma sp.			3		3	12
Simulium sp.	12	19	16		47	183
Antocha sp.						
Dicranota sp.						
Hexatoma sp.	1	1			2	8
Tipula sp.	1				1	4
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor	2	1			3	12
Optioservus sp.	148	119	132		399	1547
Zaitzevia parvula	6	5	4		15	59
Haliplus sp.						
Miscellaneous						
Hygrobates sp.			1		1	4
Lebertia sp.	5	4	8		17	66
Protzia sp.						
Sperchon sp.	2	2	1		5	20
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.		1			1	4
Ferrissia sp.						
Lymnaeidae						
Physa sp.	2	1	1		4	16
Gyraulus sp.			1		1	4
Dugesia sp.						
Polycelis coronata	4	7	1		12	47
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae	1				1	4
Glossiphonia complanata						
Lumbricidae						
Naididae	13	4			17	66
Tubificidae	1	3	3		7	28
Nematoda						
Totals	**385**	**357**	**341**		**1083**	**4211**

Table A7. Macroinvertebrate data collected from site WF-2.0 on 22 Sept. 2021.

Williams Fork						
WF-2.0		Sample				
22 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.	3	1	1		5	20
Baetis flavistriga						
Baetis notos						
Baetis (*tricaudatus*)	524	196	318		1038	4024
Diphetor hageni						
Attenella margarita	1		1		2	8
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	4	5	5		14	55
Ephemerella dorothea infrequens	8	1	3		12	47
Serratella sp.						
Serratella tibialis						
Epeorus sp.						
Epeorus deceptivus						
Epeorus longimanus	5	3	3		11	43
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	1		1		2	8
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.	2	1			3	12
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus						
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis	1				1	4
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	1				1	4
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea	1				1	4
Rhyacophila coloradensis	1				1	4
Rhyacophila sibirica group						

Table A7. cont. Macroinvertebrate data collected from site WF-2.0 on 22 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	178	84	278		540	2093
Diamesa sp.			1		1	4
Eukiefferiella sp.	50	21	60		131	508
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	105	31	83		219	849
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	3				3	12
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Pericoma sp.						
Simulium sp.	13	12	12		37	144
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.			1		1	4
Zaitzevia parvula						
Haliplus sp.						
Miscellaneous						
Hygrobates sp.						
Lebertia sp.	1	2	1		4	16
Protzia sp.						
Sperchon sp.	6	1	10		17	66
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.	1				1	4
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	50	47	49		146	566
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Glossiphonia complanata						
Lumbricidae						
Naididae	2	4	7		13	51
Tubificidae	3	4	5		12	47
Nematoda						
Totals	**964**	**413**	**839**		**2216**	**8597**

Table A8. Macroinvertebrate data collected from site WF-0.5 on 22 Sept. 2021.

Williams Fork						
WF-0.5		Sample				
22 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.	29	45	39		113	438
Baetis flavistriga						
Baetis notos						
Baetis (*tricaudatus*)	166	80	175		421	1632
Diphetor hageni						
Attenella margarita			2		2	8
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	41	40	54		135	524
Ephemerella dorothea infrequens	3	1	4		8	31
Serratella sp.						
Serratella tibialis		1	2		3	12
Epeorus sp.						
Epeorus deceptivus						
Epeorus longimanus	4	10	9		23	90
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae	1				1	4
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.	2		7		9	35
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus	6	4	2		12	47
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis						
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	12	16	14		42	163
Oecetis sp.						
Hesperophylax sp.	1				1	4
Psychomyia flavida						
Rhyacophila brunnea	1	1	2		4	16
Rhyacophila coloradensis	3	1	6		10	39
Rhyacophila sibirica group						

Table A8. cont. Macroinvertebrate data collected from site WF-0.5 on 22 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	120	157	134		411	1593
Diamesa sp.						
Eukiefferiella sp.	54	20	20		94	365
Micropsectra/Tanytarsus sp.	3	8	6		17	66
Microtendipes sp.						
Pagastia sp.	27	25	23		75	291
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.	2	1			3	12
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	3				3	12
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Pericoma sp.						
Simulium sp.	270	30	470		770	2985
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.	11	2	1		14	55
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.						
Zaitzevia parvula						
Haliplus sp.						
Miscellaneous						
Hygrobates sp.						
Lebertia sp.		2			2	8
Protzia sp.						
Sperchon sp.						
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	163	103	54		320	1241
Crangonyx sp.			1		1	4
Gammarus lacustris						
Erpobdellidae						
Glossiphonia complanata						
Lumbricidae						
Naididae	1				1	4
Tubificidae	4	22	30		56	218
Nematoda		2	1		3	12
Totals	**927**	**571**	**1056**		**2554**	**9909**

Table A9. Macroinvertebrate data collected from site CR-9.1 on 21 Sept. 2021.

Colorado River						
CR-9.1		Sample				
21 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.						
Baetis flavistriga						
Baetis notos						
Baetis (*tricaudatus*)	69	80	101		250	969
Diphetor hageni	2	1	1		4	16
Attenella margarita						
Drunella coloradensis						
Drunella doddsii	1				1	4
Drunella grandis	5	2	1		8	31
Ephemerella dorothea infrequens	48	76	44		168	652
Serratella sp.						
Serratella tibialis						
Epeorus sp.	1	3	6		10	39
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.						
Tricorythodes explicatus	1	2	1		4	16
Paraleptophlebia sp.	2	4	3		9	35
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa	1	1			2	8
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva		1			1	4
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Pteronarcys californica			1		1	4
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus	23	54	48		125	485
Brachycentrus occidentalis	1				1	4
Micrasema bactro						
Culoptila sp.	1	5	2		8	31
Glossosoma sp.	6	4	2		12	47
Protoptila sp.	13	10	7		30	117
Helicopsyche borealis						
Arctopsyche grandis						
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche sp.	11	17	6		34	132
Hydropsyche cockerelli	4	18	4		26	101
Hydropsyche oslari		27	3		30	117
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	95	150	92		337	1307
Oecetis sp.						
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea			1		1	4
Rhyacophila coloradensis		1			1	4
Rhyacophila sibirica group						

Table A9. cont. Macroinvertebrate data collected from site CR-9.1 on 21 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	3	3	2		8	31
Cricotopus nostocicola	15	4	5		24	93
Cricotopus/Orthocladius sp.	21	15	27		63	245
Diamesa sp.						
Eukiefferiella sp.	7	21	13		41	159
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	8	7	3		18	70
Parametriocnemus sp.						
Polypedilum sp.	2	3			5	20
Potthastia sp.	3	1	1		5	20
Rheocricotopus sp.						
Synorthocladius sp.		1			1	4
Thienemanniella sp.	1	1	3		5	20
Thienemannimyia group						
Tvetenia sp.	10	20	9		39	152
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.	1		2		3	12
Hemerodromia sp.		1			1	4
Pericoma sp.						
Simulium sp.	30	31	58		119	462
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus		1			1	4
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	129	64	50		243	942
Zaitzevia parvula	28	8	11		47	183
Haliplus sp.						
Miscellaneous						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.	6	7	3		16	62
Sperchon sp.		1			1	4
Torrenticola sp.						
Pisidium sp.			1		1	4
Caecidotea sp.	259	230	95		584	2264
Ferrissia sp.						
Lymnaeidae						
Physa sp.	89	68	58		215	834
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	68	211	150		429	1663
Crangonyx sp.	16	4	7		27	105
Gammarus lacustris						
Erpobdellidae						
Glossiphonia complanata						
Lumbricidae						
Naididae		2			2	8
Tubificidae	7				7	28
Nematoda						
Totals	**987**	**1160**	**821**		**2968**	**11520**

Table A10. Macroinvertebrate data collected from site CR-7.4 on 22 Sept. 2021.

Colorado River						
CR-7.4		Sample				
22 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.						
Baetis flavistriga						
Baetis notos			1		1	4
Baetis (*tricaudatus*)	50	80	52		182	706
Diphetor hageni	3	4	2		9	35
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	2				2	8
Ephemerella dorothea infrequens	86	78	83		247	958
Serratella sp.		1			1	4
Serratella tibialis						
Epeorus sp.	2		2		4	16
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.	1				1	4
Tricorythodes explicatus	9	3	6		18	70
Paraleptophlebia sp.	4	11	12		27	105
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.			1		1	4
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa	1	6	6		13	51
Perlodidae (*Cultus* sp.)		1	2		3	12
Isoperla sp.		1	1		2	8
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcella badia	1	1			2	8
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus	2		3		5	20
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.	2	2	5		9	35
Glossosoma sp.	2	2	1		5	20
Protoptila sp.		13			13	51
Helicopsyche borealis		1			1	4
Arctopsyche grandis						
Ceratopsyche morosa						
Cheumatopsyche sp.	7	16	8		31	121
Hydropsyche sp.	20	46	16		82	318
Hydropsyche cockerelli	34	110	31		175	679
Hydropsyche oslari			1		1	4
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	17	19	13		49	190
Oecetis sp.	2	2	1		5	20
Hesperophylax sp.						
Psychomyia flavida	1				1	4
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						

Table A10. cont. Macroinvertebrate data collected from site CR-7.4 on 22 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	2		3		5	20
Cricotopus nostocicola	11	9	9		29	113
Cricotopus/Orthocladius sp.	25	9	23		57	221
Diamesa sp.						
Eukiefferiella sp.	18	9	7		34	132
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	4		1		5	20
Parametriocnemus sp.	1				1	4
Polypedilum sp.		2	1		3	12
Potthastia sp.			1		1	4
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.	1				1	4
Thienemannimyia group	1		1		2	8
Tvetenia sp.	76	69	54		199	772
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.	1				1	4
Hemerodromia sp.						
Pericoma sp.						
Simulium sp.	203	111	41		355	1376
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.	2				2	8
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	115	159	66		340	1318
Zaitzevia parvula		28	4		32	124
Haliplus sp.						
Miscellaneous						
Hygrobates sp.		1			1	4
Lebertia sp.						
Protzia sp.	1				1	4
Sperchon sp.	1	1	1		3	12
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.	7	28	7		42	163
Ferrissia sp.			1		1	4
Lymnaeidae						
Physa sp.	17	40	21		78	303
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	8	3	4		15	59
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae	1				1	4
Glossiphonia complanata						
Lumbricidae		6			6	24
Naididae						
Tubificidae	1				1	4
Nematoda		1			1	4
Totals	**742**	**873**	**492**		**2107**	**8184**

Table A11. Macroinvertebrate data collected from site CR-1.7 on 22 Sept. 2021.

Colorado River						
CR-1.7		Sample				
22 Sept. 2021	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Acentrella sp.		1			1	4
Baetis flavistriga						
Baetis notos						
Baetis (*tricaudatus*)	8	33	9		50	194
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis						
Ephemerella dorothea infrequens						
Serratella sp.						
Serratella tibialis						
Epeorus sp.						
Epeorus deceptivus						
Epeorus longimanus						
Rhithrogena sp.			1		1	4
Tricorythodes explicatus	1				1	4
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcella badia						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Allomyia sp.						
Brachycentrus americanus						
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis	1				1	4
Arctopsyche grandis						
Ceratopsyche morosa						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Hydroptila sp.	1	1			2	8
Ochrotrichia sp.						
Lepidostoma sp.	6	8	5		19	74
Oecetis sp.	1		1		2	8
Hesperophylax sp.						
Psychomyia flavida						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						

Table A11. cont. Macroinvertebrate data collected from CR-1.7 on 22 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola		1			1	4
Cricotopus/Orthocladius sp.	29	55	2		86	334
Diamesa sp.						
Eukiefferiella sp.	1	3			4	16
Micropsectra/Tanytarsus sp.	1	2	1		4	16
Microtendipes sp.						
Pagastia sp.						
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.	8	1	1		10	39
Thienemannimyia group						
Tvetenia sp.	1	2	1		4	16
Other Diptera (true flies)						
Atherix pachypus						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Pericoma sp.						
Simulium sp.	4	36	14		54	210
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Helichus striatus						
Oreodytes sp.						
Heterlimnius sp.						
Narpus concolor						
Optioservus sp.	70	101	25		196	760
Zaitzevia parvula		1			1	4
Haliplus sp.	1				1	4
Miscellaneous						
Hygrobates sp.	3				3	12
Lebertia sp.						
Protzia sp.						
Sperchon sp.						
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.	105	130	37		272	1055
Ferrissia sp.		1			1	4
Lymnaeidae		1			1	4
Physa sp.			1		1	4
Gyraulus sp.	1	1	2		4	16
Dugesia sp.	1	3			4	16
Polycelis coronata						
Crangonyx sp.	5	9			14	55
Gammarus lacustris		1			1	4
Erpobdellidae	3	3	2		8	31
Glossiphonia complanata		1			1	4
Lumbricidae						
Naididae						
Tubificidae	2	2			4	16
Nematoda						
Totals	**253**	**397**	**102**		**752**	**2924**

Appendix B

Northern Water
Benthic Macroinvertebrate Data – Fall 2021

Table B1. Macroinvertebrate data collected from site CR-WGU on 21 Sept. 2021.

Colorado River						
CR-31.0 (WGU)		Sample				Estimated Total/m²
21 Sept. 2021	1	2	3		Total	
Ephemeroptera						
Acentrella turbida	2	1	3		6	24
Baetis flavistriga		3	2		5	20
Baetis (*tricaudatus*)	47	83	68		198	768
Diphetor hageni	4	2	5		11	43
Drunella grandis	1	1	1		3	12
Ephemerella dorothea infrequens	15	9	9		33	128
Epeorus sp.						
Epeorus longimanus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus	6	5	9		20	78
Paraleptophlebia sp.	3	3	2		8	31
Plecoptera						
Paracapnia angulata	6	3	1		10	39
Chloroperlidae		1			1	4
Zapada cinctipes						
Claassenia sabulosa	4	1			5	20
Hesperoperla pacifica						
Perlodidae (*Cultus* sp.)		2			2	8
Isoperla sp.						
Skwala americana						
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	28	20	31		79	307
Brachycentrus occidentalis	9	9	5		23	90
Culoptila sp.						
Glossosoma sp.	17	10	4		31	121
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis	9	6	13		28	109
Cheumatopsyche sp.	4	5	4		13	51
Hydropsyche sp.		2	34		36	140
Hydropsyche (cockerelli)	14	12	24		50	194
Hydropsyche oslari	1	6	4		11	43
Hydroptila sp.	5	2			7	28
Lepidostoma sp.	11	15	9		35	136
Ceraclea sp.	1				1	4
Oecetis sp.						
Psychomyia flavida						
Rhyacophila coloradensis						

Table B1. cont. Macroinvertebrate data collected from site CR-WGU on 21 Sept. 2021.

Diptera						
Chironomidae						
Brillia sp.			1		1	4
Cardiocladius sp.						
Cricotopus nostocicola		8			8	31
Cricotopus/Orthocladius sp.	145	98	97		340	1318
Eukiefferiella sp.	14	20	32		66	256
Lopescladius sp.						
Micropsectra/Tanytarsus sp.		1			1	4
Microtendipes sp.	2	7	9		18	70
Nanocladius sp.	1				1	4
Pagastia sp.		2	2		4	16
Parametriocnemus sp.	2	2	3		7	28
Phaenopsectra sp.	1				1	4
Polypedilum sp.						
Potthastia sp.	1	3	3		7	28
Rheocricotopus sp.						
Synorthocladius sp.			2		2	8
Thienemanniella sp.	2		1		3	12
Thienemannimyia group	2		2		4	16
Tvetenia sp.	76	49	115		240	931
Other Diptera						
Atherix pachypus						
Chelifera/Neoplasta sp.	5	2	6		13	51
Hemerodromia sp.						
Simulium sp.		3	1		4	16
Antocha sp.			1		1	4
Coleoptera						
Optioservus sp.	23	38	22		83	322
Zaitzevia parvula						
Miscellaneous						
Atractides sp.	1				1	4
Hygrobates sp.						
Lebertia sp.	2				2	8
Protzia sp.						
Sperchon sp.			1		1	4
Caecidotea sp.	288	518	535		1341	5198
Polycelis coronata	1		19		20	78
Physa sp.						
Gyraulus sp.		2			2	8
Pisidium sp.						
Crangonyx sp.	6	4	8		18	70
Hyalella azteca						
Erpobdellidae	1		1		2	8
Lumbricidae		6	3		9	35
Naididae			1		1	4
Tubificidae with hair chaetae						
Tubificidae w/o hair chaetae	12				12	47
Nematoda						
Totals	**772**	**964**	**1093**		**2829**	**10985**

Table B2. Macroinvertebrate data collected from site CR-WGD on 21 Sept. 2021.

Colorado River						
CR-28.7 (WGD)		Sample				Estimated Total/m²
21 Sept. 2021	1	2	3		Total	
Ephemeroptera						
Acentrella turbida	1				1	4
Baetis flavistriga						
Baetis (*tricaudatus*)	38	184	44		266	1031
Diphetor hageni						
Drunella grandis		1			1	4
Ephemerella dorothea infrequens	163	670	169		1002	3884
Epeorus sp.						
Epeorus longimanus		9	1		10	39
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	16	77	22		115	446
Plecoptera						
Paracapnia angulata	2	4			6	24
Chloroperlidae						
Zapada cinctipes						
Claassenia sabulosa	2	1	2		5	20
Hesperoperla pacifica						
Perlodidae (*Cultus* sp.)	7	13	1		21	82
Isoperla sp.	4	9	2		15	59
Skwala americana						
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	20	104	20		144	559
Brachycentrus occidentalis	1	10	3		14	55
Culoptila sp.	7	23	10		40	155
Glossosoma sp.	6	7	2		15	59
Protoptila sp.	43	87	27		157	609
Helicopsyche borealis						
Arctopsyche grandis		12	1		13	51
Cheumatopsyche sp.						
Hydropsyche sp.	8	133	13		154	597
Hydropsyche (cockerelli)	2	63	8		73	283
Hydropsyche oslari	12	186	35		233	904
Hydroptila sp.	1		1		2	8
Lepidostoma sp.	5	19	3		27	105
Ceraclea sp.						
Oecetis sp.		2			2	8
Psychomyia flavida		1	4		5	20
Rhyacophila coloradensis		1			1	4

Table B2. cont. Macroinvertebrate data collected from site CR-WGD on 21 Sept. 2021.

Diptera						
Chironomidae						
Brillia sp.						
Cardiocladius sp.		1			1	4
Cricotopus nostocicola		5	1		6	24
Cricotopus/Orthocladius sp.	14	48	21		83	322
Eukiefferiella sp.	4	47	22		73	283
Lopescladius sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Nanocladius sp.		3			3	12
Pagastia sp.		1			1	4
Parametriocnemus sp.			1		1	4
Phaenopsectra sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.		3			3	12
Synorthocladius sp.						
Thienemanniella sp.		2			2	8
Thienemannimyia group			1		1	4
Tvetenia sp.	5	54	13		72	280
Other Diptera						
Atherix pachypus						
Chelifera/Neoplasta sp.	1	3			4	16
Hemerodromia sp.		1			1	4
Simulium sp.			1		1	4
Antocha sp.		3			3	12
Coleoptera						
Optioservus sp.	48	59	11		118	458
Zaitzevia parvula	2	4	3		9	35
Miscellaneous						
Atractides sp.		1			1	4
Hygrobates sp.		2			2	8
Lebertia sp.						
Protzia sp.		2			2	8
Sperchon sp.	1	4			5	20
Caecidotea sp.	3	14	1		18	70
Polycelis coronata						
Physa sp.						
Gyraulus sp.						
Pisidium sp.						
Crangonyx sp.		2	1		3	12
Hyalella azteca			1		1	4
Erpobdellidae	1	1			2	8
Lumbricidae		1	1		2	8
Naididae	1	1			2	8
Tubificidae with hair chaetae	14	1	11		26	101
Tubificidae w/o hair chaetae						
Nematoda						
Totals	**432**	**1879**	**457**		**2768**	**10747**

Table B3. Macroinvertebrate data collected from site CR-HSPP on 21 Sept. 2021.

Colorado River						
CR-22.1 (HSPP)		Sample				Estimated Total/m²
21 Sept. 2021	1	2	3		Total	
Ephemeroptera						
Acentrella turbida	1				1	4
Baetis flavistriga	2	6			8	31
Baetis (*tricaudatus*)	120	43	143		306	1186
Diphetor hageni	4	4	2		10	39
Drunella grandis	1	1			2	8
Ephemerella dorothea infrequens	231	137	287		655	2539
Epeorus sp.	8	8	19		35	136
Epeorus longimanus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	5	7	2		14	55
Plecoptera						
Paracapnia angulata						
Chloroperlidae	2				2	8
Zapada cinctipes						
Claassenia sabulosa	1				1	4
Hesperoperla pacifica	1				1	4
Perlodidae (*Cultus* sp.)		2			2	8
Isoperla sp.						
Skwala americana						
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	3		5		8	31
Brachycentrus occidentalis						
Culoptila sp.	19	24	41		84	326
Glossosoma sp.	2	1	4		7	28
Protoptila sp.	2	1	1		4	16
Helicopsyche borealis						
Arctopsyche grandis	1		4		5	20
Cheumatopsyche sp.	14	6	12		32	124
Hydropsyche sp.	3		1		4	16
Hydropsyche (cockerelli)	13	10	34		57	221
Hydropsyche oslari	18	8	57		83	322
Hydroptila sp.	1	8	22		31	121
Lepidostoma sp.	103	68	24		195	756
Ceraclea sp.						
Oecetis sp.	1				1	4
Psychomyia flavida		1			1	4
Rhyacophila coloradensis						

Table B3. cont. Macroinvertebrate data collected from site CR-HSPP on 21 Sept. 2021.

Diptera						
Chironomidae						
Brillia sp.						
Cardiocladius sp.			2		2	8
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	12	25	56		93	361
Eukiefferiella sp.	14	12	44		70	272
Lopescladius sp.						
Micropsectra/Tanytarsus sp.		1			1	4
Microtendipes sp.		1			1	4
Nanocladius sp.	2				2	8
Pagastia sp.						
Parametriocnemus sp.	10	1	15		26	101
Phaenopsectra sp.						
Polypedilum sp.	3	3	6		12	47
Potthastia sp.	1				1	4
Rheocricotopus sp.						
Synorthocladius sp.		1			1	4
Thienemanniella sp.	1	3	1		5	20
Thienemannimyia group	1		4		5	20
Tvetenia sp.	20	19	103		142	551
Other Diptera						
Atherix pachypus						
Chelifera/Neoplasta sp.						
Hemerodromia sp.		2	2		4	16
Simulium sp.	2	2	14		18	70
Antocha sp.			1		1	4
Coleoptera						
Optioservus sp.	54	48	35		137	531
Zaitzevia parvula	11	10			21	82
Miscellaneous						
Atractides sp.	1				1	4
Hygrobates sp.						
Lebertia sp.	1				1	4
Protzia sp.	1				1	4
Sperchon sp.	2	3			5	20
Caecidotea sp.	22	9	14		45	175
Polycelis coronata			3		3	12
Physa sp.						
Gyraulus sp.	1				1	4
Pisidium sp.						
Crangonyx sp.						
Hyalella azteca						
Erpobdellidae	1				1	4
Lumbricidae	3	2	2		7	28
Naididae		12	20		32	124
Tubificidae with hair chaetae	16				16	62
Tubificidae w/o hair chaetae						
Nematoda			1		1	4
Totals	**735**	**489**	**981**		**2205**	**8563**

Table B4. Macroinvertebrate data collected from site CR-WFU on 21 Sept. 2021.

Colorado River						
CR-16.7 (WFU)		Sample				Estimated Total/m²
21 Sept. 2021	1	2	3		Total	
Ephemeroptera						
Acentrella turbida	1	4	4		9	35
Baetis flavistriga						
Baetis (*tricaudatus*)	134	104	160		398	1543
Diphetor hageni		4	11		15	59
Drunella grandis	2	1	2		5	20
Ephemerella dorothea infrequens	121	127	180		428	1659
Epeorus sp.	22	23	30		75	291
Epeorus longimanus						
Heptagenia sp.		2			2	8
Rhithrogena sp.			3		3	12
Tricorythodes explicatus		1			1	4
Paraleptophlebia sp.		17	38		55	214
Plecoptera						
Paracapnia angulata						
Chloroperlidae		1	2		3	12
Zapada cinctipes			1		1	4
Claassenia sabulosa			1		1	4
Hesperoperla pacifica	1				1	4
Perlodidae (*Cultus* sp.)	1	1	1		3	12
Isoperla sp.		1	2		3	12
Skwala americana	1				1	4
Pteronarcys californica		5	3		8	31
Trichoptera						
Brachycentrus americanus	11	3	8		22	86
Brachycentrus occidentalis						
Culoptila sp.	22	20	23		65	252
Glossosoma sp.	8	5	3		16	62
Protoptila sp.	5	5	19		29	113
Helicopsyche borealis	1				1	4
Arctopsyche grandis						
Cheumatopsyche sp.		8	21		29	113
Hydropsyche sp.						
Hydropsyche (cockerelli)	12	25	14		51	198
Hydropsyche oslari	4	11	8		23	90
Hydroptila sp.	3	1			4	16
Lepidostoma sp.	10	10	42		62	241
Ceraclea sp.						
Oecetis sp.			1		1	4
Psychomyia flavida	1				1	4
Rhyacophila coloradensis			2		2	8

Table B4. cont. Macroinvertebrate data collected from site CR-WFU on 21 Sept. 2021.

Diptera						
Chironomidae						
Brillia sp.						
Cardiocladius sp.		1			1	4
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	28	4	12		44	171
Eukiefferiella sp.	26	21	37		84	326
Lopescladius sp.		3	2		5	20
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Nanocladius sp.			1		1	4
Pagastia sp.		1	1		2	8
Parametriocnemus sp.	1	2	6		9	35
Phaenopsectra sp.						
Polypedilum sp.	9	19	23		51	198
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.		1			1	4
Thienemanniella sp.						
Thienemannimyia group		1			1	4
Tvetenia sp.	8	2	4		14	55
Other Diptera						
Atherix pachypus	1				1	4
Chelifera/Neoplasta sp.						
Hemerodromia sp.			1		1	4
Simulium sp.	5	6	11		22	86
Antocha sp.						
Coleoptera						
Optioservus sp.	21	37	76		134	520
Zaitzevia parvula	1	11	14		26	101
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.						
Sperchon sp.		4	1		5	20
Caecidotea sp.		9	18		27	105
Polycelis coronata	14	45	65		124	481
Physa sp.		1	1		2	8
Gyraulus sp.						
Pisidium sp.	1				1	4
Crangonyx sp.			1		1	4
Hyalella azteca						
Erpobdellidae						
Lumbricidae			4		4	16
Naididae	5	14	55		74	287
Tubificidae with hair chaetae		2	16		18	70
Tubificidae w/o hair chaetae						
Nematoda	1				1	4
Totals	**481**	**563**	**928**		**1972**	**7662**

Appendix C

Denver Water
Benthic Macroinvertebrate Data – Fall 2021

Table C1. Macroinvertebrate data collected from site FR-abvWPSD on 20 Sept. 2021.

Fraser River						
FR-23.2 (abvWPSD)		Sample				Estimated
20 Sept. 2021	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Ameletus sp.			2		2	8
Acentrella turbida	12	12	9		33	128
Baetis flavistriga	2	8	3		13	51
Baetis (*tricaudatus*)	163	143	95		401	1555
Diphetor hageni						
Drunella coloradensis		3			3	12
Drunella doddsii		1			1	4
Drunella grandis						
Ephemerella dorothea infrequens	1		1		2	8
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.		1			1	4
Epeorus longimanus						
Rhithrogena sp.						
Tricorythodes explicatus		2			2	8
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata	1		1		2	8
Chloroperlidae	1				1	4
Sweltsa sp.	10	6	12		28	109
Prostoia besametsa	6	4	9		19	74
Zapada cinctipes						
Zapada oregonensis group	1				1	4
Perlodidae						
Perlodidae (*Cultus* sp.)			1		1	4
Isoperla sp.						
Isoperla fulva						
Skwala americana						
Taenionema sp.	2		1		3	12
Trichoptera (caddisflies)						
Brachycentrus americanus	8	10	5		23	90
Brachycentrus occidentalis						
Anagapetus debilis						
Glossosoma sp.						
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Lepidostoma sp.						
Oecetis sp.						
Chimarra utahensis		1			1	4
Rhyacophila brunnea						
Rhyacophila coloradensis			1		1	4
Rhyacophila sibirica group			1		1	4
Oligophlebodes sp.	6	18	11		35	136

Table C1. cont. Macroinvertebrate data collected from site FR-abvWPSD on 20 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	128	167	115		410	1590
Diamesa sp.	6	1	3		10	39
Eukiefferiella sp.	4	2	2		8	31
Micropsectra/Tanytarsus sp.	1				1	4
Pagastia sp.	1	1	3		5	20
Parametriocnemus sp.						
Polypedilum sp.						
Rheocricotopus sp.			2		2	8
Rheotanytarsus sp.						
Stempellinella sp.						
Sublettea sp.						
Synorthocladius sp.	7	10	5		22	86
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.						
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae	3	9	11		23	90
Chelifera/Neoplasta sp.	1				1	4
Wiedemannia sp.						
Pericoma sp.		1	2		3	12
Simulium sp.	1				1	4
Antocha sp.						
Tipula sp.			2		2	8
Coleoptera (beetles)						
Cleptelmis sp.						
Heterlimnius sp.	44	39	29		112	435
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.		2	2		4	16
Lebertia sp.	64	49	27		140	543
Sperchon sp.	27	44	25		96	373
Torrenticola sp.						
Polycelis coronata	8	29	22		59	229
Crangonyx sp.						
Enchytraeidae	14	13	26		53	206
Lumbricidae						
Naididae		1			1	4
Nematoda						
Totals	**522**	**577**	**428**		**1527**	**5933**

Table C2. Macroinvertebrate data collected from site VC-WP on 20 Sept. 2021.

Vasquez Creek						
VC-WP		Sample				Estimated
20 Sept. 2021	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella turbida	1	2	3		6	24
Baetis flavistriga						
Baetis (*tricaudatus*)	44	42	54		140	543
Diphetor hageni						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis						
Ephemerella dorothea infrequens						
Serratella tibialis	2	2	5		9	35
Cinygmula sp.		11	10		21	82
Epeorus sp.	1	3	7		11	43
Epeorus longimanus						
Rhithrogena sp.	1				1	4
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.	4		3		7	28
Prostoia besametsa						
Zapada cinctipes	2	1			3	12
Zapada oregonensis group	3	2	6		11	43
Perlodidae		1			1	4
Perlodidae (*Cultus* sp.)						
Isoperla sp.	1				1	4
Isoperla fulva						
Skwala americana						
Taenionema sp.	7	1	3		11	43
Trichoptera (caddisflies)						
Brachycentrus americanus		1			1	4
Brachycentrus occidentalis						
Anagapetus debilis			3		3	12
Glossosoma sp.		1	1		2	8
Arctopsyche grandis	1	1			2	8
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Lepidostoma sp.	1				1	4
Oecetis sp.						
Chimarra utahensis						
Rhyacophila brunnea		1	2		3	12
Rhyacophila coloradensis						
Rhyacophila sibirica group	5	2	3		10	39
Oligophlebodes sp.	3	6			9	35

Table C2. cont. Macroinvertebrate data collected from site VC-WP on 20 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola		1	1		2	8
Cricotopus/Orthocladius sp.	9	15	19		43	167
Diamesa sp.						
Eukiefferiella sp.	14		10		24	93
Micropsectra/Tanytarsus sp.						
Pagastia sp.		3	7		10	39
Parametriocnemus sp.						
Polypedilum sp.						
Rheocricotopus sp.						
Rheotanytarsus sp.	1				1	4
Stempellinella sp.						
Sublettea sp.						
Synorthocladius sp.		3	6		9	35
Thienemanniella sp.			2		2	8
Thienemannimyia group						
Tvetenia sp.	4	2	9		15	59
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae	1	3			4	16
Chelifera/Neoplasta sp.						
Wiedemannia sp.						
Pericoma sp.		2			2	8
Simulium sp.	2		4		6	24
Antocha sp.		2			2	8
Tipula sp.						
Coleoptera (beetles)						
Cleptelmis sp.						
Heterlimnius sp.	26	44	40		110	427
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.	10	11	11		32	124
Sperchon sp.		2	2		4	16
Torrenticola sp.						
Polycelis coronata	7	10			17	66
Crangonyx sp.						
Enchytraeidae	7	2	1		10	39
Lumbricidae						
Naididae						
Nematoda		1			1	4
Totals	**157**	**178**	**212**		**547**	**2132**

Table C3. Macroinvertebrate data collected from site FR-Rendezvous on 20 Sept. 2021.

Fraser River						
FR-20 (Rendezvous)		Sample				Estimated
20 Sept. 2021	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella turbida	7	2	1		10	39
Baetis flavistriga						
Baetis (*tricaudatus*)	54	44	46		144	559
Diphetor hageni						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	1	2			3	12
Ephemerella dorothea infrequens	4	2			6	24
Serratella tibialis						
Cinygmula sp.	1		1		2	8
Epeorus sp.						
Epeorus longimanus						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.	4	1			5	20
Prostoia besametsa		5			5	20
Zapada cinctipes	6	7	2		15	59
Zapada oregonensis group	3	4			7	28
Perlodidae						
Perlodidae (*Cultus* sp.)	4	2	1		7	28
Isoperla sp.						
Isoperla fulva		2			2	8
Skwala americana	1		1		2	8
Taenionema sp.		3	5		8	31
Trichoptera (caddisflies)						
Brachycentrus americanus	41	63	23		127	493
Brachycentrus occidentalis						
Anagapetus debilis						
Glossosoma sp.	1		1		2	8
Arctopsyche grandis	13	8	2		23	90
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Lepidostoma sp.	4	4			8	31
Oecetis sp.						
Chimarra utahensis						
Rhyacophila brunnea	1		1		2	8
Rhyacophila coloradensis			1		1	4
Rhyacophila sibirica group	1				1	4
Oligophlebodes sp.	10	13	4		27	105

Table C3. cont. Macroinvertebrate data collected from site FR-Rendezvous on 20 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.			1		1	4
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	378	479	154		1011	3919
Diamesa sp.	5				5	20
Eukiefferiella sp.	2	20	1		23	90
Micropsectra/Tanytarsus sp.						
Pagastia sp.	6	14	3		23	90
Parametriocnemus sp.						
Polypedilum sp.	2		1		3	12
Rheocricotopus sp.						
Rheotanytarsus sp.	1	3	1		5	20
Stempellinella sp.			1		1	4
Sublettea sp.	25	115	25		165	640
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.		3	2		5	20
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae			1		1	4
Chelifera/Neoplasta sp.	1	6			7	28
Wiedemannia sp.						
Pericoma sp.	38	36	60		134	520
Simulium sp.			1		1	4
Antocha sp.	7	11	2		20	78
Tipula sp.						
Coleoptera (beetles)						
Cleptelmis sp.						
Heterlimnius sp.	145	96	78		319	1237
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Atractides sp.	2				2	8
Hygrobates sp.		2			2	8
Lebertia sp.	19	19	27		65	252
Sperchon sp.	23	33	22		78	303
Torrenticola sp.	1				1	4
Polycelis coronata	100	76	35		211	818
Crangonyx sp.						
Enchytraeidae						
Lumbricidae						
Naididae	2		9		11	43
Nematoda	2		1		3	12
Totals	**915**	**1075**	**514**		**2504**	**9725**

Table C4. Macroinvertebrate data collected from site FR-CR83 on 20 Sept. 2021.

Fraser River						
FR-14 (CR83)		Sample				Estimated
20 Sept. 2021	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella turbida	2	1			3	12
Baetis flavistriga						
Baetis (*tricaudatus*)	52	25	23		100	388
Diphetor hageni			1		1	4
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	39	22	22		83	322
Ephemerella dorothea infrequens	33	42	48		123	477
Serratella tibialis						
Cinygmula sp.						
Epeorus sp.						
Epeorus longimanus	9	7	4		20	78
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	5	20	5		30	117
Plecoptera (stoneflies)						
Paracapnia angulata		1			1	4
Chloroperlidae	1				1	4
Sweltsa sp.		1			1	4
Prostoia besametsa						
Zapada cinctipes						
Zapada oregonensis group						
Perlodidae						
Perlodidae (*Cultus* sp.)			1		1	4
Isoperla sp.						
Isoperla fulva	1	2	5		8	31
Skwala americana		1			1	4
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	7	16	8		31	121
Brachycentrus occidentalis		6	4		10	39
Anagapetus debilis						
Glossosoma sp.	36	31	62		129	500
Arctopsyche grandis	13	3	25		41	159
Cheumatopsyche sp.			1		1	4
Hydropsyche sp.		6	6		12	47
Hydropsyche cockerelli	95	81	133		309	1198
Hydropsyche oslari	7	20	18		45	175
Lepidostoma sp.	10	96	24		130	504
Oecetis sp.			2		2	8
Chimarra utahensis						
Rhyacophila brunnea						
Rhyacophila coloradensis	4		3		7	28
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table C4. cont. Macroinvertebrate data collected from site FR-CR83 on 20 Sept. 2021.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	1				1	4
Cricotopus/Orthocladius sp.	65	30	43		138	535
Diamesa sp.			1		1	4
Eukiefferiella sp.	11		8		19	74
Micropsectra/Tanytarsus sp.		2			2	8
Pagastia sp.						
Parametriocnemus sp.			1		1	4
Polypedilum sp.						
Rheocricotopus sp.						
Rheotanytarsus sp.						
Stempellinella sp.						
Sublettea sp.						
Synorthocladius sp.	1		1		2	8
Thienemanniella sp.						
Thienemannimyia group		2	4		6	24
Tvetenia sp.	5	7	10		22	86
Other Diptera (true flies)						
Atherix pachypus			1		1	4
Ceratopogoninae						
Chelifera/Neoplasta sp.	3	3	2		8	31
Wiedemannia sp.	1				1	4
Pericoma sp.						
Simulium sp.	3		1		4	16
Antocha sp.	1	3	3		7	28
Tipula sp.						
Coleoptera (beetles)						
Cleptelmis sp.	1				1	4
Heterlimnius sp.	2	5	3		10	39
Optioservus sp.	66	139	107		312	1210
Zaitzevia parvula		4	2		6	24
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.						
Sperchon sp.		3	4		7	28
Torrenticola sp.						
Polycelis coronata			1		1	4
Crangonyx sp.			2		2	8
Enchytraeidae						
Lumbricidae		4	2		6	24
Naididae		2	2		4	16
Nematoda						
Totals	**474**	**585**	**593**		**1652**	**6419**

Appendix D

Learning By Doing
Historical MMI v4 and Individual Metric Results – 2017, 2018, 2019 & 2020

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**	**WF-2.0**	**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**	**WF-2.0**	**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. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during the fall of 2020. All metric scores are based on the MMI v4 subsampling process.

Metric	Station ID									
	FR-25.1	**FR-15**	**FR-12.4**	**RC-1.1**	**WF-5.5**	**WF-2.0**	**WF-0.5**	**CR-9.1**	**CR-7.4**	**CR-1.7**
EPT Taxa	81.6	54.2	75.0	70.8	58.3	41.6	44.6	89.0	100.0	71.1
% EPT, no Baetidae	32.5	100.0	100.0	92.9	59.1	6.1	8.4	75.1	60.6	32.7
Clinger Taxa	70.0	52.9	67.3	67.3	57.7	48.1	45.4	92.6	100.0	73.6
Total Taxa	92.9	--	--	--	--	--	--	--	--	--
Intolerant Taxa	100.0	--	--	--	--	--	--	--	--	--
% Increasers, Mountains	26.4	--	--	--	--	--	--	--	--	--
Predator Taxa	92.3	--	--	--	--	--	--	--	--	--
% Scraper individuals	33.9	--	--	--	--	--	--	--	--	--
% Non-Insect individuals	--	96.2	95.8	80.0	95.8	88.6	93.6	59.6	92.2	76.7
% Coleoptera individuals	--	10.4	17.7	20.5	15.0	0.0	0.8	32.8	50.6	21.6
% Intolerant Taxa	--	64.4	84.3	77.1	71.7	89.5	99.0	74.2	100.0	70.9
% Increasers, Mid-Elev.	--	97.4	97.2	91.0	98.6	98.6	100.0	68.4	93.4	58.4
Predator/Shredder taxa	--	71.4	64.3	78.6	71.4	50.0	28.6	57.1	71.4	64.3
MMI	**66.2**	**68.4**	**75.2**	**72.3**	**66.0**	**52.8**	**52.5**	**68.6**	**83.5**	**58.7**
	Auxiliary Metrics									
Diversity	3.82	2.40	3.46	3.80	3.78	2.89	2.26	4.29	4.29	3.54
HBI	4.53	1.93	2.13	2.47	3.61	5.43	5.05	2.86	3.36	4.97
Sediment Region	SR1	SR2		SR2						
TIV	5.44	3.93	--	4.69	--	--	--	--	--	--

Table D5. 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 (mean #/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 D6. 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	WF-2.0	CR-9.1	CR-7.4	CR-1.7
Density (mean #/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 D7. 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	WF-2.0	WF-0.5	CR-9.1	CR-7.4	CR-1.7
Density (mean #/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%

Table D8. Additional individual metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in the fall of 2020. All additional metric values are based on full count Hess samples.

Metric	FR-25.1	FR-15	FR-12.4	RC-1.1	WF-5.5	WF-2.0	WF-0.5	CR-9.1	CR-7.4	CR-1.7
Density (mean #/m^2)	1,848	28,703	14,088	2,329	7,099	14,133	10,366	9,386	10,326	6,808
Taxa Richness	43	47	52	37	47	36	28	53	55	45
EPT Taxa	23	19	25	18	21	18	14	28	29	21
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	0	0	0	0
% EPT-excluding Baetidae	28.33%	78.30%	76.52%	66.00%	38.26%	2.91%	4.79%	52.63%	46.56%	24.14%
% Chironomidae	6.13%	11.73%	8.16%	15.58%	20.63%	47.87%	10.63%	8.32%	11.92%	14.16%
% Hydropsychidae	6.25%	55.37%	38.15%	5.02%	24.43%	20.00%	5.88%	14.16%	24.59%	47.88%
% Tolerant Taxa	11.63%	17.02%	23.08%	21.62%	14.89%	16.67%	14.29%	18.87%	18.18%	24.44%
% Intolerant Taxa	53.49%	31.91%	44.23%	43.24%	38.30%	38.89%	46.43%	37.74%	40.00%	31.11%

Appendix E

Northern Water (WGFP) and Denver Water
Metric Results from the fall of 2020

Table E1. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected from Northern Water sampling sites on the Colorado River on 17 September 2020. 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	62.5	75.0	58.3	75.0
% Non-Insect Individuals	38.5	95.4	94.6	76.4
% EPT Individuals (no Baetidae)	25.4	91.3	63.0	85.4
% Coleoptera Individuals	5.0	8.3	6.0	12.6
% Intolerant Taxa	56.0	63.8	67.8	87.8
% Increaser Individuals (Mid-Elev)	0.0	94.7	91.8	98.6
Clinger Taxa	67.3	81.7	62.5	76.9
Predator/Shredder Taxa	42.9	42.9	50.0	64.3
MMI v4	**37.2**	**69.1**	**61.7**	**72.1**
	Auxiliary Metrics			
Diversity	3.98	3.40	3.62	3.62
HBI	5.68	2.83	3.67	2.24
TIV (Sediment Region 2)	--	5.16	--	4.00

Table E2: Additional metrics and comparative values for macroinvertebrate samples collected from Northern Water sampling sites on the Colorado River on 17 September 2020. All metrics are based on full count Hess samples.

Metric	CR-WGU	CR-WGD	CR-HSPP	CR-WFU
EPT	18	25	18	25
Evenness	0.726	0.563	0.667	0.663
DAT	25.9	37.4	23.0	23.1
Insect Taxa	33	46	33	34
Total Taxa	45	58	41	40
Percent Shredders and Scrapers	9.50%	5.55%	20.42%	37.40%
Density of *Pteronarcys californica* (#/m^2)	0	0	0	43
Percent EPT (excluding Baetidae)	19.68%	68.42%	48.36%	67.72%
Density (mean #/m2)	3,405	22,873	8,781	5,919
Percent Chironomidae	40.73%	8.90%	20.60%	1.90%
Percent Hydropsychidae	60.84%	53.18%	45.25%	21.25%
Percent Tolerant Taxa	26.67%	24.14%	21.95%	15.00%
Percent Intolerant Taxa	33.33%	32.76%	39.02%	50.00%

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 2020. 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	54.2	91.3	66.7	70.8
% Non-Insect Individuals	38.4	47.6	54.9	96.6
% EPT Individuals, no Baetidae	12.3	20.1	17.2	99.0
% Coleoptera Individuals	19.8	74.7	18.0	13.8
% Intolerant Taxa	78.9	90.7	82.0	79.3
% Increasers Mid-Elevation	32.0	70.7	66.9	98.6
Clinger Taxa	43.3	89.2	67.3	76.9
Predator/Shredder Taxa	78.6	92.9	85.7	71.4
MMI v4	**44.7**	**72.1**	**57.3**	**75.8**
	Auxiliary Metrics			
Diversity	3.80	3.86	3.35	3.62
HBI	4.82	3.59	3.84	2.54
TIV (Sediment Region 2)	5.73	5.99	5.99	4.53

Table E4. Additional metrics and comparative values for macroinvertebrate samples collected from the Denver Water study area (Fraser River and Vasquez Creek) in September 2020. All additional metric values are based on full count Hess samples.

	FR-abvWPSD	VC-WP	FR-Rendezvous	FR-CR83
Density (#/m^2)	3,654	2,032	8,681	7,896
Taxa Richness	31	44	41	42
EPT	15	26	21	21
Density of *Pteronarcys californica*(#/m^2)	0	0	0	0
Percent EPT (excluding Baetidae)	10.22%	14.23%	13.77%	72.01%
Percent Chironomidae	22.68%	19.04%	40.79%	13.87%
Evenness	0.771	0.712	0.623	0.662
DAT Index	20.9	23.6	25.2	27.3
Percent Hydropsychidae	0.00%	5.13%	13.25%	46.35%
Percent Tolerant Taxa	19.35%	11.36%	9.76%	14.29%
Percent Intolerant Taxa	48.39%	54.55%	48.78%	45.24%

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

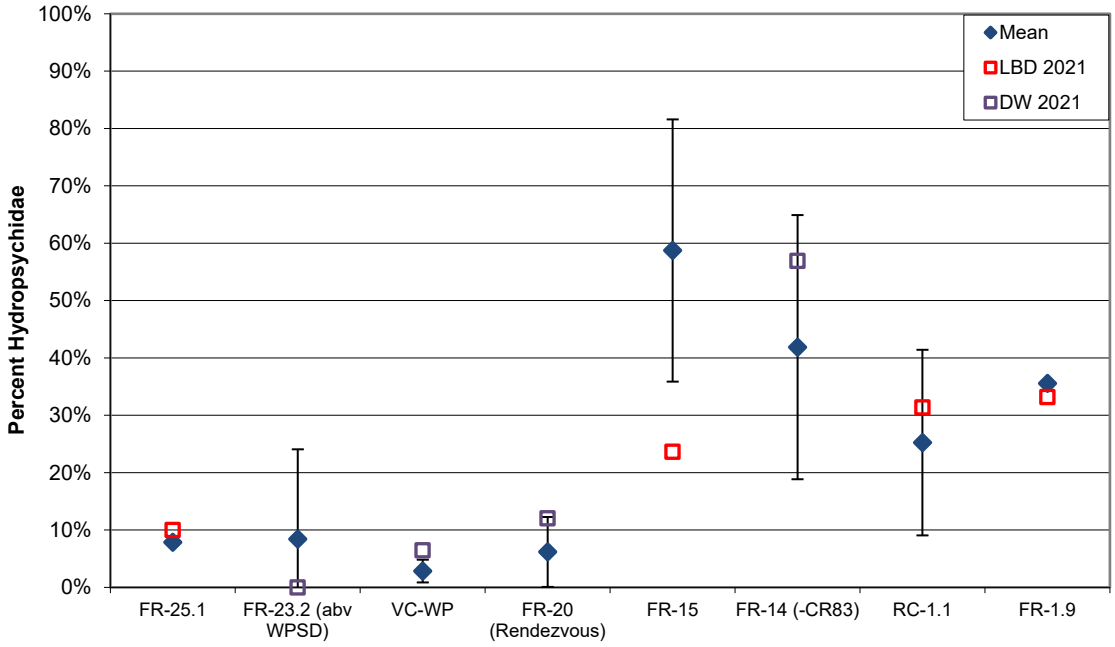

Figure F1. Percent Hydropsychidae values from study sites in the Fraser River study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

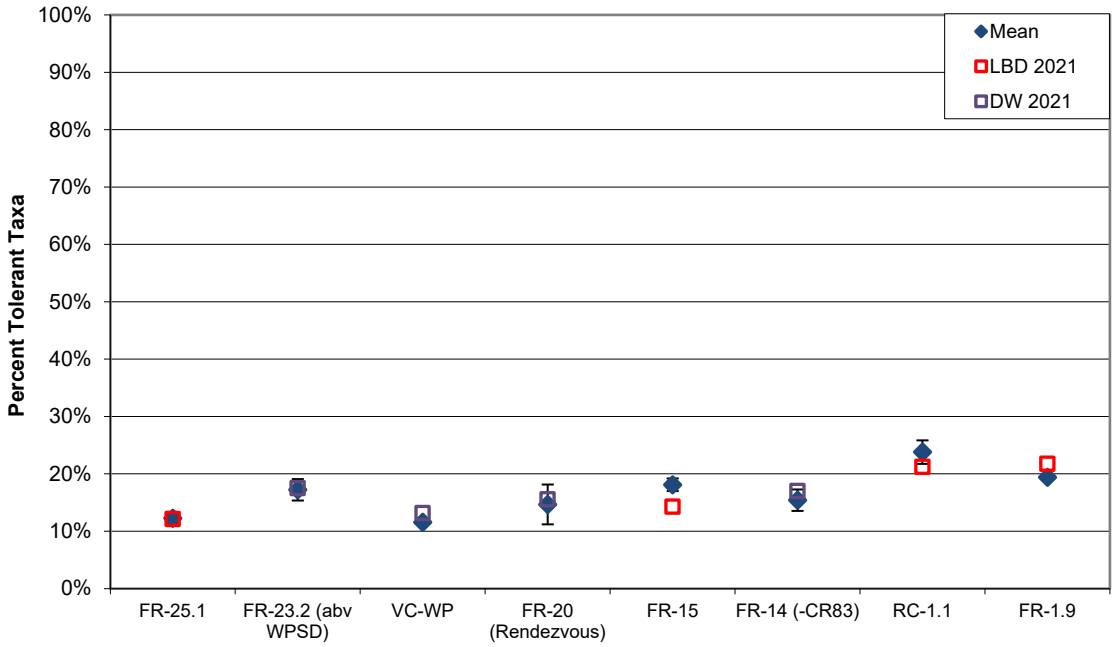

Figure F2. Percent Tolerant Taxa values from the Fraser River study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

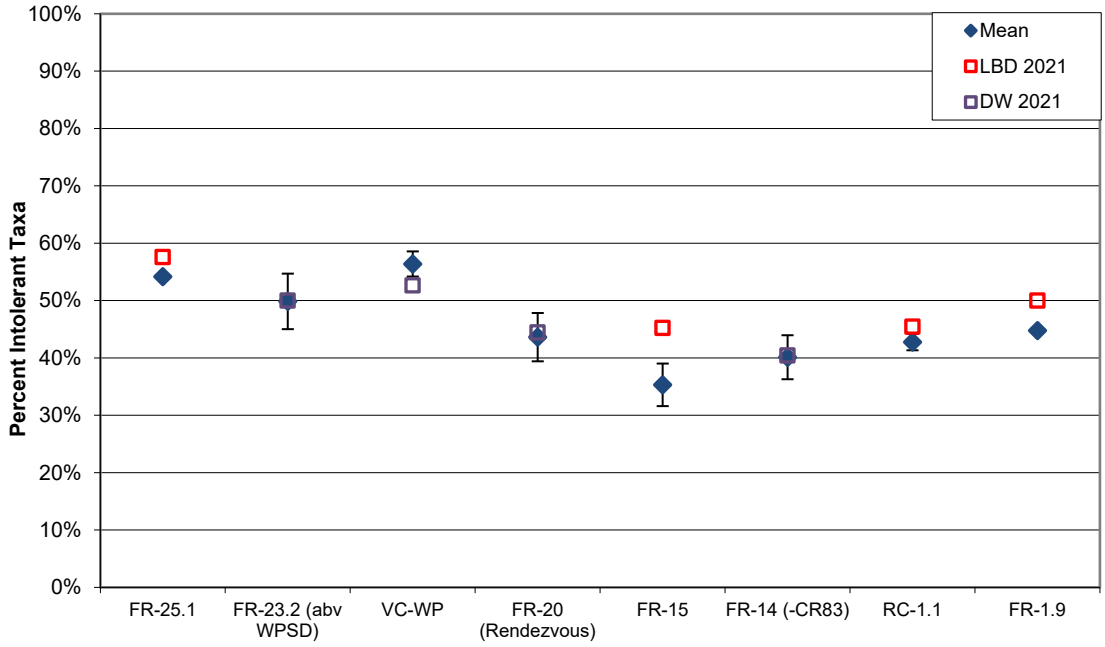

Figure F3. Percent Intolerant Taxa values from study sites in the Fraser River study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

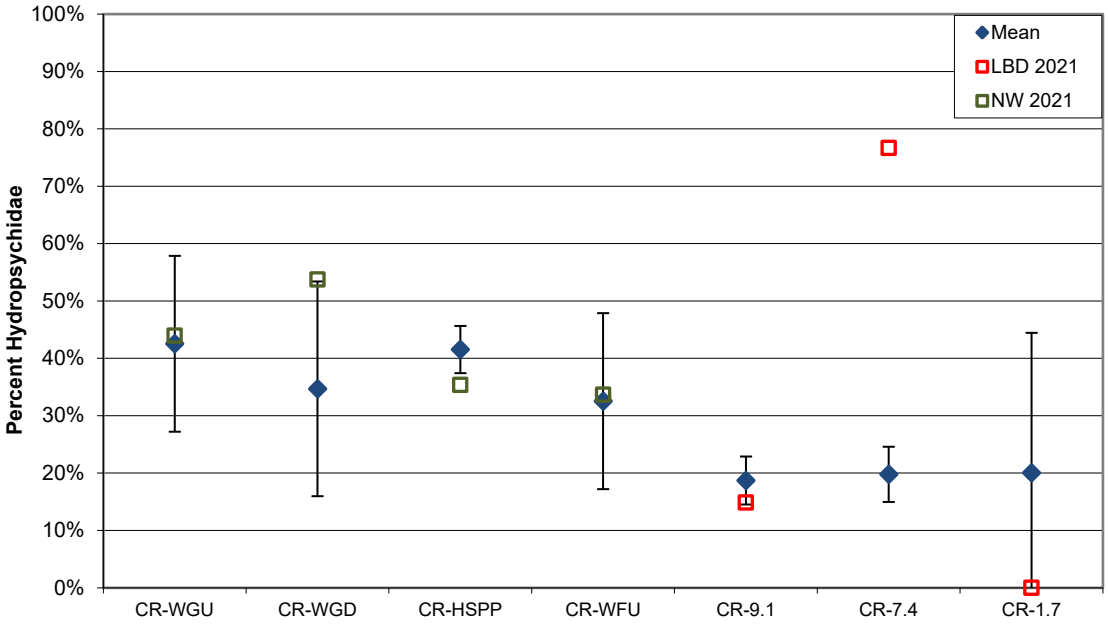

Figure F4. Percent Hydropsychidae values from study sites in the Colorado River study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

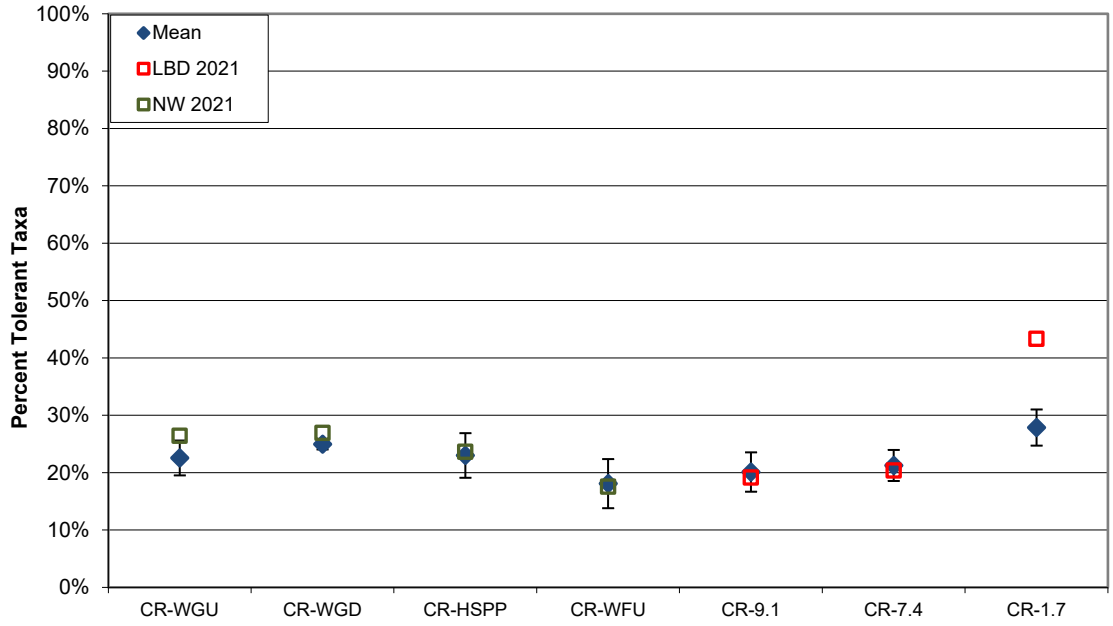

Figure F5. Percent Tolerant Taxa values from study sites in the Colorado River study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

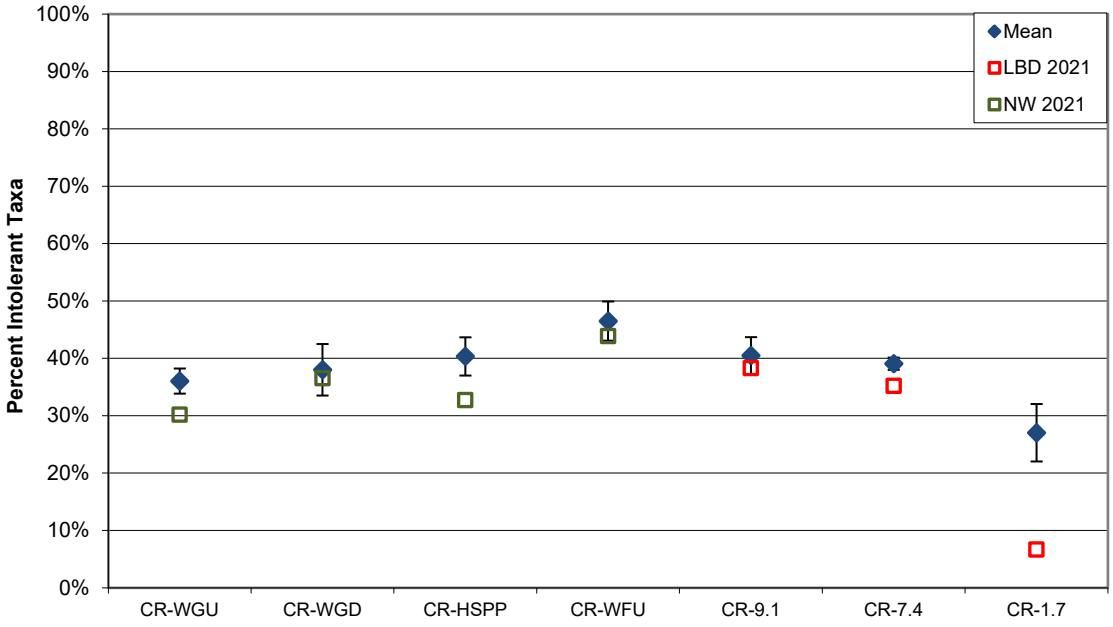

Figure F6. Percent Intolerant Taxa values from study sites in the Colorado River study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

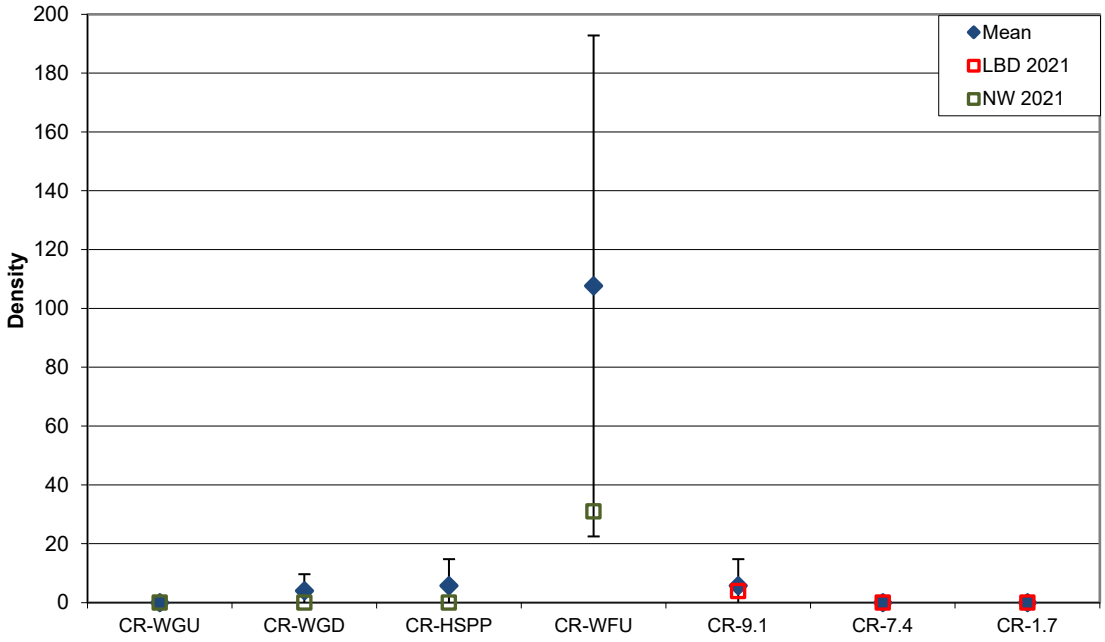

Figure F7. Density of *Pteronarcys californica* in the Colorado River study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

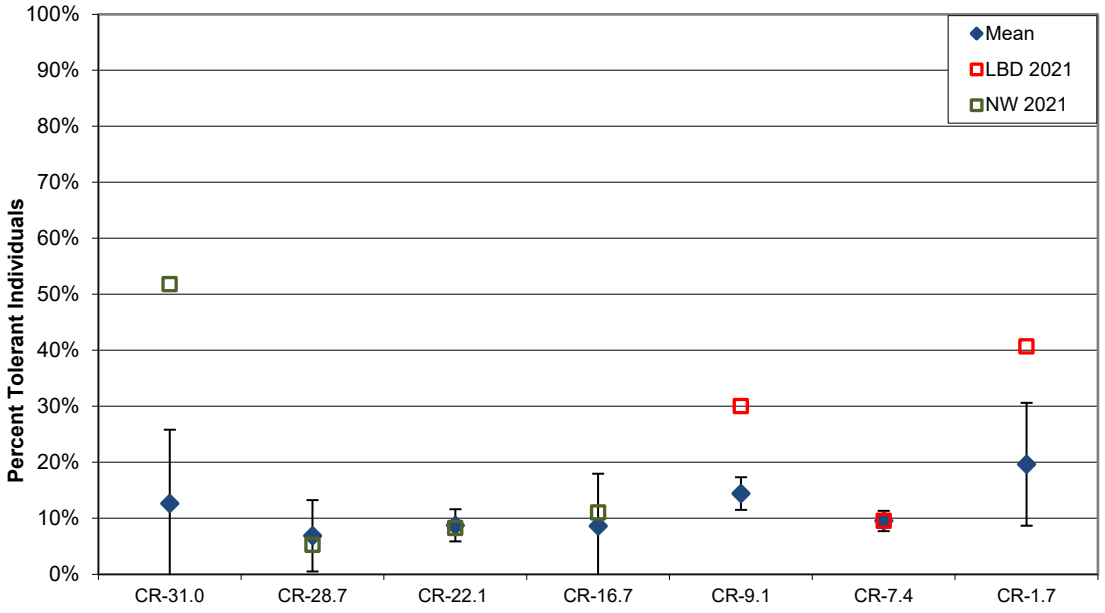

Figure F8. Percent Tolerant Individuals values in the Colorado River study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events

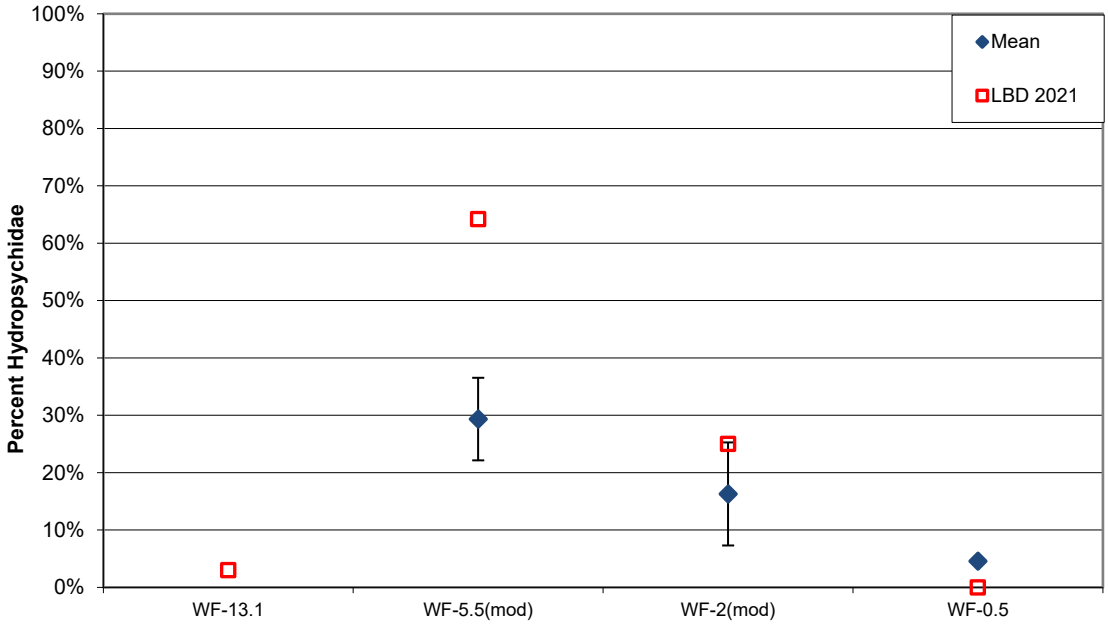

Figure F9. Percent Hydropsychidae values from study sites in the Williams Fork study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

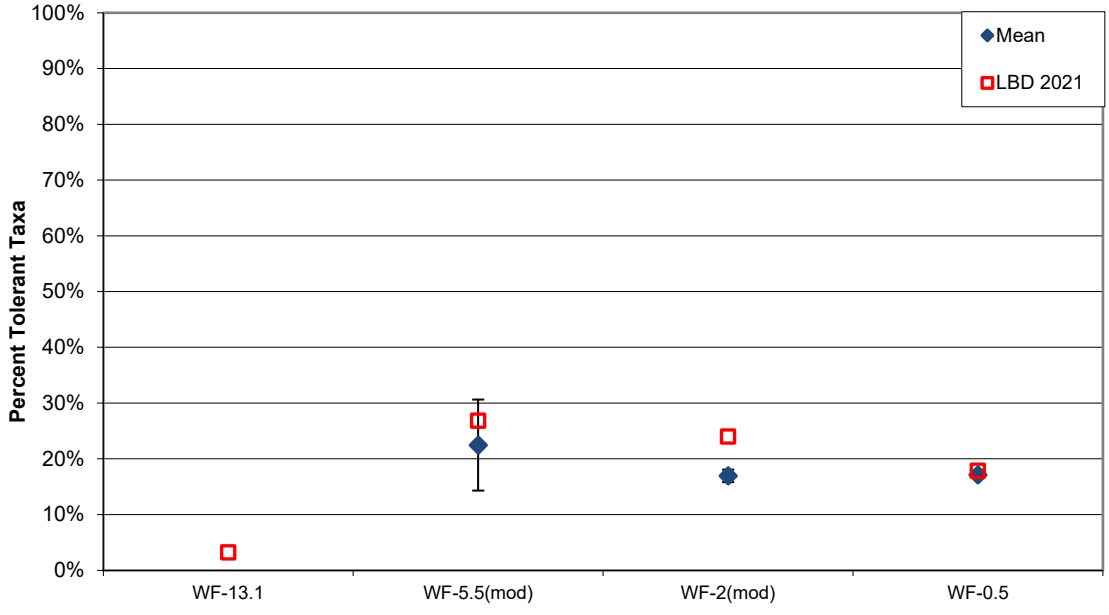

Figure F10. Percent Tolerant Taxa values from study sites in the Williams Fork study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

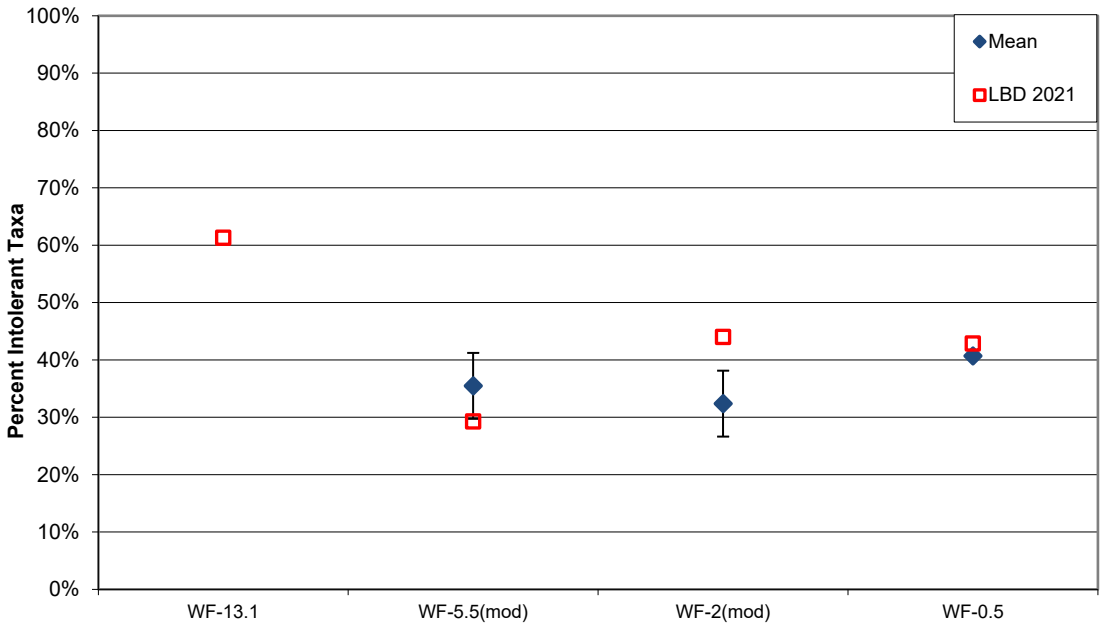

Figure F11. Percent Intolerant Taxa values from study sites in the Williams Fork study area from fall 2021 and mean values (±1 standard deviation) from previous sampling events.

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