Summary Report

Learning by Doing

Benthic Macroinvertebrate Biomonitoring

2022

Prepared for:

Grand County
Learning by Doing Stakeholder Group

Prepared by:

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

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Introduction

As human populations and associated water demands continue to expand and evolve, the need for sustained water supplies to support human activities (agricultural irrigation, municipalities, recreational opportunities, etc.), while also providing adequate habitat for a wide range of aquatic organisms, creates considerable challenges (Strayer 2010). Historically, much of the urban development that supports human populations in the USA has occurred in close proximity to river systems (Fang and Jawitz 2019), which often results in a variety of negative impacts to aquatic communities (Nelson 2011, Wooster et al. 2011, Johnson et al. 2013, Patang et al. 2018). Hydrological alterations, the addition of nutrients, and runoff from roads in nearby residential developments represent typical sources of stress to freshwater ecosystems (Søndergaard and Jeppesen 2007). To ensure the sustainability of healthy rivers and streams, and minimize anthropogenic impacts, it is essential that biological communities are routinely and accurately monitored to evaluate the level of stress to aquatic ecosystems.

Biomonitoring of benthic macroinvertebrate communities is often considered an integral part of 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). Inevitably, the 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 provide a comprehensive assessment of 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 the variety of continuously evolving anthropogenic influences (such as urban development, changes in land-use practices, and even climate change) on aquatic life (Rosenberg and Resh 1993, Likens and Lambert 1998, Voelz et al. 2005, 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). Changes in macroinvertebrate community structure and function can help identify sources of stress that range from local sources of pollution to watershed scale disturbances, thus providing opportunities for the assessment, management, and protection of aquatic resources (Rosenberg and Resh 1993, Ward et al. 2002).

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, Willow Creek, Williams Fork, and Colorado River (Table 1; Figure 1). These streams support a wide 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 provide a reliable measurement of the health of benthic macroinvertebrate communities at specific locations within the study area.

Study Area

In the fall of 2022, 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, Colorado. A comprehensive evaluation of spatial changes in benthic macroinvertebrate community health was made possible by the coordinated efforts provided by Learning By Doing (LBD), Denver Water, and Northern Water.

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

In 2022, the LBD CEA included a total of 12 study sites: one on the Fraser River, one on Saint Louis Creek, one on Ranch Creek, two on Willow Creek, three on the Williams Fork, and four on the Colorado River (Table 1; Figure 1). In the Fraser River Watershed, the most upstream study site (FR-27.2) was located in riffle habitat upstream of Jim Creek and the Union Pacific (UP) Moffat Tunnel. The single sampling location on Saint Louis Creek (SLC-0) was located immediately upstream of the confluence with the Fraser River, and the site on Ranch Creek, site RC-1.1, was located downstream from Meadow Creek and upstream from the confluence with the Fraser River (Figure 2).

The LBD Stakeholder Group was also responsible for the macroinvertebrate sampling conducted at several locations along the Colorado River and associated tributaries. In the fall of 2022, study sites on tributaries of the Colorado River included two new sampling locations on Willow Creek and three routinely sampled study sites on the Williams Fork. The most upstream site on Willow Creek was located upstream of the Bunte Highline Ditch Diversion, while the downstream site was used to assess macroinvertebrate community structure in Willow Creek upstream from the Colorado River (Table 1; Figure 3). The three study sites on the Williams Fork included one site upstream from Williams Fork Reservoir and two sites downstream from the reservoir (Figure 4). 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 while 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.

LBD sampling locations on the Colorado River included: a new site at CR-24.9 (on Sheriff Ranch), site CR-9.1 (located upstream from the CR39 Bridge), site CR-7.4 (downstream from Troublesome Creek), and the most downstream sampling location 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, Colorado (Figure 3). Several other sampling locations along 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 2022 (Table 1; Figures 1 and 2). These four study sites were selected in order to monitor aquatic macroinvertebrate communities at locations that have 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 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 'impairment' designations. 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.

Northern Water Study Sites

Study sites for the Northern Water Conservancy District (Northern Water) in 2022 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 seven years. In 2022, Northern Water sampling locations included: site CR-31.0 (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 since 2016 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 for sample sites associated with the Learning By Doing, Denver Water, and Northern Water biomonitoring studies in the Upper Colorado River Basin during fall 2022.

	Monitoring Project	Location	Latitude	Longitude
FR-27.2	Learning By Doing	Fraser River above Jim Creek	39.84536	-105.75177
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
SLC-0	Learning By Doing	Saint Louis Creek at Fraser River	39.95175	-105.81471
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
WC-BHU	Learning By Doing	Willow Creek upstream Bunte Highline Ditch Diversion	40.13765	-105.9284
WC-CRU	Learning By Doing	Willow Creek upstream Colorado River	40.12963	-105.91741
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-24.9	Learning By Doing	Colorado River at Sheriff Ranch	40.0873	-106.0671
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

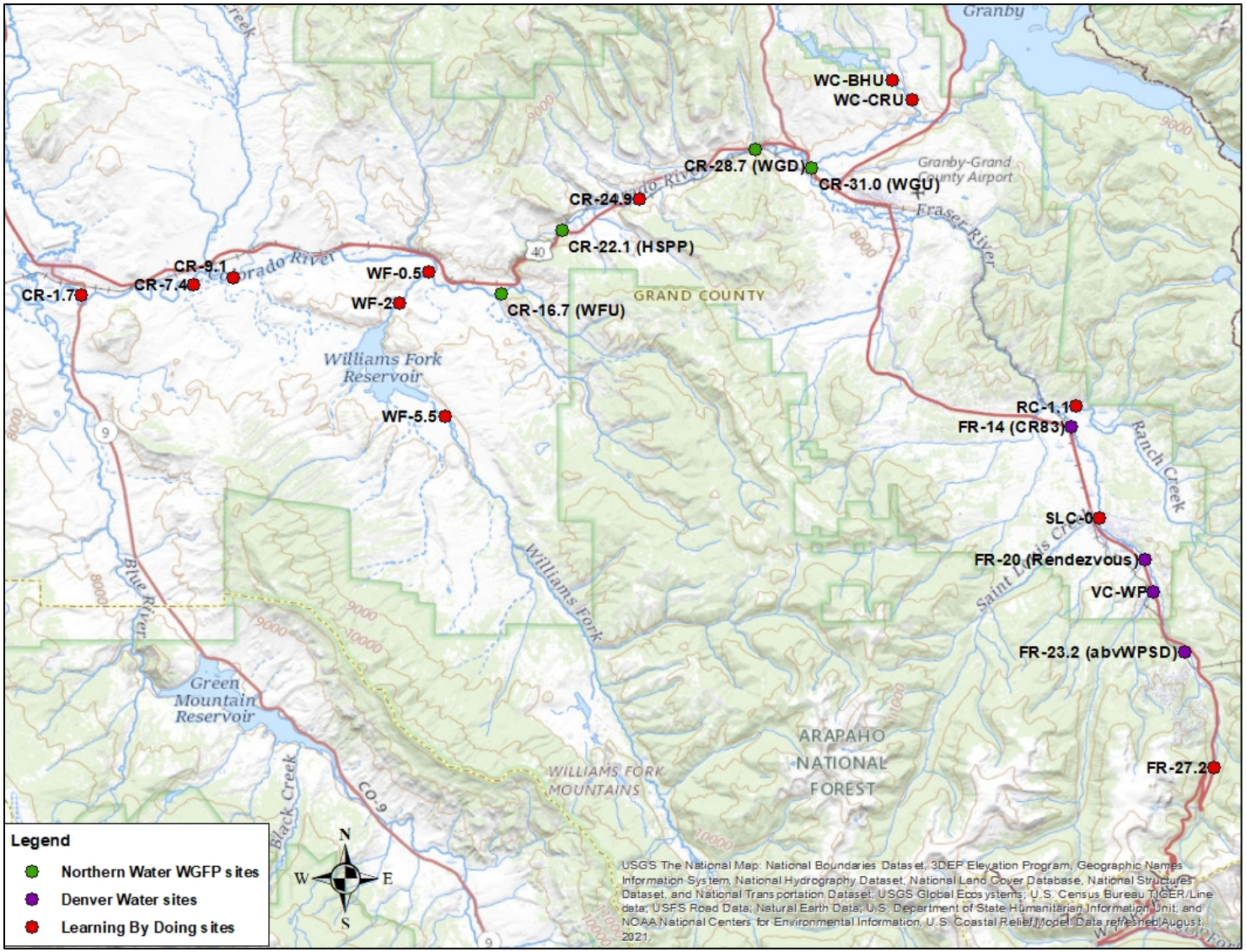

Figure 1. Map of study sites used for the Learning By Doing, Denver Water, and Northern Water biomonitoring studies in 2022.

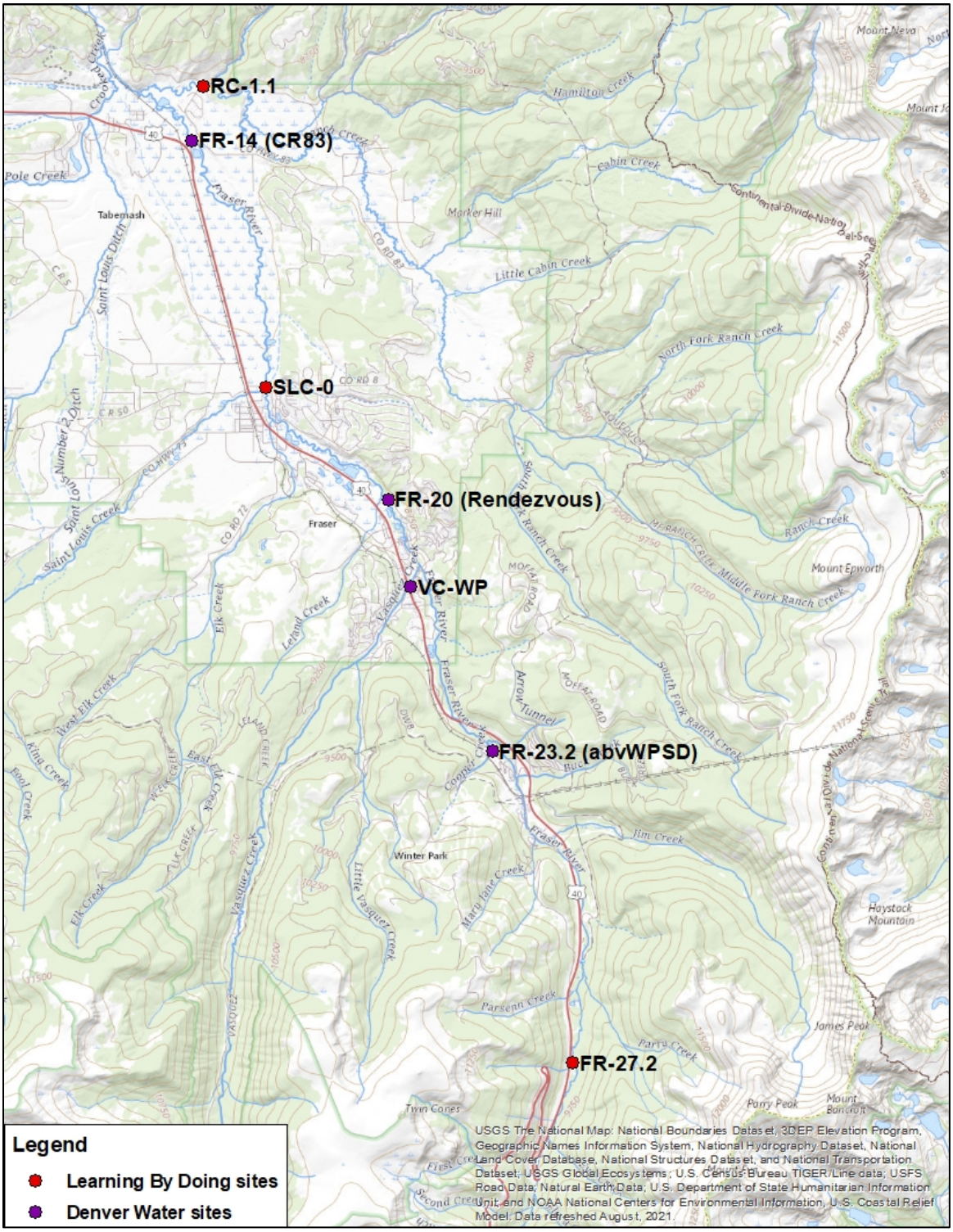

Figure 2. Map of study sites used for the Learning By Doing and Denver Water biomonitoring studies in the Fraser River Drainage during the fall of 2022.

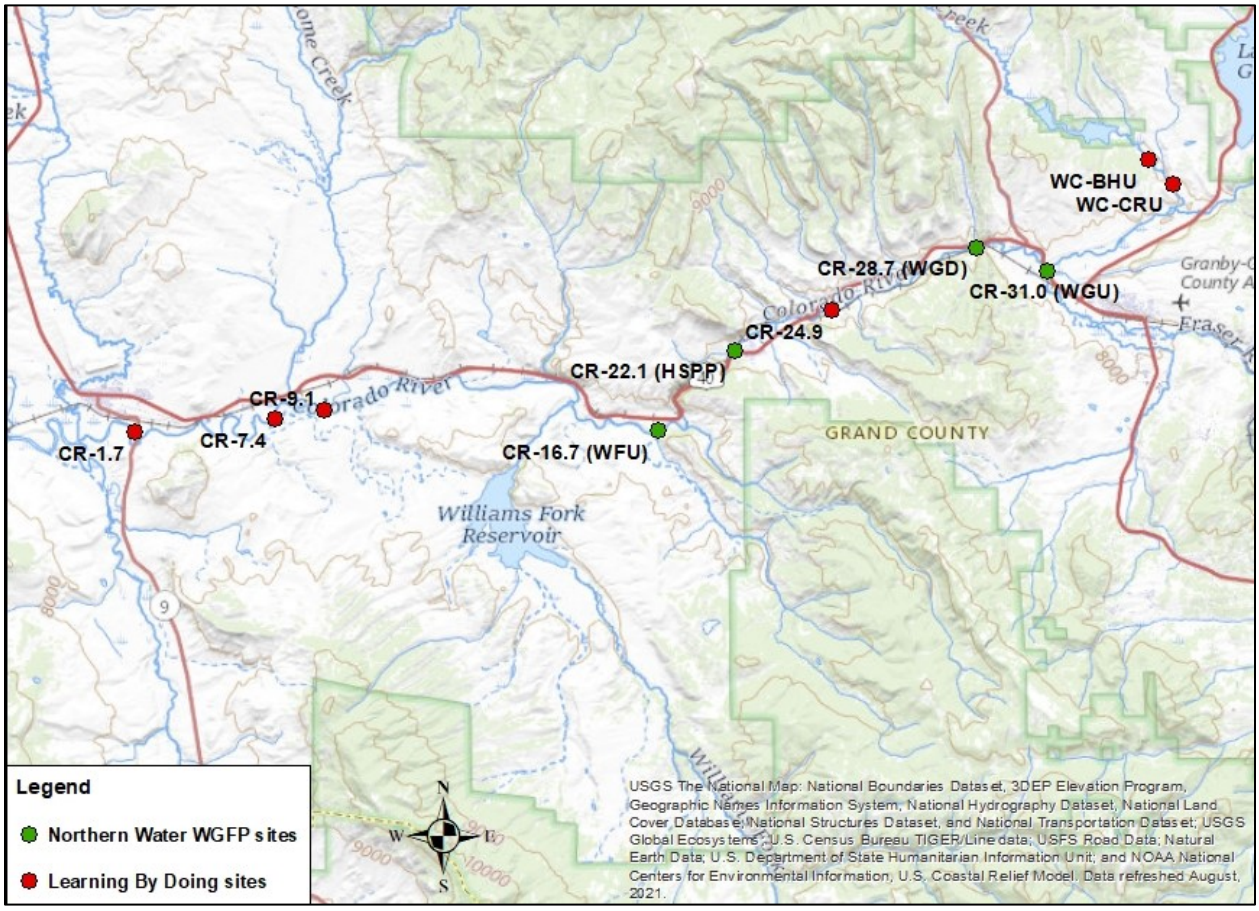

Figure 3. Map of study sites on the Colorado River and Willow Creek used for the Learning By Doing and Northern Water biomonitoring studies in 2022.

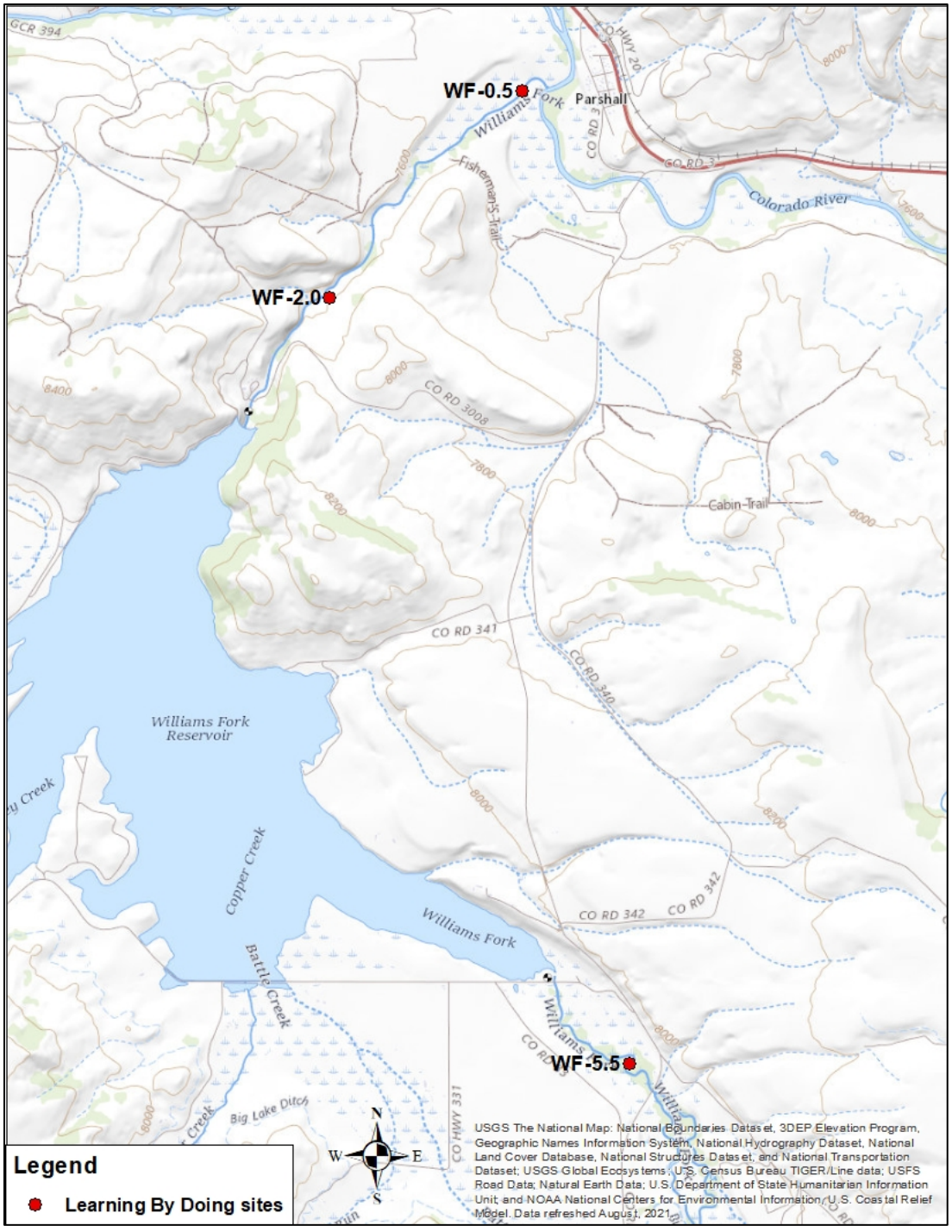

Figure 4. Map of study sites on the Williams Fork used for the Learning By Doing biomonitoring study in 2022.

Methods

Three replicate, quantitative Hess bottom samples (Jackson et al. 2019) were taken from similar riffle habitat (based on substrate type, and water depth and velocity) at each study site. Most benthic macroinvertebrate sampling occurred from 18-19 September, 2022; however, study sites on the Williams Fork were sampled on 25 October to avoid elevated reservoir releases that were occurring during September. Substrate within each sample was thoroughly agitated and individual rocks were scrubbed by hand to dislodge all benthic organisms. Each sample jar was labeled (with date, location, and sample ID number) on the outside and inside of each container, and the contents were preserved in 80% ethanol solution. 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, 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 study area were identified to a taxonomic level consistent with the Operational Taxonomic Unit (OTU) established by the Colorado Department of Public Health and Environment (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 by another certified taxonomist. The following section provides a description of the MMI v4 and other 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 (CDPHE 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 that are selected and modified based on the sampling location and corresponding Biotype (Mountains, Transitional, or Plains). In the LBD CEA, site FR-27.2 was located in Biotype 2 (Mountains), while all other sampling locations were located within Biotype 1 (the Transition Zone). Each of the individual metrics used as part of the data

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, % Increasers (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, 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). 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 can also be used to evaluate aquatic conditions in a variety of other circumstances. The HBI was originally developed using macroinvertebrate taxa from streams in Wisconsin (Hilsenhoff 1988); however, tolerance values for most taxa occurring in this study area have been derived from a variety of regional sources and provided by the CDPHE. 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 MMI v4 scores 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 or when monitoring the abundances of certain sensitive species.

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 Taxa (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 an estimated number of individuals per square meter at each study site. *Pteronarcys californica* is a large species of stonefly that requires specific aquatic conditions and a relatively long period of time (four years) to complete its life cycle (Kowalski and Richer 2020). Therefore, this species is known to be sensitive to a variety of anthropogenic disturbances. Additionally, *Pteronarcys californica* is considered an important part of the aquatic food-web because it 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 negative impacts to the aquatic environment (poor water quality or habitat limitations) may be responsible for reducing the proportions of the most sensitive individuals at a sampling location.

Percent Chironomidae: Members of the family Chironomidae are considered relatively 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 at a given location. Streams that are undisturbed often have similar proportional distributions 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*, *Cheumatopsyche* sp., *Hydropsyche* sp., *Hydropsyche cockerelli*, *Hydropsyche occidentalis*, and *Hydropsyche oslari*) were found in this study area during 2022.

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 tolerance values 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 at each site. 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 2022

Benthic macroinvertebrate biomonitoring studies in the Upper Colorado River Basin were conducted by Learning By Doing (LBD), Denver Water, and Northern Water at a total of 20 sampling locations during September and October of 2022. Data and results from these three projects were shared to provide a more comprehensive evaluation of macroinvertebrate community structure and function in the Fraser River, Vasquez Creek, Ranch Creek, Willow 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 detailed 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 5-19). Functional Feeding Group analysis was used to provide an evaluation of ecological function, as opposed to taxonomic structure (Tables 11-13; Figures 20-22). In general, results from the fall of 2022 suggested that most sampling locations maintained healthy macroinvertebrate communities; however, some evidence of stress (ranging from minor to severe) was detected at several locations. Overall, changes in the structure and function of macroinvertebrate communities were expected to be a reflection of aquatic conditions (water quality and in-stream habitat) and habitat conditions in the nearby watershed.

Results from the MMI v4

Fraser River Study Area

The assessment of macroinvertebrate communities 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 four sampling locations on the Fraser River and a single sampling location on each of three tributaries during the fall of 2022 (Table 2). Study sites on the Fraser River were distributed between two Colorado Biotypes (Biotypes 1 and 2), with each Biotype requiring a different set of component metrics to calculate MMI v4 scores (Table 2). Site FR-27.2 was located in the "Mountain Zone" (Biotype 2), whereas the remaining study sites were all located in the "Transitional Zone", between the mountains and plains (Biotype 1). 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).

In 2022, all sites in the Fraser River study area produced MMI v4 scores that were above the 'attainment' threshold (for their respective biotypes), and only site FR-23.2 (abvWPSD) achieved a relatively low MMI v4 score (51.8) that may have been indicative of minor to moderate anthropogenic stress (Tables 2-3). Interestingly, all other study sites (including sampling locations on tributaries) generated fairly high and consistent MMI v4 scores, suggesting that macroinvertebrate communities were relatively healthy and stable throughout the remainder of this study area. With the exception of site FR-23.2, MMI v4 scores ranged from 75.7 at site FR-27.2 to 84.0 at site SLC-0, showing little evidence of anthropogenic impacts (Table 2; Figure 5). While the MMI v4 score for site FR-23.2 (51.8) suggested that the aquatic community was slightly to moderately stressed, this score was similar to MMI v4 scores from previous sampling events, indicating that aquatic conditions had remained relatively stable. Consistently high MMI v4 scores at several other study sites were expected based on results from previous sampling events; however, the recent high scores at sites VC-WP, FR-20, and SLC-0 indicated that macroinvertebrate community parameters had improved at these locations (Figure 5). Results from the application of auxiliary metrics provided additional evidence suggesting 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).

A review of component metric scores (individual metrics used to calculate the MMI v4) showed the variability in specific macroinvertebrate community parameters that occurred among sites in 2022 (Table 2). For example, results from the % EPT (no Baetidae) and % Non-Insect Individuals metrics varied among sites, with the lowest scores occurring at site FR-23.2. These component metrics had a strong influence on the final MMI v4 score and helped to distinguish site FR-23.2 as a sampling location with relatively low proportions of sensitive individuals. While results from the MMI v4 indicated that all sites in the Fraser River study area were in 'attainment' for aquatic life use, a review of component metrics demonstrated the variability in community parameters that occurred within this study area during the fall of 2022 (Table 2).

Table 2. Component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Fraser River study area during the fall of 2022. 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-27.2	**FR-23.2 (abvWPSD)**	**VC-WP**	**FR-20 (Rendezvous)**	**SLC-0**	**FR-14 (CR83)**	**RC-1.1**
EPT Taxa	69.4	62.5	91.3	87.5	91.7	70.8	79.2
% EPT, no Baetidae	93.5	28.7	58.0	38.5	91.1	90.2	100.0
Clinger Taxa	60.0	48.1	94.2	91.3	91.3	76.9	81.7
Total Taxa	76.2	--	--	--	--	--	--
Intolerant Taxa	76.2	--	--	--	--	--	--
% Increasers, Mountains	82.6	--	--	--	--	--	--
Predator Taxa	76.9	--	--	--	--	--	--
% Scraper Individuals	70.6	--	--	--	--	--	--
% Non-Insect Individuals	--	52.5	76.1	69.0	92.2	96.9	92.5
% Coleoptera Individuals	--	22.7	27.0	43.9	37.5	52.4	17.2
% Intolerant Taxa	--	87.8	82.2	90.6	95.6	79.3	91.6
% Increasers, Mid-Elev.	--	40.4	92.0	87.5	94.3	97.5	100.0
Predator/Shredder Taxa	--	71.4	100.0	100.0	78.6	50.0	64.3
MMI v4	**75.7**	**51.8**	**77.6**	**76.0**	**84.0**	**76.8**	**78.3**
	Auxiliary Metrics						
Diversity	4.09	3.79	4.58	4.08	3.92	3.72	3.97
HBI	2.39	4.20	3.13	3.14	2.55	3.08	2.48
Sediment Region	SR1	SR2					
TIV	3.55	6.05	5.60	5.99	5.02	5.07	4.68

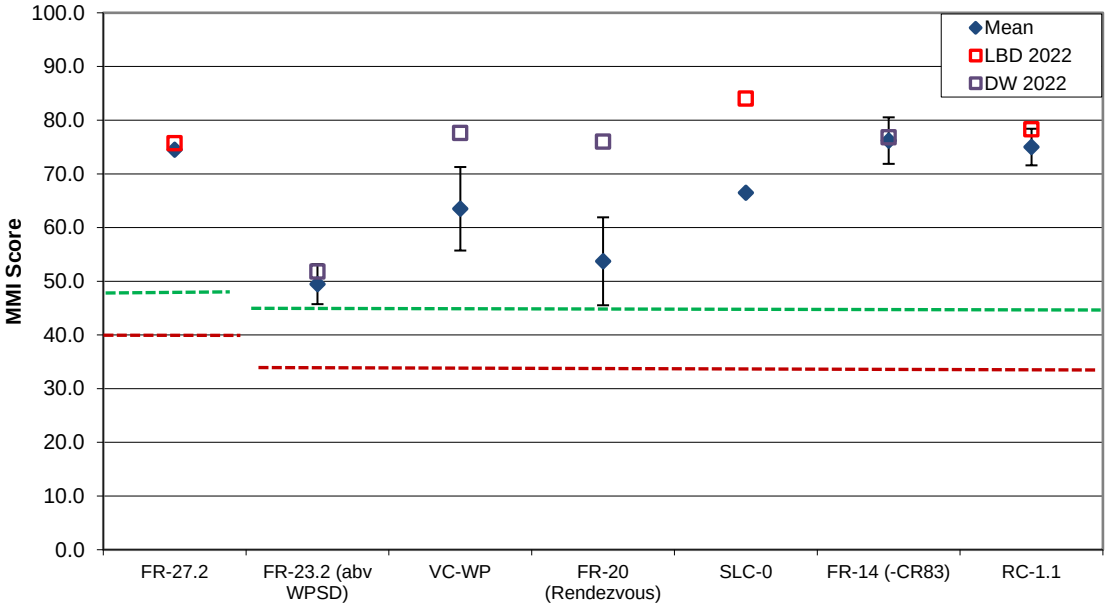

Figure 5. MMI v4 scores for the Fraser River study area from the fall of 2022 and mean MMI scores (±1 standard deviation) from previous sampling events. All scores are based on the MMI v4 subsampling process. The green line indicates the 'attainment' threshold and the red line indicates the 'impairment' threshold for Biotypes 2 and 1. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

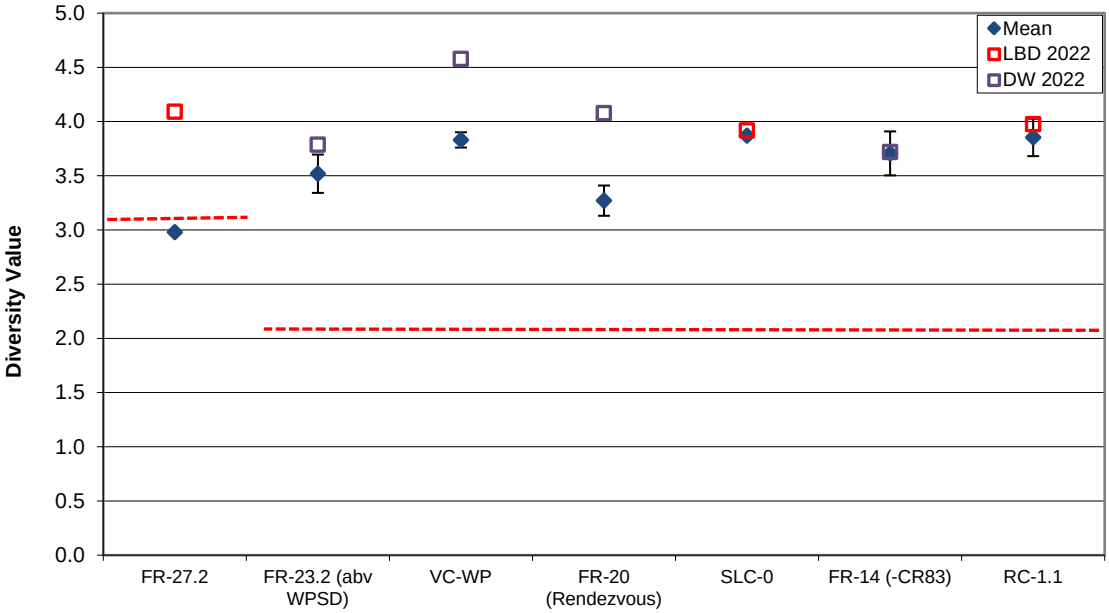

Figure 6. Diversity values in the Fraser River study area from the fall of 2022 and mean Diversity values (±1 standard deviation) from previous sampling events. The red line indicates the 'impairment' threshold for Biotypes 2 and 1. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

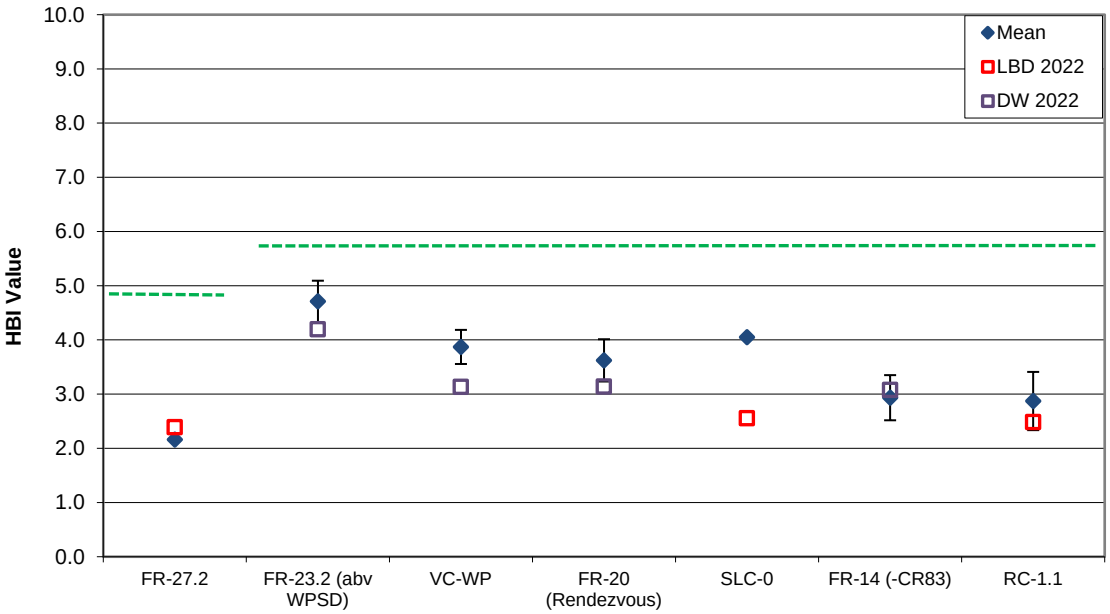

Figure 7. HBI values in the Fraser River study area from the fall of 2022 and mean HBI values (±1 standard deviation) from previous sampling events. Exceeding the green line indicates 'impairment' for Biotypes 2 and 1. Results from Denver Water (DW) sites are provided in purple and Learning By Doing (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 fall of 2022. DW = Denver Water; LBD = Learning By Doing.

Aquatic Life Use Designations		
Site	**Project**	Quantitative (Hess) Samples
FR-27.2	**LBD**	Attainment
FR-23.2 (abvWPSD)	**DW**	Attainment
VC-WP	**DW**	Attainment
FR-20 (Rendezvous)	**DW**	Attainment
SLC-0	**LBD**	Attainment
FR-14 (CR83)	**DW**	Attainment
RC-1.1	**LBD**	Attainment

Colorado River Study Area

In the fall of 2022, the Colorado River study area consisted of ten total study sites: six that were used as part of the LBD biomonitoring program, and four that were sampled as part of a Northern Water (WGFP) biomonitoring study (Table 1; Figure 3). Two new sampling locations were established in 2022 on Willow Creek (between Willow Creek Reservoir and the confluence with the Colorado River), and one new site was established on the Colorado River at Sheriff Ranch. The overall condition of site-specific macroinvertebrate communities was assessed using the MMI v4, which produced a wide range of scores in September of 2022 (Table 4).

The two new study sites on Willow Creek were used to assess the condition of benthic macroinvertebrate communities in a stream segment that is likely influenced by reservoir operations and a recent habitat improvement project. Immediately downstream from Willow Creek Reservoir, site WC-BHU produced an MMI v4 score (30.5) that was below the impairment threshold, indicating that this location was 'impaired' for aquatic life use (Tables 4-5). Farther downstream, the MMI v4 score for site WC-CRU (50.1) showed moderate improvements in macroinvertebrate community structure; however, this location was still likely influenced by low levels of stress (Table 4; Figure 8). Several component metrics (% Non-Insect Individuals, % EPT-no Baetidae, and % Increasers, Mid-Elevation) suggested that the macroinvertebrate community at site WC-BHU supported an unusually low proportion of sensitive individuals (Table 4). It is likely that alterations from the natural flow and temperature regime were responsible (at least in part) for negative impacts immediately downstream from the reservoir. Impacts to benthic macroinvertebrate communities downstream from deep-release reservoirs have been well-documented (Ward 1976, 1982, Baxter 1977, Ward and Stanford 1979, 1983, Ellis and Jones 2013, White et al. 2016, Krajenbrink et al. 2019); however, these impacts are often alleviated with distance downstream from an impoundment. This appears to be the case for study sites on Willow Creek.

The segment of the Colorado River from site CR-31.0 (upstream of Windy Gap Reservoir) to site CR-1.7 (near the confluence with the Blue River) was monitored at eight sampling locations in the fall of 2022. Scores generated by the MMI v4 ranged from 28.7 at site CR-31.0 to 76.1 at site CR-28.7 (Table 4; Figure 8). The MMI v4 score for site CR-31.0 (28.7) was well-below the impairment threshold, which resulted in an 'impairment' designation for this location (Table 5). Additionally, site CR-31.0 experienced a decline in MMI v4 scores, from 60.6 in 2019 to 37.2 in 2020, which represented a 23.4-point drop in one year. Based on the guidelines in the *Section 303(d) Listing Methodology* (CDPHE 2022), site CR-31.0 would 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 2022, the MMI v4 score for site CR-31.0 (28.7) showed a continued decline compared to the score from 2021 (36.3), and the HBI (auxiliary metric) value of 5.88 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' for aquatic life use in 2022.

Table 4. Component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Colorado River study area during the fall of 2022. All metric scores are based on the MMI v4 subsampling process and all sites are located within Biotype 1. Scores indicating 'impairment' are provided in red.

Metric	Station ID									
Monitoring Project	**LBD**		**Northern Water (NW)**		**LBD**	**Northern Water (NW)**		**LBD**		
	WC-BHU	**WC-CRU**	**CR-31.0**	**CR-28.7**	**CR-24.9**	**CR-22.1**	**CR-16.7**	**CR-9.1**	**CR-7.4**	**CR-1.7**
EPT Taxa	39.8	38.4	58.3	83.3	70.8	83.3	95.8	72.0	82.4	66.4
% Non-Insect Individuals	16.8	74.6	17.4	93.1	86.7	86.7	74.2	38.6	64.3	78.4
% EPT, no Baetidae	19.9	57.3	17.8	100.0	82.3	92.0	65.2	26.5	41.2	30.2
% Coleoptera Individuals	22.0	13.0	3.9	9.5	27.9	22.2	10.6	7.7	22.0	50.5
% Intolerant Taxa	50.4	66.7	48.2	79.8	54.6	50.4	61.9	56.8	38.7	40.0
% Increasers, Mid-Elev.	0.0	71.1	0.0	97.5	86.6	83.4	70.9	8.1	36.4	64.1
Clinger Taxa	45.1	44.1	48.1	81.7	76.9	72.1	100.0	68.2	60.3	68.3
Predator/Shredder Taxa	50.0	35.7	35.7	64.3	78.6	50.0	78.6	64.3	42.9	57.1
MMI v4	**30.5**	**50.1**	**28.7**	**76.1**	**70.6**	**67.5**	**69.6**	**42.8**	**48.5**	**56.9**
	Auxiliary Metrics									
Diversity	3.34	3.19	3.44	3.63	3.72	4.06	4.29	3.81	3.81	3.70
HBI	5.87	3.97	5.88	1.93	3.07	2.53	3.73	5.26	4.95	4.84
Sediment Region				SR2			SR2			
TIV	--	--	--	4.16	--	--	4.88	--	--	--

Most other study sites on the Colorado River generated MMI v4 scores that were above the attainment threshold in the fall of 2022; however, site CR-9.1 produced a score (42.8) that was in the 'Grey Zone' (the range of scores between the attainment and impairment thresholds). Typically, when an MMI v4 score falls into the 'Grey Zone', the study site must be further evaluated using the two auxiliary metrics to determine if the site is in 'attainment' or 'impaired'. However, in 2021, site CR-9.1 was considered 'impaired' due to the rapid decline in MMI v4 scores that occurred between 2020 and 2021 (a decline from 68.6 to 42.8, respectively). Although results from the auxiliary metrics in 2022 indicated that site CR-9.1 would normally be considered in 'attainment' for aquatic life use, the MMI v4 score for this location will need to increase to at least 55.7 during a future sampling event (based on the CDPHE guidelines for the rapid decline in MMI v4 score) before this site can be considered in 'attainment' for aquatic life use.

A comparison of recent MMI v4 scores to mean scores from previous sampling events indicated that many sampling locations along the Colorado River maintained relatively stable community parameters, while other sites experienced a recent increase in stress (Figure 8). As previously reported, the study site upstream from Windy Gap Reservoir (CR-31.0) produced an MMI v4 score that was considerably lower than the scores observed prior to 2020. Alternatively, the four study sites used to monitor the segment of the Colorado River from Windy Gap Reservoir to the confluence with the Williams Fork (sites CR-28.7, CR-24.9, CR-22.1, and CR-16.7) generated MMI v4 scores that were: 1) similar among sites, 2) similar to previous results (when available), and 3) indicative of relatively healthy aquatic conditions (Figure 8). Farther downstream, a substantial decline in community health was detected by the MMI v4 at sites CR-9.1 and CR-7.4; however, some improvement when compared to historical results was observed at site CR-1.7 (Figure 8).

A review of the MMI v4 component metrics and auxiliary metrics provided additional insight into the types of stress that may be occurring in the Colorado River. The component metrics that detected relatively healthy aquatic conditions throughout much of the Colorado River study area included EPT Taxa, % Intolerant Taxa, and Clinger Taxa metrics (Table 4). Component metrics that detected an increase in stress at study sites with low MMI v4 scores (CR-31.0 and CR-9.1) included the % EPT (no Baetidae), % Coleoptera Individuals, and % Increasers Mid Elevation metrics. Results from auxiliary metrics were somewhat inconsistent with the Diversity metric showing good community balance at all sampling locations (Figure 9), and the HBI detecting an increase in the proportion of nutrient-tolerant taxa at study sites with low MMI v4 scores (Figure 10). The compilation of these findings suggested that most sites supported a variety of sensitive and specialized taxa; however, negative impacts to macroinvertebrate communities at certain sites were detected when there was an increase in the proportion of tolerant individuals. An increase in tolerant individuals, without a corresponding decline in other metric values is often a response to habitat alterations (possibly due to nutrients, excessive algal growth, and/or runoff from portions of the watershed burned during the recent fire). Continued biomonitoring efforts in the Colorado River study area should help identify the potential conditions (temperature, flow, and changes in habitat) that could be contributing to the stress and recovery of macroinvertebrate communities.

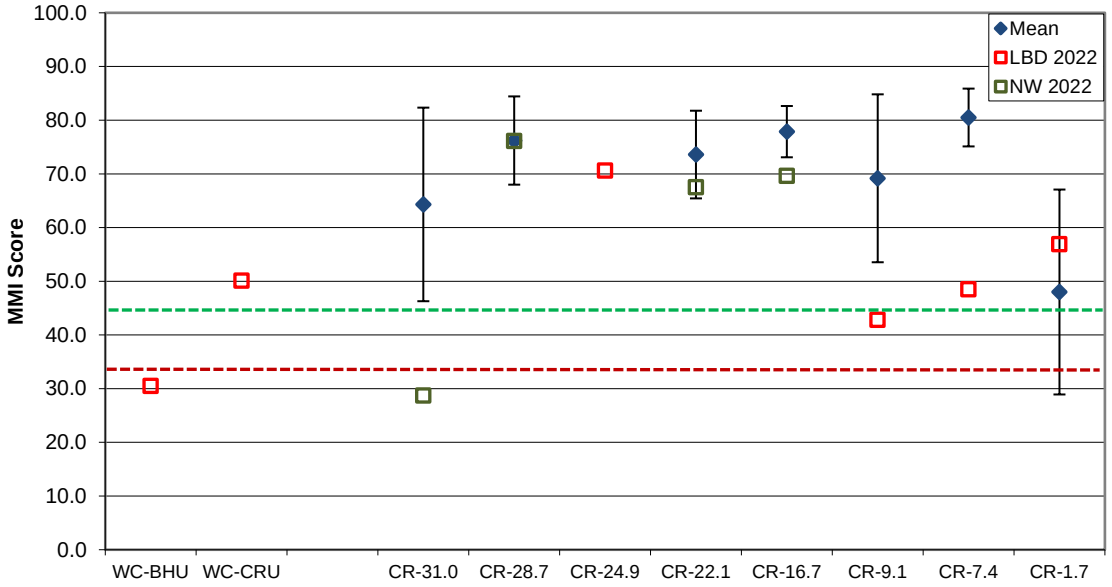

Figure 8. MMI v4 scores for the Colorado River study area from the fall of 2022 and mean MMI v4 scores (±1 standard deviation) from previous sampling events. All scores are based on the MMI v4 subsampling process. The green line indicates the 'attainment' threshold and the red line indicates the 'impairment' threshold for Biotype 1. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

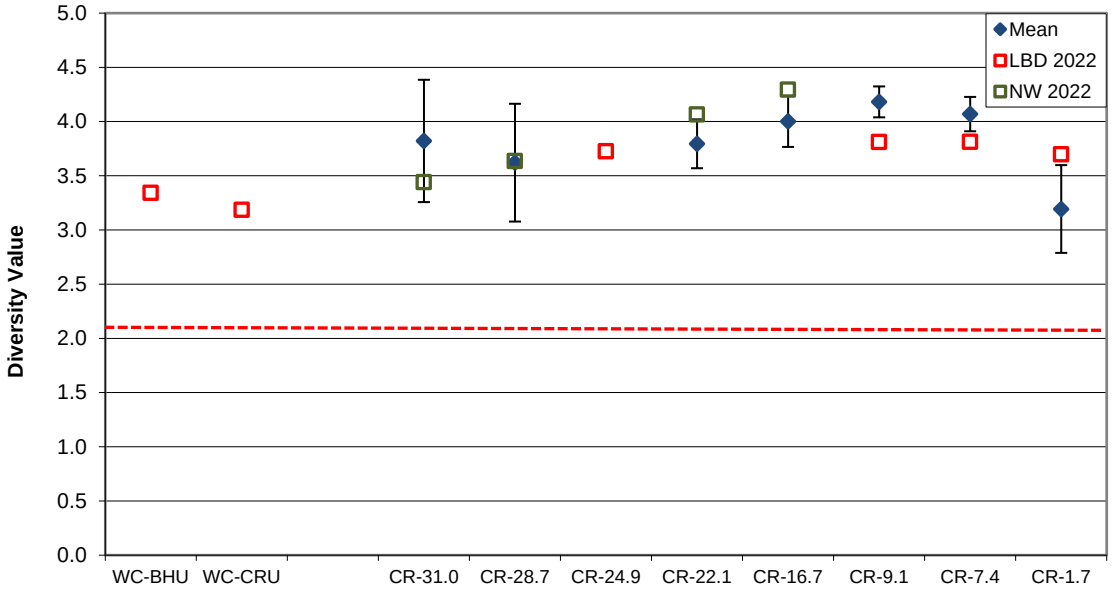

Figure 9. Diversity values for the Colorado River study area from the fall of 2022 and mean Diversity values (±1 standard deviation) from previous sampling events (when available). The red line indicates the 'impairment' threshold for Biotype 1. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

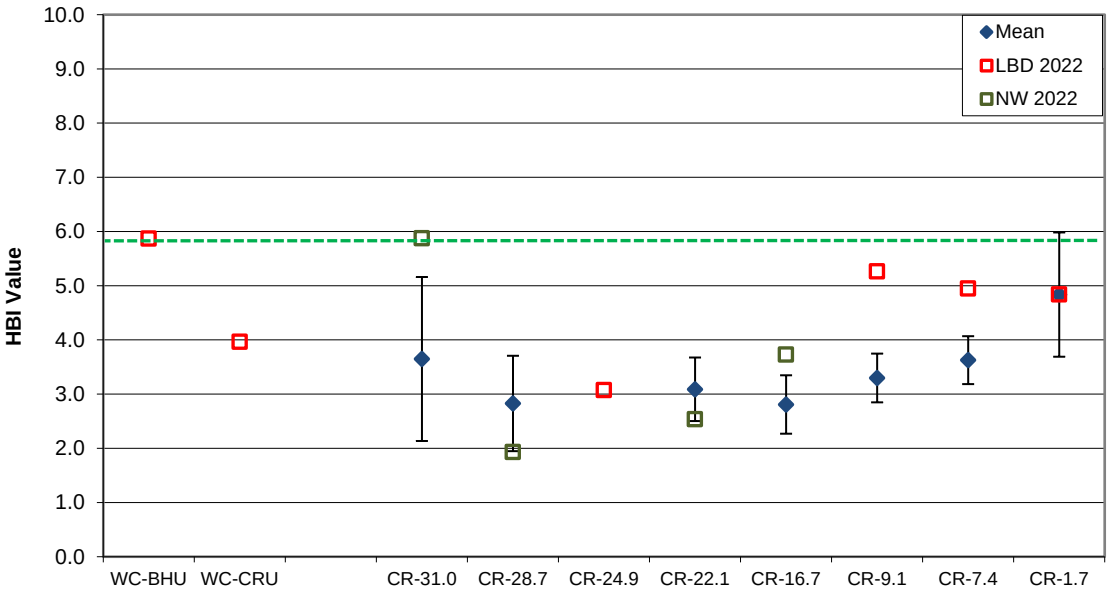

Figure 10. HBI values for the Colorado River study area from the fall of 2022 and mean HBI values (±1 standard deviation) from previous sampling events (when available). Exceeding the green line indicates 'impairment' for Biotype 1. Northern Water (NW) sites are provided in green and Learning By Doing (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 fall of 2022. NW = Northern Water; LBD = Learning By Doing.

Aquatic Life Use Designations		
Site	**Project**	Quantitative (Hess) Samples
WC-BHU	**LBD**	Impairment
WC-CRU	**LBD**	Attainment
CR-31.0	**NW**	Impairment
CR-28.7	**NW**	Attainment
CR-24.9	**LBD**	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**	Attainment

Williams Fork Study Area

Three study sites on the Williams Fork (all monitored by LBD) were sampled in October of 2022 to assess the influence of reservoir operations and recent habitat restoration work on benthic macroinvertebrate communities upstream and downstream of Williams Fork Reservoir. Results from the MMI v4 continued to indicate 'attainment' for aquatic life use at all three sites (Tables 6 and 7; Figure 10); although, scores downstream from the reservoir, at sites WF-2.0 and WF-0.5, were relatively low compared to most study sites on the Fraser and Colorado rivers. The MMI v4 score for site WF-5.5 (63.2) was the highest among sites on the Williams Fork (Table 6), although this score was slightly lower than expected based on the results from previous sampling events (Figure 11; Appendix D: Tables D2-D5). A recent habitat improvement project upstream from site WF-5.5 should continue to have a positive influence on the macroinvertebrate community at this location during future sampling events.

Downstream from Williams Fork Reservoir, a noticeable decline in MMI v4 scores was likely caused by alterations to the natural temperature and flow regime resulting from reservoir operations. Site WF-2.0 produced an MMI v4 score (42.1) that was slightly below the attainment threshold (Figure 11); however, the auxiliary metrics indicated that this sampling location was in 'attainment' for aquatic life use (Figures 12 and 13). The MMI v4 score for site WF-0.5 (48.6) was above the attainment threshold, but the relatively low score suggested that the macroinvertebrate community at this location was still slightly stressed (Table 6; Figure 11). During the past several years, MMI v4 scores for sites WF-2.0 and WF-0.5 have remained relatively stable (Figure 11).

Several component metrics (% EPT Individuals-no Baetidae, % Non-Insect Individuals, and Clinger Taxa) were particularly sensitive to changes in macroinvertebrate community structure that occurred downstream from Williams Fork Reservoir (Table 6). These metrics were expected to be easily influenced by alterations from the natural flow and temperature regime, while other component metrics (and both auxiliary metrics) were less influenced by reservoir operations (Table 6). Habitat enhancements in various segments of the Williams Fork should improve the health of aquatic life (resulting in improved MMI v4 scores) during future sampling events.

In summary, the MMI v4 (and associated analysis tools) provided a comprehensive evaluation of macroinvertebrate community structure in the Fraser River, Colorado River and Williams Fork study areas. While most monitoring sites exhibited diverse and relatively stable benthic macroinvertebrate communities, the observed variability in MMI v4 scores suggested that there were areas of stress and recovery within each major drainage (Tables 2, 4, and 6). In the Colorado River study area, study sites with 'impairment' designations or unusually low MMI v4 scores may have been influenced by a variety of stressors including nutrient-enrichment, runoff from areas impacted by recent fires, elevated water temperatures, and/or excessive algal growth. Continued biomonitoring studies will provide an opportunity to monitor future aquatic conditions and assess the persistence of the results observed during the fall of 2022.

Table 6. Component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Williams Fork study area during October of 2022. 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-5.5	**WF-2.0**	**WF-0.5**
EPT Taxa	58.3	37.4	49.0
% EPT, no Baetidae	95.1	36.1	44.3
Clinger Taxa	56.5	5.0	9.6
% Non-Insect Individuals	24.5	0.0	0.0
% Coleoptera Individuals	57.9	78.1	89.6
% Intolerant Taxa	96.3	93.8	98.5
% Increasers, Mid-Elev.	52.9	43.3	40.3
Predator/Shredder Taxa	64.3	42.9	57.1
MMI v4	**63.2**	**42.1**	**48.6**
	Auxiliary Metrics		
Diversity	3.82	2.67	2.84
HBI	3.87	3.51	3.26
Sediment Region			
TIV	--	--	--

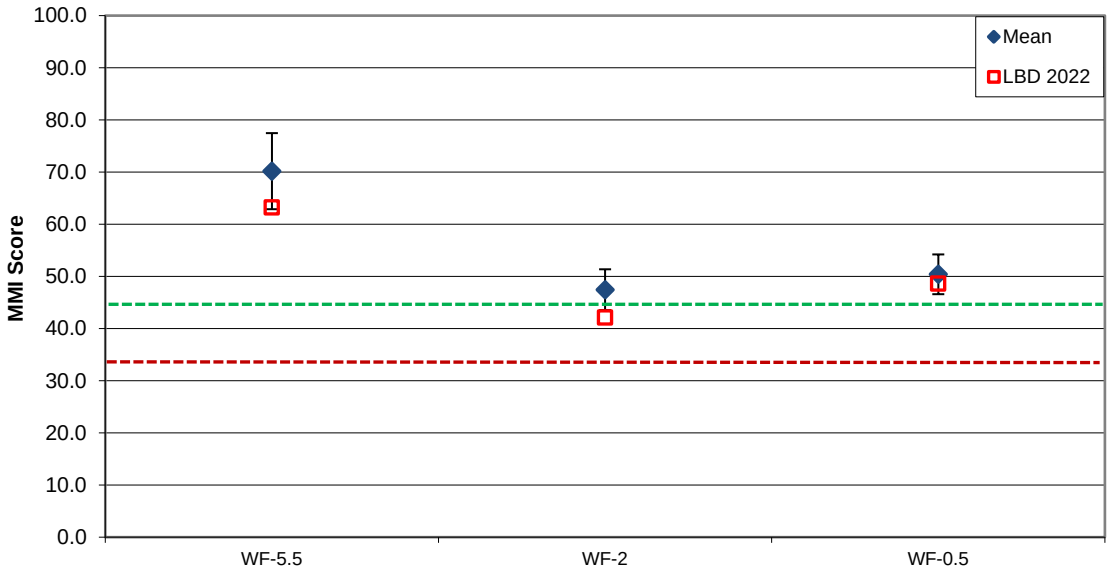

Figure 11. MMI v4 scores for the Williams Fork study area from the fall of 2022 and mean MMI scores (±1 standard deviation) from previous sampling events. All scores are based on the MMI v4 subsampling process. The green line indicates the 'attainment' threshold and the red line indicates the 'impairment' threshold for Biotype 1.

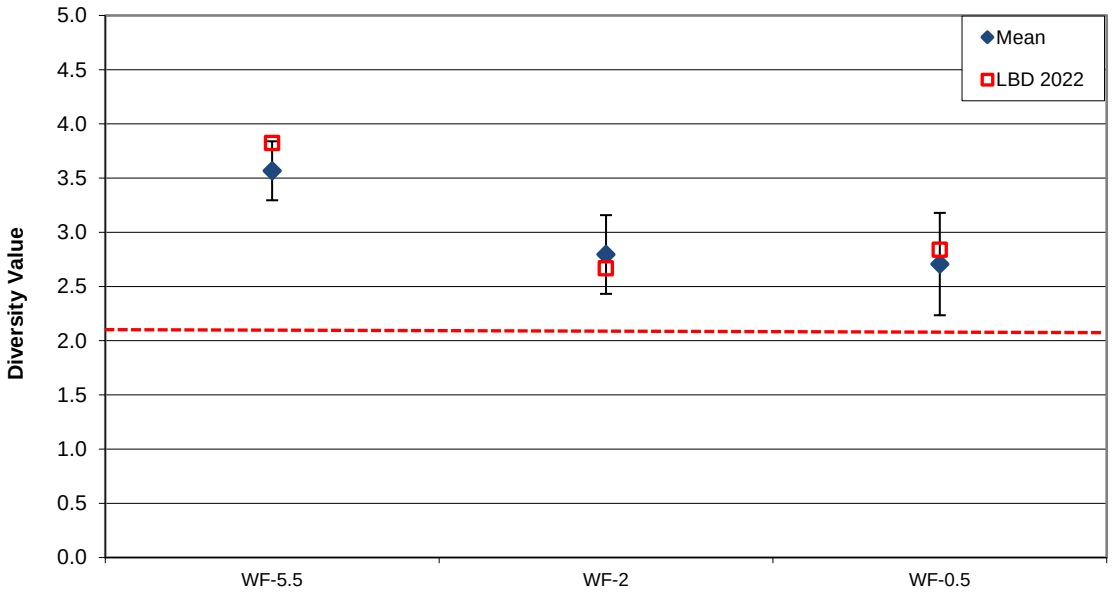

Figure 12. Diversity values for the Williams Fork study area from the fall of 2022 and mean Diversity values (±1 standard deviation) from previous sampling events. The red line indicates the 'impairment' threshold for Biotype 1.

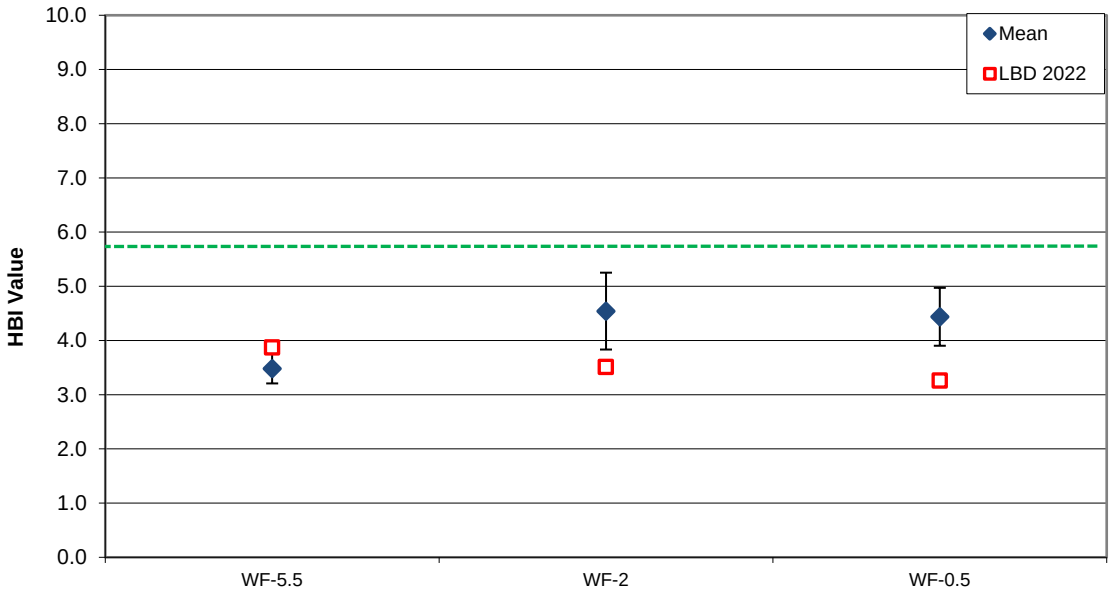

Figure 13. HBI values for the Williams Fork study area from the fall of 2022 and mean HBI values (±1 standard deviation) from previous sampling events. Exceeding the green line indicates 'impairment' for Biotype 1.

Table 7. Aquatic life use designations based on MMI v4 scores for sites in the Williams Fork study area during October of 2022. LBD = Learning By Doing study sites.

Aquatic Life Use Designations		
Site	**Project**	Quantitative (Hess) Samples
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 structure and function during the fall of 2022 (Tables 8-10). While most of the individual metrics have the ability to detect changes in macroinvertebrate community structure among sites, the environmental factors that influence the change in metric values are not always readily identifiable. Benthic macroinvertebrate communities in this study were likely impacted by regulated flows, deviations from the natural temperature regime, runoff from developed areas, runoff from portions of the watershed recently burned in wildfires, and interactions among these and other environmental conditions. Positive influences on macroinvertebrate communities can include: good water quality, natural temperature and flow regimes, and benefits associated with quality habitat and/or habitat improvement projects. The location of a study site generally determines which influences or stressors were likely contributing to macroinvertebrate community structure and function.

Most sampling locations in the Fraser River, Colorado River, and Williams Fork study areas demonstrated the ability to support a variety of macroinvertebrate taxa (based on Taxa Richness values), and many of these taxa were considered sensitive to anthropogenic perturbations (based on EPT Taxa values). In general, both of these metrics suggested that the greatest negative impacts occurred at study sites located downstream from deep-release reservoirs (Tables 8-10). Other indications of increased stress included a low relative abundance of sensitive individuals (demonstrated by the % EPT-excluding Baetidae metric) or low proportion of % Intolerant Taxa when compared to % Tolerant Taxa. It was also note-worthy 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 densities at only two sites on the Colorado River (CR-24.9 and CR-16.7) during the fall of 2022 (Table 9). The following comparison of individual metric values among study sites provides a more detailed description of macroinvertebrate community health in the Fraser River, Colorado River, and Williams Fork study areas during the fall of 2022.

Fraser River Study Area

In the fall of 2022, the Fraser River study area consisted of seven study sites (four located on the Fraser River and three located on tributaries of the Fraser River) that were sampled as part of biomonitoring studies conducted by LBD and Denver Water (Figure 2). Overall, results from the individual metrics used in this study suggested that all sampling locations in the Fraser River study area supported relatively healthy benthic macroinvertebrate communities (Table 8). Important individual metrics such as Taxa Richness, EPT Taxa, and % Intolerant Taxa clearly indicated that all study sites on the Fraser River, Vasquez Creek, St. Louis Creek, and Ranch Creek, supported benthic macroinvertebrate communities with a variety of taxa, including a variety of sensitive taxa (Table 8). Despite a general favorable consensus among metric values, a comparison of individual metric results among sites provided evidence of longitudinal and spatial changes in community structure. These changes could probably be attributed to minor changes in habitat, stream size, and local anthropogenic influences.

Most of the individual metrics showed some variability among sites within the Fraser River study area. For instance, the number of individuals per m^2 ranged from 3,604 at site FR-27.2 to 10,518 at site FR-20 (Table 8). Much of the variability in metric values could probably be attributed to changes in stream size and habitat complexity; however, there was some consistency among metrics that detected minor stress at site FR-23.2. Specifically, the Taxa Richness and EPT Taxa metrics produced their lowest values in the Fraser River study area at site FR-23.2 (35 and 17, respectively), and other metrics (% EPT-excluding Baetidae, % Chironomidae, and % Tolerant Taxa) detected a subtle shift towards stressed conditions (Table 8). Most of these metrics also showed evidence of rapid improvements in a downstream direction; however, values from the % EPT-excluding Baetidae metric remained relatively low throughout the remainder of the Fraser River (Table 8). The giant stonefly (*Pteronarcys californica*) was not collected in the Fraser River study area in the fall of 2022; however, this species typically only occurs in the most downstream reaches of this study area (which was not sampled during 2022). Despite evidence of changes in macroinvertebrate community structure, the results from individual metrics generally suggested that all sites in the Fraser River study area were able to support relatively healthy macroinvertebrate communities during the fall of 2022.

When metric values from 2022 were compared to results from previous sampling events, most results from the Fraser River study area suggested that aquatic conditions had remained relatively stable or recently improved. A review of the EPT Taxa metric results provided an example where values from 2022 were either near historical mean values or demonstrated recent improvements (Figure 14). Results from the % EPT-excluding Baetidae metric were more variable, but most sites produced values that were similar to the historical mean or demonstrated improvement (Figure 15). One exception was site FR-14, which showed a substantial decline in the proportion of sensitive individuals in the fall of 2022. Results from these metrics should be monitored closely during future sampling events. A complete review of individual metric values from previous sampling events (2017-2021) in the LBD CEA can be found in Appendix D: Tables D6-D10.

Table 8. Additional individual metrics and comparative values for benthic macroinvertebrate samples collected from the Fraser River study area during fall of 2022. 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-27.2	FR-23.2 (abvWPSD)	VC-WP	FR-20 (Rendezvous)	SLC-0	FR-14 (CR83)	RC-1.1
Biomonitoring Project	**LBD**	**Denver Water (DW)**			**LBD**	**DW**	**LBD**
Density (mean #/m^2)	3,604	5,162	3,902	10,518	4,364	9,469	7,320
Taxa Richness	37	35	48	50	49	47	47
EPT Taxa	20	17	25	26	27	24	24
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	0	0	0
% EPT-excluding Baetidae	72.35%	19.79%	6.79%	6.39%	65.57%	4.26%	80.00%
% Chironomidae	7.78%	26.41%	15.57%	28.13%	2.50%	9.43%	6.84%
% Hydropsychidae	0.00%	1.27%	23.53%	7.72%	29.04%	68.52%	31.40%
% Tolerant Taxa	16.22%	20.00%	14.58%	10.00%	18.37%	21.28%	17.02%
% Intolerant Taxa	54.05%	48.57%	50.00%	46.00%	51.02%	38.30%	51.06%

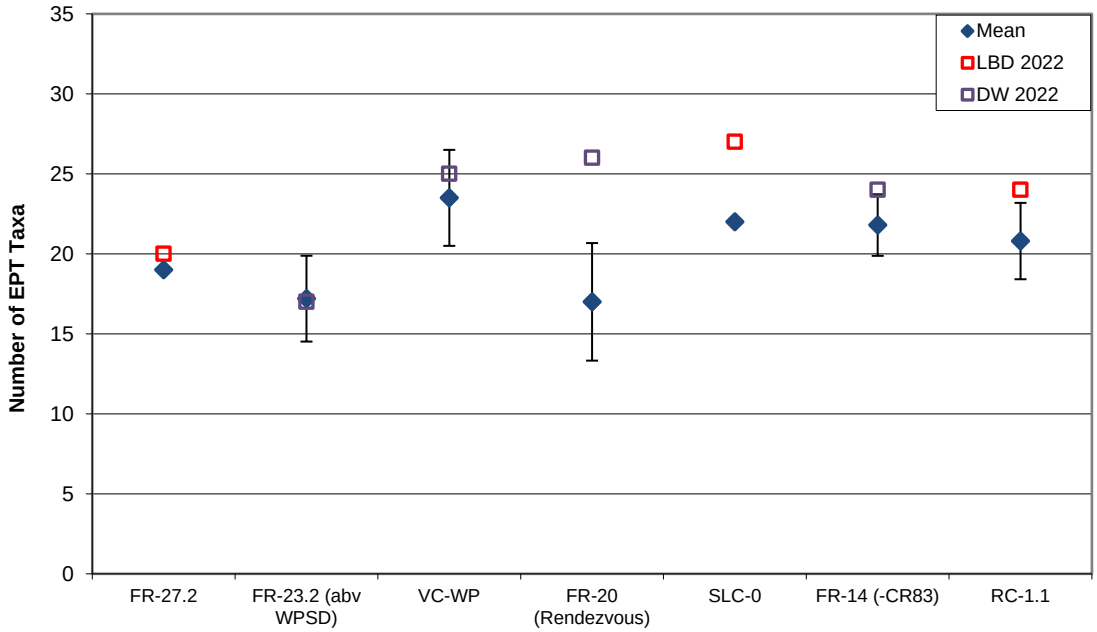

Figure 14. EPT Taxa values from the Fraser River study area during the fall of 2022 and mean values (±1 standard deviation) from previous sampling events. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

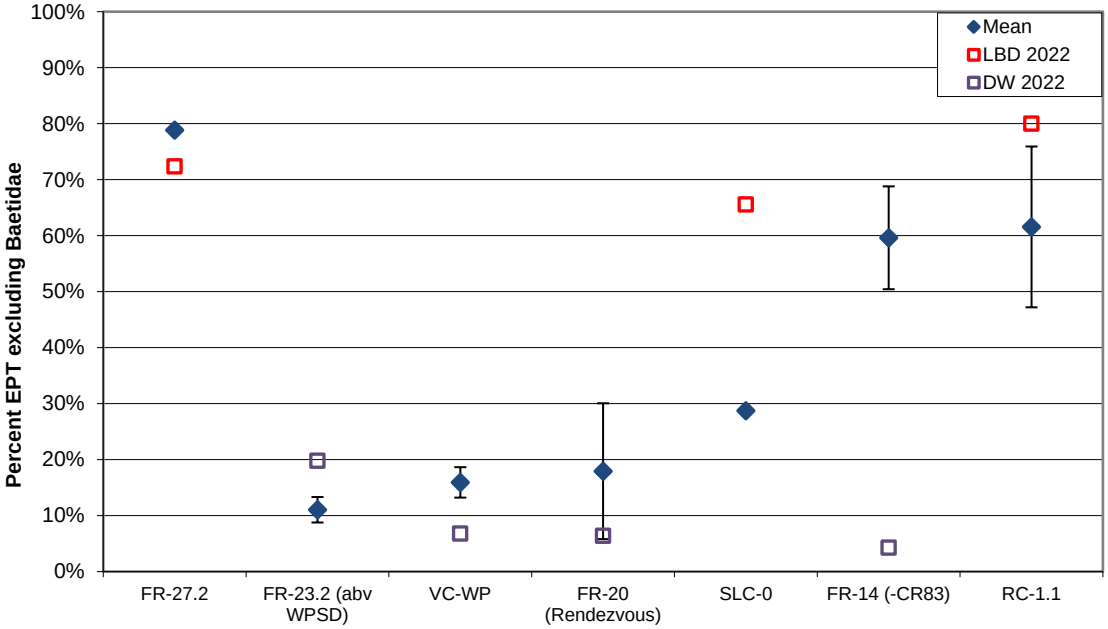

Figure 15. Percent EPT-excluding Baetidae values from the Fraser River study area during the fall of 2022 and mean values (±1 standard deviation) from previous sampling events. Denver Water (DW) sites are provided in purple and Learning By Doing (LBD) sites are provided in red.

Colorado River Study Area

A review of individual metric results from the Colorado River study area was used to assess the overall health of benthic macroinvertebrate communities and identify the changes in community structure. In 2022, individual metrics detected a wide range of community dynamics that were likely associated with the sampling location and nearby natural and anthropogenic influences. For example, evidence of impacts to aquatic communities at the two study sites on Willow Creek (WC-BHU and WC-CRU) could mostly be attributed to deviations from the natural temperature and flow regime resulting from operations at Willow Creek Reservoir. Detectable impacts to aquatic communities at sites along the Colorado River varied by site (and metric), and while the specific sources of stress were less discernable, it is likely that some sites were impacted by runoff from the East Troublesome Fire.

In the Colorado River study area, a total of ten study sites (two on Willow Creek and eight on the Colorado River) were sampled in September of 2022 in a combined effort between Northern Water and LBD (Table 1; Figure 3). As expected, macroinvertebrate communities were quite different in Willow Creek when compared to the communities in the mainstem of the Colorado River. Unique characteristics of macroinvertebrate communities at the two sites on Willow Creek included relatively low Taxa Richness and EPT Taxa values, and a low proportion of sensitive individuals (% EPT-excluding Baetidae) near the impoundment (Table 9). These characteristics in community structure are often expected downstream from deep-release reservoirs (Ward 1982).

On the mainstem of the Colorado River, indications of stress to benthic communities were mostly restricted to metrics that rely on proportions of sensitive and tolerant individuals (% EPT-excluding Baetidae and % Chironomidae, respectively), while other metrics were less sensitive to negative impacts that may have been occurring during the fall of 2022 (Table 9). For example, the richness of sensitive taxa (based on the EPT Taxa metric) remained relatively high and stable at most study sites (except CR-7.4) on the Colorado River (Table 9; Figure 16). At the same time, the % EPT-excluding Baetidae metric showed a substantial decline in the proportion of the most sensitive individuals at sites CR-31.0, CR-16.7, CR-9.1, and CR-7.4 (Figure 17). It is unusual when a study site supports a high number of sensitive taxa, while the relative abundance of sensitive individuals is reduced. In these cases, the study site is often exposed to a source of stress that is not directly harmful to macroinvertebrates but has the ability to modify habitat (such as nutrient-enrichment, excessive algal growth, sediment deposition, etc.). Additionally, the numerical abundance of *Caecidotea* sp., a taxon known to be tolerant to nutrient-enrichment and excessive algal growth, was greatest at sites CR-31.0, CR-16.7, CR-9.1, and CR-7.4 in the fall of 2022 (Appendix A: Tables A10-A12, and Appendix B: Table B1). For these reasons, it is likely that detectable stress in the Colorado River may have been caused by variety of sources including nutrient-enrichment and runoff from portions of the watershed burned during the East Troublesome Fire.

Table 9. Additional individual metrics and comparative values for benthic macroinvertebrate samples collected from the Colorado River study area during fall of 2022. All additional metric values are based on full count (quantitative) Hess samples. LBD = Learning By Doing study sites; NW = Northern Water study sites.

Metric	WC-BHU	WC-CRU	CR-31.0	CR-28.7	CR-24.9	CR-22.1	CR-16.7	CR-9.1	CR-7.4	CR-1.7
Monitoring Project	**LBD**		**Northern Water (NW)**		**LBD**	**Northern Water (NW)**		**LBD**		
Density (mean #/m^2)	5,495	8,611	14,384	9,716	19,913	6,910	8,922	9,741	5,767	10,550
Taxa Richness	34	28	57	55	56	52	55	54	45	58
EPT Taxa	11	10	24	27	25	23	26	23	17	26
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0	12	0	23	0	0	0
% EPT-excluding Baetidae	14.13%	39.03%	13.92%	83.37%	58.05%	66.20%	46.15%	18.94%	25.47%	17.56%
% Chironomidae	5.72%	2.03%	35.32%	4.04%	8.98%	11.08%	15.93%	17.86%	34.43%	17.34%
% Hydropsychidae	48.72%	27.55%	23.68%	24.52%	13.69%	6.33%	36.84%	24.04%	20.57%	9.21%
% Tolerant Taxa	38.24%	32.14%	31.58%	27.27%	25.00%	32.69%	23.64%	24.07%	28.89%	29.31%
% Intolerant Taxa	26.47%	28.57%	29.82%	36.36%	33.93%	25.00%	36.36%	31.48%	17.78%	24.14%

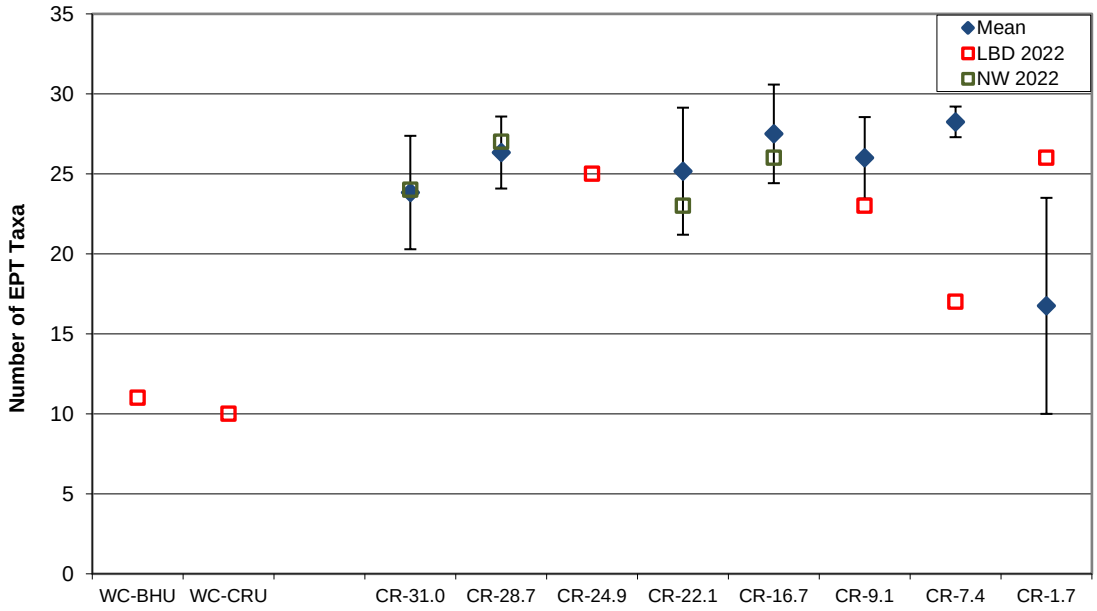

Figure 16. EPT Taxa values from the Colorado River study area during the fall of 2022 and mean values (±1 standard deviation) from previous sampling events. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

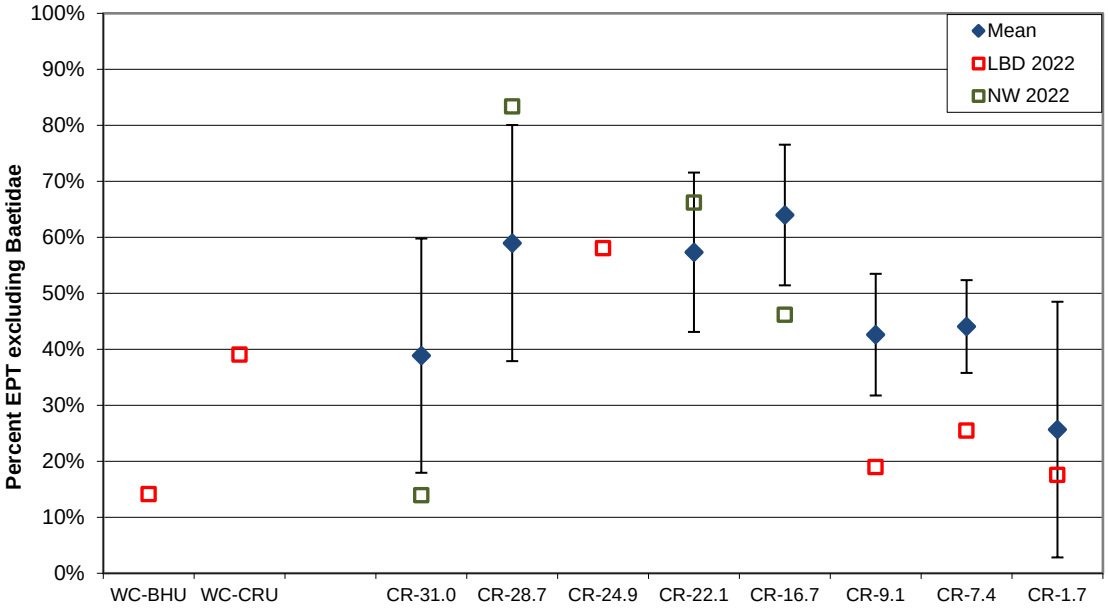

Figure 17. Percent EPT-excluding Baetidae values from the Colorado River study area during the fall of 2022 and mean values (±1 standard deviation) from previous sampling events. Northern Water (NW) sites are provided in green and Learning By Doing (LBD) sites are provided in red.

Williams Fork Study Area

A review of the results provided by the individual metrics in the Williams Fork study area showed considerable variability among the three sites sampled as part of the LBD biomonitoring study in October of 2022 (Table 10; Figures 18-19). While most metrics were indicative of healthy macroinvertebrate community parameters at site WF-5.5 (upstream of Williams Fork Reservoir), there was evidence of increased stress downstream from the reservoir at sites WF-2.0 and WF-0.5 (Table 10). Overall, results from the Taxa Richness, % EPT-excluding Baetidae, and % Hydropsychidae metrics implied that relatively healthy aquatic conditions persisted at site WF-5.5. These metrics suggest that site WF-5.5 was able to support a variety of taxa (including sensitive taxa) with high proportions of sensitive individuals. However, immediately downstream from the reservoir at site WF-2.0, there was a reduction in Taxa Richness, EPT Taxa, % EPT-excluding Baetidae, and % Hydropsychidae values, and the % EPT-excluding Baetidae metric indicated that only 2.37% of the macroinvertebrate community was sensitive to perturbations (Table 10, Figures 18-19). Farther downstream (at site WF-0.5), most metrics (except % Intolerant Taxa and % Hydropsychidae) showed improvements in macroinvertebrate community structure that may have been related to distance downstream from the impoundment and nearby habitat enhancements. Overall, these results suggest that study sites downstream from Williams Fork Reservoir continued to be influenced by an altered temperature and flow regime; however, recent habitat enhancement projects may be assisting in the recovery of macroinvertebrate communities in the lower portions of the Williams Fork study area.

Table 10. Additional individual metrics and comparative values for benthic macroinvertebrate samples collected from the Williams Fork study area during October of 2022. All additional metric values are based on full count (quantitative) Hess samples.

Metric	WF-5.5	WF-2.0	WF-0.5
Monitoring Project	**Learning By Doing (LBD)**		
Density (mean #/m^2)	6,886	13,889	13,031
Taxa Richness	45	28	30
EPT Taxa	14	11	16
Density of *Pteronarcys californica* (#/m^2)	0	0	0
% EPT-excluding Baetidae	40.91%	2.37%	7.62%
% Chironomidae	29.68%	15.72%	20.24%
% Hydropsychidae	87.37%	6.38%	3.08%
% Tolerant Taxa	26.67%	28.57%	20.00%
% Intolerant Taxa	26.67%	39.29%	33.33%

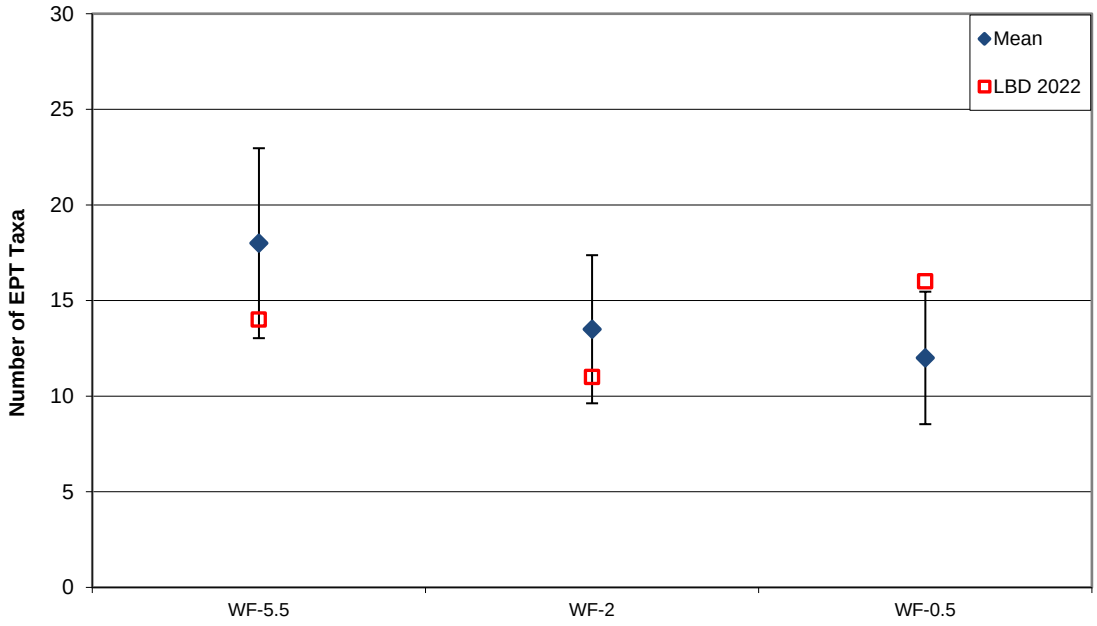

Figure 18. EPT Taxa values in the Williams Fork study area from the fall of 2022 and mean values (±1 standard deviation) from previous sampling events.

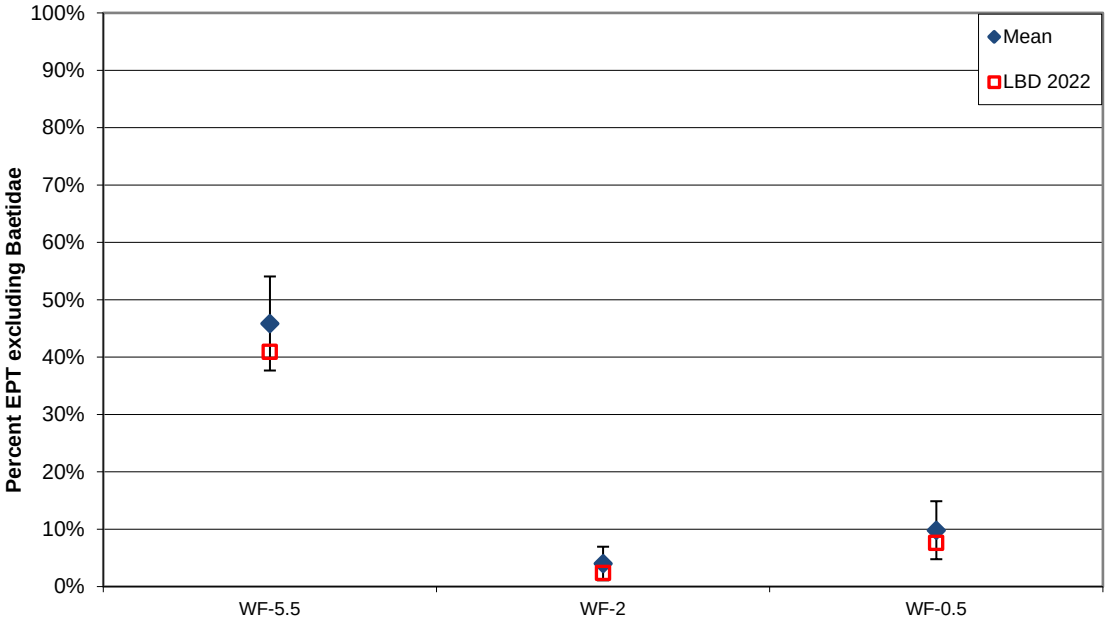

Figure 19. Percent EPT-excluding Baetidae values in the Williams Fork study area from the fall of 2022 and mean values (±1 standard deviation) from previous sampling events.

Results from Functional Feeding Group Analysis

Fraser River Study Area

An assessment of the relative percentages of functional feeding groups provided insight into the ecological balance of macroinvertebrate communities in the Fraser River study area during September of 2022. Healthy mountain streams typically support diverse macroinvertebrate communities that exhibit a variety of feeding strategies; however, it is not unusual for certain feeding groups (such as collector-gatherers) to be proportionally dominant (Ward et al. 2002).

During the fall of 2022, all sites in the Fraser River study area maintained an adequate distribution of feeding groups, and while members of the most tolerant group (collector-gatherers) were present at all sampling locations, the relative abundance of this group never exceeded 65% (Table 11; Figure 20). Other feeding groups that are considered sensitive and/or specialized (collector-filterers, shredders, and scrapers) were also well-represented within this study area, and the scraper group was even dominant at site FR-27.2 (Figure 20). Interestingly, the greatest proportion of collector-gatherers (62.38%) and lowest proportions of shredders (1.88%) and scrapers (10.99%) occurred at site FR-23.2 (Table 11). These results supported the results from the MMI v4 and other individual metrics that detected low levels of stress at this location. Improvements in the balance among feeding groups were observed downstream on the Fraser River and at the three study sites located on tributaries (Figure 20). Higher proportions of shredders at study sites on the Saint Louis Creek and Ranch Creek may have been related to a high ratio of quality riparian habitat to stream size. Overall, the results from functional feeding group analysis in the Fraser River study area suggested that most sites supported healthy community function.

Table 11. Relative abundance of functional feeding groups in the Fraser River study area during the fall of 2022. 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-27.2	**LBD**	28.51%	0.22%	10.58%	47.52%	11.23%	1.94%
FR-23.2 (abvWPSD)	**DW**	62.38%	3.46%	1.88%	10.99%	18.13%	3.16%
VC-WP	**DW**	40.62%	11.78%	13.57%	18.66%	4.49%	10.88%
FR-20 (Rendezvous)	**DW**	54.78%	13.03%	3.06%	13.18%	6.68%	9.27%
SLC-0	**LBD**	25.96%	20.52%	26.05%	18.47%	7.14%	1.87%
FR-14 (CR83)	**DW**	21.73%	41.98%	3.69%	31.08%	1.52%	0.00%
RC-1.1	**LBD**	13.74%	31.51%	26.26%	23.82%	4.56%	0.11%

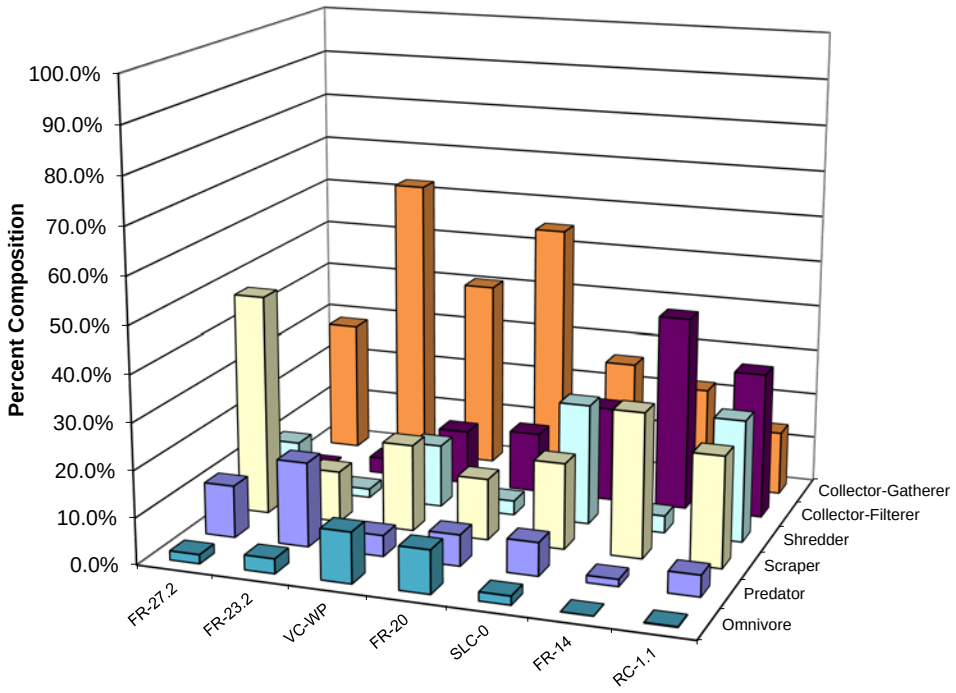

Figure 20. Functional feeding group composition for study sites in the Fraser River study area during the fall of 2022.

Colorado River Study Area

An evaluation of functional feeding groups in the Colorado River study area during the fall of 2022 included two sampling locations on Willow Creek and eight sampling sites on the mainstem of the Colorado River (Table 12; Figure 21). While the collector-gatherer group was well-represented throughout this study area, the relative abundance of this feeding group and other (more sensitive) feeding groups varied among sites. Both sampling locations on Willow Creek supported relatively high proportions of collector-gatherers and collector-filterers, although representatives from the most sensitive groups (shredders and scrapers) were also present (Figure 21). These results suggest that impacts to community function in Willow Creek may have been less severe than the impacts detected by other metrics used in this study.

On the Colorado River, the Northern Water study site CR-31.0 appeared to be moderately stressed based on the proportional dominance of collector-gatherers (77.71%) and the poor combined representation from shredders and scrapers (<8.0%). Downstream from Windy Gap Reservoir, the relative abundance of collector-gatherers decreased (improved) at most study sites, and proportion of scrapers was often much higher (Table 12). The only other sampling location with a low proportion of sensitive feeding groups (shredders + scrapers = 6.42%) was site CR-9.1. These results generally supported the conclusions provided by the MMI v4 and other individual metrics that detected moderate stress or 'impairment' at sites CR-31.0 and CR-9.1 in the fall of 2022.

Table 12. Relative abundance of functional feeding groups in the Colorado River study area during the fall of 2022. NW=Northern Water; LBD=Learning By Doing.

Site	Project	Functional Feeding Group					
		Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
WC-BHU	**LBD**	55.19%	26.78%	5.58%	9.33%	1.13%	1.98%
WC-CRU	**LBD**	39.93%	49.62%	3.02%	4.06%	1.53%	1.85%
CR-31.0	**NW**	77.71%	9.09%	4.83%	2.89%	0.86%	4.61%
CR-28.7	**NW**	44.32%	18.03%	3.92%	30.94%	2.72%	0.08%
CR-24.9	**LBD**	59.06%	11.93%	2.86%	22.16%	3.98%	0.02%
CR-22.1	**NW**	43.36%	4.67%	8.10%	38.02%	5.85%	0.00%
CR-16.7	**NW**	63.17%	11.06%	5.62%	13.37%	2.66%	4.14%
CR-9.1	**LBD**	50.96%	33.69%	3.35%	3.07%	2.27%	6.66%
CR-7.4	**LBD**	66.98%	9.30%	9.23%	11.93%	2.49%	0.07%
CR-1.7	**LBD**	34.49%	30.59%	12.04%	20.98%	1.84%	0.07%

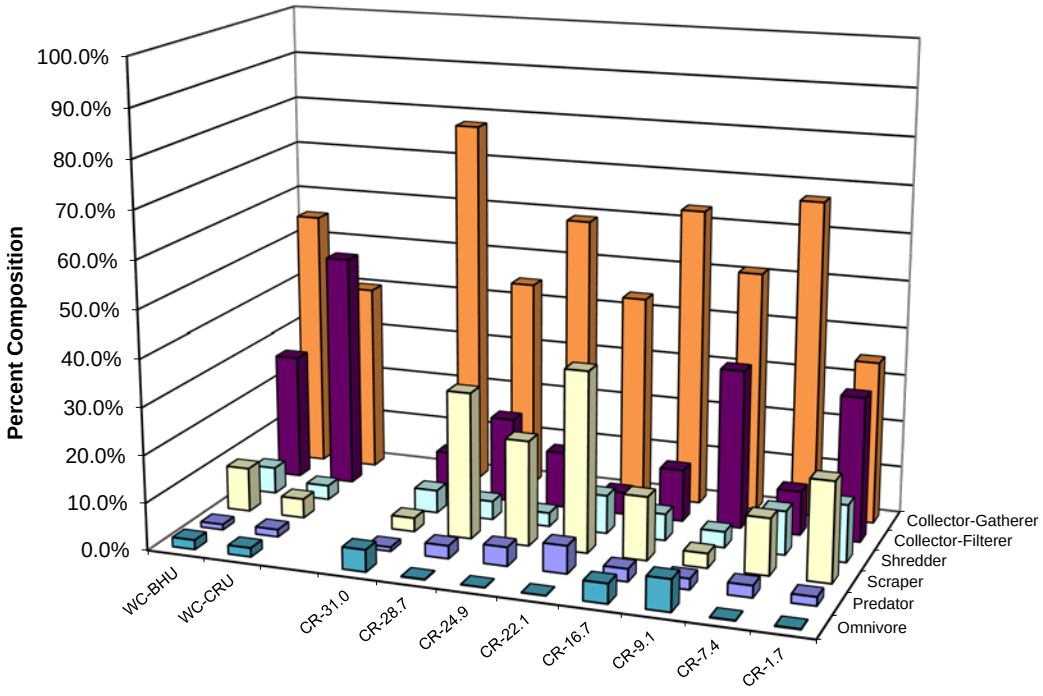

Figure 21. Functional feeding group composition for study sites in the Colorado River study area during the fall of 2022.

Williams Fork Study Area

The distribution of functional feeding groups in the Williams Fork study area demonstrated how food resources for benthic macroinvertebrates can change upstream and downstream from an impoundment. In October of 2022, the most optimal balance among feeding groups was found immediately upstream from Williams Fork Reservoir at site WF-5.5, where collector-gatherers were slightly dominant, but collector-filterers, shredders, scrapers, and predators were all represented in proportions that were greater than at other Williams Fork study sites (Table 13; Figure 22). Immediately downstream from the reservoir at site WF-2.0, there was a substantial reduction in the most sensitive feeding groups (collector-filterers, shredders, and scrapers), while the proportions of the more tolerant groups (collector-gatherers and omnivores) increased (Figure 22). While it is common for collector-gatherers to be the most abundant feeding group in 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 (particularly shredders and scrapers). This is 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). Impacts that are observed immediately downstream from impoundments are often alleviated farther downstream when tributaries and ambient conditions can help to restore a more natural thermal and flow regime.

Curiously, macroinvertebrate community function did not appear to be returning to a more normal distribution farther downstream at site WF-0.5 during the fall of 2022 (Table 13; Figure 22). Proportions of the most tolerant feeding groups (collector-gatherers and omnivores) remained high while proportions of the more sensitive groups remained low. The lack of recovery among sensitive feeding groups at site WF-0.5 was unexpected in 2022, because this site usually exhibits improvements in community structure and function. Overall, the results from the functional feeding group analysis supported the results from other metrics used in this study by detecting increased stress downstream from Williams Fork Reservoir. However, unlike other metrics (and the MMI v4), the distribution of functional feeding groups did not detect improvements in macroinvertebrate community function at the most downstream site (WF-0.5) during the fall of 2022 (Table 13; Figure 22).

Table 13. Relative abundance of functional feeding groups in the Williams Fork study area during the fall of 2022. LBD=Learning By Doing.

Site	Project	Functional Feeding Group					
		Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
WF-5.5	LBD	47.86%	33.92%	2.60%	12.30%	3.05%	0.28%
WF-2.0	LBD	57.72%	15.64%	0.39%	0.20%	1.82%	24.24%
WF-0.5	LBD	65.58%	9.05%	0.74%	0.77%	1.25%	22.60%

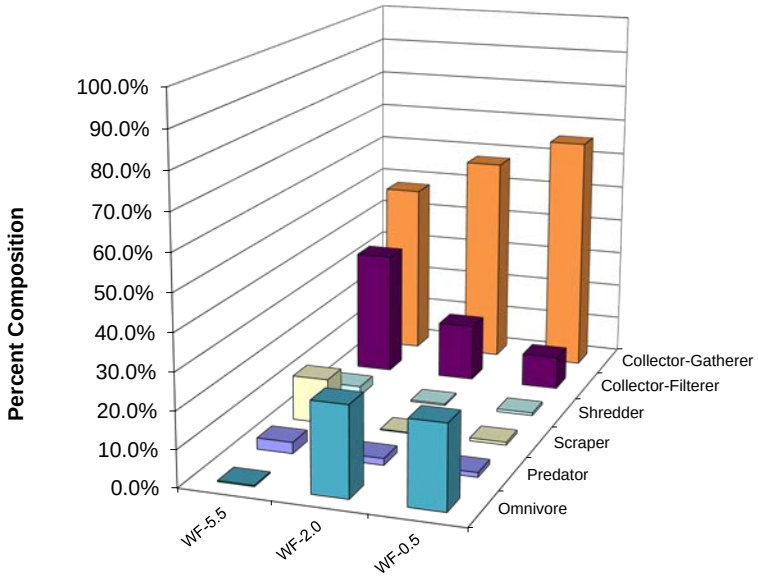

Figure 22. Functional feeding group composition for study sites in the Williams Fork study area during the fall of 2022.

Conclusions

Benthic macroinvertebrate biomonitoring studies were conducted for LBD, Denver Water, and Northern Water in three major drainages in Grand County, Colorado during the fall of 2022. These three drainages included portions of the Fraser River, Colorado River, Williams Fork, and several tributaries where community structure and function was evaluated to determine the overall condition of aquatic life. An assessment of results provided by the MMI v4, additional individual metrics, and the proportional distribution of functional feeding groups provided detailed insight into macroinvertebrate community health in all three major drainages. Results from biomonitoring studies in the Fraser River study area suggested that most study sites supported relatively stable (or recently improved) aquatic communities, although there was some evidence of minor stress at site FR-23.2 (abvWPSD). In the Colorado River study area, results provided by LBD and Northern Water biomonitoring studies indicated that there was moderate to severe stress at the two sampling locations on Willow Creek, and minor to severe stress at several locations (sites CR-31.0, CR-9.1, CR-7.4, and CR-1.7) along the Colorado River. Stressed macroinvertebrate communities on Willow Creek were likely influenced by operations of Willow Creek Reservoir while stressed communities on the Colorado River appeared to be influenced by excessive algal growth, which could have been related to nutrient-enrichment, runoff from areas impacted by recent wildfires, elevated water temperatures, or a combination of these stressors. Results from the LBD study sites on the Williams Fork were fairly predictable, with the most optimum community parameters occurring upstream from Williams Fork Reservoir, and evidence of stress (likely related to deviations from the natural temperature and flow regime) occurring downstream from the reservoir. Future biomonitoring studies will provide an opportunity to assess the persistence of these results and monitor any changes in macroinvertebrate community structure and function.

Literature Cited

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Barton, D.R. and J.L. Metcalfe-Smith. 1992. A comparison of sampling techniques and summary indices for assessment of water quality in Yamaska River, Quebec, based on benthic macroinvertebrates. Environmental Monitoring and Assessment 21:225-244.

Baxter, R. M. 1977. Environmental effects of dams and impoundments. Annual Review of Ecology and Systematics 8: 255-283.

Colorado Department of Public Health and Environment. 2017. Aquatic life use attainment: Methodology to determine use attainment for rivers and streams. Policy Statement 10-1.

Colorado Department of Public Health and Environment. 2022. Section 303(d) Listing Methodology 2024 Listing Cycle.

Courtemanch, D.L. 1996. Commentary on the subsampling procedures used for rapid bioassessments. Journal of the North American Benthological Society 15: 381-385.

Cummins, K. W., R. W. Merritt, and M. B. Berg. 2019. Pp. 117-140. Ecology and distribution of aquatic insects. *In*: Merritt, R. W., K. W. Cummins and M. B. Berg. 2019 (eds.). An Introduction to the Aquatic Insects of North America. Fifth Edition, Kendall/Hunt. Dubuque, Iowa. 1480 pp.

Delong, M. D. and M. A. Brusven. 1998. Macroinvertebrate community structure along the longitudinal gradient of an agriculturally impacted stream. Environmental Management 22: 445-457. DOI: 10.1007/s002679900118.

Ellis, L. E. and N. E. Jones. 2013. Longitudinal trends in regulated river: A review and synthesis within the context of the serial discontinuity concept. Environmental Review. NRC Research Press. Pp. 136-148.

Fang, Y. and J. W. Jawitz. 2019. The evolution of human population distance to water in the USA from 1790 to 2010. Nature Communications 10.

Hauer, F. R. and G. A. Lamberti (eds). 2017. Methods in stream ecology (3rd edition). Volume 1. Ecosystem structure. Elsevier, Amsterdam, Holland. 494 pp.

Hauer, F. R. and V. H. Resh. 2017. Pp. 297-320. Macroinvertebrates. *In*: F. R. Hauer and G. A. Lamberti (eds). Methods in stream ecology (3rd edition). Volume 1. Ecosystem structure. Elsevier, Amsterdam, Holland. 494 pp.

Hawkins, C. P. 2006. Quantifying biological integrity by taxonomic completeness: Its utility in regional and global assessments. Ecological Applications 16 (4): 1277-1294.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family level biotic index. Journal of the North American Benthological Society 7(1): 65-68.

Huryn, A. D. and J. B. Wallace. 2019. Pp. 65-116. Habitat, life history, secondary production, and behavioral adaptations of aquatic insects. *In*: Merritt, R. W., K. W. Cummins and M. B. Berg. 2019 (eds.). An Introduction to the Aquatic Insects of North America. Fifth Edition, Kendall/Hunt. Dubuque, Iowa. 1480 pp.

Jackson, J. K., V. H. Resh, D. P. Batzer, R. W. Merritt and K. W. Cummins. 2019. Pp. 17-42. Sampling aquatic insects. Collection devices, statistical considerations, and rearing procedures. *In*: Merritt, R. W., K. W. Cummins and M. B. Berg. 2019 (eds.). An Introduction to the Aquatic Insects of North America. Fifth Edition, Kendall/Hunt. Dubuque, Iowa. 1480 pp.

Johnson, R.C., H. Jin, M.M. Carreriro, and J.D. Jack. 2013. Macroinvertebrate community structure, secondary production and trophic-level dynamics in urban streams affected by non-point-source pollution. Freshwater Biology 58: 843-857.

Kowalski, D. A. and E. E. Richer. 2020. Quantifying the habitat preferences of the stonefly *Pteronarcys californica* in Colorado. River Research and Applications 36: 2043-2050.

Krajenbrink, H., J. Acreman, M., Dunbar, M. J., Hannah, D.M., Laize, C. L. R., and P. J. Wood. 2019. Macroinvertebrate community responses to river impoundment at multiple spatial scales. Science of the Total Environment 650: 2648-2656.

Lenat, D.R. 1983. Chironomid taxa richness: Natural variation and use in pollution assessment. Freshwater Invertebrate Biology 2: 192-198.

Lenat, D.R. 1988. Water quality assessment of streams using a qualitative collection method for benthic macroinvertebrates. Journal of the North American Benthological Society 7:222-33.

Likens, G. E., and K. F. Lambert. 1998. The importance of long-term data in addressing regional environmental issues. Northeastern Naturalist 5: 127-136.

Lytle, D. A., M. T. Bogan and D. S. Finn. 2008. Evolution of aquatic insect behaviors across a gradient of disturbance predictability. Proceedings of the Royal Society B: Biological Sciences 275: 453-462.

Mandaville, S.M. 2002. Benthic Macroinvertebrates in Freshwaters-Taxa Tolerance Values, Metrics, and Protocols. Project H-1. Soil and Water Conservation Society of Metro Halifax, xviii. 48. Pp., Appendices A-B 120pp.

Mazor, R. D., D. M. Rosenberg and V. H. Resh. 2019. Pp. 141-164. Use of aquatic insects in bioassessment. *In*: Merritt, R. W., K. W. Cummins and M. B. Berg (eds.). An Introduction to the Aquatic Insects of North America. Fifth Edition, Kendall/Hunt. Dubuque, Iowa. 1480 pp.

Merritt, R. W., K. W. Cummins and M. B. Berg. 2019. An Introduction to the Aquatic Insects of North America. Fifth Edition, Kendall/Hunt. Dubuque, Iowa. 1480 pp.

Nelson, M.S. 2011. Response of stream macroinvertebrate assemblages to erosion control structures in a wastewater dominated urban stream in the southwestern U.S. Hydrobiologia 663: 51-69.

Patang, F., A. Soegianto, and S. Hariyanto. 2018. Benthic Macroinvertebrates Diversity as Bioindicator of Water Quality of Some Rivers in East Kalimantan, Indonesia. Hindawi International Journal of Ecology 1-11.

Paul, M. J., J. Gerritsen, C. Hawkins, and E. Leppo. 2005. Draft. Development of biological assessment tools for Colorado. Colorado Department of Public Health and Environment, Water Quality Control Division – Monitoring Unit. Denver, Colorado.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. EPA/444/4-89/001.

Poff, N. L., J. D. Olden, N. K. M. Vieira, D. S. Finn, M. P. Simmons, and B. C. Kondratieff. 2006. Functional trait niches of North American lotic insects: traits-based ecological applications in light of phylogenetic relationships. Journal of the North American Benthological Society 25: https://doi.org/10.1899/0887-3593(2006)025[0730:FTNONA]2.0.CO;2

Rawer-Jost, C., J. Böhmer, J. Bank, and H. Rahmann. 2000. Macroinvertebrate functional feeding group methods in ecological assessment. Hydrobiologia 422:225-232.

Rosenberg, D. M. and V. H. Resh. 1993. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York, New York. 488 pp.

Søndergaard, M., and E. Jeppesen. 2007. Anthropogenic impacts on lake and stream ecosystems, and approaches to restoration. British Ecological Society, London.

Strayer, D. 2010. Freshwater biodiversity conservation: Recent progress and future challenges. Journal of the North American Benthological Society 29(1).

USEPA. 2011. A primer on using biological assessments to support water quality management. EPA 810-R-11-01. United States EPA, Office of Science and Technology, Office of Water, Washington, D.C.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Voelz, N. J., R. E. Zuellig, S. Shieh, and J. V. Ward. 2005. The effects of urban areas on benthic macroinvertebrates in two Colorado plains rivers. Environmental Monitoring and Assessment 101: 175-202.

Wang, L., D. M. Robertson, and P. J. Garrison. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. Environmental Management 39: 194-212.

Ward, J. V. 1976. Effects of flow patterns below large dams on stream benthos: A review. Instream Flow Needs. American Fisheries Society. Pp. 235-253.

Ward, J. V. 1982. Ecological aspects of stream regulation: Responses in downstream reaches. Water Pollution Management. Reviews 2: 1-26.

Ward, J. V. and J. A. Stanford (eds.). 1979. The ecology of regulated rivers. Plenum Press, New York. 398 pp.

Ward, J. V. and J. A. Stanford. 1983. The serial discontinuity concept of lotic ecosystems. Pp. 29-42. *In* Fontaine, T. D. and S. M. Bartell (eds.). Dynamics of Lotic Ecosystems. Ann Arbor Science Publishers, Ann Arbor, Michigan.

Ward, J. V., B. C. Kondratieff, and R. E. Zuellig. 2002. An illustrated guide to the mountain stream insects of Colorado. Second Edition. University Press of Colorado. Boulder, Colorado.

White, J. C., D. M. Hannah, A. House, S. J. V. Beatson, A. Martin and P. J. Wood. 2016. Macroinvertebrate responses to flow and stream temperature variability across regulated and non-regulated rivers. Ecohydrology 10: e1773.

Wooster, D.E., S.W. Miller, and S. J. Debano. 2011. An examination of the impact of multiple disturbances on a river system: taxonomic metrics versus biological traits. River Research and Application 28:1630-1643.

Appendix A

Learning By Doing
Benthic Macroinvertebrate Data – Fall 2022

Table A1. Macroinvertebrate data collected from site FR-27.2 on 18 Sept. 2022.

Fraser River						
FR-27.2		Sample				
18 Sept. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.	5				5	20
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	11	19	11		41	159
Diphetor hageni						
Attenella margarita						
Drunella coloradensis		2	3		5	20
Drunella doddsii	44	44	65		153	593
Drunella grandis						
Ephemerella dorothea infrequens	22	11	12		45	175
Cinygmula sp.	6	2			8	31
Epeorus deceptivus	2	12	7		21	82
Epeorus longimanus						
Heptagenia sp.						
Rhithrogena sp.	16	43	27		86	334
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Capniidae	3	2	2		7	28
Paracapnia angulata						
Chloroperlidae	1	14	1		16	62
Sweltsa sp.	12	15	8		35	136
Zapada cinctipes						
Zapada oregonensis group	21	63	7		91	353
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.	8	7	6		21	82
Isoperla fulva						
Megarcys signata		3			3	12
Skwala americana						
Pteronarcys californica						
Taenionema sp.	19	80	33		132	512
Trichoptera (caddisflies)						
Brachycentrus americanus						
Brachycentrus occidentalis						
Micrasema bactro						
Agapetus sp.						
Culoptila sp.						
Glossosoma sp.	1		1		2	8
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche occidentalis						
Hydropsyche oslari						
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.						
Oecetis sp.						
Limnephilidae		2			2	8
Hesperophylax sp.						
Rhyacophila brunnea						
Rhyacophila coloradensis		2	1		3	12
Rhyacophila harmstoni	2	1	1		4	16
Oligophlebodes sp.	16	7	8		31	121

Table A1. cont. Macroinvertebrate data collected from FR-27.2 on 18 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	3		1		4	16
Cryptochironomus sp.						
Diamesa sp.			1		1	4
Eukiefferiella sp.		2	2		4	16
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.	6	9	6		21	82
Microtendipes sp.						
Pagastia sp.	2				2	8
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.		1			1	4
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	1	35	3		39	152
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae	1	4	5		10	39
Chelifera/Neoplasta sp.	1				1	4
Hemerodromia sp.						
Lispoides sp.						
Pericoma sp.						
Simulium sp.		2			2	8
Antocha sp.						
Dicranota sp.						
Hexatoma sp.	2				2	8
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	16	8	4		28	109
Optioservus sp.						
Zaitzevia parvula						
Haliplus sp.						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.	1	3	1		5	20
Protzia sp.						
Sperchon sp.	2	1	1		4	16
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	4	10	4		18	70
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Enchytraeidae		34	27		61	237
Lumbricidae						
Naididae	2		10		12	47
Tubificidae						
Nematoda						
Totals	**230**	**438**	**258**		**926**	**3604**

Table A2. Macroinvertebrate data collected from site SLC-0 on 18 Sept. 2022.

St. Louis Creek						
SLC-0		Sample				
18 Sept. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.	1				1	4
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	38	53	53		144	559
Diphetor hageni	1	3			4	16
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	8	5	3		16	62
Ephemerella dorothea infrequens	1	2	1		4	16
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus	5	10	3		18	70
Heptagenia sp.						
Rhithrogena sp.	6	18	1		25	97
Tricorythodes explicatus						
Paraleptophlebia sp.	16	20	11		47	183
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata			1		1	4
Chloroperlidae		5			5	20
Sweltsa sp.	6	13	2		21	82
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa	1	3	1		5	20
Perlodidae (*Cultus* sp.)						
Isoperla sp.	2	4			6	24
Isoperla fulva	2		1		3	12
Megarcys signata						
Skwala americana		1			1	4
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	14	23	12		49	190
Brachycentrus occidentalis	2	4	4		10	39
Micrasema bactro	6	4	5		15	59
Agapetus sp.		1			1	4
Culoptila sp.						
Glossosoma sp.	6	3	5		14	55
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis	5				5	20
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli		4	2		6	24
Hydropsyche occidentalis						
Hydropsyche oslari	63	43	52		158	613
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	111	126	38		275	1066
Oecetis sp.						
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea	1		1		2	8
Rhyacophila coloradensis			1		1	4
Rhyacophila harmstoni						
Oligophlebodes sp.	13	24	9		46	179

Table A2. cont. Macroinvertebrate data collected from site SLC-0 on 18 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	2		2		4	16
Cryptochironomus sp.						
Diamesa sp.						
Eukiefferiella sp.	1				1	4
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.			1		1	4
Microtendipes sp.						
Pagastia sp.	5	4	6		15	59
Parametriocnemus sp.						
Polypedilum sp.			1		1	4
Potthastia sp.						
Rheocricotopus sp.		1			1	4
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	1		4		5	20
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	2	2	2		6	24
Hemerodromia sp.						
Lispoides sp.						
Pericoma sp.	7	1	1		9	35
Simulium sp.	1				1	4
Antocha sp.		2	2		4	16
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.	12	11	18		41	159
Optioservus sp.	33	24	30		87	338
Zaitzevia parvula		5	4		9	35
Haliplus sp.						
Miscellaneous						
Atractides sp.						
Hygrobates sp.		1			1	4
Lebertia sp.	9	3	2		14	55
Protzia sp.	2	1			3	12
Sperchon sp.	3	5			8	31
Torrenticola sp.	2	2			4	16
Pisidium sp.		1			1	4
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	12	7	2		21	82
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae		1			1	4
Tubificidae						
Nematoda						
Totals	**400**	**440**	**281**		**1121**	**4364**

Table A3. Macroinvertebrate data collected from site RC-1.1 on 18 Sept. 2022.

Ranch Creek						
RC-1.1		Sample				
18 Sept. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	6	6	8		20	78
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	46	32	48		126	489
Ephemerella dorothea infrequens	40	41	42		123	477
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus	43	25	32		100	388
Heptagenia sp.						
Rhithrogena sp.		2	2		4	16
Tricorythodes explicatus						
Paraleptophlebia sp.	9	14	15		38	148
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata	3	1			4	16
Chloroperlidae	1		1		2	8
Sweltsa sp.		1			1	4
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa			3		3	12
Perlodidae (*Cultus* sp.)						
Isoperla sp.	1				1	4
Isoperla fulva			1		1	4
Megarcys signata						
Skwala americana						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	91	101	53		245	950
Brachycentrus occidentalis						
Micrasema bactro	8	27	24		59	229
Agapetus sp.						
Culoptila sp.	28	19	28		75	291
Glossosoma sp.	5	1	3		9	35
Protoptila sp.	7	1			8	31
Helicopsyche borealis						
Arctopsyche grandis	1	1	2		4	16
Cheumatopsyche sp.						
Hydropsyche sp.	1				1	4
Hydropsyche cockerelli	15	15	28		58	225
Hydropsyche occidentalis						
Hydropsyche oslari	80	101	103		284	1101
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	108	136	114		358	1388
Oecetis sp.						
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea	1	1	1		3	12
Rhyacophila coloradensis	1				1	4
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A3. cont. Macroinvertebrate data collected from site RC-1.1 on 18 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	36	16	22		74	287
Cricotopus/Orthocladius sp.		1	3		4	16
Cryptochironomus sp.						
Diamesa sp.						
Eukiefferiella sp.	9	8	19		36	140
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	1		2		3	12
Parametriocnemus sp.			1		1	4
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.			1		1	4
Thienemanniella sp.						
Thienemannimyia group		1			1	4
Tvetenia sp.	2	5	2		9	35
Other Diptera (true flies)						
Atherix pachypus	9	3	10		22	86
Ceratopogoninae			1		1	4
Chelifera/Neoplasta sp.	2	2			4	16
Hemerodromia sp.						
Lispoides sp.						
Pericoma sp.		1	2		3	12
Simulium sp.	1	1			2	8
Antocha sp.	1				1	4
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	37	30	55		122	473
Zaitzevia parvula	2	5	12		19	74
Haliplus sp.						
Miscellaneous						
Atractides sp.						
Hygrobates sp.	1				1	4
Lebertia sp.	4		4		8	31
Protzia sp.		2	14		16	62
Sperchon sp.	7	7	7		21	82
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.						
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.	1	2	2		5	20
Dugesia sp.						
Polycelis coronata	1	1			2	8
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Enchytraeidae						
Lumbricidae			1		1	4
Naididae						
Tubificidae						
Nematoda						
Totals	**609**	**610**	**666**		**1885**	**7320**

Table A4. Macroinvertebrate data collected from site WC-BHU on 19 Sept. 2022.

Willow Creek						
WC-BHU		Sample				
19 Sept. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	67	50	66		183	710
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis						
Ephemerella dorothea infrequens	1				1	4
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus			1		1	4
Paraleptophlebia sp.	1		2		3	12
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	4	12	6		22	86
Brachycentrus occidentalis						
Micrasema bactro						
Agapetus sp.						
Culoptila sp.						
Glossosoma sp.		2	6		8	31
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis	2	1	1		4	16
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche occidentalis						
Hydropsyche oslari	33	35	23		91	353
Hydroptila sp.		1			1	4
Ochrotrichia sp.						
Lepidostoma sp.	16	30	22		68	264
Oecetis sp.						
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea						
Rhyacophila coloradensis	1				1	4
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A4. cont. Macroinvertebrate data collected from WC-BHU on 19 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	9	25	16		50	194
Cryptochironomus sp.						
Diamesa sp.						
Eukiefferiella sp.	8	14	5		27	105
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.		2			2	8
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.		2			2	8
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.		1			1	4
Hemerodromia sp.						
Lispoides sp.						
Pericoma sp.						
Simulium sp.	68	91	102		261	1012
Antocha sp.						
Dicranota sp.		1			1	4
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	20	34	63		117	454
Zaitzevia parvula						
Haliplus sp.	1	7	3		11	43
Miscellaneous						
Atractides sp.						
Hygrobates sp.		1	2		3	12
Lebertia sp.	1	1			2	8
Protzia sp.						
Sperchon sp.		2	3		5	20
Torrenticola sp.						
Pisidium sp.		1			1	4
Caecidotea sp.	99	104	248		451	1749
Ferrissia sp.						
Lymnaeidae	2				2	8
Physa sp.						
Gyraulus sp.	1	2	1		4	16
Dugesia sp.						
Polycelis coronata	7	3	7		17	66
Crangonyx sp.	5	13	15		33	128
Gammarus lacustris		1	10		11	43
Erpobdellidae	1		1		2	8
Enchytraeidae						
Lumbricidae						
Naididae	3	2	4		9	35
Tubificidae	3	1	15		19	74
Nematoda	1				1	4
Totals	**354**	**439**	**622**		**1415**	**5495**

Table A5. Macroinvertebrate data collected from WC-CRU on 19 Sept. 2022.

Willow Creek						
WC-CRU		Sample				
19 Sept. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	170	317	234		721	2795
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	1				1	4
Ephemerella dorothea infrequens						
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus		1			1	4
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	165	127	238		530	2055
Brachycentrus occidentalis						
Micrasema bactro	1	2			3	12
Agapetus sp.						
Culoptila sp.						
Glossosoma sp.	2		2		4	16
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis	3	2	2		7	28
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche occidentalis						
Hydropsyche oslari	66	50	115		231	896
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	15	39	10		64	249
Oecetis sp.						
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea	7	9	9		25	97
Rhyacophila coloradensis						
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A5. cont. Macroinvertebrate data collected from WC-CRU on 19 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	3	2	10		15	59
Cryptochironomus sp.						
Diamesa sp.						
Eukiefferiella sp.	3		10		13	51
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.			1		1	4
Microtendipes sp.						
Pagastia sp.						
Parametriocnemus sp.	2		2		4	16
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group	1				1	4
Tvetenia sp.	3	2	6		11	43
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	1		2		3	12
Hemerodromia sp.						
Lispoides sp.						
Pericoma sp.						
Simulium sp.	50	109	174		333	1291
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	18	41	25		84	326
Zaitzevia parvula	2	2			4	16
Haliplus sp.						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.		1			1	4
Protzia sp.		1			1	4
Sperchon sp.		1	1		2	8
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.	29	23	48		100	388
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	10	23	8		41	159
Crangonyx sp.	5	9	2		16	62
Gammarus lacustris						
Erpobdellidae			1		1	4
Enchytraeidae						
Lumbricidae						
Naididae	1				1	4
Tubificidae						
Nematoda						
Totals	**558**	**761**	**900**		**2219**	**8611**

Table A6. Macroinvertebrate data collected from CR-24.9 on 19 Sept. 2022.

Colorado River						
CR-24.9		Sample				
19 Sept. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	206	165	151		522	2024
Diphetor hageni	8	3	4		15	59
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis		1	5		6	24
Ephemerella dorothea infrequens	474	659	625		1758	6814
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus	6	6	21		33	128
Heptagenia sp.						
Rhithrogena sp.	2	3	5		10	39
Tricorythodes explicatus		1			1	4
Paraleptophlebia sp.	33	24	16		73	283
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata	1	4	1		6	24
Chloroperlidae	1				1	4
Sweltsa sp.						
Zapada cinctipes			1		1	4
Zapada oregonensis group						
Claassenia sabulosa	6	3	11		20	78
Perlodidae (*Cultus* sp.)		1			1	4
Isoperla sp.	4	1	2		7	28
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcys californica	1	2			3	12
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	40	49	53		142	551
Brachycentrus occidentalis						
Micrasema bactro						
Agapetus sp.						
Culoptila sp.	77	167	127		371	1438
Glossosoma sp.						
Protoptila sp.	13	4	3		20	78
Helicopsyche borealis						
Arctopsyche grandis	1	8	3		12	47
Cheumatopsyche sp.	6		3		9	35
Hydropsyche sp.						
Hydropsyche cockerelli	1	4	1		6	24
Hydropsyche occidentalis						
Hydropsyche oslari	21	35	62		118	458
Hydroptila sp.	81	85	78		244	946
Ochrotrichia sp.						
Lepidostoma sp.	53	39	34		126	489
Oecetis sp.	6	2	3		11	43
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A6. cont. Macroinvertebrate data collected from CR-24.9 on 19 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	2	1	2		5	20
Cricotopus nostocicola	2	5	4		11	43
Cricotopus/Orthocladius sp.	20	11	24		55	214
Cryptochironomus sp.	1				1	4
Diamesa sp.	1				1	4
Eukiefferiella sp.	76	57	66		199	772
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.						
Parametriocnemus sp.	24	13	4		41	159
Polypedilum sp.						
Potthastia sp.	9	4	4		17	66
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.	1				1	4
Thienemannimyia group	2		2		4	16
Tvetenia sp.	58	36	32		126	489
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae	1	3			4	16
Chelifera/Neoplasta sp.	12	12	15		39	152
Hemerodromia sp.	25	24	24		73	283
Lispoides sp.						
Pericoma sp.						
Simulium sp.	155	110	60		325	1260
Antocha sp.	2	1	3		6	24
Dicranota sp.						
Hexatoma sp.	2				2	8
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	128	196	128		452	1752
Zaitzevia parvula	17	14	11		42	163
Haliplus sp.						
Miscellaneous						
Atractides sp.						
Hygrobates sp.		2	1		3	12
Lebertia sp.						
Protzia sp.	6	10	1		17	66
Sperchon sp.	3	7	4		14	55
Torrenticola sp.						
Pisidium sp.						
Caecidotea sp.	13	17	1		31	121
Ferrissia sp.						
Lymnaeidae						
Physa sp.			1		1	4
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata		1			1	4
Crangonyx sp.			1		1	4
Gammarus lacustris						
Erpobdellidae	1				1	4
Enchytraeidae						
Lumbricidae	8	9	11		28	109
Naididae	4	11			15	59
Tubificidae	42	35	22		99	384
Nematoda		1			1	4
Totals	**1656**	**1846**	**1630**		**5132**	**19913**

Table A7. Macroinvertebrate data collected from WF-5.5 on 25 Oct. 2022.

Williams Fork						
WF-5.5		Sample				
25 Oct. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	1	1			2	8
Baetis flavistriga						
Baetis (*tricaudatus*)	65	48	41		154	597
Diphetor hageni	42	6	28		76	295
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	11	8	5		24	93
Ephemerella dorothea infrequens	3		2		5	20
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus	2	4	3		9	35
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	30	10	54		94	365
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata	4		3		7	28
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	9	12	8		29	113
Brachycentrus occidentalis						
Micrasema bactro						
Agapetus sp.						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	2	4	12		18	70
Hydropsyche occidentalis						
Hydropsyche oslari	265	70	159		494	1915
Hydroptila sp.	2		1		3	12
Ochrotrichia sp.						
Lepidostoma sp.	7	4	10		21	82
Oecetis sp.						
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea	4	10	7		21	82
Rhyacophila coloradensis						
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A7. cont. Macroinvertebrate data collected from site WF-5.5 on 25 Oct. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	1		1		2	8
Cricotopus/Orthocladius sp.	34	15	30		79	307
Cryptochironomus sp.						
Diamesa sp.	68	25	20		113	438
Eukiefferiella sp.	36	42	11		89	345
Heterotrissocladius sp.			1		1	4
Micropsectra/Tanytarsus sp.	1	1	3		5	20
Microtendipes sp.						
Pagastia sp.	98	61	32		191	741
Parametriocnemus sp.	1		2		3	12
Polypedilum sp.	6	1	8		15	59
Potthastia sp.	2	2	3		7	28
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.	3		1		4	16
Thienemannimyia group		1	4		5	20
Tvetenia sp.	7	1	4		12	47
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	4	6	4		14	55
Hemerodromia sp.						
Lispoides sp.						
Pericoma sp.			1		1	4
Simulium sp.	25	28	7		60	233
Antocha sp.						
Dicranota sp.	1				1	4
Hexatoma sp.			1		1	4
Tipula sp.	1				1	4
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.	74	43	58		175	679
Zaitzevia parvula		2			2	8
Haliplus sp.						
Miscellaneous						
Atractides sp.						
Hygrobates sp.			1		1	4
Lebertia sp.	2		1		3	12
Protzia sp.	1	3	1		5	20
Sperchon sp.	1		1		2	8
Torrenticola sp.			1		1	4
Pisidium sp.						
Caecidotea sp.			2		2	8
Ferrissia sp.						
Lymnaeidae						
Physa sp.	1	1	4		6	24
Gyraulus sp.	1				1	4
Dugesia sp.						
Polycelis coronata		2	3		5	20
Crangonyx sp.						
Gammarus lacustris						
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae	2	1	5		8	31
Tubificidae						
Nematoda						
Totals	**817**	**412**	**543**		**1772**	**6886**

Table A8. Macroinvertebrate data collected from site WF-2.0 on 25 Oct. 2022.

Williams Fork						
WF-2.0		Sample				
25 Oct. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga						
Baetis (*tricaudatus*)	516	462	461		1439	5578
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	1		6		7	28
Ephemerella dorothea infrequens	4	7	16		27	105
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus						
Paraleptophlebia sp.	1				1	4
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva	2	1			3	12
Megarcys signata						
Skwala americana						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	5	1	13		19	74
Brachycentrus occidentalis						
Micrasema bactro						
Agapetus sp.						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis			2		2	8
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche occidentalis						
Hydropsyche oslari	1				1	4
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	3	4	7		14	55
Oecetis sp.						
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea	5	1	1		7	28
Rhyacophila coloradensis	1	3			4	16
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A8. cont. Macroinvertebrate data collected from site WF-2.0 on 25 Oct. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	90	43	117		250	969
Cryptochironomus sp.						
Diamesa sp.		1			1	4
Eukiefferiella sp.	19	17	41		77	299
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.	1	1	3		5	20
Microtendipes sp.						
Pagastia sp.	60	44	99		203	787
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.	9	2	15		26	101
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.	1				1	4
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Lispoides sp.						
Pericoma sp.						
Simulium sp.	150	183	205		538	2086
Antocha sp.			2		2	8
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.						
Zaitzevia parvula						
Haliplus sp.						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.	11	5	17		33	128
Protzia sp.						
Sperchon sp.	2	1	5		8	31
Torrenticola sp.	4	2	2		8	31
Pisidium sp.						
Caecidotea sp.	4	1	3		8	31
Ferrissia sp.						
Lymnaeidae						
Physa sp.						
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	247	219	402		868	3365
Crangonyx sp.			3		3	12
Gammarus lacustris						
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae	11	13			24	93
Tubificidae						
Nematoda	1	1			2	8
Totals	**1149**	**1012**	**1420**		**3581**	**13889**

Table A9. Macroinvertebrate data collected from site WF-0.5 on 25 Oct. 2022.

Williams Fork						
WF-0.5		Sample				
25 Oct. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	8	3	3		14	55
Baetis flavistriga		1			1	4
Baetis (*tricaudatus*)	521	423	466		1410	5466
Diphetor hageni	1				1	4
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	3	2			5	20
Ephemerella dorothea infrequens	20	47	27		94	365
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus	10	7	4		21	82
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus		1	1		2	8
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva	2	2			4	16
Megarcys signata						
Skwala americana						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	17	40	10		67	260
Brachycentrus occidentalis						
Micrasema bactro						
Agapetus sp.						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis						
Arctopsyche grandis	1	1	1		3	12
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche occidentalis						
Hydropsyche oslari	1				1	4
Hydroptila sp.						
Ochrotrichia sp.						
Lepidostoma sp.	11	11			22	86
Oecetis sp.						
Limnephilidae						
Hesperophylax sp.	1				1	4
Rhyacophila brunnea	8	19	7		34	132
Rhyacophila coloradensis	2				2	8
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A9. cont. Macroinvertebrate data collected from site WF-0.5 on 25 Oct. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.						
Cricotopus nostocicola	1		1		2	8
Cricotopus/Orthocladius sp.	144	118	71		333	1291
Cryptochironomus sp.						
Diamesa sp.	18	12	5		35	136
Eukiefferiella sp.	29	18	9		56	218
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.	1	3			4	16
Microtendipes sp.						
Pagastia sp.	87	97	51		235	911
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.		10	3		13	51
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.	1				1	4
Thienemannimyia group						
Tvetenia sp.		1			1	4
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Hemerodromia sp.						
Lispoides sp.						
Pericoma sp.						
Simulium sp.	106	86	41		233	904
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.						
Heterlimnius sp.						
Optioservus sp.						
Zaitzevia parvula						
Haliplus sp.						
Miscellaneous						
Atractides sp.						
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	200	417	142		759	2942
Crangonyx sp.		1			1	4
Gammarus lacustris						
Erpobdellidae						
Enchytraeidae						
Lumbricidae						
Naididae	2				2	8
Tubificidae						
Nematoda						
Totals	**1195**	**1322**	**842**		**3359**	**13031**

Table A10. Macroinvertebrate data collected from site CR-9.1 on 19 Sept. 2022.

Colorado River						
CR-9.1		Sample				
19 Sept. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.	3	3	1		7	28
Baetis flavistriga		1			1	4
Baetis (*tricaudatus*)	50	32	75		157	609
Diphetor hageni						
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	1	2	2		5	20
Ephemerella dorothea infrequens	14	10	23		47	183
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus	3	5	3		11	43
Heptagenia sp.						
Rhithrogena sp.		2	1		3	12
Tricorythodes explicatus	10	6	13		29	113
Paraleptophlebia sp.	2	2	5		9	35
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata	1				1	4
Chloroperlidae		1			1	4
Sweltsa sp.						
Zapada cinctipes	1				1	4
Zapada oregonensis group						
Claassenia sabulosa		1			1	4
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Isoperla fulva						
Megarcys signata						
Skwala americana			1		1	4
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	93	25	54		172	667
Brachycentrus occidentalis						
Micrasema bactro						
Agapetus sp.						
Culoptila sp.		1			1	4
Glossosoma sp.						
Protoptila sp.		2	5		7	28
Helicopsyche borealis						
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli	6	1	4		11	43
Hydropsyche occidentalis						
Hydropsyche oslari	29	25	23		77	299
Hydroptila sp.	2	1	2		5	20
Ochrotrichia sp.						
Lepidostoma sp.	18	28	31		77	299
Oecetis sp.	9	2	4		15	59
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea			1		1	4
Rhyacophila coloradensis						
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A10. cont. Macroinvertebrate data collected from CR-9.1 on 19 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.	6		3		9	35
Cricotopus nostocicola	4		1		5	20
Cricotopus/Orthocladius sp.	87	64	67		218	845
Cryptochironomus sp.			1		1	4
Diamesa sp.	1				1	4
Eukiefferiella sp.	27	16	26		69	268
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	1	1	1		3	12
Parametriocnemus sp.	54	18	27		99	384
Polypedilum sp.						
Potthastia sp.	1		2		3	12
Rheocricotopus sp.	1				1	4
Synorthocladius sp.						
Thienemanniella sp.	5	7	12		24	93
Thienemannimyia group						
Tvetenia sp.	3	7	5		15	59
Other Diptera (true flies)						
Atherix pachypus		3	1		4	16
Ceratopogoninae						
Chelifera/Neoplasta sp.	4	2			6	24
Hemerodromia sp.	1	1	1		3	12
Lispoides sp.	1				1	4
Pericoma sp.						
Simulium sp.	226	85	273		584	2264
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.	1		1		2	8
Heterlimnius sp.						
Optioservus sp.	9	10	21		40	155
Zaitzevia parvula	4	4	5		13	51
Haliplus sp.						
Miscellaneous						
Atractides sp.						
Hygrobates sp.						
Lebertia sp.	1	1			2	8
Protzia sp.			3		3	12
Sperchon sp.						
Torrenticola sp.						
Pisidium sp.	1				1	4
Caecidotea sp.	186	121	257		564	2186
Ferrissia sp.						
Lymnaeidae	2				2	8
Physa sp.	1		2		3	12
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	15	18	91		124	481
Crangonyx sp.						
Gammarus lacustris	25	6	12		43	167
Erpobdellidae	2		5		7	28
Enchytraeidae						
Lumbricidae	5		1		6	24
Naididae						
Tubificidae		3	9		12	47
Nematoda						
Totals	**916**	**517**	**1075**		**2508**	**9741**

Table A11. Macroinvertebrate data collected from site CR-7.4 on 19 Sept. 2022.

Colorado River						
CR-7.4		Sample				
19 Sept. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.		1			1	4
Baetis flavistriga						
Baetis (*tricaudatus*)	42	41	16		99	384
Diphetor hageni	1		3		4	16
Attenella margarita						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis						
Ephemerella dorothea infrequens	15	29	22		66	256
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus	2	5	1		8	31
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus	40	17	27		84	326
Paraleptophlebia sp.	1	7			8	31
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.		1			1	4
Isoperla fulva						
Megarcys signata						
Skwala americana		1	1		2	8
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus		4	7		11	43
Brachycentrus occidentalis						
Micrasema bactro						
Agapetus sp.						
Culoptila sp.						
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis	2	2			4	16
Arctopsyche grandis						
Cheumatopsyche sp.						
Hydropsyche sp.						
Hydropsyche cockerelli						
Hydropsyche occidentalis			1		1	4
Hydropsyche oslari	5	18	19		42	163
Hydroptila sp.	1	2	2		5	20
Ochrotrichia sp.		1			1	4
Lepidostoma sp.	42	69	22		133	516
Oecetis sp.	10	2			12	47
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A11. cont. Macroinvertebrate data collected from CR-7.4 on 19 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.		1			1	4
Cricotopus nostocicola	1	1	1		3	12
Cricotopus/Orthocladius sp.	59	184	78		321	1245
Cryptochironomus sp.		1	1		2	8
Diamesa sp.	1	2			3	12
Eukiefferiella sp.	3	15	3		21	82
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.						
Microtendipes sp.	2				2	8
Pagastia sp.						
Parametriocnemus sp.	44	44	50		138	535
Polypedilum sp.						
Potthastia sp.	2		3		5	20
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.	1	2	3		6	24
Thienemannimyia group						
Tvetenia sp.	3	1	5		9	35
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Hemerodromia sp.		1			1	4
Lispoides sp.						
Pericoma sp.						
Simulium sp.	25	28	25		78	303
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.	1				1	4
Coleoptera (beetles)						
Oreodytes sp.		1			1	4
Heterlimnius sp.						
Optioservus sp.	33	97	25		155	601
Zaitzevia parvula	1	7			8	31
Haliplus sp.						
Miscellaneous						
Atractides sp.		1			1	4
Hygrobates sp.						
Lebertia sp.						
Protzia sp.						
Sperchon sp.		1			1	4
Torrenticola sp.						
Pisidium sp.		4			4	16
Caecidotea sp.	52	81	35		168	652
Ferrissia sp.	1				1	4
Lymnaeidae						
Physa sp.	1	3			4	16
Gyraulus sp.						
Dugesia sp.						
Polycelis coronata	1				1	4
Crangonyx sp.	1	5			6	24
Gammarus lacustris						
Erpobdellidae	9	4	2		15	59
Enchytraeidae						
Lumbricidae	1	1	2		4	16
Naididae						
Tubificidae	30	11	1		42	163
Nematoda						
Totals	**433**	**696**	**355**		**1484**	**5767**

Table A12. Macroinvertebrate data collected from site CR-1.7 on 19 Sept. 2022.

Colorado River						
CR-1.7		Sample				
19 Sept. 2022	1	2	3		Total	Estimated #/m²
Ephemeroptera (mayflies)						
Ameletus sp.						
Acentrella sp.						
Baetis flavistriga			1		1	4
Baetis (*tricaudatus*)	33	38	43		114	442
Diphetor hageni		1	1		2	8
Attenella margarita		1			1	4
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	1				1	4
Ephemerella dorothea infrequens	6	5	20		31	121
Cinygmula sp.						
Epeorus deceptivus						
Epeorus longimanus		1	1		2	8
Heptagenia sp.			7		7	28
Rhithrogena sp.						
Tricorythodes explicatus	2	11	22		35	136
Paraleptophlebia sp.			2		2	8
Plecoptera (stoneflies)						
Capniidae						
Paracapnia angulata			1		1	4
Chloroperlidae			2		2	8
Sweltsa sp.						
Zapada cinctipes						
Zapada oregonensis group						
Claassenia sabulosa	1				1	4
Perlodidae (*Cultus* sp.)			1		1	4
Isoperla sp.	2				2	8
Isoperla fulva						
Megarcys signata						
Skwala americana						
Pteronarcys californica						
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	4	3	1		8	31
Brachycentrus occidentalis						
Micrasema bactro						
Agapetus sp.						
Culoptila sp.			2		2	8
Glossosoma sp.						
Protoptila sp.						
Helicopsyche borealis	1				1	4
Arctopsyche grandis						
Cheumatopsyche sp.			7		7	28
Hydropsyche sp.						
Hydropsyche cockerelli			1		1	4
Hydropsyche occidentalis			1		1	4
Hydropsyche oslari	10	7	10		27	105
Hydroptila sp.	1	2	4		7	28
Ochrotrichia sp.	7	2	1		10	39
Lepidostoma sp.	68	68	187		323	1252
Oecetis sp.	1		3		4	16
Limnephilidae						
Hesperophylax sp.						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila harmstoni						
Oligophlebodes sp.						

Table A12. cont. Macroinvertebrate data collected from CR-1.7 on 19 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Cardiocladius sp.		1	6		7	28
Cricotopus nostocicola		1	1		2	8
Cricotopus/Orthocladius sp.	52	41	122		215	834
Cryptochironomus sp.			1		1	4
Diamesa sp.						
Eukiefferiella sp.	6	19	88		113	438
Heterotrissocladius sp.						
Micropsectra/Tanytarsus sp.			3		3	12
Microtendipes sp.						
Pagastia sp.						
Parametriocnemus sp.	10	6	18		34	132
Polypedilum sp.		1			1	4
Potthastia sp.	1	1	1		3	12
Rheocricotopus sp.						
Synorthocladius sp.						
Thienemanniella sp.		3			3	12
Thienemannimyia group			2		2	8
Tvetenia sp.	5	7	75		87	338
Other Diptera (true flies)						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.						
Hemerodromia sp.	1				1	4
Lispoides sp.			1		1	4
Pericoma sp.						
Simulium sp.	47	83	653		783	3035
Antocha sp.						
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Oreodytes sp.	1				1	4
Heterlimnius sp.						
Optioservus sp.	56	74	414		544	2109
Zaitzevia parvula	1	2	14		17	66
Haliplus sp.						
Miscellaneous						
Atractides sp.						
Hygrobates sp.		1			1	4
Lebertia sp.			2		2	8
Protzia sp.						
Sperchon sp.						
Torrenticola sp.						
Pisidium sp.			4		4	16
Caecidotea sp.	78	33	82		193	749
Ferrissia sp.						
Lymnaeidae			1		1	4
Physa sp.		2			2	8
Gyraulus sp.	2		1		3	12
Dugesia sp.		1	2		3	12
Polycelis coronata	2				2	8
Crangonyx sp.	12		9		21	82
Gammarus lacustris						
Erpobdellidae	8	5	8		21	82
Enchytraeidae						
Lumbricidae			2		2	8
Naididae	26	16	1		43	167
Tubificidae			7		7	28
Nematoda						
Totals	**445**	**436**	**1836**		**2717**	**10550**

Appendix B

Northern Water
Benthic Macroinvertebrate Data – Fall 2022

Table B1. Macroinvertebrate data collected from site CR-WGU on 19 Sept. 2022.

Colorado River						
CR-31.0 (WGU)		Sample				Estimated Total/m²
19 Sept. 2022	1	2	3		Total	
Ephemeroptera						
Acentrella turbida		2	1		3	12
Baetis flavistriga		5	1		6	24
Baetis (*tricaudatus*)	34	55	167		256	993
Diphetor hageni		1	3		4	16
Attenella margarita		1			1	4
Drunella grandis		1			1	4
Ephemerella dorothea infrequens	14	14	6		34	132
Epeorus sp.		1	1		2	8
Epeorus longimanus						
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus	8	13	13		34	132
Paraleptophlebia sp.	1	1			2	8
Plecoptera						
Paracapnia angulata	3	2	2		7	28
Chloroperlidae						
Claassenia sabulosa						
Perlodidae (*Cultus* sp.)						
Isoperla sp.						
Skwala americana						
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	23	27	47		97	376
Brachycentrus occidentalis	14	12	12		38	148
Culoptila sp.		1			1	4
Glossosoma sp.	8	11	1		20	78
Protoptila sp.	1	1			2	8
Helicopsyche borealis						
Arctopsyche grandis	3		13		16	62
Cheumatopsyche sp.			5		5	20
Hydropsyche sp.						
Hydropsyche (cockerelli)	11	9	62		82	318
Hydropsyche occidentalis						
Hydropsyche oslari						
Hydroptila sp.		1	3		4	16
Lepidostoma sp.	48	57	62		167	648
Ceraclea sp.		1			1	4
Oecetis sp.						
Limnephilidae		1			1	4
Psychomyia flavida	1				1	4

Table B1. cont. Macroinvertebrate data collected from site CR-WGU on 19 Sept. 2022.

Diptera						
Chironomidae						
Cardiocladius sp.						
Corynoneura sp.		1			1	4
Cricotopus nostocicola	1		1		2	8
Cricotopus/Orthocladius sp.	342	402	157		901	3493
Cryptochironomus sp.						
Diamesa sp.						
Eukiefferiella sp.	28	49	46		123	477
Micropsectra/Tanytarsus sp.		2			2	8
Microtendipes sp.	14	30	1		45	175
Pagastia sp.	3	2			5	20
Parametriocnemus sp.	10	8	17		35	136
Polypedilum sp.		1	2		3	12
Potthastia sp.	3	7	7		17	66
Rheotanytarsus sp.		2	1		3	12
Synorthocladius sp.	2	1	1		4	16
Thienemanniella sp.						
Thienemannimyia group	2	2	2		6	24
Tvetenia sp.	30	67	65		162	628
Other Diptera						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.	2	6	8		16	62
Hemerodromia sp.						
Simulium sp.	1	1	49		51	198
Antocha sp.		2			2	8
Coleoptera						
Heterlimnius corpulentus						
Optioservus sp.	31	20	17		68	264
Zaitzevia parvula						
Miscellaneous						
Atractides sp.		1	2		3	12
Hygrobates sp.	1	2			3	12
Lebertia sp.		1			1	4
Protzia sp.		1			1	4
Sperchon sp.	1				1	4
Caecidotea sp.	236	279	595		1110	4303
Polycelis coronata	27	42	102		171	663
Lymnaeidae		1			1	4
Physa sp.	2	3	2		7	28
Gyraulus sp.						
Pisidium sp.						
Crangonyx sp.	3	3	5		11	43
Hyalella azteca						
Erpobdellidae	1				1	4
Enchytraeidae		1			1	4
Lumbricidae		1	3		4	16
Naididae	107	1	15		123	477
Tubificidae w/o hair chaetae	9	4	24		37	144
Totals	**1025**	**1160**	**1521**		**3706**	**14384**

Table B2. Macroinvertebrate data collected from site CR-WGD on 19 Sept. 2022.

Colorado River						
CR-28.7 (WGD)		Sample				Estimated Total/m²
19 Sept. 2022	1	2	3		Total	
Ephemeroptera						
Acentrella turbida						
Baetis flavistriga	2	1	5		8	31
Baetis (*tricaudatus*)	28	64	34		126	489
Diphetor hageni			2		2	8
Attenella margarita						
Drunella grandis						
Ephemerella dorothea infrequens	227	343	237		807	3128
Epeorus sp.						
Epeorus longimanus	4	1	6		11	43
Heptagenia sp.						
Rhithrogena sp.						
Tricorythodes explicatus	1		4		5	20
Paraleptophlebia sp.	5	11	18		34	132
Plecoptera						
Paracapnia angulata			1		1	4
Chloroperlidae	2		2		4	16
Claassenia sabulosa	5		6		11	43
Perlodidae (*Cultus* sp.)	2	1	7		10	39
Isoperla sp.		2			2	8
Skwala americana		1	1		2	8
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus	28	56	36		120	466
Brachycentrus occidentalis	2	16	5		23	90
Culoptila sp.	28	66	85		179	694
Glossosoma sp.	19	19	26		64	249
Protoptila sp.	41	15	357		413	1601
Helicopsyche borealis						
Arctopsyche grandis	2	10	4		16	62
Cheumatopsyche sp.	1				1	4
Hydropsyche sp.		6			6	24
Hydropsyche (cockerelli)	31	102	28		161	624
Hydropsyche occidentalis						
Hydropsyche oslari	25	52	33		110	427
Hydroptila sp.	1		2		3	12
Lepidostoma sp.	18	15	63		96	373
Ceraclea sp.						
Oecetis sp.			2		2	8
Limnephilidae						
Psychomyia flavida	2	1	2		5	20

Table B2. cont. Macroinvertebrate data collected from site CR-WGD on 19 Sept. 2022.

Diptera						
Chironomidae						
Cardiocladius sp.						
Corynoneura sp.						
Cricotopus nostocicola		1			1	4
Cricotopus/Orthocladius sp.	22	8	11		41	159
Cryptochironomus sp.	1				1	4
Diamesa sp.						
Eukiefferiella sp.	4	14	6		24	93
Micropsectra/*Tanytarsus* sp.						
Microtendipes sp.			1		1	4
Pagastia sp.						
Parametriocnemus sp.	1		1		2	8
Polypedilum sp.						
Potthastia sp.						
Rheotanytarsus sp.						
Synorthocladius sp.	1	1			2	8
Thienemanniella sp.		1			1	4
Thienemannimyia group						
Tvetenia sp.	4	20	4		28	109
Other Diptera						
Atherix pachypus	3		6		9	35
Ceratopogoninae						
Chelifera/Neoplasta sp.	2		2		4	16
Hemerodromia sp.						
Simulium sp.	6	5	1		12	47
Antocha sp.		1	1		2	8
Coleoptera						
Heterlimnius corpulentus	1				1	4
Optioservus sp.	29	27	47		103	400
Zaitzevia parvula	2		3		5	20
Miscellaneous						
Atractides sp.	1		3		4	16
Hygrobates sp.	2		1		3	12
Lebertia sp.	1				1	4
Protzia sp.	1	1	5		7	28
Sperchon sp.	3	1	4		8	31
Caecidotea sp.		1	2		3	12
Polycelis coronata	1	1			2	8
Lymnaeidae						
Physa sp.						
Gyraulus sp.			1		1	4
Pisidium sp.			1		1	4
Crangonyx sp.						
Hyalella azteca		1			1	4
Erpobdellidae						
Enchytraeidae						
Lumbricidae			3		3	12
Naididae						
Tubificidae w/o hair chaetae	4	1	4		9	35
Totals	**563**	**866**	**1073**		**2502**	**9716**

Table B3. Macroinvertebrate data collected from site CR-HSPP on 19 Sept. 2022.

Colorado River						
CR-22.1 (HSPP)		Sample				Estimated Total/m²
19 Sept. 2022	1	2	3		Total	
Ephemeroptera						
Acentrella turbida	4	2	1		7	28
Baetis flavistriga						
Baetis (*tricaudatus*)	8	74	35		117	454
Diphetor hageni	2	8	1		11	43
Attenella margarita						
Drunella grandis						
Ephemerella dorothea infrequens	57	151	97		305	1183
Epeorus sp.						
Epeorus longimanus	12	19	14		45	175
Heptagenia sp.	1				1	4
Rhithrogena sp.	5	2	2		9	35
Tricorythodes explicatus	3	1			4	16
Paraleptophlebia sp.	12	15	4		31	121
Plecoptera						
Paracapnia angulata	3		1		4	16
Chloroperlidae						
Claassenia sabulosa	1		1		2	8
Perlodidae (*Cultus* sp.)			1		1	4
Isoperla sp.						
Skwala americana			1		1	4
Pteronarcys californica						
Trichoptera						
Brachycentrus americanus						
Brachycentrus occidentalis		1			1	4
Culoptila sp.	75	103	181		359	1392
Glossosoma sp.						
Protoptila sp.	102	14	5		121	469
Helicopsyche borealis						
Arctopsyche grandis						
Cheumatopsyche sp.	2	11	3		16	62
Hydropsyche sp.						
Hydropsyche (cockerelli)	3	15	8		26	101
Hydropsyche occidentalis						
Hydropsyche oslari		4	3		7	28
Hydroptila sp.	8	9	17		34	132
Lepidostoma sp.	47	58	35		140	543
Ceraclea sp.						
Oecetis sp.	40	15	10		65	252
Limnephilidae						
Psychomyia flavida	1	2	2		5	20

Table B3. cont. Macroinvertebrate data collected from site CR-HSPP on 19 Sept. 2022.

Diptera						
Chironomidae						
Cardiocladius sp.		1			1	4
Corynoneura sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	32	55	52		139	539
Cryptochironomus sp.	1				1	4
Diamesa sp.						
Eukiefferiella sp.	3	20	6		29	113
Micropsectra/*Tanytarsus* sp.						
Microtendipes sp.	1	1	1		3	12
Pagastia sp.						
Parametriocnemus sp.	1	3			4	16
Polypedilum sp.						
Potthastia sp.	1	1	2		4	16
Rheotanytarsus sp.						
Synorthocladius sp.	2				2	8
Thienemanniella sp.						
Thienemannimyia group			2		2	8
Tvetenia sp.	3	2	7		12	47
Other Diptera						
Atherix pachypus						
Ceratopogoninae						
Chelifera/Neoplasta sp.		1			1	4
Hemerodromia sp.		1	2		3	12
Simulium sp.	1	16	1		18	70
Antocha sp.						
Coleoptera						
Heterlimnius corpulentus						
Optioservus sp.	32	44	29		105	407
Zaitzevia parvula	1	10	4		15	59
Miscellaneous						
Atractides sp.		2	1		3	12
Hygrobates sp.		1			1	4
Lebertia sp.		2			2	8
Protzia sp.	1	7	5		13	51
Sperchon sp.	1	3	1		5	20
Caecidotea sp.	7	58	1		66	256
Polycelis coronata						
Lymnaeidae						
Physa sp.						
Gyraulus sp.	1		1		2	8
Pisidium sp.		12			12	47
Crangonyx sp.	1	1			2	8
Hyalella azteca		2			2	8
Erpobdellidae	2		1		3	12
Enchytraeidae						
Lumbricidae			1		1	4
Naididae	4	6	1		11	43
Tubificidae w/o hair chaetae		4			4	16
Totals	**481**	**757**	**540**		**1778**	**6910**

Table B4. Macroinvertebrate data collected from site CR-WFU on 19 Sept. 2022.

Colorado River						
CR-16.7 (WFU)		Sample				Estimated Total/m²
19 Sept. 2022	1	2	3		Total	
Ephemeroptera						
Acentrella turbida	2	5			7	28
Baetis flavistriga						
Baetis (*tricaudatus*)	115	151	130		396	1535
Diphetor hageni	2	7			9	35
Attenella margarita						
Drunella grandis		2	1		3	12
Ephemerella dorothea infrequens	166	128	186		480	1861
Epeorus sp.						
Epeorus longimanus	11	16	10		37	144
Heptagenia sp.						
Rhithrogena sp.		3			3	12
Tricorythodes explicatus						
Paraleptophlebia sp.	5	20	2		27	105
Plecoptera						
Paracapnia angulata						
Chloroperlidae						
Claassenia sabulosa	2	4			6	24
Perlodidae (*Cultus* sp.)	2		1		3	12
Isoperla sp.		1			1	4
Skwala americana						
Pteronarcys californica		5	1		6	24
Trichoptera						
Brachycentrus americanus		9	6		15	59
Brachycentrus occidentalis	1	3	2		6	24
Culoptila sp.	15	20	55		90	349
Glossosoma sp.						
Protoptila sp.	11	8	8		27	105
Helicopsyche borealis	6	2	1		9	35
Arctopsyche grandis		1			1	4
Cheumatopsyche sp.	11	23	2		36	140
Hydropsyche sp.						
Hydropsyche (cockerelli)	13	38	18		69	268
Hydropsyche occidentalis	12	4	2		18	70
Hydropsyche oslari	16	11	31		58	225
Hydroptila sp.	12	18	8		38	148
Lepidostoma sp.	30	64	27		121	469
Ceraclea sp.						
Oecetis sp.	1	4			5	20
Limnephilidae						
Psychomyia flavida	1				1	4

Table B4. cont. Macroinvertebrate data collected from site CR-WFU on 19 Sept. 2022.

Diptera						
Chironomidae						
Cardiocladius sp.						
Corynoneura sp.						
Cricotopus nostocicola			1		1	4
Cricotopus/Orthocladius sp.	39	97	26		162	628
Cryptochironomus sp.						
Diamesa sp.		1			1	4
Eukiefferiella sp.	32	87	27		146	566
Micropsectra/*Tanytarsus* sp.						
Microtendipes sp.						
Pagastia sp.	2	1			3	12
Parametriocnemus sp.	2	4			6	24
Polypedilum sp.			1		1	4
Potthastia sp.	1	1			2	8
Rheotanytarsus sp.						
Synorthocladius sp.		1			1	4
Thienemanniella sp.	1		1		2	8
Thienemannimyia group	3	1			4	16
Tvetenia sp.	7	11	19		37	144
Other Diptera						
Atherix pachypus	1	5			6	24
Ceratopogoninae			1		1	4
Chelifera/Neoplasta sp.						
Hemerodromia sp.	3	12	2		17	66
Simulium sp.	10	19	20		49	190
Antocha sp.						
Coleoptera						
Heterlimnius corpulentus						
Optioservus sp.	27	46	26		99	384
Zaitzevia parvula	3	12	1		16	62
Miscellaneous						
Atractides sp.		2			2	8
Hygrobates sp.						
Lebertia sp.						
Protzia sp.	3				3	12
Sperchon sp.	4	7	2		13	51
Caecidotea sp.	19	55	2		76	295
Polycelis coronata	15	50	30		95	369
Lymnaeidae						
Physa sp.	1				1	4
Gyraulus sp.						
Pisidium sp.	2				2	8
Crangonyx sp.		1			1	4
Hyalella azteca						
Erpobdellidae						
Enchytraeidae						
Lumbricidae		1			1	4
Naididae	6	5	1		12	47
Tubificidae w/o hair chaetae	6	59			65	252
Totals	**621**	**1025**	**651**		**2297**	**8922**

Appendix C

Denver Water
Benthic Macroinvertebrate Data – Fall 2022

Table C1. Macroinvertebrate data collected from site FR-abvWPSD on 18 Sept. 2022.

Fraser River						
FR-23.2 (abvWPSD)		Sample				Estimated
18 Sept. 2022	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Acentrella turbida	9	18	2		29	113
Baetis flavistriga	6	2	9		17	66
Baetis (*tricaudatus*)	61	82	74		217	842
Diphetor hageni						
Drunella coloradensis						
Drunella doddsii		9	4		13	51
Drunella grandis						
Ephemerella dorothea infrequens	5	8	16		29	113
Serratella tibialis						
Cinygmula sp.						
Epeorus longimanus						
Rhithrogena sp.						
Paraleptophlebia sp.						
Plecoptera (stoneflies)						
Paracapnia angulata			2		2	8
Chloroperlidae						
Sweltsa sp.	2	3	5		10	39
Zapada cinctipes		8	4		12	47
Zapada oregonensis group	1	5	4		10	39
Diura knowltoni						
Isoperla sp.	3	4	6		13	51
Isoperla fulva						
Megarcys signata	1				1	4
Skwala americana						
Taenionema sp.	3	12	7		22	86
Trichoptera (caddisflies)						
Brachycentrus americanus	13	29	2		44	171
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.		4			4	16
Protoptila sp.						
Arctopsyche grandis	2				2	8
Cheumatopsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Hydroptila sp.						
Ochrotrichia sp.			1		1	4
Lepidostoma sp.						
Oecetis sp.						
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.	25	25	57		107	415

Table C1. cont. Macroinvertebrate data collected from site FR-abvWPSD on 18 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Brillia sp.						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	74	111	107		292	1132
Diamesa sp.		1			1	4
Eukiefferiella sp.	7	14	3		24	93
Micropsectra/Tanytarsus sp.			1		1	4
Microtendipes sp.						
Pagastia sp.	4	3	2		9	35
Parametriocnemus sp.						
Polypedilum sp.						
Potthastia sp.						
Rheocricotopus sp.						
Rheotanytarsus sp.						
Sublettea sp.						
Synorthocladius sp.	10	5	7		22	86
Thienemanniella sp.						
Thienemannimyia group						
Tvetenia sp.		1	1		2	8
Other Diptera (true flies)						
Ceratopogoninae	2	7	8		17	66
Chelifera/Neoplasta sp.						
Pericoma sp.	7	4	5		16	62
Simulium sp.						
Antocha sp.						
Dicranota sp.						
Hexatoma sp.			1		1	4
Tipula sp.			1		1	4
Coleoptera (beetles)						
Heterlimnius sp.	19	35	67		121	469
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Hygrobates sp.	1				1	4
Lebertia sp.	35	19	87		141	547
Protzia sp.						
Sperchon sp.	8	10	39		57	221
Pisidium sp.						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	7	10	25		42	163
Enchytraeidae	8	6	4		18	70
Lumbricidae						
Naididae	9	9	12		30	117
Tubificidae						
Totals	**322**	**444**	**563**		**1329**	**5162**

Table C2. Macroinvertebrate data collected from site VC-WP on 18 Sept. 2022.

Vasquez Creek						
VC-WP (VC-0)		Sample				Estimated
18 Sept. 2022	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Acentrella turbida	2	3	1		6	24
Baetis flavistriga						
Baetis (*tricaudatus*)	32	20	10		62	241
Diphetor hageni						
Drunella coloradensis	1	3			4	16
Drunella doddsii	11	35	3		49	190
Drunella grandis						
Ephemerella dorothea infrequens	1				1	4
Serratella tibialis	12	6	7		25	97
Cinygmula sp.	4	6	4		14	55
Epeorus longimanus	1	2			3	12
Rhithrogena sp.						
Paraleptophlebia sp.		1			1	4
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae		1			1	4
Sweltsa sp.	4		1		5	20
Zapada cinctipes	39	26	1		66	256
Zapada oregonensis group	36	18	2		56	218
Diura knowltoni						
Isoperla sp.		1	1		2	8
Isoperla fulva						
Megarcys signata		1			1	4
Skwala americana						
Taenionema sp.	19	42	5		66	256
Trichoptera (caddisflies)						
Brachycentrus americanus	8	2	9		19	74
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.	3	2	8		13	51
Protoptila sp.						
Arctopsyche grandis	13	11	4		28	109
Cheumatopsyche sp.						
Hydropsyche cockerelli						
Hydropsyche oslari						
Hydroptila sp.	1				1	4
Ochrotrichia sp.						
Lepidostoma sp.	3	1			4	16
Oecetis sp.						
Rhyacophila brunnea	5	5	2		12	47
Rhyacophila coloradensis		2	1		3	12
Rhyacophila sibirica group	2				2	8
Oligophlebodes sp.	8	6	23		37	144

Table C2. cont. Macroinvertebrate data collected from site VC-WP on 18 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Brillia sp.	1				1	4
Cardiocladius sp.	5				5	20
Cricotopus nostocicola	7		1		8	31
Cricotopus/Orthocladius sp.	23	20	13		56	218
Diamesa sp.						
Eukiefferiella sp.	28	12	3		43	167
Micropsectra/Tanytarsus sp.						
Microtendipes sp.						
Pagastia sp.	8	8	4		20	78
Parametriocnemus sp.						
Polypedilum sp.	1				1	4
Potthastia sp.						
Rheocricotopus sp.	1				1	4
Rheotanytarsus sp.						
Sublettea sp.						
Synorthocladius sp.	1				1	4
Thienemanniella sp.	3	1			4	16
Thienemannimyia group						
Tvetenia sp.	11	5			16	62
Other Diptera (true flies)						
Ceratopogoninae		3			3	12
Chelifera/Neoplasta sp.	1				1	4
Pericoma sp.	14	7			21	82
Simulium sp.	20	39	12		71	276
Antocha sp.	4				4	16
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Heterlimnius sp.	47	49	33		129	500
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Hygrobates sp.						
Lebertia sp.	2		3		5	20
Protzia sp.						
Sperchon sp.	3		2		5	20
Pisidium sp.						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	41	62	6		109	423
Enchytraeidae	2	4	1		7	28
Lumbricidae						
Naididae	5	3			8	31
Tubificidae		2			2	8
Totals	**433**	**409**	**160**		**1002**	**3902**

Table C3. Macroinvertebrate data collected from site FR-Rendezvous on 18 Sept. 2022.

Fraser River						
FR-20 (Rendezvous)		Sample				Estimated
18 Sept. 2022	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Acentrella turbida	1	2	6		9	35
Baetis flavistriga						
Baetis (*tricaudatus*)	56	34	73		163	632
Diphetor hageni		1			1	4
Drunella coloradensis						
Drunella doddsii	6	10	15		31	121
Drunella grandis	6	1	6		13	51
Ephemerella dorothea infrequens		2	3		5	20
Serratella tibialis						
Cinygmula sp.						
Epeorus longimanus	1	2			3	12
Rhithrogena sp.	3	2	7		12	47
Paraleptophlebia sp.			1		1	4
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae						
Sweltsa sp.	3		2		5	20
Zapada cinctipes	15	1	14		30	117
Zapada oregonensis group	15	5	6		26	101
Diura knowltoni	1				1	4
Isoperla sp.	5	4	5		14	55
Isoperla fulva						
Megarcys signata			1		1	4
Skwala americana	5	1	3		9	35
Taenionema sp.	11	9	15		35	136
Trichoptera (caddisflies)						
Brachycentrus americanus	66	58	131		255	989
Brachycentrus occidentalis						
Micrasema bactro						
Culoptila sp.						
Glossosoma sp.	2	1	8		11	43
Protoptila sp.						
Arctopsyche grandis	11	16	11		38	148
Cheumatopsyche sp.						
Hydropsyche cockerelli		1			1	4
Hydropsyche oslari	4		2		6	24
Hydroptila sp.			1		1	4
Ochrotrichia sp.						
Lepidostoma sp.	11	1	5		17	66
Oecetis sp.						
Rhyacophila brunnea						
Rhyacophila coloradensis			4		4	16
Rhyacophila sibirica group						
Oligophlebodes sp.	53	52	145		250	969

Table C3. cont. Macroinvertebrate data collected from site FR-Rendezvous on 18 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Brillia sp.						
Cardiocladius sp.	6	8	20		34	132
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	154	191	254		599	2322
Diamesa sp.	1				1	4
Eukiefferiella sp.	15	17	15		47	183
Micropsectra/*Tanytarsus* sp.	2				2	8
Microtendipes sp.						
Pagastia sp.	6	4	9		19	74
Parametriocnemus sp.						
Polypedilum sp.	3	2	5		10	39
Potthastia sp.	1				1	4
Rheocricotopus sp.	1	1			2	8
Rheotanytarsus sp.			5		5	20
Sublettea sp.	4	1	6		11	43
Synorthocladius sp.						
Thienemanniella sp.			1		1	4
Thienemannimyia group						
Tvetenia sp.	4	5	21		30	117
Other Diptera (true flies)						
Ceratopogoninae			1		1	4
Chelifera/Neoplasta sp.	1	2			3	12
Pericoma sp.	58	16	41		115	446
Simulium sp.	9	8	20		37	144
Antocha sp.	13	8	6		27	105
Dicranota sp.	1				1	4
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Heterlimnius sp.	163	52	240		455	1764
Optioservus sp.						
Zaitzevia parvula						
Miscellaneous						
Hygrobates sp.						
Lebertia sp.	29	8	13		50	194
Protzia sp.						
Sperchon sp.	20	22	17		59	229
Pisidium sp.						
Physa sp.						
Gyraulus sp.						
Polycelis coronata	63	47	141		251	973
Enchytraeidae						
Lumbricidae						
Naididae	6				6	24
Tubificidae						
Totals	**835**	**595**	**1279**		**2709**	**10518**

Table C4. Macroinvertebrate data collected from site FR-CR83 on 18 Sept. 2022.

Fraser River						
FR-14 (CR83)		Sample				Estimated
18 Sept. 2022	1	2	3		Total	Total # /m²
Ephemeroptera (mayflies)						
Acentrella turbida	1				1	4
Baetis flavistriga						
Baetis (*tricaudatus*)	33	40	30		103	400
Diphetor hageni						
Drunella coloradensis						
Drunella doddsii						
Drunella grandis	28	22	23		73	283
Ephemerella dorothea infrequens	100	36	22		158	613
Serratella tibialis						
Cinygmula sp.						
Epeorus longimanus	10	9	27		46	179
Rhithrogena sp.						
Paraleptophlebia sp.	6	3	11		20	78
Plecoptera (stoneflies)						
Paracapnia angulata						
Chloroperlidae			3		3	12
Sweltsa sp.	1				1	4
Zapada cinctipes						
Zapada oregonensis group						
Diura knowltoni						
Isoperla sp.	1				1	4
Isoperla fulva	2	1	3		6	24
Megarcys signata						
Skwala americana		1	2		3	12
Taenionema sp.						
Trichoptera (caddisflies)						
Brachycentrus americanus	16	24	28		68	264
Brachycentrus occidentalis	19	20	33		72	280
Micrasema bactro	1		1		2	8
Culoptila sp.	14	4	4		22	86
Glossosoma sp.	61	49	36		146	566
Protoptila sp.	3		1		4	16
Arctopsyche grandis	20	25	13		58	225
Cheumatopsyche sp.			1		1	4
Hydropsyche cockerelli	234	230	193		657	2547
Hydropsyche oslari	54	56	51		161	624
Hydroptila sp.	1				1	4
Ochrotrichia sp.						
Lepidostoma sp.	40	7	39		86	334
Oecetis sp.	2				2	8
Rhyacophila brunnea						
Rhyacophila coloradensis						
Rhyacophila sibirica group						
Oligophlebodes sp.						

Table C4. cont. Macroinvertebrate data collected from site FR-CR83 on 18 Sept. 2022.

Diptera (true flies)						
Chironomidae (chironomids)						
Brillia sp.						
Cardiocladius sp.						
Cricotopus nostocicola						
Cricotopus/Orthocladius sp.	46	49	34		129	500
Diamesa sp.	10	15	10		35	136
Eukiefferiella sp.	4	3	3		10	39
Micropsectra/Tanytarsus sp.			2		2	8
Microtendipes sp.	1	1			2	8
Pagastia sp.	14	3	3		20	78
Parametriocnemus sp.		1			1	4
Polypedilum sp.			2		2	8
Potthastia sp.						
Rheocricotopus sp.						
Rheotanytarsus sp.						
Sublettea sp.						
Synorthocladius sp.						
Thienemanniella sp.						
Thienemannimyia group			3		3	12
Tvetenia sp.	5	13	8		26	101
Other Diptera (true flies)						
Ceratopogoninae			1		1	4
Chelifera/Neoplasta sp.	2		3		5	20
Pericoma sp.						
Simulium sp.	1	2	1		4	16
Antocha sp.	4	2	5		11	43
Dicranota sp.						
Hexatoma sp.						
Tipula sp.						
Coleoptera (beetles)						
Heterlimnius sp.						
Optioservus sp.	222	57	184		463	1795
Zaitzevia parvula	1		4		5	20
Miscellaneous						
Hygrobates sp.						
Lebertia sp.						
Protzia sp.	3				3	12
Sperchon sp.	6		3		9	35
Pisidium sp.	1				1	4
Physa sp.			1		1	4
Gyraulus sp.	2				2	8
Polycelis coronata						
Enchytraeidae						
Lumbricidae			1		1	4
Naididae		2	6		8	31
Tubificidae						
Totals	**969**	**675**	**795**		**2439**	**9469**

Appendix D

Learning By Doing
Historical MMI v4 and Individual Metric Results – 2017, 2018, 2019, 2020 & 2021

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. Individual component metrics and MMI v4 scores from benthic macroinvertebrate samples collected in the Learning By Doing study area during the fall of 2021. All metric scores are based on the MMI v4 subsampling process.

Metric	Station ID										
	FR-25.1	FR-15	RC-1.1	FR-1.9	WF-13.1	WF-5.5 (mod)	WF-2 (mod)	WF-0.5	CR-9.1	CR-7.4	CR-1.7
EPT Taxa	65.3	66.7	70.8	100.0	70.8	58.3	33.3	53.5	67.8	100.0	23.7
% EPT, no Baetidae	38.4	80.3	100.0	63.8	79.7	58.4	3.4	17.9	39.1	47.2	5.5
Clinger Taxa	70.0	67.3	67.3	100.0	72.1	52.9	38.5	45.4	77.9	84.4	21.0
Total Taxa	64.3	--	--	--	--	--	--	--	--	--	--
Intolerant Taxa	85.7	--	--	--	--	--	--	--	--	--	--
% Increasers, Mountains	41.2	--	--	--	--	--	--	--	--	--	--
Predator Taxa	69.2	--	--	--	--	--	--	--	--	--	--
% Scraper individuals	39.3	--	--	--	--	--	--	--	--	--	--
% Non-Insect individuals	--	92.5	93.4	95.2	88.4	87.1	77.8	70.5	10.1	85.9	15.4
% Coleoptera individuals	--	12.8	27.7	95.9	28.5	96.2	0.8	0.0	22.2	46.7	70.1
% Intolerant Taxa	--	82.0	79.1	100.0	100.0	60.9	77.7	85.5	74.9	68.5	16.1
% Increasers, Mid-Elev.	--	91.7	100.0	97.6	100.0	84.4	92.3	91.3	0.0	82.0	0.0
Predator/Shredder taxa	--	64.3	57.1	71.4	78.6	71.4	35.7	57.1	50.0	78.6	35.7
MMI	**59.2**	**69.7**	**74.4**	**90.5**	**77.3**	**71.2**	**44.9**	**52.7**	**42.8**	**74.2**	**23.4**
	Auxiliary Metrics										
Diversity	3.23	3.65	3.75	3.63	3.39	3.18	2.40	3.20	3.96	3.91	2.77
HBI	4.01	2.27	2.25	3.05	2.28	3.76	4.31	4.19	4.02	4.29	6.02
Sediment Region	SR1	SR2	SR2		SR2						
TIV	4.54	4.58	4.47	--	4.54	--	--	--	--	--	--

Table D6. 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 D7. 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 D8. 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 D9. 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%

Table D10. Additional individual metrics and comparative values for macroinvertebrate samples collected from the Learning By Doing study area in the fall of 2021. All additional metric values are based on full count Hess samples.

Metric	FR-25.1	FR-15	RC-1.1	FR-1.9	WF-13.1	WF-5.5 (mod)	WF-2 (mod)	WF-0.5	CR-9.1	CR-7.4	CR-1.7
Density (#/m^2)	1,795	6,993	3,436	4,871	3,539	4,211	8,597	9,909	11,520	8,184	2,924
Taxa Richness	33	42	33	46	31	41	25	28	47	54	30
EPT	19	19	21	26	20	16	12	14	22	27	8
Density of *Pteronarcys californica* (#/m^2)	0	0	0	4	0	0	0	0	4	0	0
Percent EPT excluding Baetidae	27.61%	59.58%	79.75%	46.77%	56.26%	41.74%	2.17%	9.79%	27.26%	33.13%	3.46%
Percent Chironomidae	13.70%	27.37%	5.20%	3.43%	2.97%	2.95%	40.34%	23.61%	7.04%	15.99%	14.49%
Percent Hydropsychidae	10.00%	23.63%	31.37%	33.19%	3.01%	64.18%	25.00%	0.00%	14.88%	76.66%	0.00%
Percent Tolerant Taxa	12.12%	14.29%	21.21%	21.74%	3.23%	26.83%	24.00%	17.86%	19.15%	20.37%	43.33%
Percent Intolerant Taxa	57.58%	45.24%	45.45%	50.00%	61.29%	29.27%	44.00%	42.86%	38.30%	35.19%	6.67%

Appendix E

Northern Water (WGFP) and Denver Water
Metric Results from the fall of 2021

Table E1. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected from Northern Water sampling sites on the Colorado River on 21 September 2021. 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-HSU	CR-WFU
EPT Taxa	75.0	83.3	79.2	95.8
% Non-Insect Individuals	0.0	92.7	88.3	76.8
% EPT Individuals, no Baetidae	23.4	100.0	76.2	65.7
% Coleoptera Individuals	4.8	11.5	21.8	22.9
% Intolerant Taxa	64.7	89.4	56.1	76.0
% Increasers Individuals, Mid-Elevation	0.0	88.9	82.5	75.9
Clinger Taxa	72.1	91.3	86.5	100.0
Predator/Shredder Taxa	50.0	64.3	64.3	78.6
MMI	**36.3**	**77.7**	**69.3**	**74.0**
Auxiliary Metrics				
Diversity	3.23	3.59	3.78	4.06
HBI	6.08	2.62	3.16	3.45
TIV (Sediment Region 2)	--	4.75	--	4.55

Table E2: Additional metrics and comparative values for macroinvertebrate samples collected from Northern Water sampling sites on the Colorado River on 21 September 2021. All metrics are based on full count Hess samples.

Metric	CR-WGU	CR-WGD	CR-HSPP	CR-WFU
EPT	23	24	25	31
Evenness	0.544	0.627	0.657	0.695
DAT	28.7	29.3	31.3	34.0
Insect Taxa	42	41	43	47
Total Taxa	53	52	55	57
Percent Shredders and Scrapers	6.40%	13.80%	23.04%	23.23%
Density of *Pteronarcys californica* (#/m^2)	0	0	0	31
Percent EPT (excluding Baetidae)	14.00%	74.24%	55.51%	45.44%
Density (mean #/m^2)	10,985	10,747	8,563	7,662
Percent Chironomidae	24.85%	8.89%	16.37%	10.80%
Percent Hydropsychidae	43.95%	53.75%	35.35%	33.66%
Percent Tolerant Taxa	26.42%	26.92%	23.64%	17.54%
Percent Intolerant Taxa	30.19%	36.54%	32.73%	43.86%

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 2021. MMI v4 scores indicating 'impairment' would be provided in red.

Metric	Station ID			
	FR-abvWPSD	VC-WP	FR-Rendezvous	FR-CR83
	Biotype 1			
EPT Taxa	58.3	78.3	70.8	79.2
% Non-Insect Individuals	53.1	74.9	71.9	97.6
% EPT Individuals, no Baetidae	13.4	29.2	16.1	81.2
% Coleoptera Individuals	21.5	47.0	30.6	59.6
% Intolerant Taxa	75.7	88.9	87.1	72.3
% Increasers Mid-Elevation	48.8	67.8	89.9	100.0
Clinger Taxa	33.7	84.3	67.3	86.5
Predator/Shredder Taxa	71.4	71.4	78.6	71.4
MMI	**47.0**	**67.7**	**64.0**	**81.0**
	Auxiliary Metrics			
Diversity	3.34	3.91	3.31	3.83
HBI	4.84	4.22	3.74	2.80
TIV (Sediment Region 2)	6.09	6.07	6.22	4.80

Table E4. Additional metrics and comparative values for macroinvertebrate samples collected from the Denver Water study area (Fraser River and Vasquez Creek) in September 2021. All additional metric values are based on full count Hess samples.

	FR-abvWPSD	VC-WP	FR-Rendezvous	FR-CR83
Density (#/m^2)	5933	2132	9725	6419
Taxa Richness	40	38	45	47
EPT	21	20	21	24
Density of *Pteronarcys californica* (#/m^2)	0	0	0	0
Percent EPT excluding Baetidae	8.32%	19.56%	10.10%	59.69%
Percent Chironomidae	29.99%	19.38%	49.60%	11.62%
Evenness	0.623	0.737	0.587	0.692
DAT Index	22.3	21.8	25.5	27.8
Percent Hydropsychidae	0.00%	6.45%	12.04%	56.90%
Percent Tolerant Taxa	17.50%	13.16%	15.56%	17.02%
Percent Intolerant Taxa	50.00%	52.63%	44.44%	40.43%

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

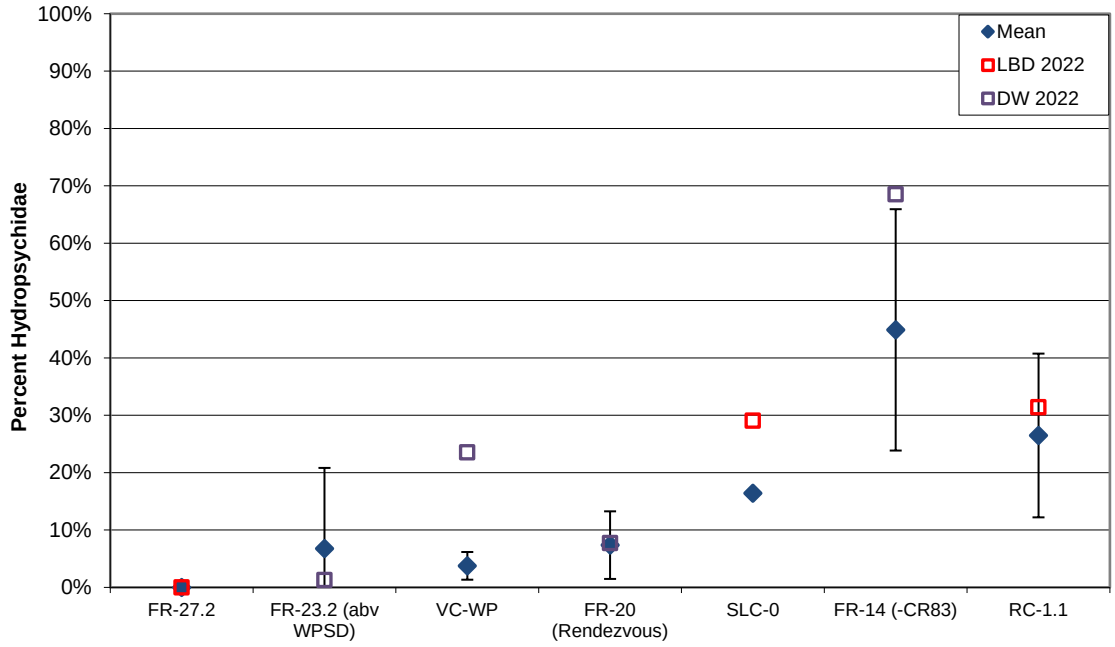

Figure F1. Percent Hydropsychidae values from study sites in the Fraser River study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

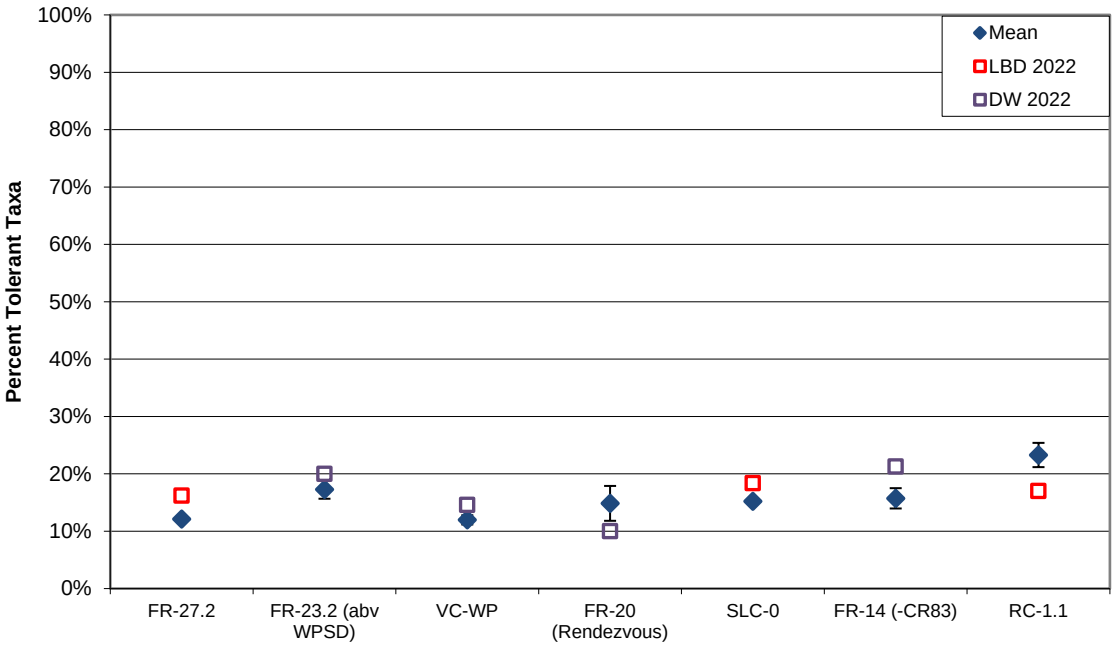

Figure F2. Percent Tolerant Taxa values from the Fraser River study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

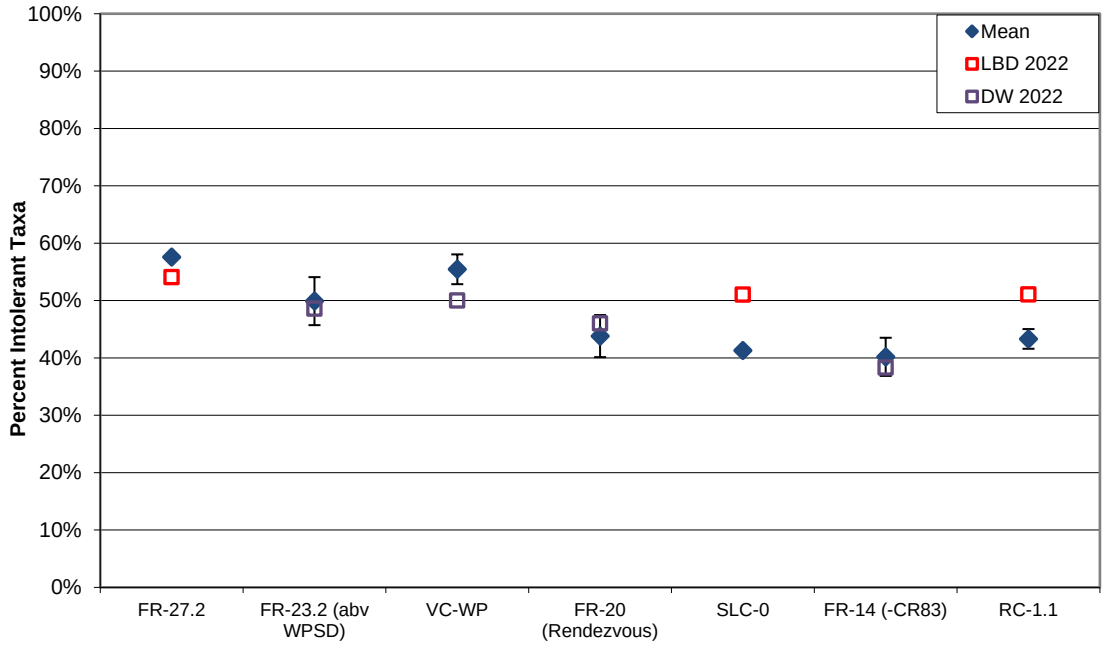

Figure F3. Percent Intolerant Taxa values from study sites in the Fraser River study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

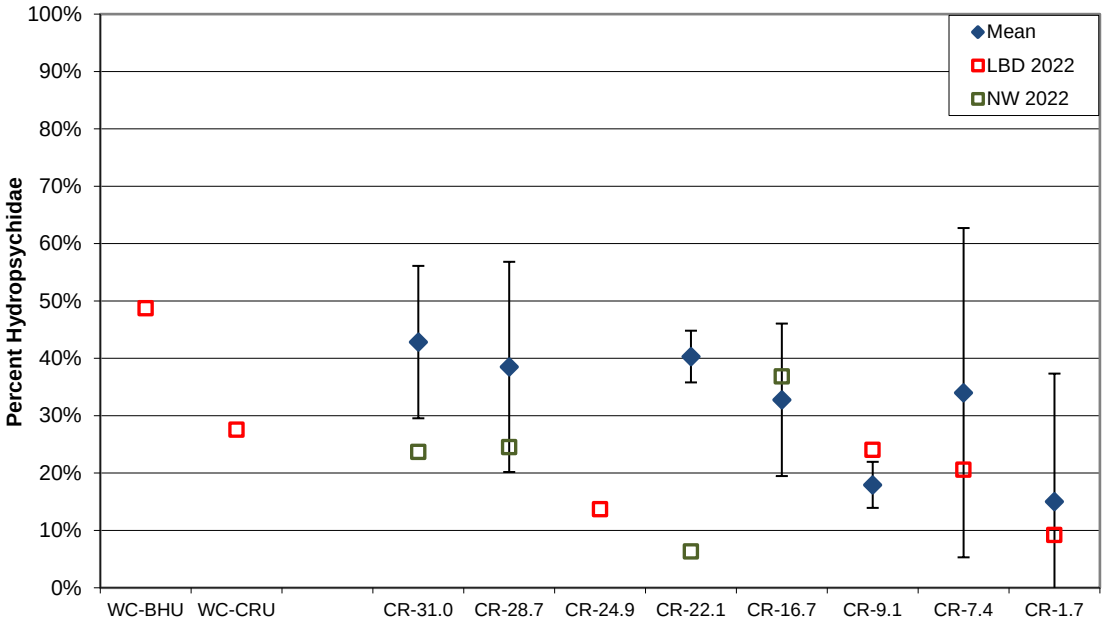

Figure F4. Percent Hydropsychidae values from study sites in the Colorado River study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

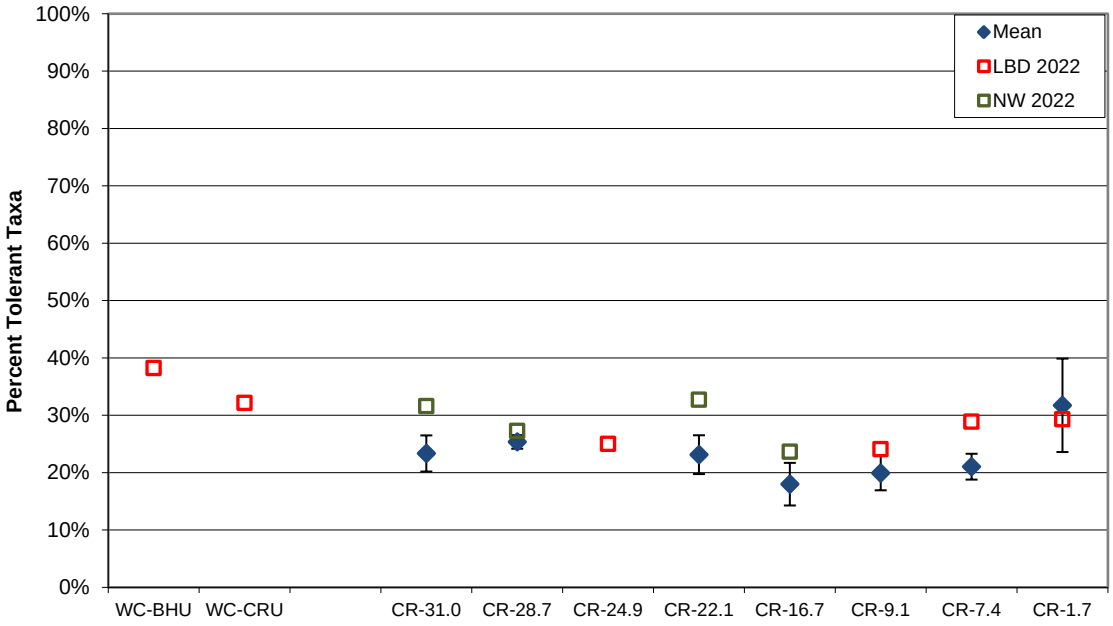

Figure F5. Percent Tolerant Taxa values from study sites in the Colorado River study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

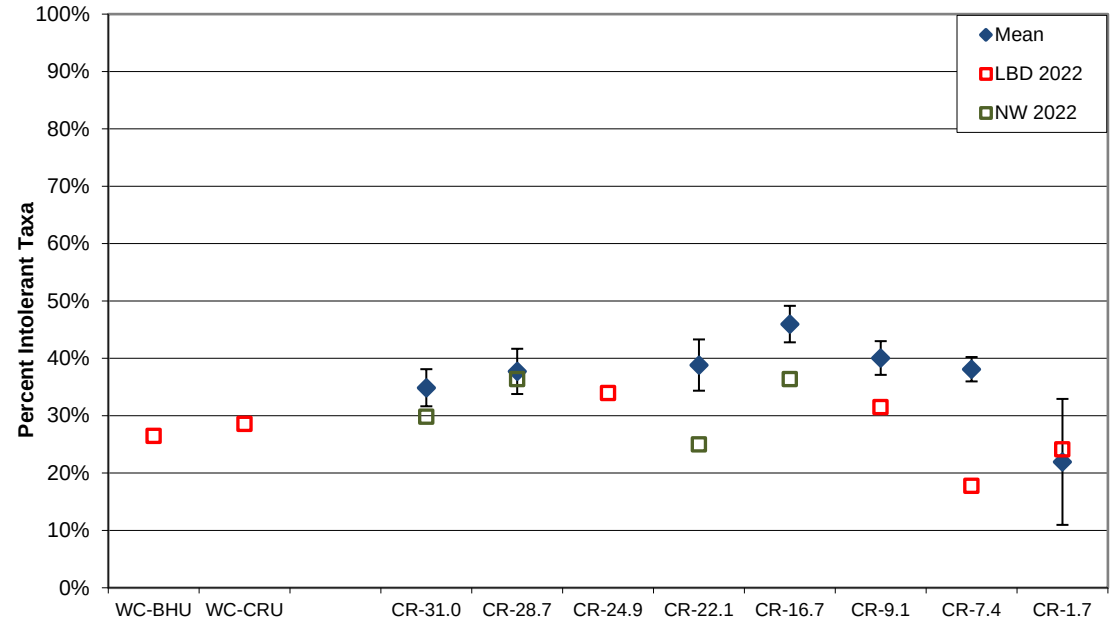

Figure F6. Percent Intolerant Taxa values from study sites in the Colorado River study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

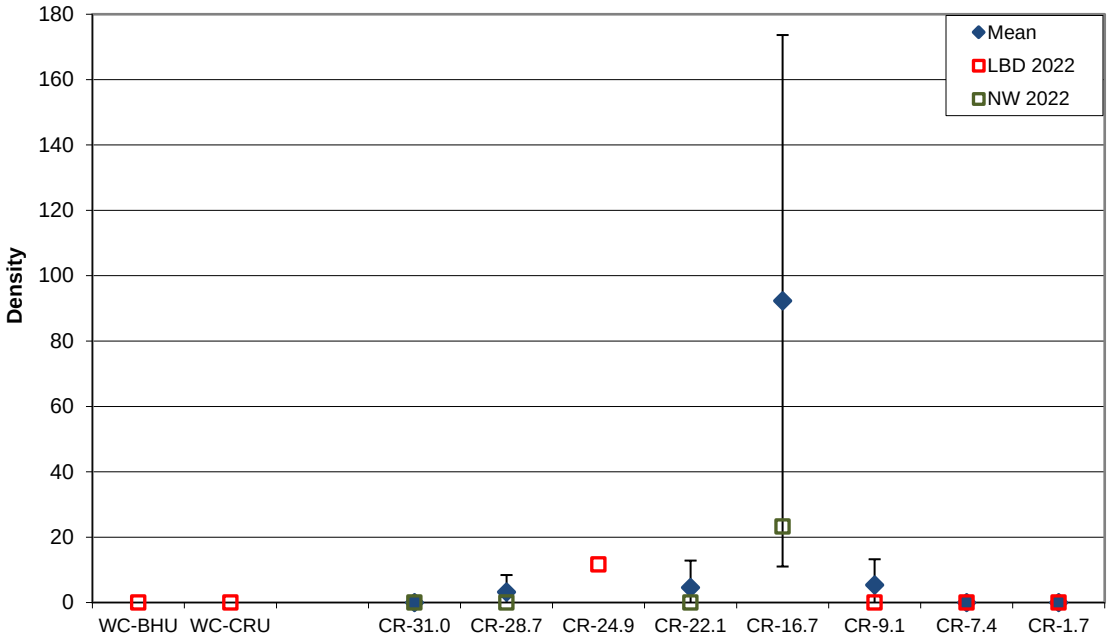

Figure F7. Density of *Pteronarcys californica* in the Colorado River study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

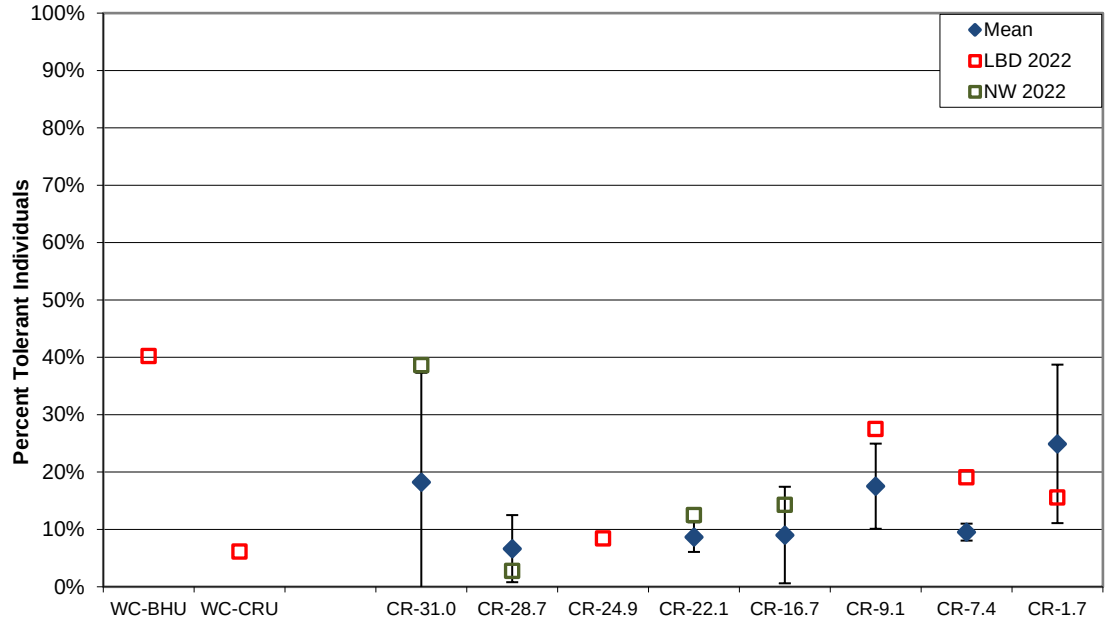

Figure F8. Percent Tolerant Individuals values in the Colorado River study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events

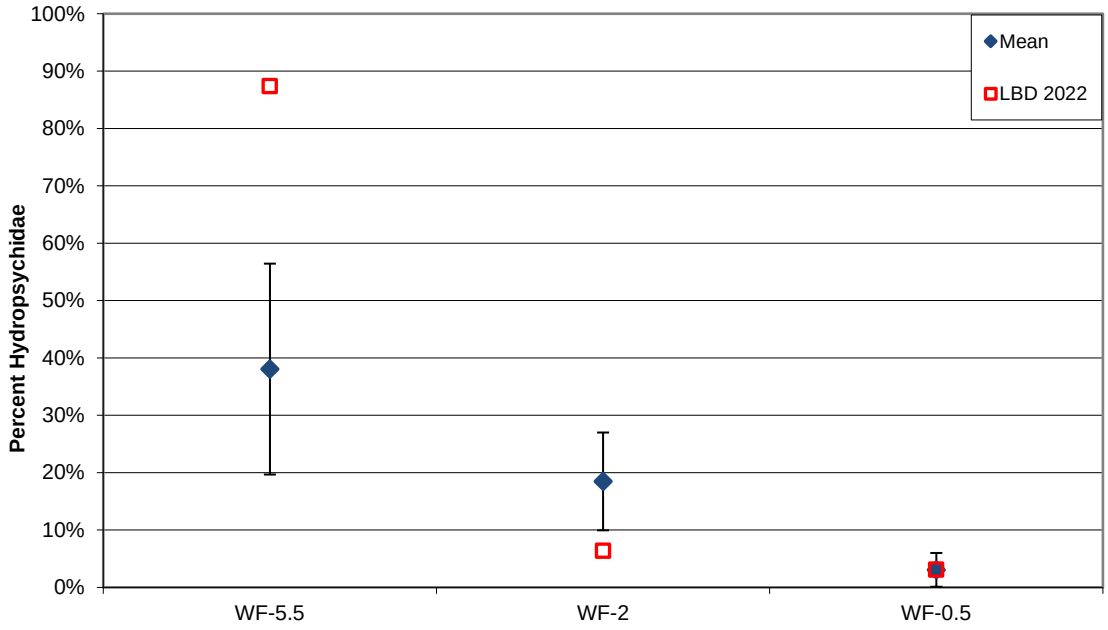

Figure F9. Percent Hydropsychidae values from study sites in the Williams Fork study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

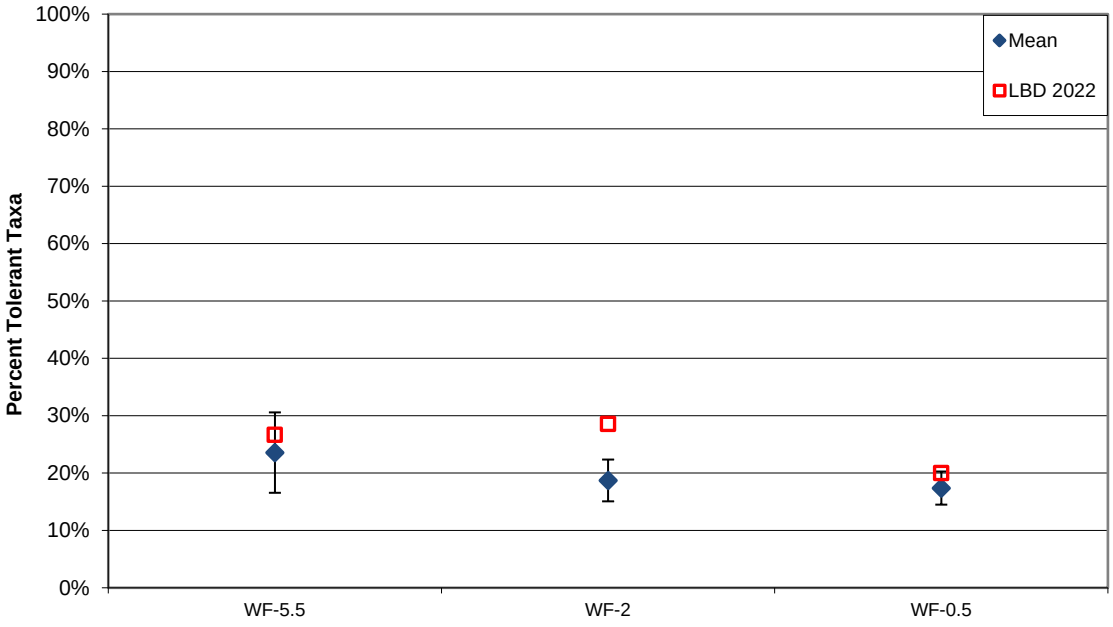

Figure F10. Percent Tolerant Taxa values from study sites in the Williams Fork study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

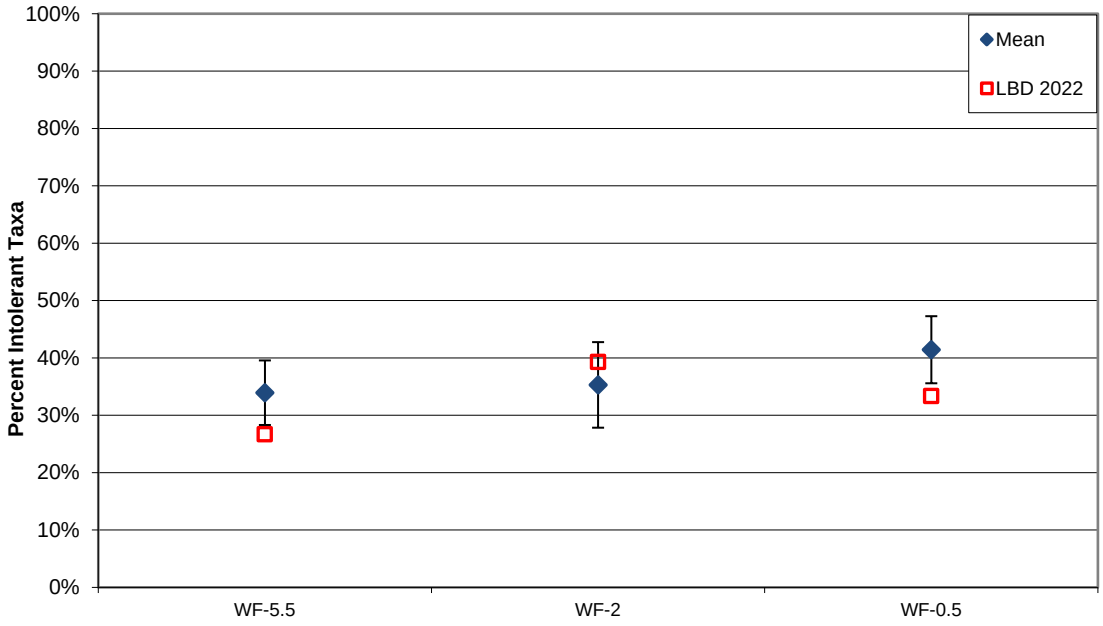

Figure F11. Percent Intolerant Taxa values from study sites in the Williams Fork study area from fall 2022 and mean values (±1 standard deviation) from previous sampling events.

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