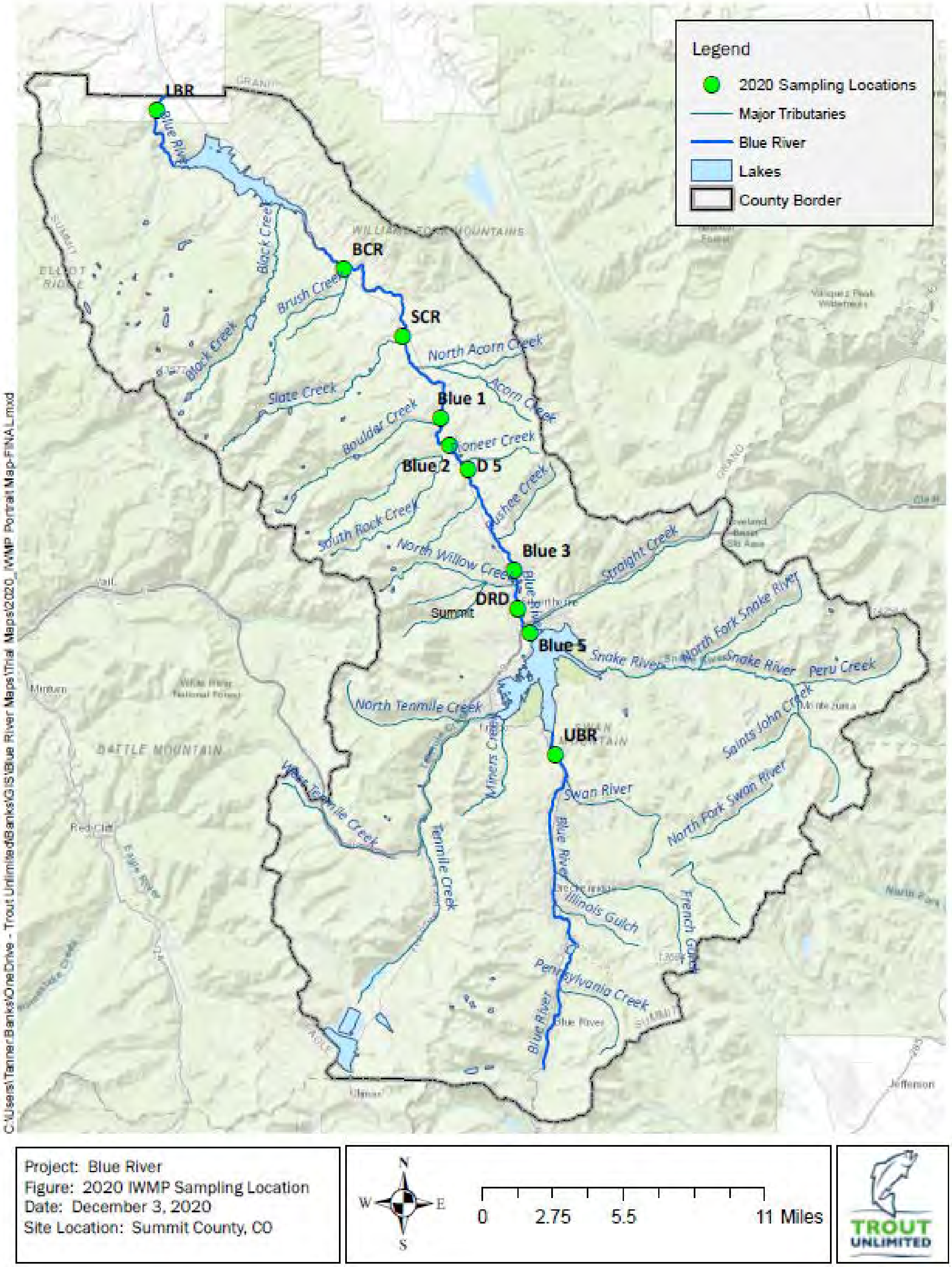

Figure 1. Map of study sites used for Blue River benthic macroinvertebrate monitoring in 2020.

Methods

The purpose of this biomonitoring study was to assess seasonal variability in benthic macroinvertebrate communities at specific locations along the Blue River where releases from Dillon Reservoir and/or other anthropogenic stressors (e.g., urban runoff, etc.) may be influencing the health of aquatic life. The objective of this study required that three (3) quantitative replicate Hess samples were taken from similar habitat at each study site. Several biotic analysis tools (metrics) were included in this study to account for different types of responses to various stressors. This approach was designed to identify the spatial distribution of disturbances as well as any seasonal variability.

Three replicate, quantitative samples were collected from ten study sites on the Blue River during April, August, and November (spring, summer, and fall) of 2020. All samples were collected from similar habitat (riffle habitat) to provide benthic macroinvertebrate data that was representative and comparable throughout the study area. Substrate within each sample was thoroughly agitated and individual rocks were scrubbed by hand to dislodge benthic organisms. All macroinvertebrates were rinsed into sample jars and preserved in 80% ethanol solution. Each sample jar was labeled with date, location, and sample ID number on the outside and inside of each container. All samples were transported to the lab at Timberline Aquatics, Inc. where benthic macroinvertebrates were sorted, identified, and enumerated. The sorting and identification process was conducted for each entire sample to avoid any potential problems or controversy associated with subsampling.

The sorting process involved separating macroinvertebrates from debris in each sample. All macroinvertebrates were removed from each sample and placed into vials containing coarse taxonomic groups. Benthic macroinvertebrates were then identified to a taxonomic level consistent with the Operational Taxonomic Unit (OTU) established by the Water Quality Control Division (WQCD) for the Colorado Department of Public Health and Environment (CDPHE). 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. Specimens were identified using a variety of taxonomic keys including Ward et al. (2002) and Merritt et al. (2008). As part of the quality control protocols at Timberline Aquatics, Inc., all sorted macroinvertebrate samples were checked by a qualified taxonomist, and 10% of identifications were checked for accuracy at Colorado State University.

Population densities and species lists were developed for each sampling event during 2020 and a variety analysis tools were used to provide information regarding aquatic conditions. All macroinvertebrate data were analyzed using the MMI v4 and an assortment of individual metrics. The following section provides a brief description of each tool that was used to assess the health of aquatic communities in this study.

Multi-Metric Index (MMI v4)

In the fall of 2010, the WQCD developed a Multi-Metric Index (MMI) to assist in the evaluation of benthic macroinvertebrate data from across the State of Colorado (Colorado Department of Public Health and Environment 2010). In 2017, the MMI was recalibrated and updated to produce a new analysis tool (the MMI v4) that relies on specific methods and protocols for sample processing and analysis (Colorado Department of Public Health and Environment 2017). This most recent version of the MMI provides a single index score based on eight equally weighted metrics. The MMI v4 was applied to quantitative macroinvertebrate data collected from the Blue River in 2020 using the guidelines established in the WQCD Listing Methodology, 2020 Listing Cycle (Colorado Department of Public Health and Environment 2019).

The group of metrics used in MMI v4 calculations depends on the sampling location and corresponding Biotype (Mountains, Transitional, or Plains). In the Blue River study area, the eight most upstream study sites were located in Biotype 2 (Mountains), while sites BRC and LBR were located within Biotype 1 (the Transition Zone), which includes lower mountain areas in the State of Colorado. Each of the individual metrics used in the analysis produces a score that is adjusted to a scale from 1 to 100 based on the range of metric scores found at “reference sites”. In Biotype 1, these metrics include: EPT Taxa, % Non-Insect Individuals, % EPT Individuals (no Baetidae), % Coleoptera Individuals, % Intolerant Taxa, % Increaser Individuals (Mid-Elevation), Clinger Taxa, and Predator/Shredder Taxa. In Biotype 2, these metrics include: EPT Taxa, % EPT Individuals (no Baetidae), Clinger Taxa, Total Taxa, Intolerant Taxa, % Increasers (Mountains), Predator Taxa, and % Scraper Individuals. A detailed description of the component 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* (Colorado Department of Public Health and Environment 2017 and 2019). The MMI v4 was developed using macroinvertebrate data that was mostly collected during the late summer or fall; therefore, it is expected to be most accurate when applied during those seasons. 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

MMI v4 scores that fall between the thresholds for attainment and impairment (the ‘Grey Zone’) require further evaluation using additional metrics to determine an aquatic life use designation. The additional metrics include Shannon Diversity (Diversity) and the Hilsenhoff Biotic Index (HBI). The specific thresholds for the auxiliary metrics in Biotypes 1 and 2 are listed below, followed by descriptions of each metric:

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

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

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

Additional Metrics Used in this Study

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

Richness measures:

Ephemeroptera Plecoptera Trichoptera (EPT Taxa): The effectiveness 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/perturbations than other benthic macroinvertebrate orders (Lenat 1988). The EPT metric is currently an important and widely used metric in many regions of the United States (Barbour et al. 1999). The EPT Taxa value is simply given as the total number of distinguishable taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera found at each sampling location. For the purpose of this study, each major component (insect order) used in this metric was viewed separately in addition to the total EPT Taxa value. Results from this metric are expected to naturally vary among river systems, but this tool can be an excellent indicator of disturbances within a specific drainage. The EPT value is expected to decrease in response to a variety of stressors including nutrients (Wang et al. 2007).

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

Number of Clinger Taxa: This metric requires the reorganization of macroinvertebrates into groups based on their habits or modes of locomotion. The Number of Clinger Taxa metric includes those macroinvertebrates which are adapted to attach to relatively clean benthic substrate. Perturbations such as excessive sedimentation, rapid changes in discharge, or excessive algal growth can cause a reduction in this metric value (Hughes and Brossett 2009).

***Composition measures*:**

Percent Clinger Taxa: The Percent Clinger Taxa metric generally relies on the assumption that changes in preferred habitat will result in negative impacts to benthic macroinvertebrates with specific habitat adaptations. The above list of perturbations (sedimentation, rapid changes in discharge, and excessive algal growth) should not only reduce the richness of clinger taxa, but these types of impacts should also cause a decline in the proportion of these specialized macroinvertebrates.

Percent Scrapers and Shredders: Scrapers and shredders are often considered sensitive to disturbances because they are specialized feeders (Barbour et al. 1999). Consequently, these sensitive feeding groups are expected to be well-represented in healthy streams. Much of the value in this type of analysis comes from a comparison of sites within a specific study area.

Percent Chironomidae: The midge family Chironomidae is generally considered to be fairly tolerant of environmental stress compared to other aquatic insect families (Plafkin et al. 1989). The Percent Chironomidae metric relies on the assumption that the proportion of representatives from this family will increase with increasing stress or pollution. Streams that are undisturbed often have a relatively even distribution of Ephemeroptera, Plecoptera, Trichoptera, and Chironomidae (Mandaville 2002); while the family Chironomidae often dominates (75% or more of the macroinvertebrate density) at sites degraded by metals or other pollutants (Barton and Metcalf-Smith 1992). Most species in the family Chironomidae tend to have a relatively short life-cycle which enables them to continually re-colonize unstable or polluted habitats, making their abundance a relatively reliable indicator of environmental stress (Lenat 1983).

Percent EPT: As previously stated, most taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera are expected to be sensitive to environmental perturbations or pollution. Therefore, the percentage of individuals from EPT orders provides a measure of benthic macroinvertebrates (at each sampling location) that are expected to be sensitive to anthropogenic stressors or pollution. To improve accuracy and provide context to the Biomass analysis, each component of the Percent EPT metric (Ephemeroptera, Plecoptera, and Trichoptera) was calculated separately. A decrease in the Percent EPT value suggests that the benthic macroinvertebrate community consists of a higher proportion of tolerant taxa.

***Abundance measures*:**

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

Biomass: Biomass was reported as the mean dry weight of benthic macroinvertebrates per m^2 at each site. Biomass values were obtained by drying macroinvertebrates from each sample in a scientific drying oven at 100° C for 24 hours or until all water content had evaporated (no decrease in weight could be detected). Biomass values provided production-related information in terms of weight of macroinvertebrates produced at each site. Density and Biomass values offered a means of measuring standing crop, which provided an indication of productivity for the macroinvertebrate portion of the food web at each sampling location.

***Trophic measures*:**

Functional Feeding Groups: Most of the previously described metrics use macroinvertebrate information that is based upon community structure; however, macroinvertebrate taxa were also separated into functional guilds based on methods of food acquisition to provide a measure of ecological function. All specimens were categorized according to feeding strategy to determine the relative proportion of various groups. Some representation of each feeding group usually indicates healthy aquatic conditions; however, it is normal for certain groups (such as collector-gatherers) to be more abundant than others (Ward et al. 2002). Scrapers and shredders are often considered sensitive to disturbance because they are specialized feeders (Barbour et al. 1999). Consequently, these sensitive groups are expected to be well-represented in healthy streams. Much of the value in this type of analysis comes from the comparison of sites within a specific drainage. Changes in the proportion of functional feeding groups can provide insight into various types of stress in river systems (Ward et al. 2002).

Results/Discussion

Quantitative benthic samples were collected from ten (10) study sites on the Blue River during the spring (20 April), summer (17 August), and fall (6-7 November) of 2020 to evaluate the health (structure and function) of benthic macroinvertebrate communities. After samples were collected, they were transported to the lab at Timberline Aquatics, Inc. where specimens were sorted, identified, and enumerated (Appendix A; Tables A1-A10, Appendix B; Tables B1-B10, Appendix C; Tables C1-C10). The previously described metrics and analysis tools (including the MMI v4) were applied to the macroinvertebrate data to provide a comprehensive assessment of macroinvertebrate community health in the study area.

In general, results from 2020 demonstrated considerable variability in the structure, function, and health of benthic macroinvertebrate communities among sites on the Blue River. Despite the variability observed among study sites, certain sampling locations showed consistent evidence of stress, while other sites tended to support relatively healthy aquatic communities, regardless of the season. The presence of impoundments and other anthropogenic activities appeared to have a substantial influence on the health of macroinvertebrate communities within the study area.

The MMI v4

In the spring, summer, and fall of 2020, a comprehensive evaluation of benthic macroinvertebrate community health in the Blue River was provided by the MMI v4. All samples were processed according to the guidelines provided in Appendix D of the *Section 303(d) Listing Methodology 2020 Listing Cycle* (WQCD 2019). Changes in macroinvertebrate community health from upstream to downstream were demonstrated by MMI v4 and the individual (component) metrics used in MMI v4 calculations (Tables 2-4). A comparison of MMI v4 scores among seasons showed some spatial consistencies in the health of aquatic communities; however, certain study sites showed greater variability in macroinvertebrate community structure and function.

Study sites on the Blue River were distributed between two Biotypes in the State of Colorado (based on State classifications). The eight most upstream sampling sites were located in mountain habitat (Biotype 2), while the remaining two study sites (BRC and LBR) were located in a transitional area (Biotype 1) between the mountains and plains. In order to correctly utilize the MMI v4, all specimens were identified to the Operational Taxonomic Unit (OTU) that was established by the WQCD. For each Biotype, the MMI v4 was calculated using the appropriate set of component metrics, and final scores were evaluated using the corresponding thresholds for ‘attainment’ and ‘impairment’. While it is not always appropriate to compare MMI v4 scores between Biotypes, some of the component metrics or individual metrics in the following section provided an opportunity to make comparisons throughout the study area.

During the spring season (20 April 2020), the MMI v4 indicated that the greatest stress to benthic macroinvertebrate communities occurred immediately downstream from Dillon Reservoir, with gradual improvements generally detected in a downstream direction (Table 2, Figure 2). Scores from the MMI v4 in Biotype 2 ranged from 15.0 at site Blue 5 to 64.8 at site SCR. Farther downstream, the two study sites located in Biotype 1 (BRC and LBR) generated relatively high MMI v4 scores (71.6 and 66.8, respectively) both upstream and downstream from Green Mountain Reservoir (Table 2). Components of the MMI v4 suggested that much of the stress to aquatic life downstream from Dillon Reservoir could be attributed to the loss of sensitive and specialized macroinvertebrates (based on the EPT Taxa, % EPT Individuals [no Baetidae], and % Scraper Individuals scores). As the richness of sensitive taxa and relative abundance of sensitive and specialized individuals increased, MMI v4 scores responded by indicating consistent improvements in macroinvertebrate community health with distance downstream from the impoundment (Figure 2). During the spring of 2020, the only study site that produced a MMI v4 score in the 'Grey Zone' (the range of scores between the 'attainment' and 'impairment' thresholds) was the 'reference site' (UBR). Although this site provided reference information related to reservoir influences, it is likely that this location was also impacted by other anthropogenic stressors (including runoff from an adjacent highway). The three consecutive study sites immediately downstream from Dillon Reservoir were the only sampling locations that produced MMI v4 scores below the 'impairment' threshold, while data from remaining study sites generated scores above the 'attainment' threshold. The auxiliary metrics (Diversity and HBI) followed a similar pattern showing general improvements (with distance) downstream from the reservoir (Table 2). The results provided by the MMI v4 (and auxiliary metrics) in the spring of 2020 provided strong evidence suggesting that most of the stress to benthic macroinvertebrate communities in the study area was likely associated with the existence and operations of Dillon Reservoir. The health of macroinvertebrate communities gradually improved for more than 12 kilometers downstream from this impoundment.

During the summer (17 August) of 2020, the MMI v4 continued to detect impacts to aquatic life downstream from Dillon Reservoir, with some recovery near the downstream boundary of the study area (Table 3). Once again, the reference site (UBR) produced a MMI v4 score in the 'Grey Zone', and auxiliary metrics indicated that this sampling location remained in 'attainment' for aquatic life use. Downstream from the Dillon Reservoir, relatively severe impacts to aquatic life were observed at site Blue 5, followed by rapid recovery at site Blue 3. A second decline in MMI v4 scores was observed at site D 5 followed by slow recovery in a downstream direction (Figure 3). Detectable impacts downstream from the impoundment could mostly be attributed to a reduction in the proportion of sensitive and specialized individuals (based on % EPT Individuals [no Baetidae] and % Scraper Individuals, respectively), and an increase in the proportion of taxa that are resistant to environmental stressors or pollution (% Increasers, Mountain Trn). MMI v4 scores in Biotype 2 ranged from 18.2 at site Blue 5 to 56.4 at site Blue 3 (Table 3). Downstream from site D 5, improvements in the overall health of communities were gradual, with site SCR generating one of the few MMI v4 scores that was above the 'attainment' threshold for Biotype 2. Both sites in Biotype 1 (BRC and LBR) produced similar MMI v4 scores during August 2020, indicating 'attainment' for aquatic life use at those locations (Figure 3). While the influences of releases from Dillon Reservoir continued to be the most likely source of disturbance to macroinvertebrate communities in the summer season, the low MMI v4 score at site D 5 and slow rate of recovery in a downstream direction suggested that there may be other sources of anthropogenic stress (e.g., urban runoff, etc.) in this study area (Table 3).

Benthic macroinvertebrate sampling continued on 6-7 November, 2020 at the same ten study sites that were sampled during the spring and summer seasons. Results from the MMI v4 (and associated metrics) generally displayed a longitudinal pattern of change during the fall season that was similar to the pattern observed during the spring (Figures 2 and 4). Scores generated by the MMI v4 in Biotype 2 ranged from 18.1 (site Blue 5) to 68.9 (site SCR), while the two study sites in Biotype 1 (BRC and LBR) generated relatively high MMI v4 scores (82.7 and 72.1, respectively) both upstream and downstream from Green Mountain Reservoir (Table 4). The component metrics for the MMI v4 that detected the greatest stress downstream from Dillon Reservoir included the % EPT Individuals (no Baetidae), Clinger Taxa, % Increasers (Mountain Trn), and % Scraper Individuals. These metrics suggested that the macroinvertebrate community below the reservoir consisted of high proportions of tolerant taxa that were less specialized in their habits and habitat requirements. Many component metric scores improved rapidly between sites Blue 5 and DRD; however, MMI v4 scores remained relatively stable from site DRD to site D 5 (Table 4, Figure 4). It is possible that the potential for continued recovery in this stream segment was somewhat inhibited by other sources of anthropogenic stress. Eventually, improvements in most component metrics led to considerably higher MMI v4 scores in the downstream portion of the study area (Table 4). Based on the results provided by the MMI v4, the presence of Green Mountain Reservoir had much less of a negative influence on the benthic macroinvertebrate community at site LBR during the fall (and other seasons) in 2020 (Figures 2-4).

Over the course of seasonal sampling, several study sites produced MMI v4 scores that fell into the 'Grey Zone' (the range of scores between the 'attainment' and 'impairment' thresholds). Auxiliary metrics (HBI and Diversity) were applied to all macroinvertebrate data collected in 2020 to determine the status of MMI v4 scores that were in the 'Grey Zone', and to assist in the evaluation of macroinvertebrate data throughout the study area (Figures 5 and 6).

During all seasons, the majority of HBI values remained relatively low and showed little variability in the proportions of nutrient-tolerant individuals among study sites (Figure 5). In most cases, HBI values were below the threshold set by the WQCD, and the only exceedances were found at site Blue 5 (in Biotype 2) during the spring and summer (Tables 2 and 3). It is possible that the altered thermal regime immediately downstream from Dillon Reservoir was at least partially responsible for elevated HBI values during these two seasons. Overall, results from the HBI exhibited some spatial and seasonal variability, but most values remained below the State's threshold, suggesting that nutrient-enrichment was probably not a substantial cause for stress within the study area (Figure 5). It is important to note that the elevated HBI values produced for site Blue 5 had no influence on the aquatic life use designations, because MMI v4 scores for these sampling events were already below the 'impairment' threshold.

The Diversity metric was also calculated (as part of the MMI v4 tool) using macroinvertebrate data from all three seasons. In 2020, several study sites produced values that were below the State's 'impairment' threshold (3.2) in Biotype 2, indicating that community balance may have been adversely affected by reservoir operations or other anthropogenic activities (Figure 6). Alternatively, Diversity values from the two sites in Biotype 1 were among the highest in the study area and well-above the threshold of 2.1 (Figure 6). During the spring season, only one site (UBR) produced an MMI v4 score in the 'Grey Zone', and data from this site generated HBI and Diversity values indicating that it was in 'attainment' for aquatic life use (Table 2). During the summer, low Diversity values were responsible for 'impairment' designations for two study sites (Blue 2 and Blue 1) that generated MMI v4 scores in the 'grey zone', and in the fall, sites DRD and Blue 3 were also determined to be 'impaired' based on low Diversity values (Tables 3 and 4). In general, macroinvertebrate community balance appeared to be consistently impacted immediately downstream from Dillon Reservoir, and the somewhat inconsistent pattern of recovery that followed in a downstream direction supported the possibility of influences from other seasonal anthropogenic stressors.

In summary, a wide range of MMI v4 scores were obtained within the study area during the three seasons in 2020. Results from the MMI v4 consistently indicated that the reference site (UBR) was in 'attainment' for aquatic life use during 2020; however, component metrics from all three seasons suggested that there was likely mild to moderate stress occurring at this location. Results from the MMI v4 and auxiliary metrics indicated that benthic macroinvertebrate communities were 'impaired' at the three study sites downstream from Dillon Reservoir (Blue 5, DRD, and Blue 3) in the spring and fall, while a total of five sampling locations generated MMI v4 scores indicating 'impairment' during the summer (Table 5). Farther downstream, improvements in MMI v4 scores were consistently observed near the downstream boundary of the study area. Alterations from the natural flow and temperature regime imposed by reservoir operations were likely responsible for a decline in the richness and abundance of sensitive and specialized taxa. Several components of the MMI v4 that consistently detected these types of impacts included the EPT Taxa, % EPT Individuals (no Baetidae), Clinger Taxa, % Increasers (Mountain Trn), and % Scraper Individuals. Seasonal and spatial variability in the pattern of recovery with distance downstream from the reservoir suggested that there may be other factors (such as gradient, substrate, tributaries, and/or other sources of anthropogenic stress) influencing the health and recovery of benthic macroinvertebrate communities. In addition to the MMI v4, a variety of other metrics and analysis tools were used to further describe the overall health (structure and function) of benthic macroinvertebrate communities in this study area.

Table 2. MMI v4 scores from composited replicate Hess samples collected from ten study sites on the Blue River on 20 April 2020. Scores indicating 'impairment' are provided in red.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
	Biotype 2								Biotype 1	
EPT Taxa	65.7	21.9	51.1	73.1	73.1	87.7	95.0	80.4	62.5	70.8
% EPT individuals, no Baetidae	32.3	0.8	5.2	10.6	59.2	44.8	53.9	62.4	100.0	42.1
Clinger Taxa	45.0	15.0	30.0	45.0	50.0	55.0	55.0	50.0	72.1	81.7
Total Taxa	57.1	28.6	42.9	54.8	64.3	59.5	57.1	64.3	--	--
Intolerant Taxa	52.4	19.0	38.1	47.6	57.1	66.7	61.9	61.9	--	--
% Increasers, Mountain Trn	34.5	0.5	6.2	14.4	22.0	41.6	51.9	67.6	--	--
Predator Taxa	53.8	23.1	30.8	38.5	46.2	38.5	53.8	46.2	--	--
% Scraper individuals	24.5	11.2	5.5	17.5	29.0	73.0	78.7	85.5	--	--
% Non-Insect individuals	--	--	--	--	--	--	--	--	92.4	94.2
% Coleoptera individuals	--	--	--	--	--	--	--	--	3.5	3.3
% Intolerant Taxa	--	--	--	--	--	--	--	--	82.0	84.8
% Increasers, Mid-Elevation	--	--	--	--	--	--	--	--	95.8	100.0
Predator/Shredder taxa	--	--	--	--	--	--	--	--	64.3	57.1
MMI Score	**45.7**	**15.0**	**26.2**	**37.7**	**50.1**	**58.3**	**63.4**	**64.8**	**71.6**	**66.8**
Auxiliary Metrics										
Shannon Diversity	3.69	2.70	1.49	2.76	3.31	3.59	3.60	3.82	3.59	3.77
HBI	4.29	5.13	4.80	4.82	2.73	3.80	3.43	3.59	2.65	3.86
TIV (Sediment Region 1)	4.84	6.06	4.34	5.00	4.31	5.00	4.63	4.50	NA	NA

Table 3. MMI v4 scores from composited replicate Hess samples collected from ten study sites on the Blue River on 17 August 2020. Scores indicating 'impairment' are provided in red.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
	Biotype 2								Biotype 1	
EPT Taxa	48.2	21.9	48.2	65.7	35.0	52.5	61.3	52.5	54.2	54.2
% EPT individuals, no Baetidae	41.5	3.5	16.4	52.9	29.4	27.6	30.3	44.3	27.5	24.1
Clinger Taxa	50.0	30.0	45.0	70.0	35.0	55.0	60.0	50	52.9	38.5
Total Taxa	57.1	33.3	47.6	61.9	45.2	64.3	61.9	71.4	--	--
Intolerant Taxa	42.9	28.6	52.4	71.4	42.9	61.9	61.9	66.7	--	--
% Increasers, Mountain Trn	42.5	3.8	15.3	54.6	4.1	12.8	15.0	28.0	--	--
Predator Taxa	38.5	23.1	30.8	46.2	30.8	76.9	69.2	61.5	--	--
% Scraper individuals	2.1	1.3	9.8	28.9	3.3	8.1	5.4	8.8	--	--
% Non-Insect individuals	--	--	--	--	--	--	--	--	92.2	99.3
% Coleoptera individuals	--	--	--	--	--	--	--	--	9.0	2.6
% Intolerant Taxa	--	--	--	--	--	--	--	--	67.8	78.7
% Increasers, Mid-Elevation	--	--	--	--	--	--	--	--	94.8	100.0
Predator/Shredder taxa	--	--	--	--	--	--	--	--	57.1	50.0
MMI Score	**40.3**	**18.2**	**33.2**	**56.4**	**28.2**	**44.9**	**45.6**	**47.9**	**56.9**	**55.9**
Auxiliary Metrics										
Shannon Diversity	3.21	0.98	2.02	3.21	1.98	2.86	2.72	4.00	3.33	3.73
HBI	3.49	4.91	4.52	3.37	4.61	4.57	4.60	3.35	4.51	3.83
TIV (Sediment Region 1)	4.21	4.33	4.38	3.97	5.55	5.24	5.02	4.74	NA	NA

Table 4. MMI v4 scores from composited replicate Hess samples collected from ten study sites on the Blue River on 6-7 November 2020. Scores indicating 'impairment' are provided in red.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
	Biotype 2								Biotype 1	
EPT Taxa	36.7	20.4	49.0	40.8	44.9	49.0	53.1	57.1	79.2	66.7
% EPT individuals, no Baetidae	70.5	4.6	45.7	36.7	50.8	54.9	54.0	76.2	100.0	66.0
Clinger Taxa	45.0	15.0	50.0	50.0	45.0	65.0	60.0	70.0	96.2	72.1
Total Taxa	42.9	33.3	52.4	50.0	50.0	66.7	59.5	71.4	--	--
Intolerant Taxa	47.6	28.6	57.1	52.4	61.9	66.7	76.2	81.0	--	--
% Increasers, Mountain Trn	67.4	4.6	54.0	58.4	29.7	46.1	49.2	57.0	--	--
Predator Taxa	30.8	30.8	38.5	38.5	30.8	61.5	53.8	69.2	--	--
% Scraper individuals	84.3	7.5	2.7	11.1	13.1	71.9	61.5	69.2	--	--
% Non-Insect individuals	--	--	--	--	--	--	--	--	96.4	86.7
% Coleoptera individuals	--	--	--	--	--	--	--	--	4.5	21.2
% Intolerant Taxa	--	--	--	--	--	--	--	--	100.0	100.0
% Increasers, Mid-Elevation	--	--	--	--	--	--	--	--	100.0	100.0
Predator/Shredder taxa	--	--	--	--	--	--	--	--	85.7	64.3
MMI Score	**53.2**	**18.1**	**43.7**	**42.2**	**40.8**	**60.2**	**58.4**	**68.9**	**82.7**	**72.1**
Auxiliary Metrics										
Shannon Diversity	2.78	2.81	2.81	3.03	3.35	3.55	3.13	3.88	3.96	3.45
HBI	3.10	2.97	3.27	3.76	2.75	3.31	3.65	2.67	2.42	3.11
TIV (Sediment Region 1)	3.49	4.87	3.75	4.31	4.09	4.41	3.84	4.02	NA	NA

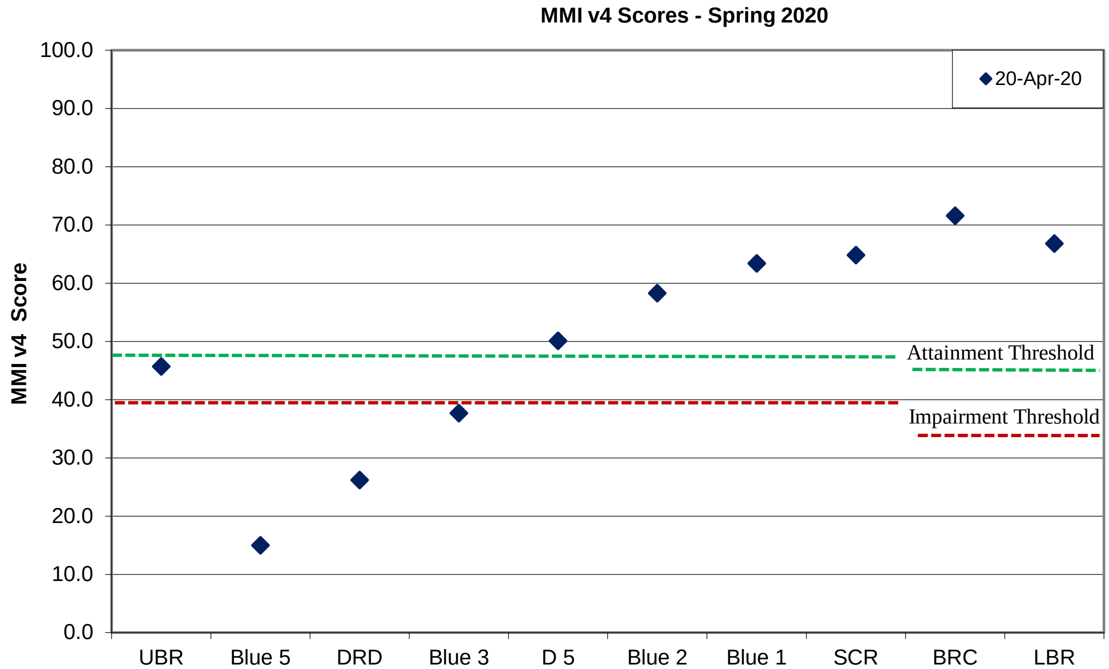

Figure 2. MMI v4 scores from composited quantitative (Hess) samples at study sites on the Blue River during April 2020.

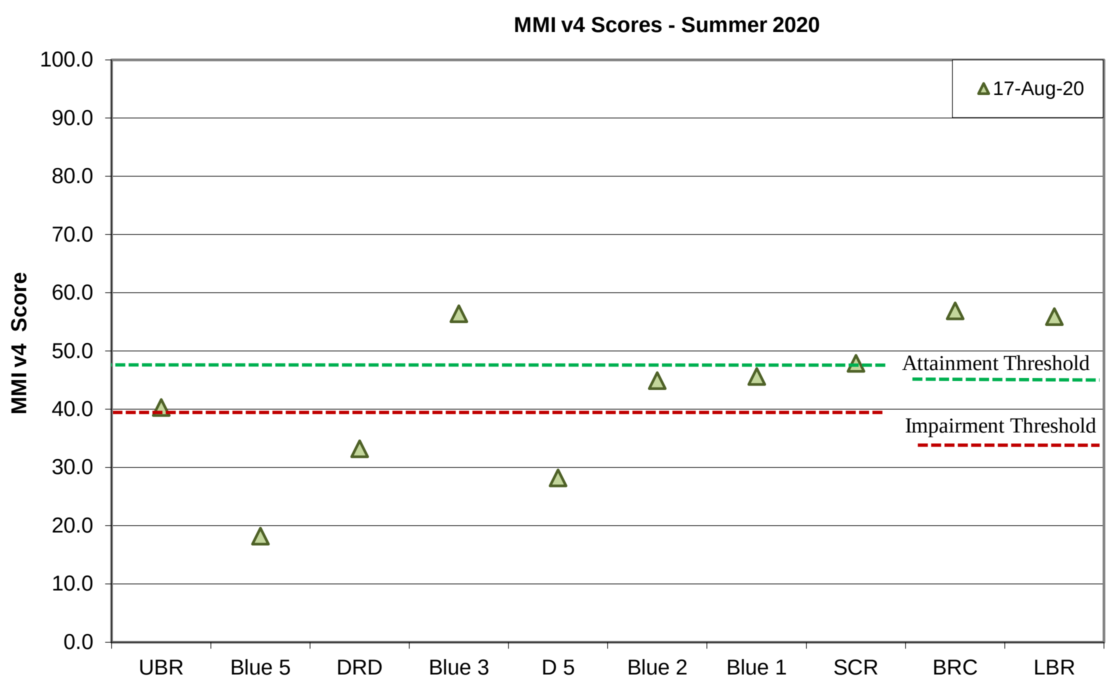

Figure 3. MMI v4 scores from composited quantitative (Hess) samples at study sites on the Blue River during August 2020.

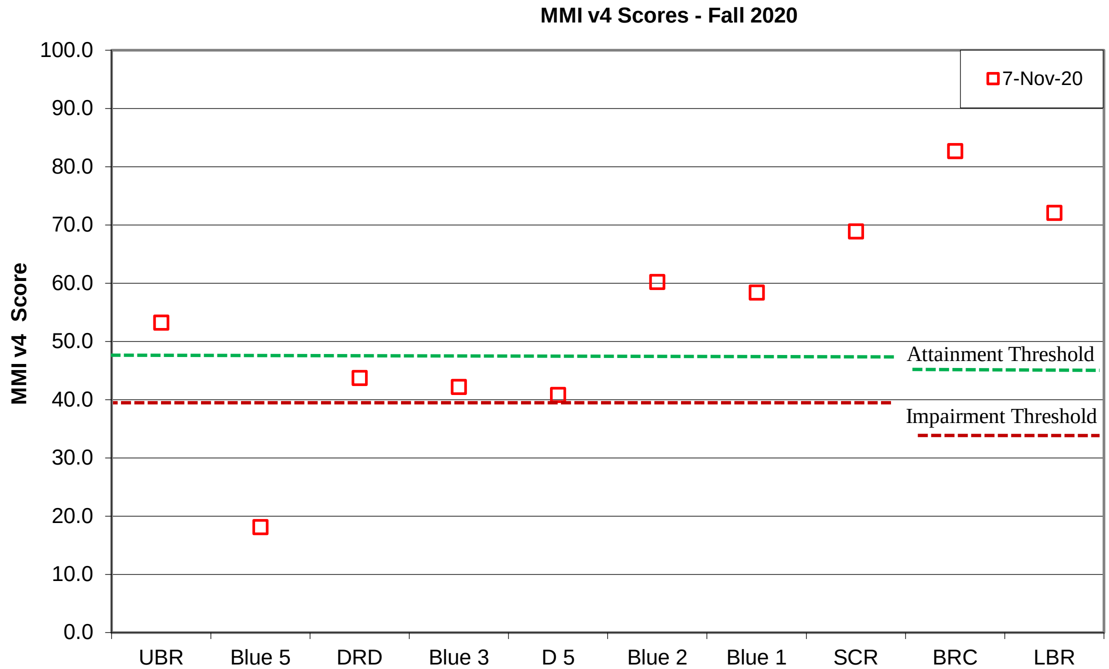

Figure 4. MMI v4 scores from composited quantitative (Hess) samples at study sites on the Blue River during November 2020.

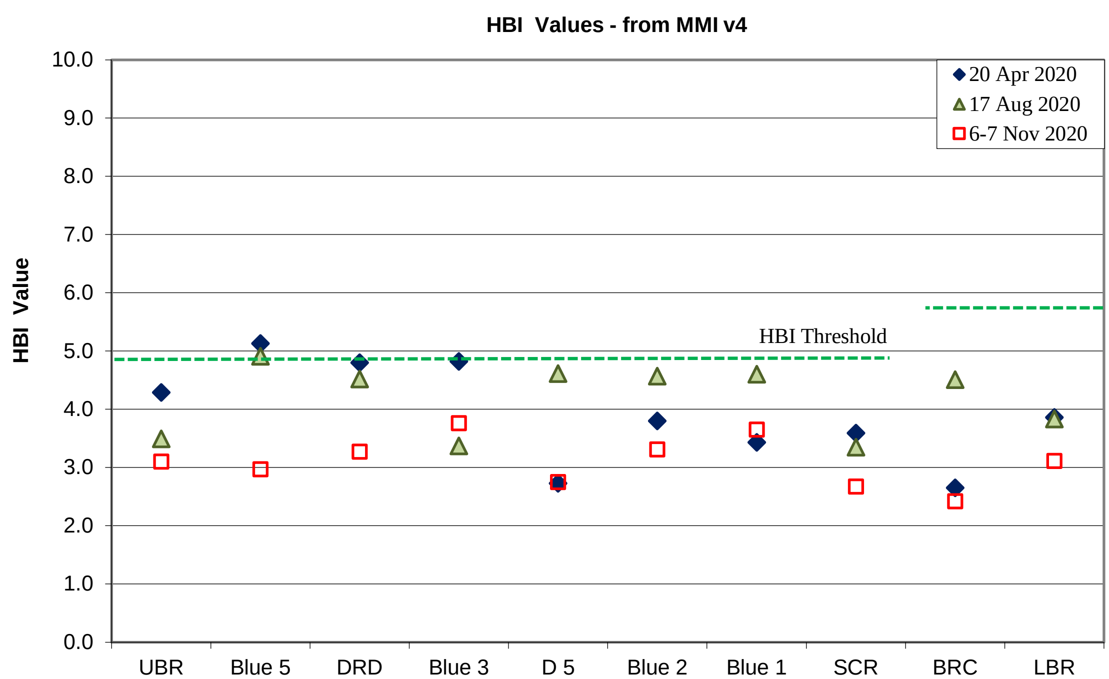

Figure 5. HBI values from composited quantitative (Hess) samples at study sites on the Blue River during April, August and November of 2020.

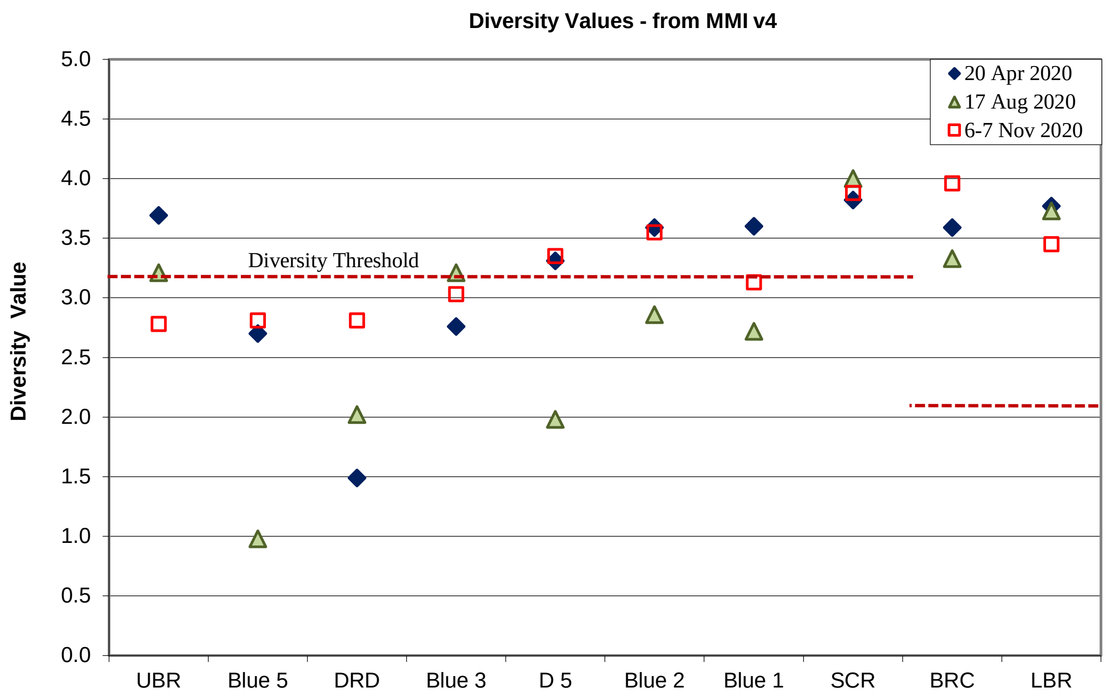

Figure 6. Shannon Diversity values from composited quantitative (Hess) samples at study sites on the Blue River during April, August and November 2020.

Table 5. Aquatic life use designations based on MMI v4 scores from quantitative (Hess) samples at sites in the Blue River study area, 2020.

Aquatic Life Use Designations in 2020 based on MMI (v4)			
Site	**Spring 2020**	**Summer 2020**	**Fall 2020**
UBR	Attainment	Attainment	Attainment
Blue 5	Impairment	Impairment	Impairment
DRD	Impairment	Impairment	Impairment
Blue 3	Impairment	Attainment	Impairment
D 5	Attainment	Impairment	Attainment
Blue 2	Attainment	Impairment	Attainment
Blue 1	Attainment	Impairment	Attainment
SCR	Attainment	Attainment	Attainment
BRC	Attainment	Attainment	Attainment
LBR	Attainment	Attainment	Attainment

Additional Evaluation (Individual Metrics)

In the previous section, results from the MMI v4 (and associated metrics) were based on a subset of specimens (approximately 300) from composited Hess samples. This rarefication process is built into the MMI v4 program to ensure that a consistent allotment of data can be compared when using different sampling techniques throughout the State of Colorado. It should be noted that some bias may occur during this rarefication process, and inevitably some taxa may be excluded or poorly represented. Therefore, the following data analysis was conducted using all specimens from each quantitative sample (Tables 6-11). This was done to provide a more replicable and accurate examination of community composition, structure, balance, and function during each season in 2020.

On 20 April 2020, results from most of the additional applied metrics identified an area of stressed aquatic conditions immediately below Dillon Reservoir followed by apparent recovery of macroinvertebrate structure and function with distance downstream. It is likely that the hypolimnetic releases had a substantial impact directly below the dam on the most environmentally sensitive taxa (EPT Taxa), but minimal deleterious effects on these taxa farther downstream (Table 6). The summation of these sensitive macroinvertebrate taxa ranged from a low of 4 at site Blue 5 (directly below Dillon Reservoir) to a high of 17 EPT taxa at two study sites farther downstream (Table 6). As has been previously reported in similar studies (see Introduction), relatively few taxa comprised the macroinvertebrate community at site Blue 5 (the site closest to the dam). In the spring of 2020, ninety-three percent of the macroinvertebrate community at Blue 5 was numerically dominated by the geographically widespread and resilient baetid mayfly, *Baetis tricaudatus* (33% of the total abundance), chironomid midges (38% of the total abundance), and black flies of the genus *Simulium* (22% of the total abundance) (Appendix A, Table A2). Whereas, farther downstream at site Blue 1, 32 different taxa were collected including 17 EPT taxa (Appendix A, Table A7).

Generally, stoneflies and caddisflies are considered the most sensitive groups of aquatic insects in regulated streams. Directly below the dam, at site Blue 5, only two species of stoneflies occurred, the tolerant widespread western species, *Isoperla fulva*, and an unidentified chloroperlid. Only one caddisfly species, *Brachycentrus americanus*, another geographically wide spread and common North American taxon was collected (Appendix A, Table A2). At site Blue 1, six stonefly taxa and seven caddisfly taxa were collected (Appendix A, Table A7), reflecting a more typical healthy southern Rocky Mountain assemblage of macroinvertebrate taxa. This increase in EPT taxa downstream may have been enhanced by select taxa drifting and recolonizing downstream from the numerous tributaries along the Blue River.

Other individual metrics (including Taxa Richness, Clinger Taxa, % Shredders and Scrapers, and % EPT individuals) also detected a reduction in sensitive and specialized macroinvertebrates directly below the dam (Table 6 and 7). A comparison of Density values to Dry Weight values suggested that while aquatic organisms remained abundant immediately downstream from Dillon Reservoir, they were typically smaller in body size during the spring of 2020. Again, improvements were detected farther downstream.

Table 6. Individual metrics and comparative values for quantitative benthic macroinvertebrate samples collected from the Blue River, 20 April 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
# Ephemeroptera Taxa	4	1	3	3	3	4	4	4	5	7
# Plecoptera Taxa	4	2	3	7	3	3	6	3	4	2
# Trichoptera Taxa	2	1	2	4	4	5	7	4	7	8
Total EPT Taxa	**10**	**4**	**8**	**14**	**10**	**12**	**17**	**11**	**16**	**17**
Taxa Richness	26	13	20	29	30	28	32	28	33	33
Clinger Taxa	13	4	11	15	14	15	19	15	19	17
Hydropsychidae Density (estimated #/m²)	63	0	8	16	78	32	105	55	79	431
% Clingers	60.86%	23.26%	5.59%	13.24%	44.83%	38.58%	47.77%	55.85%	57.71%	43.75%
% Shredders and Scrapers	12.95%	0.00%	2.51%	7.84%	13.24%	28.44%	31.97%	38.13%	64.86%	8.85%
% Chironomidae	17.34%	38.00%	10.06%	29.51%	30.83%	31.24%	27.74%	20.89%	15.10%	28.65%

Table 7. Additional metrics and comparative values for quantitative benthic macroinvertebrate samples collected on the Blue River, 20 April 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
% Ephemeroptera individuals	29.11%	32.94%	83.10%	59.80%	29.79%	40.45%	48.22%	51.11%	41.97%	40.24%
% Plecoptera individuals	9.22%	0.37%	0.98%	4.41%	4.51%	3.20%	4.97%	8.86%	3.34%	0.21%
% Trichoptera individuals	12.22%	0.06%	0.42%	0.69%	26.85%	10.55%	5.64%	6.33%	34.82%	16.78%
% EPT individuals	**50.55%**	**33.37%**	**84.50%**	**64.90%**	**61.15%**	**54.21%**	**58.83%**	**66.30%**	**80.13%**	**57.23%**
Ephemeroptera (estimated #/m²)	1544	2070	2308	2366	2435	1176	2521	1253	1025	2224
Plecoptera (estimated #/m²)	490	24	28	177	370	95	262	218	83	12
Trichoptera (estimated #/m²)	649	4	12	28	2196	309	297	158	853	930
Other (estimated #/m²)	2629	4190	434	1394	3183	1336	2158	832	491	2368
Total Density (estimated #/m²)	**5,312**	**6,288**	**2,782**	**3,965**	**8,184**	**2,916**	**5,238**	**2,461**	**2,452**	**5,534**
Ephemeroptera Dry Wt (estimated g/m²)	0.3977	0.3298	0.3318	0.3054	0.9012	0.2488	0.5950	0.2814	0.1833	0.6880
Plecoptera Dry Wt (estimated g/m²)	0.4085	0.0783	0.0205	0.1105	0.5682	0.1031	0.5357	0.3353	0.6240	0.0802
Trichoptera Dry Wt (estimated g/m²)	0.7647	0.0016	0.0922	0.1721	5.4578	0.1733	0.7322	0.2845	0.2872	0.6140
Other Dry Wt (estimated g/m²)	0.5721	0.8213	0.0477	0.1438	0.9783	0.2074	0.3213	0.2008	0.0395	0.3120
Total Dry Wt (estimated g/m²)	**2.1430**	**1.2310**	**0.4922**	**0.7318**	**7.9054**	**0.7326**	**2.1841**	**1.1019**	**1.1341**	**1.6942**

Benthic macroinvertebrate sampling and analysis continued in the summer (17 August) of 2020 to provide a seasonal perspective on longitudinal patterns of community structure and function. The most likely sources of stress during the summer months continued to include hypolimnetic releases from Dillon Reservoir and runoff from urban development (adjacent to the Blue River) within the Town of Silverthorne. Results from data analysis generally detected evidence of stressed conditions at sites Blue 5 and D 5 with robust recovery gradients downstream from these locations (Tables 8 and 9). There were also differences in terms of community structure and taxa richness when site UBR (the "reference" site) was compared to most of the study sites downstream from Dillon Reservoir.

The summation of sensitive macroinvertebrate taxa (EPT Taxa) ranged from a low of 5 at the site directly below Dillon Reservoir (Blue 5) to a high of 18 at sites Blue 2 and Blue 1, indicating a substantial increase in sensitive taxa with distance downstream from the dam (Table 8). Generally, stoneflies and caddisflies are considered the most sensitive groups of macroinvertebrates, usually demonstrating significant reductions in regulated streams. The average number of EPT Taxa reported in healthy Colorado mountain streams typically ranges between 21-30+ (Ward et al. 2002). The increase in EPT taxa at the downstream sampling locations was likely enhanced by contributions (drifting or aerial colonization) from numerous tributaries along the Blue River study segment. Interestingly, the site below Green Mountain Reservoir, site LBR, consisted of a more diverse macroinvertebrate community, including 14 EPT taxa (Appendix B, Table B10), whereas, at site Blue 5, only five EPT were collected (Appendix B, Table B2). It was also important to note that the EPT Taxa metric (and several other individual metrics) detected greater stress at the "reference site" (UBR) compared to most sampling locations in the lower portion of the Blue River study area.

Overall, other individual metrics used in this assessment (Taxa Richness, Clinger Taxa, Hydropsychidae Density, % Clingers, and % Shredders and Scrapers) were consistent in detecting increased stress immediately downstream from Dillon Reservoir, while improvements in metric values often varied throughout the remainder of the study area (Table 8). The % Chironomidae and % EPT individuals metrics were the only two analysis tools that did not detect additional stress at site Blue 5 (Tables 8 and 9), but both of these metrics were greatly influenced by the dominance of the relatively tolerant mayfly, *Baetis tricaudatus*, (Appendix B, Table B2). Total density (estimated #/m^2) values ranged from a low of 989 individuals/m^2 at site DRD (1.9 km below the dam) to a high of 24,589 individuals/m^2 at site D 5 (11.7 km downstream from the dam). Total Dry Weight generally reflected Total Density estimates except at site Blue 5 where the ratio of Total Density to Total Dry Weight clearly showed that the majority of specimens exhibited a smaller body size (Table 9). Almost the entire macroinvertebrate community at site Blue 5 was numerically composed of the geographically widespread and resilient baetid mayfly, *Baetis tricaudatus* and a few dipterans (primarily chironomid midges and black flies) (Appendix B, Table B2). Many of the taxa that were found at downstream sampling locations exhibited a larger body size, increasing the ratio of Total Dry Weight to Total Density. Again, much of the variability in metric values in the middle reaches of the study area may have been influenced by additional impacts from other anthropogenic sources (urban and agricultural runoff) and tributaries. The influence of Dillon Reservoir and other anthropogenic stressors in this study area appeared to be offset by improvements in aquatic conditions and additional faunal contributions downstream from tributaries.

Table 8. Individual metrics and comparative values for quantitative benthic macroinvertebrate samples collected from the Blue River, 17 August 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
# Ephemeroptera Taxa	4	2	4	5	4	5	8	6	4	8
# Plecoptera Taxa	4	2	5	5	2	6	5	4	3	4
# Trichoptera Taxa	5	1	3	5	3	7	5	5	7	2
Total EPT Taxa	**13**	**5**	**12**	**15**	**9**	**18**	**18**	**15**	**14**	**14**
Taxa Richness	**26**	**14**	**21**	**26**	**26**	**34**	**36**	**38**	**31**	**28**
Clinger Taxa	**13**	**6**	**12**	**17**	**12**	**19**	**19**	**16**	**16**	**11**
Hydropsychidae Density (estimated #/m^2)	**109**	**0**	**4**	**12**	**249**	**566**	**586**	**225**	**187**	**55**
% Clingers	**49.44%**	**7.22%**	**13.83%**	**48.89%**	**83.41%**	**59.15%**	**58.53%**	**31.64%**	**63.58%**	**17.46%**
% Shredders and Scrapers	**1.75%**	**0.28%**	**3.56%**	**13.06%**	**0.69%**	**3.83%**	**6.12%**	**13.74%**	**7.36%**	**10.05%**
% Chironomidae	**9.57%**	**4.44%**	**12.25%**	**6.94%**	**4.21%**	**10.54%**	**8.43%**	**28.04%**	**22.08%**	**33.94%**

Table 9. Additional metrics and comparative values for quantitative benthic macroinvertebrate samples collected on the Blue River, 17 August 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
% Ephemeroptera individuals	33.17%	86.11%	73.91%	46.94%	9.86%	23.52%	24.72%	26.58%	11.55%	53.38%
% Plecoptera individuals	11.64%	2.50%	6.72%	14.17%	2.21%	6.24%	6.57%	9.37%	3.43%	0.82%
% Trichoptera individuals	22.65%	0.28%	3.16%	15.28%	20.31%	12.65%	13.54%	21.30%	14.97%	9.06%
% EPT individuals	**67.46%**	**88.89%**	**83.79%**	**76.39%**	**32.38%**	**42.41%**	**44.83%**	**57.25%**	**29.95%**	**63.26%**
Ephemeroptera (estimated #/m²)	809	1202	727	657	2423	2502	1914	1486	355	1258
Plecoptera (estimated #/m²)	284	36	68	200	544	665	509	525	106	20
Trichoptera (estimated #/m²)	552	4	32	214	4994	1347	1048	1192	460	214
Other (estimated #/m²)	796	158	162	333	16628	6128	4271	2396	2148	872
Total Density (estimated #/m²)	**2,441**	**1,400**	**989**	**1,404**	**24,589**	**10,642**	**7,742**	**5,599**	**3,069**	**2,364**
Ephemeroptera Dry Wt (estimated g/m²)	0.0461	0.0795	0.0864	0.1070	0.3081	0.2105	0.2054	0.1384	0.0446	0.2996
Plecoptera Dry Wt (estimated g/m²)	0.0446	0.0043	0.0198	0.0267	0.0624	0.0895	0.0864	0.1240	0.1147	0.0008
Trichoptera Dry Wt (estimated g/m²)	0.2535	0.0039	0.0264	0.0043	0.5101	0.2388	0.6120	0.1500	0.2492	0.0306
Other Dry Wt (estimated g/m²)	0.1380	0.0074	0.0085	0.0318	2.0194	0.7477	0.5473	0.3868	0.4167	0.0845
Total Dry Wt (estimated g/m²)	**0.4822**	**0.0950**	**0.1411**	**0.1698**	**2.9000**	**1.2864**	**1.4512**	**0.7992**	**0.8252**	**0.4155**

Seasonal benthic macroinvertebrate monitoring continued on the Blue River during the fall (6-7 November) of 2020 with the same individual metrics that were utilized during previous sampling events (spring and summer). Results from data analysis were used to assess changes in macroinvertebrate community health and ultimately provide insight into the overall ecological integrity of the aquatic system. In general, results from November of 2020 reflected a strong recovery gradient of macroinvertebrate structure and function downstream from Dillon Dam to the lower portion of the study area (Tables 10 and 11). While the sampling location upstream from Dillon Reservoir (UBR) supported a benthic macroinvertebrate community that was generally healthier than the site immediately downstream from the reservoir (Blue 5), results from most metrics suggested that the most optimum community parameters (in terms of community structure and taxa richness) occurred in the lower half of the study area (Tables 10 and 11). Interestingly, site LBR (located approximately 7.2 km downstream from Green Mountain Reservoir) did not show the same evidence of stress that was observed at sites downstream from Dillon Reservoir.

The summation of the most sensitive macroinvertebrate taxa, EPT Taxa, ranged from a low of only five taxa at the site directly below Dillon Dam (Blue 5) to a high of 21 EPT Taxa at site BRC (immediately upstream from Green Mountain Reservoir). A review of EPT values generally showed a substantial positive increase in these sensitive taxa in a downstream direction (Table 10). At site Blue 5, only one species of stonefly was collected, whereas eight species of stoneflies were collected at site BRC, including the sensitive and uncommon Colorado perlodidine taxon, *Diura knowltoni* (Appendix C, Table C9). Surprisingly, the site below Green Mountain Reservoir (LBR), also supported a much more diverse macroinvertebrate community than site Blue 5, with 20 EPT taxa (Table 10).

In November of 2020, most of the individual metrics detected relatively rapid improvements in macroinvertebrate community health with distance downstream from Dillon Reservoir. Sites Blue 2, Blue 1, and SCR exhibited diverse macroinvertebrate communities (Appendix C, Tables C6-C8), including relatively high values from the following metrics: EPT Taxa, Taxa Richness, Clinger Taxa, and % Shredders and Scrapers (Table 10). Metric values generally improved from site Blue 5 to site Blue 2 before becoming somewhat stable between sites Blue 2 and LBR (Table 10). At site BRC, mayflies and caddisflies composed 47% and 34% respectively, of the benthic community (Table 11), which could be considered “healthy” for a southern Rocky Mountain riverine macroinvertebrate community. Again, the high number of taxa (and repopulation of sensitive taxa) found in the middle reaches of this study area likely reflected faunal contributions from the numerous tributaries along the sampled reach of the Blue River.

Total Density estimates varied from a low of 953 individuals/m^2 at site Blue 3 to a high at site Blue 1 of 9,074 individuals/m^2, while Total Dry Weight ranged from 0.1450 g/m^2 at site Blue 5 to 3.1163 g/m^2 at site SCR (Table 11). Interestingly, the ratio of Total Density to Total Dry Weight indicated that the macroinvertebrate specimens with the smallest body size occurred at sites Blue 5, DRD, and Blue 3. Farther downstream at site BRC, the average Dry Weight of individual specimens was more than 7 times greater than those found at site Blue 5. These results suggested that the feeding habits and energy expenditures of fish below Dillon Dam (sites Blue 5, DRD, and Blue 3) were potentially limited by the small body size (and biomass) of the available benthic macroinvertebrates during the fall of 2020.

Table 10. Individual metrics and comparative values for quantitative benthic macroinvertebrate samples collected from the Blue River, 6-7 November 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
# Ephemeroptera Taxa	3	2	3	3	5	5	5	4	6	7
# Plecoptera Taxa	4	1	6	5	4	7	6	6	8	6
# Trichoptera Taxa	4	2	4	3	4	5	8	7	7	7
Total EPT Taxa	**11**	**5**	**13**	**11**	**13**	**17**	**19**	**17**	**21**	**20**
Taxa Richness	**21**	**14**	**23**	**22**	**28**	**38**	**36**	**38**	**33**	**35**
Clinger Taxa	**13**	**4**	**9**	**12**	**14**	**19**	**20**	**21**	**23**	**21**
Hydropsychidae Density (estimated #/m²)	**202**	**0**	**4**	**39**	**299**	**206**	**411**	**291**	**268**	**1,207**
% Clingers	**64.14%**	**7.32%**	**9.56%**	**32.79%**	**37.64%**	**39.17%**	**43.03%**	**48.48%**	**77.94%**	**52.67%**
% Shredders and Scrapers	**34.34%**	**0.00%**	**2.39%**	**3.69%**	**9.04%**	**29.90%**	**38.24%**	**34.33%**	**53.78%**	**27.63%**
% Chironomidae	**1.52%**	**33.06%**	**12.35%**	**11.48%**	**19.87%**	**19.30%**	**9.67%**	**20.31%**	**7.14%**	**6.43%**

Table 11. Additional metrics and comparative values for quantitative benthic macroinvertebrate samples collected on the Blue River, 6-7 November 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
% Ephemeroptera individuals	63.64%	17.62%	37.45%	37.30%	32.14%	50.16%	67.32%	44.58%	47.48%	32.63%
% Plecoptera individuals	4.88%	3.25%	33.86%	20.90%	11.31%	8.38%	5.00%	7.66%	5.46%	1.78%
% Trichoptera individuals	18.01%	0.54%	1.99%	5.74%	27.77%	12.95%	11.72%	21.41%	34.24%	40.70%
% EPT individuals	**86.53%**	**21.41%**	**73.31%**	**63.93%**	**71.21%**	**71.49%**	**84.05%**	**73.65%**	**87.18%**	**75.10%**
Ephemeroptera (estimated #/m²)	1467	253	365	354	2083	3063	6102	2665	880	1851
Plecoptera (estimated #/m²)	114	47	331	199	733	513	455	460	103	103
Trichoptera (estimated #/m²)	416	8	20	55	1800	793	1065	1282	635	2310
Other (estimated #/m²)	314	1129	264	345	1871	1748	1452	1581	241	1418
Total Density (estimated #/m²)	**2,311**	**1,437**	**980**	**953**	**6,487**	**6,117**	**9,074**	**5,988**	**1,859**	**5,682**
Ephemeroptera Dry Wt (estimated g/m²)	0.0640	0.0209	0.0229	0.0182	0.1500	0.1678	0.4035	0.8725	0.2236	0.2961
Plecoptera Dry Wt (estimated g/m²)	0.0345	0.0233	0.1302	0.0721	0.3740	0.2791	0.2605	0.2519	0.2109	0.0457
Trichoptera Dry Wt (estimated g/m²)	0.3678	0.0035	0.0035	0.0271	1.7895	1.0810	1.1833	1.6864	0.9422	1.6523
Other Dry Wt (estimated g/m²)	0.0829	0.0973	0.0306	0.0698	0.5167	0.6376	0.5116	0.3054	0.0271	0.2302
Total Dry Wt (estimated g/m²)	**0.5492**	**0.1450**	**0.1872**	**0.1872**	**2.8302**	**2.1655**	**2.3589**	**3.1163**	**1.4039**	**2.2244**

When comparing results from select metrics during all three sampling periods, 20 April (Spring), 17 August (Summer), and 6-7 November (Fall) of 2020, there were certain measures of macroinvertebrate community structure and function that appeared to respond similarly to spatial changes in aquatic conditions while other individual metrics detected more variable responses depending on site location and/or season (Figures 7-14).

The EPT Taxa, Taxa Richness, Clinger Taxa, and Percent Shredders and Scrapers metrics demonstrated considerable spatial similarity among seasons, due to low values from these metrics found at site Blue 5 followed by a general recovery in a downstream direction (Figures 7-10). During each sampling event (April, August, and November), these metrics showed that higher numbers of sensitive and specialized taxa were present in the downstream portion of the study area, providing a typical pattern of impact and recovery that is expected downstream from a hypolimnetic release reservoir. EPT Taxa and Taxa Richness values were reduced at site Blue 5 (immediately downstream from Dillon Reservoir) and increased to substantially higher values at sites Blue 2 and Blue 1 during all seasons (Figures 7 and 8). Clinger Taxa values also improved in a downstream direction with consistently higher numbers (19-20) found at site Blue 1 (Figure 9). While many representatives from the Clinger Taxa metric may be adversely impacted by an unnatural shift in the thermal regime, these taxa also respond poorly to rapid changes in discharge (often associated with regulated streams) because they are typically poor swimmers. It should be noted that the Clinger Taxa metric also showed a slight decline downstream from Green Mountain Reservoir (site LBR) during each season (Figure 9).

The pattern of Percent Scrapers and Shredders suggested that these specialized feeding guilds had the greatest capacity for recovery downstream from Dillon Reservoir during April and November of 2020; however, both feeding groups were consistently absent (or nearly so) at site Blue 5 (Figure 10). The coarse particulate organic material that provides a food resource for shredders is expected to be poorly represented immediately downstream from reservoirs. Improvements in percent composition of Scrapers and Shredders in a downstream direction could likely be attributed to changes in periphyton community composition and/or increased riparian habitat along the length of the Blue River and its tributaries.

While most metrics detected a pattern of impact followed by recovery downstream of Dillon Reservoir, the Percent EPT, Density, and Dry Weight measures exhibited greater variability among sampling locations and seasons (Figures 11-14). The lowest Percent EPT values were found at site Blue 5 during April and November; however, low Percent EPT values were observed at sites D 5, Blue 2, Blue 1 and BRC in August (Figure 11). The highest Total Density value occurred at site D 5 during August of 2020 where black flies of the genus *Simulium* sp. and the humpless casemaking caddisfly, *Brachycentrus occidentalis* comprised more than 81% of the density (Figure 12, Appendix B; Table B5). Both black flies and *Brachycentrus* are collector-filterers, indicating a probable abundance of fine particulate organic matter at this sampling location.

Measures of macroinvertebrate dry weight (estimated g/m^2 and mg/individual) detected a large increase in biomass at site D 5 in April, with seasonal variability throughout the remainder of the study area in 2020 (Figures 13 and 14). At site D 5 in the spring, both of these measures were positively influenced by a high proportion of mature caddisflies (*Brachycentrus occidentalis*), while macroinvertebrate densities and site-specific species composition likely influenced the overall dry weights of macroinvertebrates at other sites during other seasons. During all sampling events, the total Dry Weight (g/m^2) of the benthic macroinvertebrate portion of the food-web appeared to be relatively limited at sites Blue 5, DRD, and Blue 3 (Figure 13). This was particularly evident in the summer and fall when the production of macroinvertebrates (in terms of g/m^2) at these sites was the lowest in the study area. The average body size (individual dry weight) of macroinvertebrate specimens was also lowest at sites Blue 5, DRD, and Blue 3 in the spring and fall, but showed substantial improvement in the downstream portion of the study area (Figure 14). In general, the sampling locations in the lower half of the study area tended to support individuals of slightly larger size/mass, and during most sampling events these sites supported a greater biomass (in terms of g/m^2) of benthic macroinvertebrates. This evaluation provided some insight into possible limitations in food resources for fish populations in the segment of the Blue River from Dillon Reservoir downstream for at least 4.7 km.

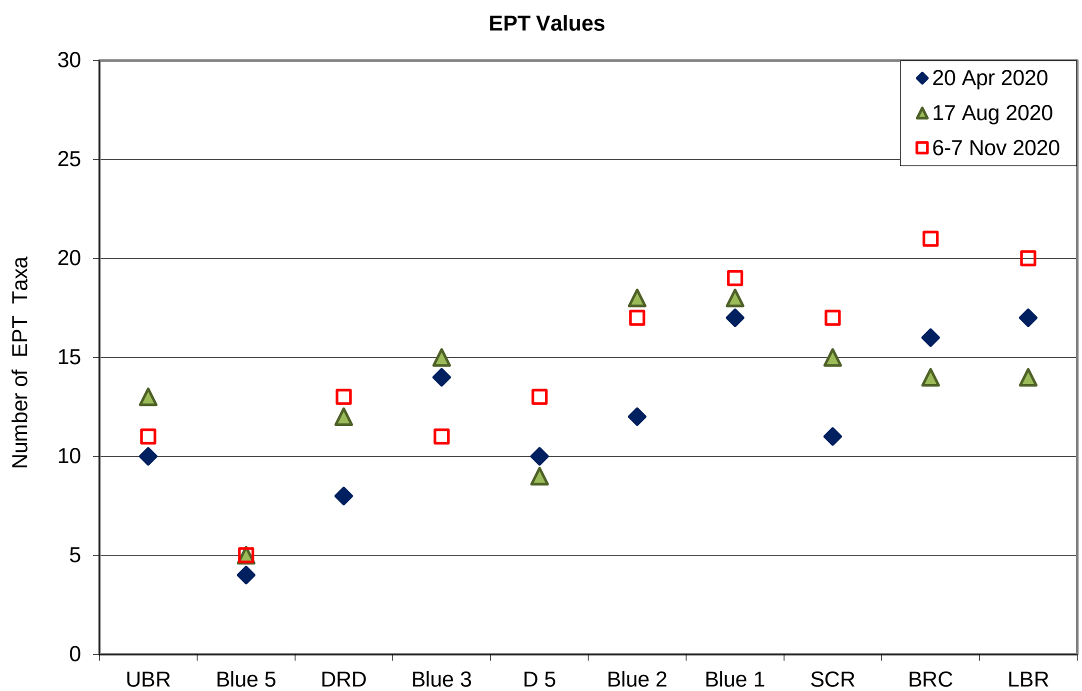

Figure 7. EPT Taxa values from spring, summer, and fall sampling on the Blue River during 2020.

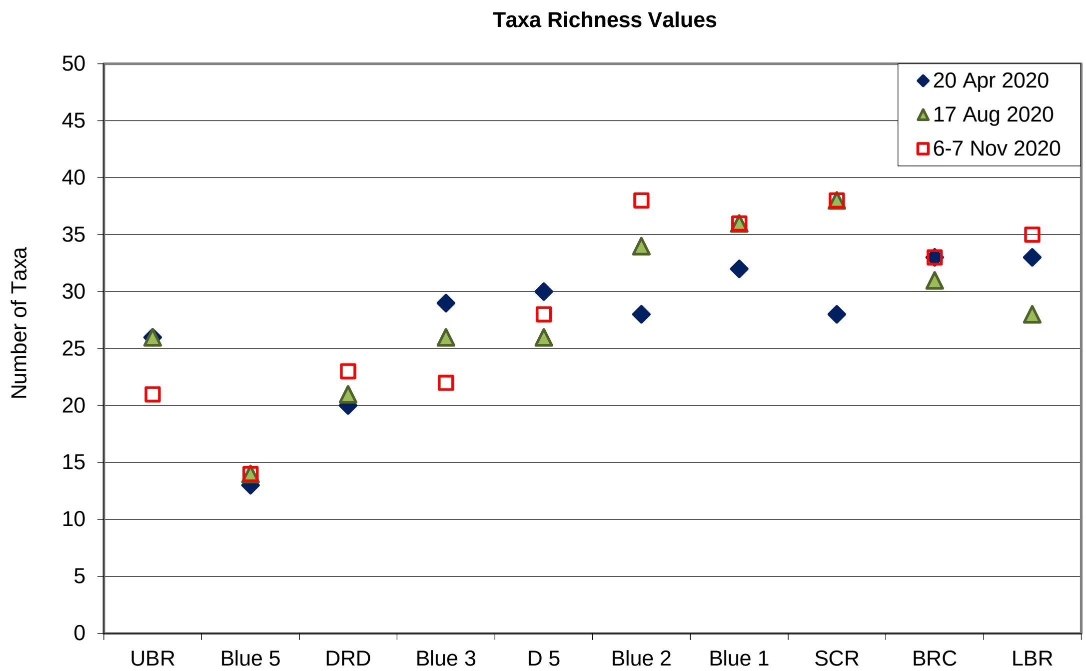

Figure 8. Taxa Richness values from spring, summer, and fall sampling on the Blue River during 2020.

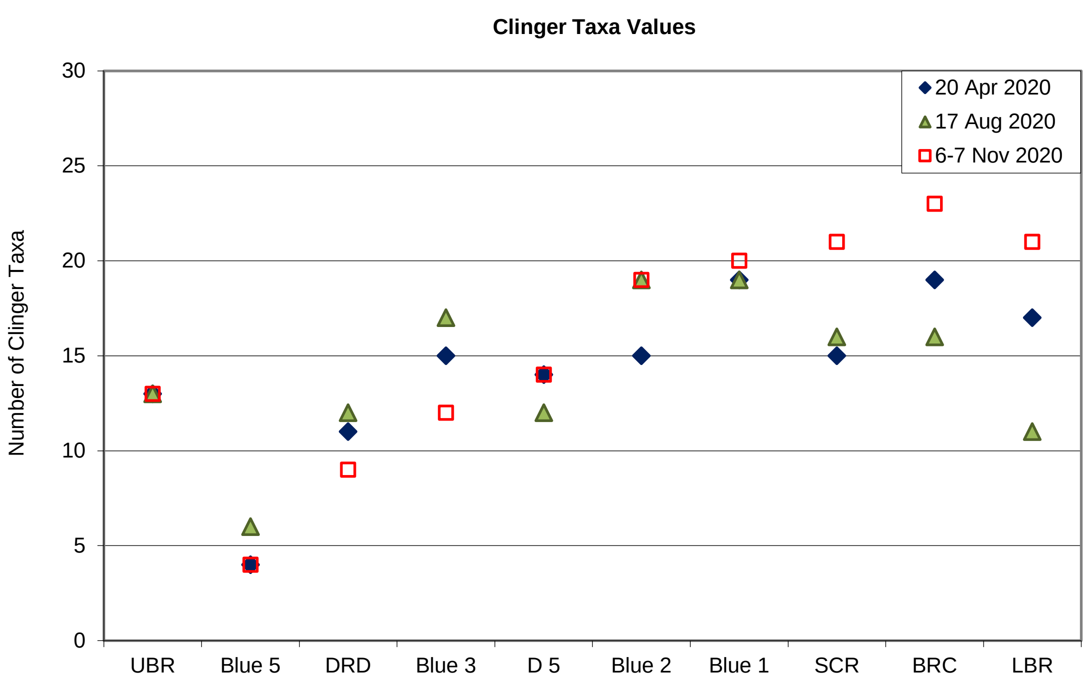

Figure 9. Clinger Taxa values from spring, summer, and fall sampling on the Blue River during 2020.

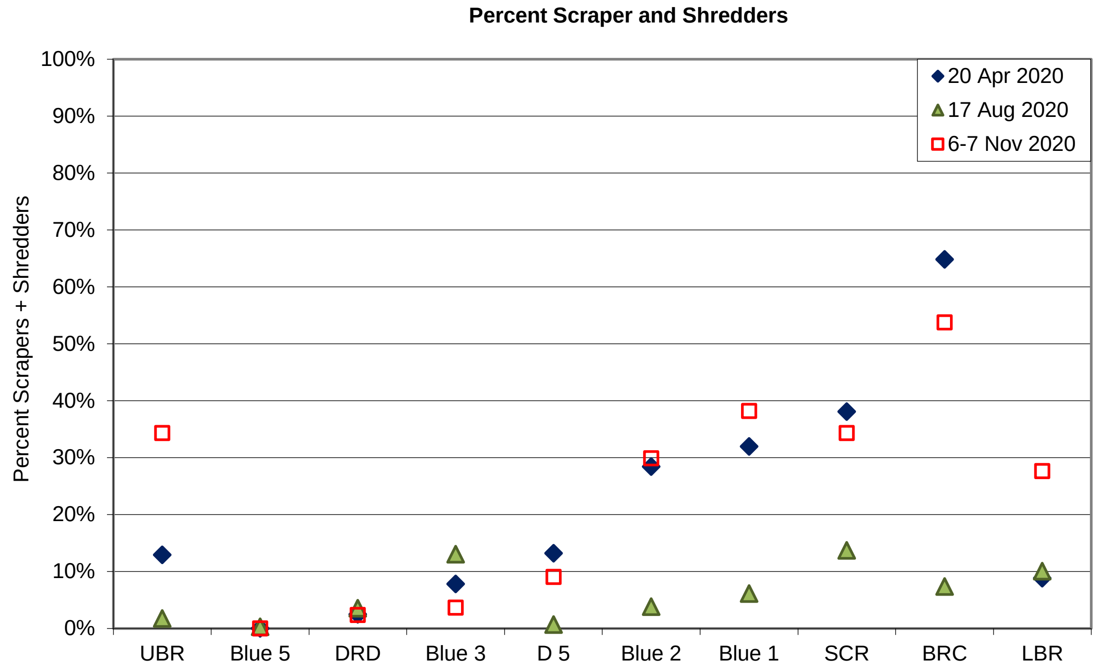

Figure 10. Percent Scrapers and Shredders from spring, summer, and fall sampling on the Blue River during 2020.

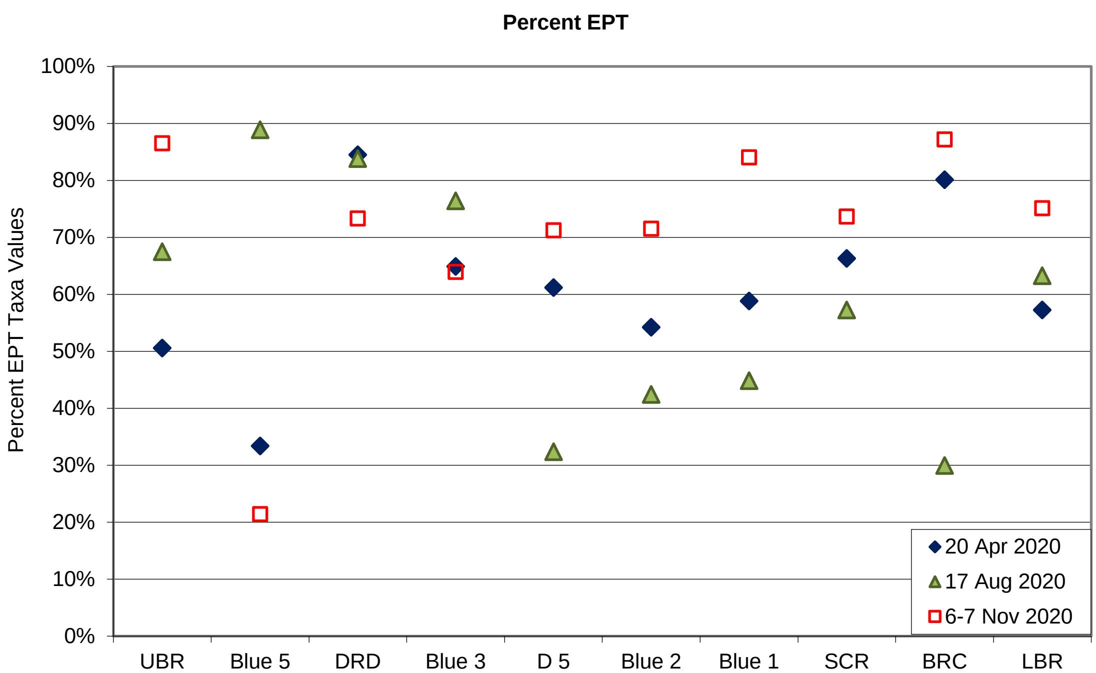

Figure 11. Percent EPT values from spring, summer and fall sampling on the Blue River during 2020.

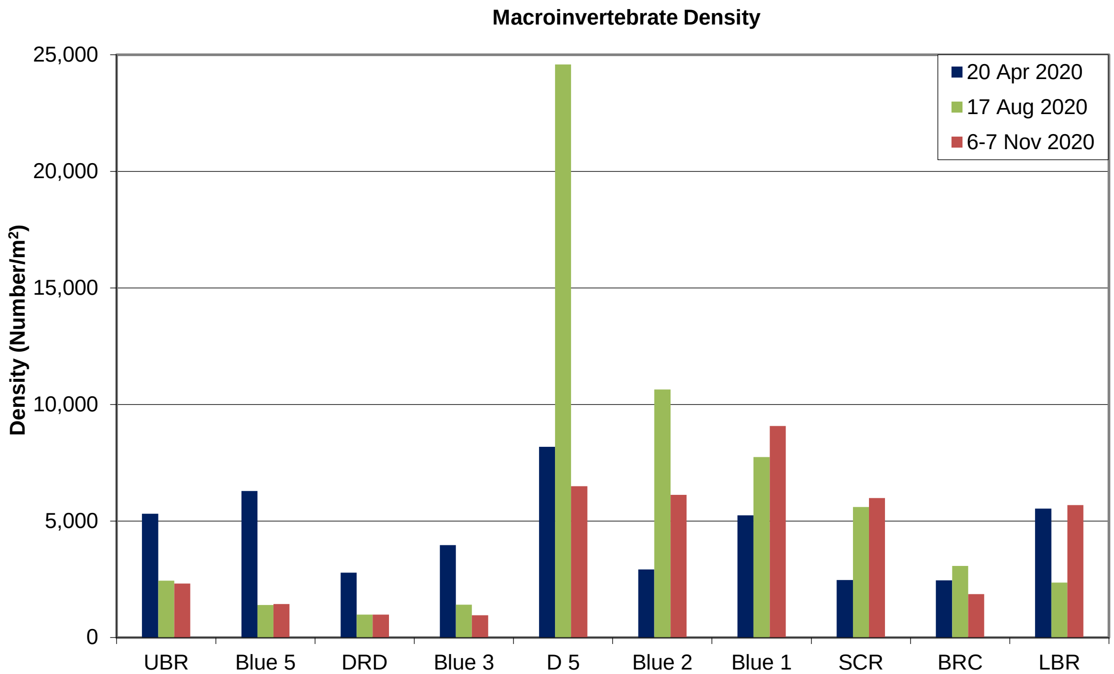

Figure 12. Estimated Density values (number/m2) from spring, summer and fall sampling on the Blue River, 2020.

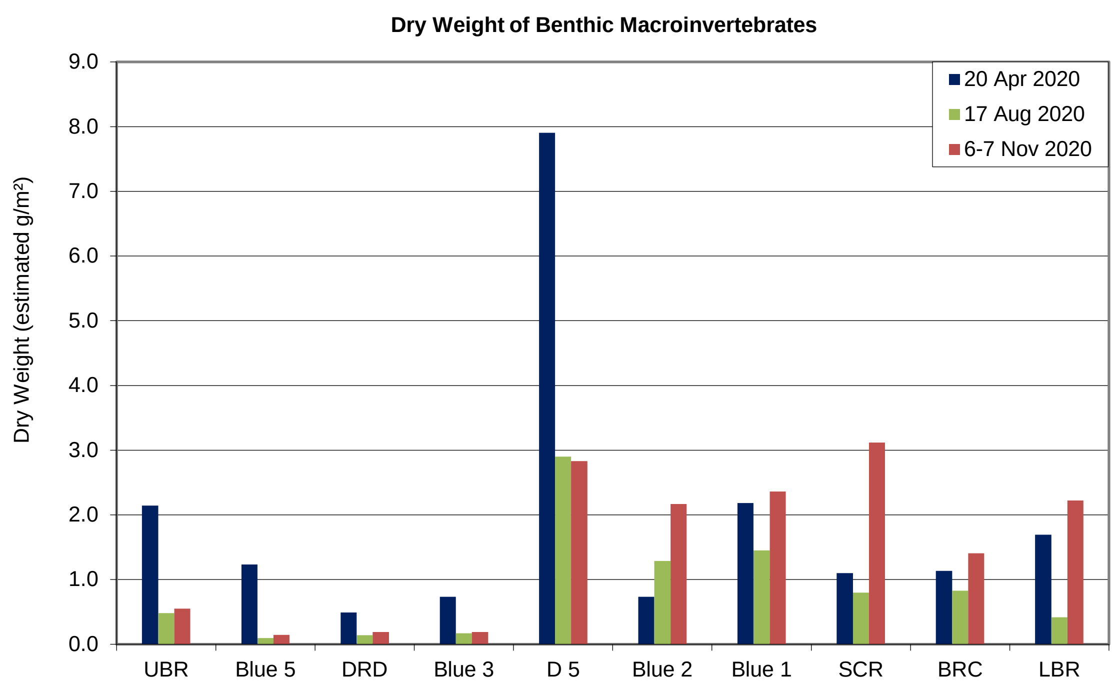

Figure 13. Estimated dry weight (g/m2) of benthic macroinvertebrates during spring, summer, and fall sampling on the Blue River, 2020.

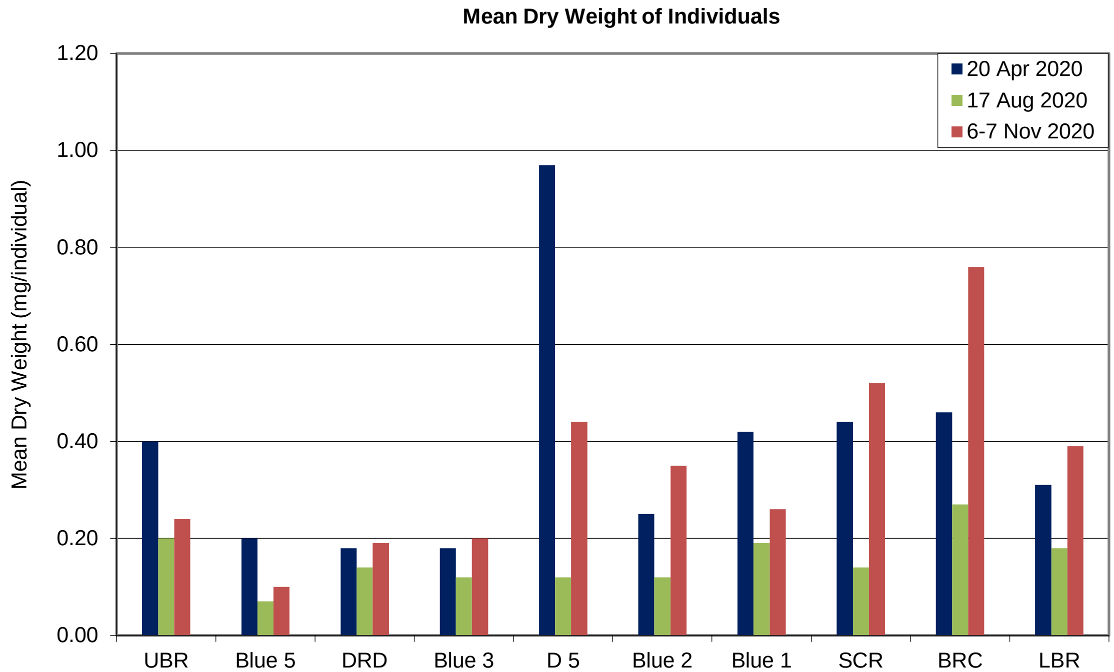

Figure 14. Mean dry weight (mg/individual) for benthic macroinvertebrate specimens during spring, summer, and fall of 2020.

Functional Feeding Groups

In order to provide an assessment of ecological function at each sampling location, benthic macroinvertebrates were classified according to their method of food acquisition (Tables 12-14, Figures 15-17). In healthy streams, all feeding groups should be adequately represented; however, it is common for certain groups (collector-gatherers) to be slightly dominant. An evaluation of functional guilds in the Blue River study area during the spring, summer, and fall of 2020 showed evidence of spatial and seasonal changes in community function (Figures 15-17). In general, the most tolerant group (collector-gatherers) was consistently abundant (and often dominated) at the three study sites below Dillon Reservoir (Blue 5, DRD, and Blue 3), while the most sensitive feeding groups (shredders and scrapers) were often absent or poorly represented at these locations (Tables 12-14). Farther downstream there were improvements in the representation of various feeding guilds; however, a reduction of specialized feeding groups was again observed at site LBR in the spring and summer, suggesting probable impacts from Green Mountain Reservoir (Figures 15 and 16). The large proportion of collector-gatherers at study sites below Dillon Reservoir was primarily due to one mayfly (*Baetis tricaudatus*) and chironomid midges. Improvements downstream were likely dependent on the stability of diverse food resources which may have also been tied to influences from tributaries.

Table 12. Relative abundance of functional feeding groups on 20 April 2020 at sampling locations in the Blue River study area.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
UBR	49.16%	30.29%	6.66%	6.29%	5.05%	2.56%
Blue 5	70.94%	22.89%	0.00%	0.00%	0.49%	5.68%
DRD	92.32%	1.54%	0.42%	2.09%	1.12%	2.51%
Blue 3	88.33%	0.88%	3.24%	4.61%	2.16%	0.78%
D 5	49.95%	28.89%	1.14%	12.10%	5.36%	2.56%
Blue 2	53.54%	9.75%	6.14%	22.30%	4.14%	4.14%
Blue 1	47.63%	7.86%	2.67%	29.30%	7.42%	5.12%
SCR	39.87%	6.96%	2.85%	35.28%	11.87%	3.16%
BRC	20.83%	6.52%	25.28%	39.59%	7.15%	0.64%
LBR	65.45%	20.51%	2.04%	6.81%	0.77%	4.42%

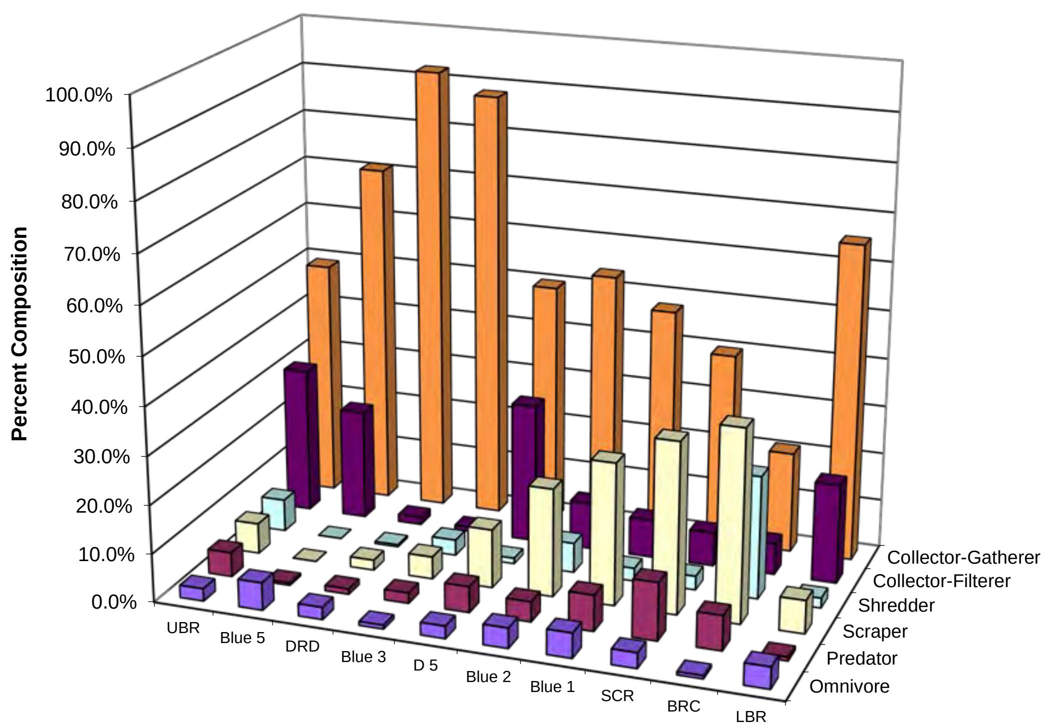

Figure 15. Functional feeding group composition for study sites in the Blue River study area, 20 April 2020.

Table 13. Relative abundance of functional feeding groups on 17 August 2020 at sampling locations in the Blue River study area.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
UBR	59.97%	22.81%	0.32%	1.44%	15.47%	0.00%
Blue 5	90.83%	6.11%	0.28%	0.00%	2.78%	0.00%
DRD	84.19%	5.53%	0.40%	3.16%	6.72%	0.00%
Blue 3	54.44%	18.06%	0.28%	12.78%	14.44%	0.00%
D 5	14.08%	82.40%	0.65%	0.05%	2.82%	0.00%
Blue 2	33.33%	54.96%	2.15%	1.68%	7.88%	0.00%
Blue 1	33.25%	51.86%	5.07%	1.05%	8.78%	0.00%
SCR	49.13%	22.69%	10.20%	3.54%	14.43%	0.00%
BRC	29.06%	56.22%	2.41%	4.95%	7.36%	0.00%
LBR	81.71%	3.62%	6.92%	3.13%	4.61%	0.00%

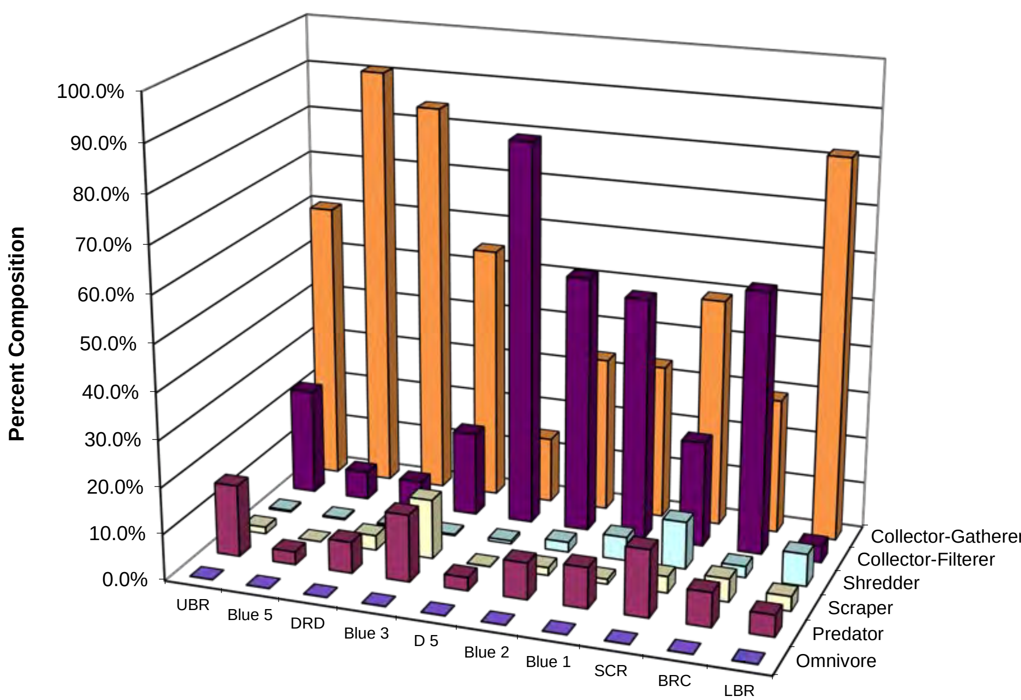

Figure 16. Functional feeding group composition for study sites in the Blue River study area, 17 August 2020.

Table 14. Relative abundance of functional feeding groups on 6-7 November 2020 at sampling locations in the Blue River study area.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
UBR	41.08%	18.35%	1.18%	33.16%	4.88%	1.35%
Blue 5	50.68%	6.50%	0.00%	0.00%	4.07%	38.75%
DRD	54.58%	1.99%	1.99%	0.40%	33.47%	7.57%
Blue 3	66.80%	5.74%	1.23%	2.46%	22.54%	1.23%
D 5	50.57%	24.96%	1.86%	7.18%	12.51%	2.93%
Blue 2	51.94%	7.43%	4.76%	25.14%	8.89%	1.84%
Blue 1	48.93%	5.99%	6.54%	31.69%	5.47%	1.37%
SCR	40.49%	15.38%	7.46%	26.87%	8.89%	0.91%
BRC	19.96%	18.91%	7.77%	46.01%	6.93%	0.42%
LBR	36.53%	23.46%	3.42%	24.21%	2.74%	9.64%

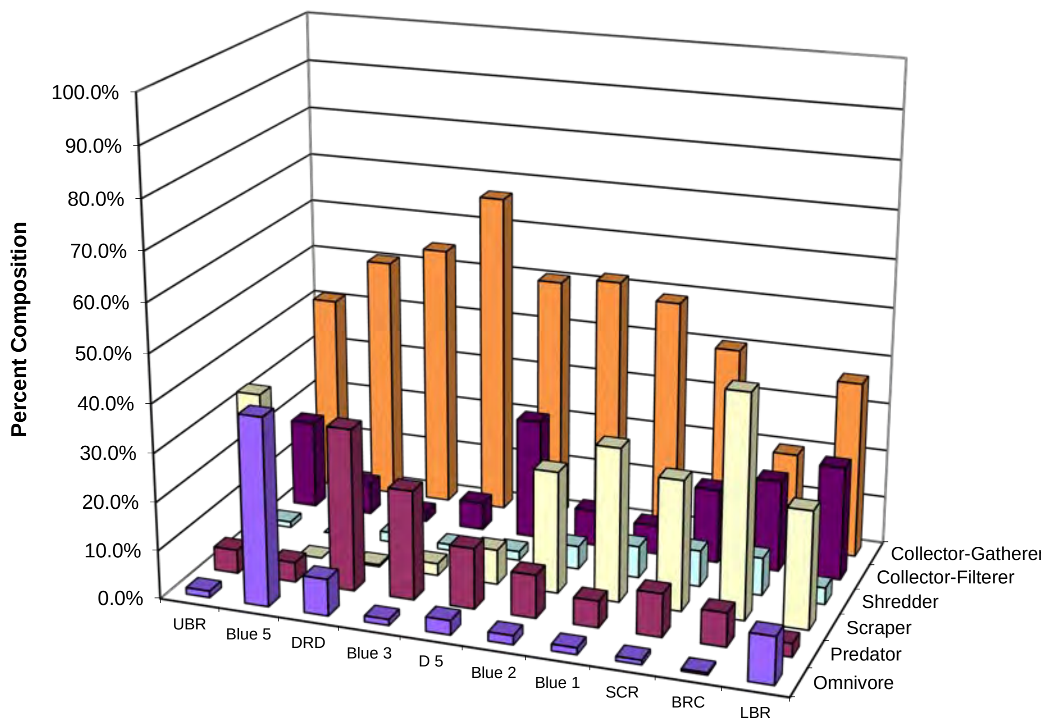

Figure 17. Functional feeding group composition for study sites in the Blue River study area, 6-7 November 2020.

Conclusion

In conclusion, the 2020 study of macroinvertebrate community structure and function in the Blue River indicated: 1) the "reference site" (UBR) consistently showed evidence of minor to moderate stress, despite supporting a benthic macroinvertebrate community that was considered in 'attainment' for aquatic life use, 2) the three study sites immediately downstream from Dillon Reservoir (Blue 5, DRD, and Blue 3) were consistently 'impaired' based on MMI v4 scores, and these results were supported by additional analysis tools, 3) recovery occurred in a downstream direction with some seasonal variability, and 4) impacts to benthic macroinvertebrate communities that are normally expected downstream from impoundments appeared to be less severe below Green Mountain Reservoir (at site LBR).

A fairly predictable recovery gradient of macroinvertebrate structure and function occurred downstream from Dillon Reservoir from site Blue 5 to site BRC during 2020. It is not known (currently) how biotic and abiotic factors may have collectively influenced the health of macroinvertebrate communities or how these influences may change seasonally. It is likely that the hypolimnetic releases altered the river temperature regime below the dam negatively impacting community structure and function, while the numerous tributaries ameliorated the natural thermal regime in the downstream portion of the study area. Additionally, the hydrology of the Blue River below Dillon Reservoir may also impact the structure and function of benthic macroinvertebrate communities. Research has shown that changes in timing, magnitude, and frequency of low and high flows can affect the abundance and diversity of macroinvertebrate communities (Ward and Stanford 1979, Stanford and Ward 2001). It is recommended that additional physical, chemical and biological factors be measured, such as water chemistry, water temperature, discharge, substrate, periphyton, and sedimentary detritus to ascertain how these factors may impact various longitudinal macroinvertebrate community patterns in the section of the Blue River between Dillon and Green Mountain reservoirs. Additional study sites may also be needed on tributaries along the Blue River to accurately assess the contributions from these additional water sources.

The results of this study, when compared with previous research conducted on the Blue River and other Colorado montane impounded rivers, indicated that there is a predictability in longitudinal patterns and recovery potential of macroinvertebrate structure and function in regulated Colorado streams. In the Blue River, the most rapid change in a sequential macroinvertebrate gradient occurred within the first 11.0 km below the impoundment. This and other studies indicated that the stretch of the river directly below the impoundment had depressed macroinvertebrate community health. While negative impacts to the abundance (Density) of individuals were less consistent below the dam, Dry Weight measurements indicated that most individuals were smaller in body size. Reductions in the Density and Dry Weight of benthic macroinvertebrates below Dillon Reservoir may impose food-web limitations, particularly when supporting the desired fish populations. Additional research may be needed to determine if the results from this seasonal benthic macroinvertebrate assessment can be extrapolated to other years and other seasons.

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Appendix A

Benthic Macroinvertebrate Data – Spring 2020

Table A1. Macroinvertebrate data collected from site UBR on 20 April 2020.

Blue River				
UBR		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	193	59	56	**1194**
Diphetor hageni	3	1		**16**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	4	9	6	**74**
Epeorus longimanus	22	27	18	**260**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Sweltsa sp.	4	11	5	**78**
Prostoia besametsa	49	15	27	**353**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	3	5	1	**35**
Kogotus modestus	4	2		**24**
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	67	48	36	**586**
Brachycentrus occidentalis				
Glossosoma sp.				
Arctopsyche grandis	12	1	3	**63**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.				
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/Orthocladius sp.	3	3	1	**28**
Diamesa sp.	3	3	1	**28**
Eukiefferiella sp.	17	5	10	**125**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	19	22	15	**218**
Microtendipes sp.				
Pagastia sp.	14	7	10	**121**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.	9	73	10	**357**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group		1		**4**
Tvetenia sp.	5	3	3	**43**

Table A1. cont. Macroinvertebrate data collected from site UBR on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	221	9	17	**958**
Antocha sp.	15	8	13	**140**
Dicranota sp.	1			**4**
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	22	13	31	**256**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	12	9	5	**101**
Protzia sp.				
Sperchon sp.	4	2		**24**
Crangonyx sp.				
Polycelis coronata	19	9	7	**136**
Enchytraeidae		3	19	**86**
Nematoda				
Totals	**725**	**348**	**294**	**5312**
Shannon Weaver Diversity				**3.69**
Calculated Evenness				**0.784**
EPT				**10**
% EPT				**50.55%**
Density				**5312**
% Non-Insect				**6.51%**
% Shredder/Scraper				**12.95%**
Taxa Richness				**26**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**2**
% Ephemeroptera individuals				**29.11%**
% Plectopera individuals				**9.22%**
% Trichoptera individuals				**12.22%**
Percent Chironomidae				**17.34%**
Percent Tolerant Organisms				**10.39%**
# Intolerant Taxa				**11**

Table A2. Macroinvertebrate data collected from site Blue 5 on 20 April 2020.

Blue River				
Blue 5		Sample		
20 April 2020	1	2	3	**Estimated #/m^2**
Ephemeroptera				
Baetis tricaudatus	221	161	152	**2070**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae			2	**8**
Sweltsa sp.				
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	2	2		**16**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis				
Glossosoma sp.				
Arctopsyche grandis				
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.				
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/Orthocladius sp.	29	30	7	**256**
Diamesa sp.	1	1	1	**12**
Eukiefferiella sp.	33	25	4	**241**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	43	23	44	**427**
Microtendipes sp.				
Pagastia sp.	29	28	25	**318**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	201	68	24	**1136**

Table A2. cont. Macroinvertebrate data collected from site Blue 5 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons		1	1	**8**
Simulium sp.	168	150	52	**1435**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus				
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.				
Crangonyx sp.				
Polycelis coronata	43	11	38	**357**
Enchytraeidae				
Nematoda				
Totals	**771**	**500**	**350**	**6288**
Shannon Weaver Diversity				**2.61**
Calculated Evenness				**0.706**
EPT				**4**
% EPT				**33.37%**
Density				**6,288**
% Non-Insect				**5.68%**
% Shredder/Scraper				**0.00%**
Taxa Richness				**13**
# Ephemeroptera Taxa				**1**
# Plecoptera Taxa				**2**
# Trichoptera Taxa				**1**
% Ephemeroptera individuals				**32.94%**
% Plectopera individuals				**0.37%**
% Trichoptera individuals				**0.06%**
Percent Chironomidae				**38.00%**
Percent Tolerant Organisms				**10.61%**
# Intolerant Taxa				**5**

Table A3. Macroinvertebrate data collected from site DRD on 20 April 2020.

Blue River				
DRD		Sample		
20 April 2020	1	2	3	**Estimated #/m^2**
Ephemeroptera				
Baetis tricaudatus	120	199	261	**2249**
Diphetor hageni				
Drunella doddsii			1	**4**
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.				
Epeorus longimanus	6	3	5	**55**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae	1		1	**8**
Sweltsa sp.		1	1	**8**
Prostoia besametsa		3		**12**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva				
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis				
Glossosoma sp.				
Arctopsyche grandis	1	1		**8**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.				
Rhyacophila brunnea				
Rhyacophila coloradensis	1			**4**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/Orthocladius sp.	6	17	4	**105**
Diamesa sp.				
Eukiefferiella sp.	2	1	1	**16**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	5	3	3	**43**
Microtendipes sp.				
Pagastia sp.	5	3	3	**43**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.			2	**8**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	3	4	10	**66**

Table A3. cont. Macroinvertebrate data collected from site DRD on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	8		1	**35**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	1	1	1	**12**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	1			**4**
Protzia sp.				
Sperchon sp.		2		**8**
Crangonyx sp.				
Polycelis coronata	3	13	2	**70**
Enchytraeidae	2	4		**24**
Nematoda				
Totals	**165**	**255**	**296**	**2782**
Shannon Weaver Diversity				**1.39**
Calculated Evenness				**0.321**
EPT				**8**
% EPT				**84.50%**
Density				**2,782**
% Non-Insect				**3.77%**
% Shredder/Scraper				**2.51%**
Taxa Richness				**20**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**2**
% Ephemeroptera individuals				**83.10%**
% Plectopera individuals				**0.98%**
% Trichoptera individuals				**0.42%**
Percent Chironomidae				**10.06%**
Percent Tolerant Organisms				**3.35%**
# Intolerant Taxa				**9**

Table A4. Macroinvertebrate data collected from site Blue 3 on 20 April 2020.

Blue River				
Blue 3		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	200	238	126	**2187**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	2	5	2	**35**
Epeorus longimanus	19	12	6	**144**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae	4		1	**20**
Sweltsa sp.	5	1	1	**28**
Prostoia besametsa	7	11		**70**
Zapada cinctipes	1			**4**
Zapada oregonensis group	10	1		**43**
Claassenia sabulosa				
Isoperla fulva	1	1		**8**
Kogotus modestus				
Megarcys signata	1			**4**
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	1			**4**
Glossosoma sp.				
Arctopsyche grandis	2	2		**16**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.				
Rhyacophila brunnea	1			**4**
Rhyacophila coloradensis	1			**4**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.	3			**12**
Cricotopus/*Orthocladius* sp.	28	22	23	**283**
Diamesa sp.				
Eukiefferiella sp.	16	15	11	**163**
Hydrobaenus sp.		1		**4**
Micropsectra/Tanytarsus sp.	24	4		**109**
Microtendipes sp.				
Pagastia sp.	46	27	14	**338**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.	16	6	1	**90**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	26	14	4	**171**

Table A4. cont. Macroinvertebrate data collected from site Blue 3 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae		1		**4**
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	2	1	1	**16**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	10	13	2	**97**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.		1	1	**8**
Protzia sp.				
Sperchon sp.	1	1		**8**
Crangonyx sp.				
Polycelis coronata	5	3		**32**
Enchytraeidae	10	5		**59**
Nematoda				
Totals	**442**	**385**	**193**	**3965**
Shannon Weaver Diversity				**2.68**
Calculated Evenness				**0.551**
EPT				**14**
% EPT				**64.90%**
Density				**3,965**
% Non-Insect				**2.65%**
% Shredder/Scraper				**7.84%**
Taxa Richness				**29**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**7**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**59.80%**
% Plectopera individuals				**4.41%**
% Trichoptera individuals				**0.69%**
Percent Chironomidae				**29.51%**
Percent Tolerant Organisms				**8.82%**
# Intolerant Taxa				**14**

Table A5. Macroinvertebrate data collected from site D 5 on 20 April 2020.

Blue River				
D 5		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	111	181	87	**1469**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	10	16	26	**202**
Epeorus longimanus	89	55	53	**764**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Sweltsa sp.	27	25	19	**276**
Prostoia besametsa	6	3	2	**43**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	3	1	9	**51**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	202	188	141	**2059**
Glossosoma sp.	3			**12**
Arctopsyche grandis	9	8	3	**78**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.	1	3	8	**47**
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.		1		**4**
Cricotopus/*Orthocladius* sp.	105	208	99	**1597**
Diamesa sp.	8	5	6	**74**
Eukiefferiella sp.	13	23	4	**156**
Hydrobaenus sp.		1		**4**
Micropsectra/Tanytarsus sp.	14	3	70	**338**
Microtendipes sp.				
Pagastia sp.	14	17	46	**299**
Parametriocnemus sp.	2			**8**
Pseudorthocladius sp.				
Rheocricotopus sp.		1	6	**28**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group	1			**4**
Tvetenia sp.		3		**12**

Table A5. cont. Macroinvertebrate data collected from site D 5 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.	1	1		**8**
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	32	26		**225**
Antocha sp.			5	**20**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	7	7	7	**82**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	4	2	10	**63**
Protzia sp.				
Sperchon sp.	2	1	6	**35**
Crangonyx sp.	1			**4**
Polycelis coronata	10	12	32	**210**
Enchytraeidae				
Nematoda	1	2		**12**
Totals	**676**	**793**	**639**	**8184**
Shannon Weaver Diversity				**3.31**
Calculated Evenness				**0.674**
EPT				**10**
% EPT				**61.15%**
Density				**8,184**
% Non-Insect				**3.94%**
% Shredder/Scraper				**13.24%**
Taxa Richness				**30**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**29.79%**
% Plectopera individuals				**4.51%**
% Trichoptera individuals				**26.85%**
Percent Chironomidae				**30.83%**
Percent Tolerant Organisms				**7.26%**
# Intolerant Taxa				**12**

Table A6. Macroinvertebrate data collected from site Blue 2 on 20 April 2020.

Blue River				
Blue 2		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	45	69	25	**539**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	10	16	8	**132**
Epeorus longimanus	47	43	38	**497**
Rhithrogena sp.			2	**8**
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Sweltsa sp.	6	8	2	**63**
Prostoia besametsa	1	1	1	**12**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	4		1	**20**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	11	8	5	**94**
Glossosoma sp.	2		1	**12**
Arctopsyche grandis	4	4		**32**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.	10	25	8	**167**
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group		1		**4**
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	20	109	7	**528**
Diamesa sp.		1		**4**
Eukiefferiella sp.	12	40	6	**225**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	3	3	1	**28**
Microtendipes sp.				
Pagastia sp.	3	18	1	**86**
Parametriocnemus sp.		2	2	**16**
Pseudorthocladius sp.				
Rheocricotopus sp.		4	1	**20**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.		1		**4**

Table A6. cont. Macroinvertebrate data collected from site Blue 2 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae		1		**4**
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	9	19	13	**159**
Antocha sp.	1			**4**
Dicranota sp.				
Hexatoma sp.		1		**4**
Coleoptera				
Heterlimnius corpulentus	10	11	6	**105**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	1	4		**20**
Protzia sp.				
Sperchon sp.	1	1		**8**
Crangonyx sp.				
Polycelis coronata	6	20	5	**121**
Enchytraeidae				
Nematoda				
Totals	**206**	**410**	**133**	**2916**
Shannon Weaver Diversity				**3.58**
Calculated Evenness				**0.745**
EPT				**12**
% EPT				**54.21%**
Density				**2,916**
% Non-Insect				**5.07%**
% Shredder/Scraper				**28.44%**
Taxa Richness				**28**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**40.45%**
% Plectopera individuals				**3.20%**
% Trichoptera individuals				**10.55%**
Percent Chironomidae				**31.24%**
Percent Tolerant Organisms				**9.61%**
# Intolerant Taxa				**14**

Table A7. Macroinvertebrate data collected from site Blue 1 on 20 April 2020.

Blue River				
Blue 1		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	79	93	83	**989**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens	2			**8**
Cinygmula sp.	24	19	27	**272**
Epeorus longimanus	75	99	149	**1252**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae		1	6	**28**
Sweltsa sp.	4	2	11	**66**
Prostoia besametsa	2	4	1	**28**
Zapada cinctipes				
Zapada oregonensis group			1	**4**
Claassenia sabulosa				
Isoperla fulva	16	7	11	**132**
Kogotus modestus				
Megarcys signata			1	**4**
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis	5	4	4	**51**
Glossosoma sp.	1			**4**
Arctopsyche grandis	7	6	14	**105**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.	10	11	7	**109**
Rhyacophila brunnea				
Rhyacophila coloradensis			4	**16**
Rhyacophila sibirica group	1	1		**8**
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/Orthocladius sp.	61	73	52	**721**
Diamesa sp.	1	2		**12**
Eukiefferiella sp.	16	20	20	**218**
Hydrobaenus sp.			1	**4**
Micropsectra/Tanytarsus sp.	8	3	17	**109**
Microtendipes sp.			1	**4**
Pagastia sp.	20	15	22	**221**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.	13	6	21	**156**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	2			**8**

Table A7. cont. Macroinvertebrate data collected from site Blue 1 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae		1		**4**
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	5	49	10	**249**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	4	3	6	**51**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	12	6	12	**117**
Protzia sp.				
Sperchon sp.	2	1	1	**16**
Crangonyx sp.				
Polycelis coronata	22	18	29	**268**
Enchytraeidae				
Nematoda				
Totals	**393**	**444**	**511**	**5238**
Shannon Weaver Diversity				**3.58**
Calculated Evenness				**0.716**
EPT				**17**
% EPT				**58.83%**
Density				**5,238**
% Non-Insect				**7.64%**
% Shredder/Scraper				**31.97%**
Taxa Richness				**32**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**48.22%**
% Plectopera individuals				**4.97%**
% Trichoptera individuals				**5.64%**
Percent Chironomidae				**27.74%**
Percent Tolerant Organisms				**8.83%**
# Intolerant Taxa				**17**

Table A8. Macroinvertebrate data collected from site SCR on 20 April 2020.

Blue River				
SCR		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	27	36	38	**392**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	22	23	36	**314**
Epeorus longimanus	51	43	46	**543**
Rhithrogena sp.	1			**4**
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Sweltsa sp.	10	4	11	**97**
Prostoia besametsa	2			**8**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	15	6	8	**113**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	2			**8**
Brachycentrus occidentalis	2	1	5	**32**
Glossosoma sp.				
Arctopsyche grandis	1	6	7	**55**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.	5	4	7	**63**
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	4	9	7	**78**
Diamesa sp.				
Eukiefferiella sp.	6	8	11	**97**
Hydrobaenus sp.		1		**4**
Micropsectra/Tanytarsus sp.	7	9	15	**121**
Microtendipes sp.		1		**4**
Pagastia sp.	8	11	6	**97**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.	11	4	4	**74**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group	3	3	2	**32**
Tvetenia sp.			2	**8**

Table A8. cont. Macroinvertebrate data collected from site SCR on 20 April 2020.

Other Diptera				
Atherix pachypus		1	2	**12**
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.	1		1	**8**
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	1	6	12	**74**
Antocha sp.		1	1	**8**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	10	8	9	**105**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.			2	**8**
Protzia sp.				
Sperchon sp.	2	1	3	**24**
Crangonyx sp.				
Polycelis coronata	2	4	14	**78**
Enchytraeidae				
Nematoda				
Totals	**193**	**190**	**249**	**2461**
Shannon Weaver Diversity				**3.79**
Calculated Evenness				**0.788**
EPT				**11**
% EPT				**66.30%**
Density				**2,461**
% Non-Insect				**4.43%**
% Shredder/Scraper				**38.13%**
Taxa Richness				**28**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**51.11%**
% Plectopera individuals				**8.86%**
% Trichoptera individuals				**6.33%**
Percent Chironomidae				**20.89%**
Percent Tolerant Organisms				**10.28%**
# Intolerant Taxa				**13**

Table A9. Macroinvertebrate data collected from site BRC on 20 April 2020.

Blue River				
BRC		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	8	6	4	**70**
Diphetor hageni				
Drunella doddsii				
Drunella grandis	1			**4**
Ephemerella dorothea infrequens	4	10	5	**74**
Cinygmula sp.	12	18	17	**183**
Epeorus longimanus	30	94	55	**694**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae		1		**4**
Sweltsa sp.		2		**8**
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa	4	3	1	**32**
Isoperla fulva	5	1	4	**39**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	2	10		**47**
Brachycentrus occidentalis	2	3	1	**24**
Glossosoma sp.	1	13	6	**78**
Arctopsyche grandis	7	3	6	**63**
Hydropsyche cockerelli	3	1		**16**
Hydropsyche oslari				
Lepidostoma sp.	21	113	25	**617**
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.		2		**8**
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	2	4	9	**59**
Diamesa sp.				
Eukiefferiella sp.	7	6	9	**86**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	9	10	1	**78**
Microtendipes sp.				
Pagastia sp.	5	2	2	**35**
Parametriocnemus sp.				
Pseudorthocladius sp.		1		**4**
Rheocricotopus sp.		11	3	**55**
Stempellinella sp.		1		**4**
Synorthocladius sp.				
Thienemannimyia genus group	2	5	2	**35**
Tvetenia sp.	1	1	2	**16**

Table A9. cont. Macroinvertebrate data collected from site BRC on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.	1			**4**
Clinocera sp.		1		**4**
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	1	1		**8**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus		9		**35**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	1	3		**16**
Protzia sp.	1			**4**
Sperchon sp.	3	4	1	**32**
Crangonyx sp.				
Polycelis coronata		1	3	**16**
Enchytraeidae				
Nematoda				
Totals	**133**	**340**	**156**	**2452**
Shannon Weaver Diversity				**3.53**
Calculated Evenness				**0.699**
EPT				**16**
% EPT				**80.13%**
Density				**2,452**
% Non-Insect				**2.70%**
% Shredder/Scraper				**64.86%**
Taxa Richness				**33**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**41.97%**
% Plectopera individuals				**3.34%**
% Trichoptera individuals				**34.82%**
Percent Chironomidae				**15.10%**
Percent Tolerant Organisms				**8.74%**
# Intolerant Taxa				**16**

Table A10. Macroinvertebrate data collected from site LBR on 20 April 2020.

Blue River				
LBR		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	112	124	131	**1423**
Diphetor hageni	1			**4**
Drunella doddsii				
Drunella grandis	5	2	4	**43**
Ephemerella dorothea infrequens	81	43	11	**524**
Cinygmula sp.	1		1	**8**
Epeorus longimanus	20	9	6	**136**
Rhithrogena sp.				
Paraleptophlebia sp.	16	6		**86**
Plecoptera				
Chloroperlidae				
Sweltsa sp.				
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	1		1	**8**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia	1			**4**
Trichoptera				
Brachycentrus americanus	21	15	10	**179**
Brachycentrus occidentalis	6	4	4	**55**
Glossosoma sp.	7	23	7	**144**
Arctopsyche grandis	7	9	3	**74**
Hydropsyche cockerelli	32	29	12	**283**
Hydropsyche oslari	14	3	2	**74**
Lepidostoma sp.	18	7	3	**109**
Rhyacophila brunnea				
Rhyacophila coloradensis	1	2		**12**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	80	90	47	**842**
Diamesa sp.	1	4		**20**
Eukiefferiella sp.	9	19	10	**148**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	12	1		**51**
Microtendipes sp.				
Pagastia sp.	19	8	5	**125**
Parametriocnemus sp.	1			**4**
Pseudorthocladius sp.				
Rheocricotopus sp.	75	11	4	**349**
Stempellinella sp.				
Synorthocladius sp.	1			**4**
Thienemannimyia genus group	4			**16**
Tvetenia sp.	1	6		**28**

Table A10. cont. Macroinvertebrate data collected from site LBR on 20 April 2020.

Other Diptera				
Atherix pachypus	1			**4**
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.		1		**4**
Lispoides aequifrons				
Simulium sp.	16	45	60	**469**
Antocha sp.		3		**12**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus				
Optioservus sp.	6	5	1	**47**
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.				
Crangonyx sp.				
Polycelis coronata	46	16	1	**245**
Enchytraeidae				
Nematoda				
Totals	**616**	**485**	**323**	**5534**
Shannon Weaver Diversity				**3.71**
Calculated Evenness				**0.736**
EPT				**17**
% EPT				**57.23%**
Density				**5,534**
% Non-Insect				**4.42%**
% Shredder/Scraper				**8.85%**
Taxa Richness				**33**
# Ephemeroptera Taxa				**7**
# Plecoptera Taxa				**2**
# Trichoptera Taxa				**8**
% Ephemeroptera individuals				**40.24%**
% Plectopera individuals				**0.21%**
% Trichoptera individuals				**16.78%**
Percent Chironomidae				**28.65%**
Percent Tolerant Organisms				**3.58%**
# Intolerant Taxa				**17**

Appendix B

Benthic Macroinvertebrate Data – Summer 2020

Table B1. Macroinvertebrate data collected from site UBR on 17 August 2020.

Blue River				
UBR		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	7	7	1	**59**
Baetis flavistriga		2		**8**
Baetis tricaudatus	77	44	64	**718**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis				
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	3		3	**24**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.	1		2	**12**
Sweltsa sp.	33	16	9	**225**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae	4	1	4	**35**
Diura knowltoni		2	1	**12**
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus	59	21	30	**427**
Brachycentrus occidentalis				
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	14	2	11	**105**
Hydropsyche oslari	1			**4**
Hydroptila sp.				
Ochrotrichia sp.		2		**8**
Lepidostoma sp.	2			**8**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	4	15	3	**86**
Diamesa sp.				
Eukiefferiella sp.	1	2	1	**16**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	1			**4**
Odontomesa sp.				
Pagastia sp.	7	4	10	**82**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.	4	5	2	**43**
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.			1	**4**

Table B1. cont. Macroinvertebrate data collected from site UBR on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.	1			**4**
Clinocera sp.	1			**4**
Simulium sp.		1	4	**20**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	46	33	29	**419**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.	7	4	5	**63**
Protzia sp.				
Sperchon sp.	1	4	4	**35**
Torrenticola sp.				
Enchytraeidae			4	**16**
Nematoda				
Totals	**274**	**165**	**188**	**2441**
Shannon Weaver Diversity				**3.23**
Calculated Evenness				**0.686**
EPT				**13**
% EPT				**67.46%**
Density				**2,441**
% Non-Insect				**4.63%**
% Shredder/Scraper				**1.75%**
Taxa Richness				**26**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**33.17%**
% Plectopera individuals				**11.64%**
% Trichoptera individuals				**22.65%**
Percent Chironomidae				**9.57%**
Percent Tolerant Organisms				**5.42%**
# Intolerant Taxa				**9**

Table B2. Macroinvertebrate data collected from site Blue 5 on 17 August 2020.

Blue River				
Blue 5		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.		1		**4**
Baetis flavistriga				
Baetis tricaudatus	81	129	99	**1198**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis				
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.		1		**4**
Sweltsa sp.	3	1	4	**32**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae				
Diura knowltoni				
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis				
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis				
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.				
Diamesa sp.				
Eukiefferiella sp.		2		**8**
Heleniella sp.				
Micropsectra/Tanytarsus sp.		1	1	**8**
Odontomesa sp.				
Pagastia sp.	1	2	3	**24**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.		1		**4**
Rheocricotopus sp.				
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.		4	1	**20**

Table B2. cont. Macroinvertebrate data collected from site Blue 5 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	1	17	3	**82**
Antocha sp.	1			**4**
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus		1		**4**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.		1		**4**
Protzia sp.				
Sperchon sp.				
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**88**	**161**	**111**	**1400**
Shannon Weaver Diversity				**0.98**
Calculated Evenness				**0.258**
EPT				**5**
% EPT				**88.89%**
Density				**1,400**
% Non-Insect				**0.28%**
% Shredder/Scraper				**0.28%**
Taxa Richness				**14**
# Ephemeroptera Taxa				**2**
# Plecoptera Taxa				**2**
# Trichoptera Taxa				**1**
% Ephemeroptera individuals				**86.11%**
% Plectopera individuals				**2.50%**
% Trichoptera individuals				**0.28%**
Percent Chironomidae				**4.44%**
Percent Tolerant Organisms				**1.39%**
# Intolerant Taxa				**5**

Table B3. Macroinvertebrate data collected from site DRD on 17 August 2020.

Blue River				
DRD		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	1		1	**8**
Baetis flavistriga				
Baetis tricaudatus	51	68	58	**687**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis				
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus	2	3	2	**28**
Epeorus longimanus		1		**4**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.	1			**4**
Sweltsa sp.	6	2		**32**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae		3		**12**
Diura knowltoni				
Isoperla sp.				
Megarcys signata	2			**8**
Skwala americana		3		**12**
Trichoptera				
Brachycentrus americanus		2		**8**
Brachycentrus occidentalis	3	2		**20**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	1			**4**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.		1		**4**
Diamesa sp.				
Eukiefferiella sp.		3		**12**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	2	1		**12**
Odontomesa sp.				
Pagastia sp.	1	3	1	**20**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.			1	**4**
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	2	14	2	**70**

Table B3. cont. Macroinvertebrate data collected from site DRD on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	2	4		**24**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.	1			**4**
Coleoptera				
Heterlimnius corpulentus	3			**12**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.				
Protzia sp.				
Sperchon sp.				
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**78**	**110**	**65**	**989**
Shannon Weaver Diversity				**2.02**
Calculated Evenness				**0.460**
EPT				**12**
% EPT				**83.79%**
Density				**989**
% Non-Insect				**0.00%**
% Shredder/Scraper				**3.56%**
Taxa Richness				**21**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**5**
# Trichoptera Taxa				**3**
% Ephemeroptera individuals				**73.91%**
% Plectopera individuals				**6.72%**
% Trichoptera individuals				**3.16%**
Percent Chironomidae				**12.25%**
Percent Tolerant Organisms				**2.37%**
# Intolerant Taxa				**11**

Table B4. Macroinvertebrate data collected from site Blue 3 on 17 August 2020.

Blue River				
Blue 3		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	2		2	**16**
Baetis flavistriga				
Baetis tricaudatus	67	30	23	**466**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis				
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus	8	16	9	**128**
Epeorus longimanus	8	1	2	**43**
Rhithrogena sp.	1			**4**
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.		1	2	**12**
Sweltsa sp.	15	2	21	**148**
Zapada cinctipes				
Zapada oregonensis group		1		**4**
Claassenia sabulosa				
Perlodidae				
Diura knowltoni				
Isoperla sp.				
Megarcys signata		2	2	**16**
Skwala americana		3	2	**20**
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis	7	41	2	**194**
Micrasema bactro				
Glossosoma sp.		1		**4**
Arctopsyche grandis			1	**4**
Hydropsyche oslari	2			**8**
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.		1		**4**
Cricotopus/Orthocladius sp.			1	**4**
Diamesa sp.				
Eukiefferiella sp.				
Heleniella sp.				
Micropsectra/Tanytarsus sp.	3	1	5	**35**
Odontomesa sp.				
Pagastia sp.	2	3	1	**24**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.	1	1	2	**16**
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.		4		**16**

Table B4. cont. Macroinvertebrate data collected from site Blue 3 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	10	1		**43**
Antocha sp.		1		**4**
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	28	8	10	**179**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.	1			**4**
Protzia sp.				
Sperchon sp.	1			**4**
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**157**	**118**	**85**	**1404**
Shannon Weaver Diversity				**3.21**
Calculated Evenness				**0.683**
EPT				**15**
% EPT				**76.39%**
Density				**1,404**
% Non-Insect				**0.56%**
% Shredder/Scraper				**13.06%**
Taxa Richness				**26**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**5**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**46.94%**
% Plectopera individuals				**14.17%**
% Trichoptera individuals				**15.28%**
Percent Chironomidae				**6.94%**
Percent Tolerant Organisms				**3.33%**
# Intolerant Taxa				**14**

Table B5. Macroinvertebrate data collected from site D 5 on 17 August 2020.

Blue River				
D 5		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	5	19	9	**128**
Baetis flavistriga				
Baetis tricaudatus	102	290	197	**2283**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis		1		**4**
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	1	1		**8**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.	1	2	1	**16**
Sweltsa sp.	24	66	46	**528**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae				
Diura knowltoni				
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	83	699	401	**4586**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	11	32	21	**249**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.		28	13	**159**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.	1	7	3	**43**
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	1	27	10	**148**
Diamesa sp.				
Eukiefferiella sp.	10	49	6	**252**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	3	2	1	**24**
Odontomesa sp.				
Pagastia sp.	4	76	22	**396**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.	3	9	3	**59**
Stempellinella sp.	1		1	**8**
Sublettea sp.				
Synorthocladius sp.			2	**8**
Thienemannimyia genus group		11	3	**55**
Tvetenia sp.	2	8	2	**47**

Table B5. cont. Macroinvertebrate data collected from site D 5 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	355	3104	517	**15411**
Antocha sp.		1	2	**12**
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	9	7	11	**105**
Optioservus sp.				
Zaitzevia parvula		1		**4**
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.		6	1	**28**
Protzia sp.				
Sperchon sp.	1	3	2	**24**
Torrenticola sp.				
Enchytraeidae				
Nematoda		1		**4**
Totals	**617**	**4450**	**1274**	**24589**
Shannon Weaver Diversity				**1.84**
Calculated Evenness				**0.391**
EPT				**9**
% EPT				**32.38%**
Density				**24,589**
% Non-Insect				**0.22%**
% Shredder/Scraper				**0.69%**
Taxa Richness				**26**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**2**
# Trichoptera Taxa				**3**
% Ephemeroptera individuals				**9.86%**
% Plectopera individuals				**2.21%**
% Trichoptera individuals				**20.31%**
Percent Chironomidae				**4.21%**
Percent Tolerant Organisms				**1.32%**
# Intolerant Taxa				**10**

Table B6. Macroinvertebrate data collected from site Blue 2 on 17 August 2020.

Blue River				
Blue 2		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	2		2	**16**
Baetis flavistriga				
Baetis tricaudatus	153	305	176	**2458**
Diphetor hageni				
Drunella coloradensis		1		**4**
Drunella grandis	1		1	**8**
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	1	2	1	**16**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.		3	2	**20**
Sweltsa sp.	30	75	54	**617**
Zapada cinctipes	1			**4**
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae	3			**12**
Diura knowltoni				
Isoperla sp.			1	**4**
Megarcys signata		1	1	**8**
Skwala americana				
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis	61	19	21	**392**
Micrasema bactro	1			**4**
Glossosoma sp.	30	6	3	**152**
Arctopsyche grandis	96	31	19	**566**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.	12	30	15	**221**
Rhyacophila sibirica group	1	1		**8**
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.	6	1	2	**35**
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	6	11	5	**86**
Diamesa sp.				
Eukiefferiella sp.	21	15	6	**163**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	8	21	2	**121**
Odontomesa sp.				
Pagastia sp.	26	18	13	**221**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.	11	14	2	**105**
Stempellinella sp.	5	32	8	**175**
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group	3	4	1	**32**
Tvetenia sp.	40	7	1	**187**

Table B6. cont. Macroinvertebrate data collected from site Blue 2 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	739	218	257	**4706**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.		1	1	**8**
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	17	19	13	**190**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.	3	7	4	**55**
Protzia sp.		2		**8**
Sperchon sp.	6	2		**32**
Torrenticola sp.				
Enchytraeidae				
Nematoda	1			**4**
Totals	**1285**	**846**	**611**	**10642**
Shannon Weaver Diversity				**2.79**
Calculated Evenness				**0.549**
EPT				**18**
% EPT				**42.41%**
Density				**10,642**
% Non-Insect				**0.91%**
% Shredder/Scraper				**3.83%**
Taxa Richness				**34**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**23.52%**
% Plectopera individuals				**6.24%**
% Trichoptera individuals				**12.65%**
Percent Chironomidae				**10.54%**
Percent Tolerant Organisms				**3.54%**
# Intolerant Taxa				**18**

Table B7. Macroinvertebrate data collected from site Blue 1 on 17 August 2020.

Blue River				
Blue 1		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	1	1	1	**12**
Baetis flavistriga	1			**4**
Baetis tricaudatus	202	158	106	**1807**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis	2	1		**12**
Ephemerella dorothea infrequens	1			**4**
Serratella sp.	1	1		**8**
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	9	2	5	**63**
Rhithrogena sp.	1			**4**
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae			1	**4**
Suwallia sp.	1	1		**8**
Sweltsa sp.	39	59	15	**438**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae	5	3	3	**43**
Diura knowltoni				
Isoperla sp.				
Megarcys signata	1	3		**16**
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	10	4	3	**66**
Micrasema bactro				
Glossosoma sp.	1			**4**
Arctopsyche grandis	68	50	33	**586**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.	51	36	13	**388**
Rhyacophila sibirica group		1		**4**
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.	4	2	1	**28**
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	9	11	2	**86**
Diamesa sp.				
Eukiefferiella sp.	13	7	5	**97**
Heleniella sp.			1	**4**
Micropsectra/Tanytarsus sp.	11	11	1	**90**
Odontomesa sp.				
Pagastia sp.	13	8	3	**94**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.		1		**4**
Rheocricotopus sp.	11	14		**97**
Stempellinella sp.	1	1	1	**12**
Sublettea sp.				
Synorthocladius sp.		1		**4**
Thienemannimyia genus group	3	2		**20**
Tvetenia sp.	19	11	1	**121**

Table B7. cont. Macroinvertebrate data collected from site Blue 1 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.	1			**4**
Clinocera sp.				
Simulium sp.	415	137	311	**3345**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	15	14	9	**148**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.	1			**4**
Lebertia sp.	8	6	4	**70**
Protzia sp.				
Sperchon sp.	4	5	2	**43**
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**922**	**551**	**521**	**7742**
Shannon Weaver Diversity				**2.78**
Calculated Evenness				**0.538**
EPT				**18**
% EPT				**44.83%**
Density				**7,742**
% Non-Insect				**1.50%**
% Shredder/Scraper				**6.12%**
Taxa Richness				**36**
# Ephemeroptera Taxa				**8**
# Plecoptera Taxa				**5**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**24.72%**
% Plectopera individuals				**6.57%**
% Trichoptera individuals				**13.54%**
Percent Chironomidae				**8.43%**
Percent Tolerant Organisms				**3.91%**
# Intolerant Taxa				**17**

Table B8. Macroinvertebrate data collected from site SCR on 17 August 2020.

Blue River				
SCR		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.		1		**4**
Acentrella sp.	4	4	1	**35**
Baetis flavistriga				
Baetis tricaudatus	80	134	109	**1252**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis		17	20	**144**
Ephemerella dorothea infrequens				
Serratella sp.		1		**4**
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	4	5	3	**47**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.			1	**4**
Sweltsa sp.	29	36	60	**485**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa			1	**4**
Perlodidae	4	3	1	**32**
Diura knowltoni				
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus			3	**12**
Brachycentrus occidentalis	14	31	54	**384**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	4	25	29	**225**
Hydropsyche oslari				
Hydroptila sp.		1	1	**8**
Ochrotrichia sp.				
Lepidostoma sp.	35	43	67	**563**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.			1	**4**
Cardiocladius sp.				
Cladotanytarsus sp.		2		**8**
Cricotopus/Orthocladius sp.	22	45	68	**524**
Diamesa sp.	1			**4**
Eukiefferiella sp.	8	2	11	**82**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	11	13	6	**117**
Odontomesa sp.				
Pagastia sp.	15	15	29	**229**
Parametriocnemus sp.	1	4	2	**28**
Phaenopsectra sp.				
Polypedilum sp.			1	**4**
Rheocricotopus sp.		37	5	**163**
Stempellinella sp.	16	14	11	**159**
Sublettea sp.				
Synorthocladius sp.	5	11	1	**66**
Thienemannimyia genus group	2	8	14	**94**
Tvetenia sp.		9	14	**90**

Table B8. cont. Macroinvertebrate data collected from site SCR on 17 August 2020.

Other Diptera				
Atherix pachypus			1	**4**
Chelifera/Neoplasta sp.	8	3	6	**66**
Clinocera sp.				
Simulium sp.	4	39	83	**489**
Antocha sp.				
Dicranota sp.			1	**4**
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	9	19	9	**144**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.	2	7	9	**70**
Protzia sp.			1	**4**
Sperchon sp.	3	4	3	**39**
Torrenticola sp.				
Enchytraeidae				
Nematoda		1		**4**
Totals	**281**	**534**	**626**	**5599**
Shannon Weaver Diversity				**3.94**
Calculated Evenness				**0.751**
EPT				**15**
% EPT				**57.25%**
Density				**5,599**
% Non-Insect				**2.08%**
% Shredder/Scraper				**13.74%**
Taxa Richness				**38**
# Ephemeroptera Taxa				**6**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**26.58%**
% Plectopera individuals				**9.37%**
% Trichoptera individuals				**21.30%**
Percent Chironomidae				**28.04%**
Percent Tolerant Organisms				**5.69%**
# Intolerant Taxa				**16**

Table B9. Macroinvertebrate data collected from site BRC on 17 August 2020.

Blue River				
BRC		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	3	7	3	**51**
Baetis flavistriga				
Baetis tricaudatus	21	21	18	**233**
Diphetor hageni	1		1	**8**
Drunella coloradensis				
Drunella grandis	3	7	6	**63**
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.				
Sweltsa sp.	1	14	4	**74**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa	2		1	**12**
Perlodidae				
Diura knowltoni				
Isoperla sp.		5		**20**
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus		2		**8**
Brachycentrus occidentalis	2	31	9	**163**
Micrasema bactro				
Glossosoma sp.		1		**4**
Arctopsyche grandis	15	19	14	**187**
Hydropsyche oslari				
Hydroptila sp.		3	2	**20**
Ochrotrichia sp.				
Lepidostoma sp.		12	7	**74**
Rhyacophila sibirica group				
Oligophlebodes sp.		1		**4**
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	17	49	28	**365**
Diamesa sp.				
Eukiefferiella sp.	7	4	3	**55**
Heleniella sp.				
Micropsectra/Tanytarsus sp.		2	1	**12**
Odontomesa sp.				
Pagastia sp.	5	14	8	**105**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.		1	2	**12**
Stempellinella sp.		14	4	**70**
Sublettea sp.		1		**4**
Synorthocladius sp.		6		**24**
Thienemannimyia genus group		5	2	**28**
Tvetenia sp.	1			**4**

Table B9. cont. Macroinvertebrate data collected from site BRC on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.			3	**12**
Clinocera sp.				
Simulium sp.	243	42	47	**1287**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus		3	3	**24**
Optioservus sp.	2	8	6	**63**
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.			5	**20**
Protzia sp.				
Sperchon sp.		3	9	**47**
Torrenticola sp.	1	3		**16**
Enchytraeidae				
Nematoda				
Totals	**324**	**278**	**186**	**3069**
Shannon Weaver Diversity				**3.28**
Calculated Evenness				**0.662**
EPT				**14**
% EPT				**29.95%**
Density				**3,069**
% Non-Insect				**2.66%**
% Shredder/Scraper				**7.36%**
Taxa Richness				**31**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**11.55%**
% Plectopera individuals				**3.43%**
% Trichoptera individuals				**14.97%**
Percent Chironomidae				**22.08%**
Percent Tolerant Organisms				**4.82%**
# Intolerant Taxa				**12**

Table B10. Macroinvertebrate data collected from site LBR on 17 August 2020.

Blue River				
LBR		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	24	18	27	**268**
Baetis flavistriga			25	**97**
Baetis tricaudatus	39	89	20	**574**
Diphetor hageni	5	20	9	**132**
Drunella coloradensis				
Drunella grandis	1	5	3	**35**
Ephemerella dorothea infrequens		17	11	**109**
Serratella sp.				
Epeorus sp.		1	1	**8**
Epeorus deceptivus				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.	1	6	2	**35**
Plecoptera				
Chloroperlidae		1		**4**
Suwallia sp.				
Sweltsa sp.		2		**8**
Zapada cinctipes		1		**4**
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae			1	**4**
Diura knowltoni				
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis				
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis		10	4	**55**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.	4	20	17	**159**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	6	5	4	**59**
Diamesa sp.				
Eukiefferiella sp.			3	**12**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	30	4	5	**152**
Odontomesa sp.	1			**4**
Pagastia sp.	33	11	33	**299**
Parametriocnemus sp.	3	2		**20**
Phaenopsectra sp.	2			**8**
Polypedilum sp.				
Rheocricotopus sp.	22	2	8	**125**
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.	3	4	3	**39**
Thienemannimyia genus group	7	11	3	**82**
Tvetenia sp.		1		**4**

Table B10. cont. Macroinvertebrate data collected from site LBR on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	1	5	2	**32**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus				
Optioservus sp.	1	3	2	**24**
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.				
Protzia sp.				
Sperchon sp.		2	1	**12**
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**183**	**240**	**184**	**2364**
Shannon Weaver Diversity				**3.74**
Calculated Evenness				**0.778**
EPT				**14**
% EPT				**63.26%**
Density				**2,364**
% Non-Insect				**0.49%**
% Shredder/Scraper				**10.05%**
Taxa Richness				**28**
# Ephemeroptera Taxa				**8**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**2**
% Ephemeroptera individuals				**53.38%**
% Plectopera individuals				**0.82%**
% Trichoptera individuals				**9.06%**
Percent Chironomidae				**33.94%**
Percent Tolerant Organisms				**7.74%**
# Intolerant Taxa				**12**

Appendix C

Benthic Macroinvertebrate Data – Fall 2020

Table C1. Macroinvertebrate data collected from site UBR on 7 November 2020.

Blue River				
UBR		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	73	22	86	**702**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	5		2	**28**
Epeorus sp.	72	44	74	**737**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.		6	3	**35**
Paraleuctra sp.				
Prostoia besametsa	1	2	3	**24**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae	4	3	5	**47**
Diura knowltoni				
Isoperla fulva		1	1	**8**
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus	13	15	24	**202**
Brachycentrus occidentalis				
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	12	17	23	**202**
Hydropsyche cockerelli				
Lepidostoma sp.			1	**4**
Rhyacophila coloradensis		1	1	**8**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.				
Diamesa sp.				
Eukiefferiella sp.			1	**4**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.				
Microtendipes sp.				
Pagastia sp.	2	2	4	**32**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.				

Table C1. cont. Macroinvertebrate data collected from site UBR on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.		1	4	**20**
Antocha sp.	2	7	9	**70**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	4	10	19	**128**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.		1		**4**
Protzia sp.				
Sperchon sp.			1	**4**
Torrenticola sp.				
Polycelis coronata	3	1	4	**32**
Enchytraeidae			3	**12**
Nematoda	1		1	**8**
Totals	**192**	**133**	**269**	**2311**
Shannon Weaver Diversity				**2.80**
Calculated Evenness				**0.639**
EPT				**11**
% EPT				**86.53%**
Density				**2,311**
% Non-Insect				**2.53%**
% Shredder/Scraper				**34.34%**
Taxa Richness				**21**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**63.64%**
% Plectopera individuals				**4.88%**
% Trichoptera individuals				**18.01%**
Percent Chironomidae				**1.52%**
Percent Tolerant Organisms				**1.01%**
# Intolerant Taxa				**12**

Table C2. Macroinvertebrate data collected from site Blue 5 on 7 November 2020.

Blue River				
Blue 5		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.		2	1	**12**
Baetis tricaudatus	18	15	29	**241**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.				
Epeorus sp.				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.	3	5	4	**47**
Paraleuctra sp.				
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis		1		**4**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis				
Hydropsyche cockerelli				
Lepidostoma sp.				
Rhyacophila coloradensis			1	**4**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	8	4	12	**94**
Diamesa sp.	3	8	12	**90**
Eukiefferiella sp.	1	8	3	**47**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.	1	1		**8**
Microtendipes sp.				
Pagastia sp.	1	5	22	**109**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	4	15	14	**128**

Table C2. cont. Macroinvertebrate data collected from site Blue 5 on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.	9	3	11	**90**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus				
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	2			**8**
Protzia sp.				
Sperchon sp.				
Torrenticola sp.				
Polycelis coronata	46	33	64	**555**
Enchytraeidae				
Nematoda				
Totals	**96**	**100**	**173**	**1437**
Shannon Weaver Diversity				**2.82**
Calculated Evenness				**0.740**
EPT				**5**
% EPT				**21.41%**
Density				**1,437**
% Non-Insect				**39.30%**
% Shredder/Scraper				**0.00%**
Taxa Richness				**14**
# Ephemeroptera Taxa				**2**
# Plecoptera Taxa				**1**
# Trichoptera Taxa				**2**
% Ephemeroptera individuals				**17.62%**
% Plectopera individuals				**3.25%**
% Trichoptera individuals				**0.54%**
Percent Chironomidae				**33.06%**
Percent Tolerant Organisms				**4.34%**
# Intolerant Taxa				**5**

Table C3. Macroinvertebrate data collected from site DRD on 7 November 2020.

Blue River				
DRD		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.			1	**4**
Baetis tricaudatus	19	46	27	**357**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.		1		**4**
Epeorus sp.				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.	11	52	13	**295**
Paraleuctra sp.				
Prostoia besametsa				
Zapada cinctipes		1		**4**
Zapada oregonensis group		1	1	**8**
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae		1	1	**8**
Diura knowltoni				
Isoperla fulva			1	**4**
Megarcys signata		3		**12**
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	1			**4**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis		1		**4**
Hydropsyche cockerelli				
Lepidostoma sp.			1	**4**
Rhyacophila coloradensis	2			**8**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.		1		**4**
Cricotopus/*Orthocladius* sp.	2	2	1	**20**
Diamesa sp.	2	4	1	**28**
Eukiefferiella sp.	2			**8**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.				
Microtendipes sp.				
Pagastia sp.	2		2	**16**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	2	8	2	**47**

Table C3. cont. Macroinvertebrate data collected from site DRD on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.	2	1		**12**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	3	3	4	**39**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.				
Torrenticola sp.				
Polycelis coronata	5	12	2	**74**
Enchytraeidae		2	2	**16**
Nematoda				
Totals	**53**	**139**	**59**	**980**
Shannon Weaver Diversity				**2.81**
Calculated Evenness				**0.620**
EPT				**13**
% EPT				**73.31%**
Density				**980**
% Non-Insect				**9.16%**
% Shredder/Scraper				**2.39%**
Taxa Richness				**23**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**37.45%**
% Plectopera individuals				**33.86%**
% Trichoptera individuals				**1.99%**
Percent Chironomidae				**12.35%**
Percent Tolerant Organisms				**2.39%**
# Intolerant Taxa				**12**

Table C4. Macroinvertebrate data collected from site Blue 3 on 7 November 2020.

Blue River				
Blue 3		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	9	45	31	**330**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.		1	1	**8**
Epeorus sp.		1	3	**16**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.	12	11	18	**159**
Paraleuctra sp.				
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group		3		**12**
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae		2	2	**16**
Diura knowltoni				
Isoperla fulva		1		**4**
Megarcys signata	2			**8**
Skwala americana				
Trichoptera				
Brachycentrus americanus		1		**4**
Brachycentrus occidentalis		1	2	**12**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	3	3	4	**39**
Hydropsyche cockerelli				
Lepidostoma sp.				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	3	10	5	**70**
Diamesa sp.				
Eukiefferiella sp.	2	2	2	**24**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.		1		**4**
Microtendipes sp.				
Pagastia sp.	3			**12**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.				

Table C4. cont. Macroinvertebrate data collected from site Blue 3 on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.		1		**4**
Wiedemannia sp.				
Simulium sp.				
Antocha sp.	1			**4**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	13	19	14	**179**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.		1	1	**8**
Protzia sp.				
Sperchon sp.	1	1	2	**16**
Torrenticola sp.				
Polycelis coronata	1	2		**12**
Enchytraeidae	2	1		**12**
Nematoda				
Totals	**52**	**107**	**85**	**953**
Shannon Weaver Diversity				**3.03**
Calculated Evenness				**0.679**
EPT				**11**
% EPT				**63.93%**
Density				**953**
% Non-Insect				**4.92%**
% Shredder/Scraper				**3.69%**
Taxa Richness				**22**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**5**
# Trichoptera Taxa				**3**
% Ephemeroptera individuals				**37.30%**
% Plectopera individuals				**20.90%**
% Trichoptera individuals				**5.74%**
Percent Chironomidae				**11.48%**
Percent Tolerant Organisms				**6.56%**
# Intolerant Taxa				**12**

Table C5. Macroinvertebrate data collected from site D 5 on 7 November 2020.

Blue River				
D 5		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.		1		**4**
Baetis tricaudatus	183	113	138	**1683**
Drunella doddsii				
Drunella grandis		2		**8**
Ephemerella dorothea infrequens				
Cinygmula sp.	53		4	**221**
Epeorus sp.	32	5	6	**167**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.	114	60	12	**721**
Paraleuctra sp.				
Prostoia besametsa		1		**4**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva	1			**4**
Megarcys signata	1			**4**
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	64	173	102	**1314**
Micrasema bactro				
Glossosoma sp.	7	6	5	**70**
Arctopsyche grandis	29	32	16	**299**
Hydropsyche cockerelli				
Lepidostoma sp.	5	23	2	**117**
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	41	32	25	**380**
Diamesa sp.	17	10	10	**144**
Eukiefferiella sp.	5	9		**55**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.	2			**8**
Microtendipes sp.				
Pagastia sp.	71	63	41	**679**
Polypedilum sp.				
Pseudorthocladius sp.		2		**8**
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group		4		**16**
Tvetenia sp.				

Table C5. cont. Macroinvertebrate data collected from site D 5 on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.	1	2		**12**
Wiedemannia sp.				
Simulium sp.			1	**4**
Antocha sp.	9	19	2	**117**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	33	11	8	**202**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.	2	2	1	**20**
Sperchon sp.	1	1		**8**
Torrenticola sp.				
Polycelis coronata	28	20	1	**190**
Enchytraeidae				
Nematoda	2	3	2	**28**
Totals	**701**	**594**	**376**	**6487**
Shannon Weaver Diversity				**3.35**
Calculated Evenness				**0.697**
EPT				**13**
% EPT				**71.21%**
Density				**6,487**
% Non-Insect				**3.77%**
% Shredder/Scraper				**9.04%**
Taxa Richness				**28**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**32.14%**
% Plectopera individuals				**11.31%**
% Trichoptera individuals				**27.77%**
Percent Chironomidae				**19.87%**
Percent Tolerant Organisms				**1.38%**
# Intolerant Taxa				**14**

Table C6. Macroinvertebrate data collected from site Blue 2 on 7 November 2020.

Blue River				
Blue 2		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	180	107	175	**1791**
Drunella doddsii			1	**4**
Drunella grandis			2	**8**
Ephemerella dorothea infrequens				
Cinygmula sp.	28	22	31	**314**
Epeorus sp.	96	65	83	**946**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.	1	1		**8**
Chloroperlidae				
Sweltsa sp.	45	27	41	**438**
Paraleuctra sp.	1			**4**
Prostoia besametsa	2	4	4	**39**
Zapada cinctipes				
Zapada oregonensis group	1			**4**
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva	2	1		**12**
Megarcys signata	1	1		**8**
Skwala americana				
Trichoptera				
Brachycentrus americanus			1	**4**
Brachycentrus occidentalis	11	9	19	**152**
Micrasema bactro				
Glossosoma sp.	30	38		**264**
Arctopsyche grandis	14	27	12	**206**
Hydropsyche cockerelli				
Lepidostoma sp.	6	6	31	**167**
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	27	9	25	**237**
Diamesa sp.	23	6	5	**132**
Eukiefferiella sp.	32	39	18	**345**
Heterotrissocladius sp.			1	**4**
Micropsectra/Tanytarsus sp.	4	2		**24**
Microtendipes sp.		1		**4**
Pagastia sp.	34	27	28	**345**
Polypedilum sp.	9	1	8	**70**
Pseudorthocladius sp.		1	1	**8**
Rheocricotopus sp.		1	1	**8**
Synorthocladius sp.				
Thienemannimyia genus group	1			**4**
Tvetenia sp.				

Table C6. cont. Macroinvertebrate data collected from site Blue2 on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.			1	**4**
Wiedemannia sp.				
Simulium sp.	13	10		**90**
Antocha sp.	3	2	5	**39**
Dicranota sp.				
Hexatoma sp.	1		1	**8**
Coleoptera				
Heterlimnius corpulentus	20	11	31	**241**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	1	1	3	**20**
Protzia sp.	1	1	1	**12**
Sperchon sp.	1	4	2	**28**
Torrenticola sp.				
Polycelis coronata	11	13	5	**113**
Enchytraeidae				
Nematoda	1	2		**12**
Totals	**600**	**439**	**536**	**6117**
Shannon Weaver Diversity				**3.65**
Calculated Evenness				**0.695**
EPT				**17**
% EPT				**71.49%**
Density				**6,117**
% Non-Insect				**2.98%**
% Shredder/Scraper				**29.90%**
Taxa Richness				**38**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**7**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**50.16%**
% Plectopera individuals				**8.38%**
% Trichoptera individuals				**12.95%**
Percent Chironomidae				**19.30%**
Percent Tolerant Organisms				**6.98%**
# Intolerant Taxa				**21**

Table C7. Macroinvertebrate data collected from site Blue 1 on 7 November 2020.

Blue River				
Blue 1		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.	1			**4**
Baetis tricaudatus	306	307	226	**3252**
Drunella doddsii				
Drunella grandis		4	5	**35**
Ephemerella dorothea infrequens				
Cinygmula sp.	60	77	127	**1024**
Epeorus sp.	129	159	173	**1787**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.	2		2	**16**
Chloroperlidae				
Sweltsa sp.	25	22	43	**349**
Paraleuctra sp.				
Prostoia besametsa	4	3	2	**35**
Zapada cinctipes				
Zapada oregonensis group			2	**8**
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva	4	3	4	**43**
Megarcys signata				
Skwala americana			1	**4**
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis	7	6	9	**86**
Micrasema bactro	1			**4**
Glossosoma sp.	1		2	**12**
Arctopsyche grandis	58	27	21	**411**
Hydropsyche cockerelli				
Lepidostoma sp.	40	37	56	**516**
Rhyacophila coloradensis	4	1	1	**24**
Rhyacophila sibirica group	1	1		**8**
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	16	27	35	**303**
Diamesa sp.	17	13	12	**163**
Eukiefferiella sp.	39	12	14	**252**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.				
Microtendipes sp.				
Pagastia sp.	15	6	15	**140**
Polypedilum sp.	3		1	**16**
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group			1	**4**
Tvetenia sp.				

Table C7. cont. Macroinvertebrate data collected from site Blue 1 on 7 November 2020.

Other Diptera				
Atherix pachypus			2	**8**
Bibiocephala grandis		3		**12**
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.	4	6	1	**43**
Antocha sp.	1		3	**16**
Dicranota sp.		1		**4**
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	24	15	40	**307**
Optioservus sp.			1	**4**
Miscellaneous (Non-insects)				
Lebertia sp.	2		1	**12**
Protzia sp.	3	1	5	**35**
Sperchon sp.				
Torrenticola sp.				
Polycelis coronata	7	11	14	**125**
Enchytraeidae				
Nematoda		2		**8**
Totals	**775**	**744**	**819**	**9074**
Shannon Weaver Diversity				**3.12**
Calculated Evenness				**0.604**
EPT				**19**
% EPT				**84.05%**
Density				**9,074**
% Non-Insect				**1.97%**
% Shredder/Scraper				**38.24%**
Taxa Richness				**36**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**8**
% Ephemeroptera individuals				**67.32%**
% Plectopera individuals				**5.00%**
% Trichoptera individuals				**11.72%**
Percent Chironomidae				**9.67%**
Percent Tolerant Organisms				**3.29%**
# Intolerant Taxa				**22**

Table C8. Macroinvertebrate data collected from site SCR on 6 November 2020.

Blue River				
SCR		Sample		
6 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	79	69	129	**1074**
Drunella doddsii				
Drunella grandis	8	22	19	**190**
Ephemerella dorothea infrequens				
Cinygmula sp.	17	27	28	**280**
Epeorus sp.	84	78	127	**1121**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.		1		**4**
Chloroperlidae		3		**12**
Sweltsa sp.	13	28	43	**326**
Paraleuctra sp.				
Prostoia besametsa	3	4		**28**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva	2	7	12	**82**
Megarcys signata				
Skwala americana	1	1		**8**
Trichoptera				
Brachycentrus americanus	1	1	5	**28**
Brachycentrus occidentalis	60	39	42	**547**
Micrasema bactro				
Glossosoma sp.	2	1		**12**
Arctopsyche grandis	17	16	41	**287**
Hydropsyche cockerelli		1		**4**
Lepidostoma sp.	16	51	34	**392**
Rhyacophila coloradensis	1		2	**12**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	51	15	47	**438**
Diamesa sp.	22	3	13	**148**
Eukiefferiella sp.	10	7	37	**210**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.	1			**4**
Microtendipes sp.		1		**4**
Pagastia sp.	25	27	38	**349**
Polypedilum sp.		1	5	**24**
Pseudorthocladius sp.	3	2		**20**
Rheocricotopus sp.		1		**4**
Synorthocladius sp.				
Thienemannimyia genus group	1	1	2	**16**
Tvetenia sp.				

Table C8. cont. Macroinvertebrate data collected from site SCR on 6 November 2020.

Other Diptera				
Atherix pachypus		1	2	**12**
Bibiocephala grandis				
Chelifera/Neoplasta sp.		1		**4**
Wiedemannia sp.			1	**4**
Simulium sp.	9	3	1	**51**
Antocha sp.	4	10	5	**74**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	7	14	5	**101**
Optioservus sp.	1			**4**
Miscellaneous (Non-insects)				
Lebertia sp.	1	2	1	**16**
Protzia sp.				
Sperchon sp.	4	4	2	**39**
Torrenticola sp.				
Polycelis coronata	5	5	4	**55**
Enchytraeidae				
Nematoda			1	**4**
Totals	**448**	**447**	**646**	**5988**
Shannon Weaver Diversity				**3.84**
Calculated Evenness				**0.731**
EPT				**17**
% EPT				**73.65%**
Density				**5,988**
% Non-Insect				**1.88%**
% Shredder/Scraper				**34.33%**
Taxa Richness				**38**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**44.58%**
% Plectopera individuals				**7.66%**
% Trichoptera individuals				**21.41%**
Percent Chironomidae				**20.31%**
Percent Tolerant Organisms				**4.48%**
# Intolerant Taxa				**19**

Table C9. Macroinvertebrate data collected from site BRC on 7 November 2020.

Blue River				
BRC		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	11	6	7	**94**
Drunella doddsii				
Drunella grandis	2	4	9	**59**
Ephemerella dorothea infrequens	10	9	10	**113**
Cinygmula sp.	9	1	9	**74**
Epeorus sp.				
Epeorus longimanus	43	66	27	**528**
Rhithrogena sp.		3		**12**
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae			1	**4**
Sweltsa sp.	9		3	**47**
Paraleuctra sp.				
Prostoia besametsa	1		2	**12**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa	1		1	**8**
Hesperoperla pacifica				
Perlodidae	1		1	**8**
Diura knowltoni	1		1	**8**
Isoperla fulva	1	1	1	**12**
Megarcys signata				
Skwala americana	1			**4**
Trichoptera				
Brachycentrus americanus	2	2		**16**
Brachycentrus occidentalis	4	6	5	**59**
Micrasema bactro				
Glossosoma sp.	11	18	12	**159**
Arctopsyche grandis	21	9	21	**198**
Hydropsyche cockerelli	9	5	4	**70**
Lepidostoma sp.	16	9	7	**125**
Rhyacophila coloradensis	1		1	**8**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.				
Diamesa sp.				
Eukiefferiella sp.	5	5	9	**74**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.		1	1	**8**
Microtendipes sp.				
Pagastia sp.		3	6	**35**
Polypedilum sp.	1		1	**8**
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group	2			**8**
Tvetenia sp.				

Table C9. cont. Macroinvertebrate data collected from site BRC on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.	1			**4**
Simulium sp.	1		1	**8**
Antocha sp.	5	1		**24**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus		1	5	**24**
Optioservus sp.	2	1		**12**
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.	3	3	1	**28**
Torrenticola sp.				
Polycelis coronata	1		1	**8**
Enchytraeidae				
Nematoda				
Totals	**175**	**154**	**147**	**1859**
Shannon Weaver Diversity				**3.84**
Calculated Evenness				**0.762**
EPT				**21**
% EPT				**87.18%**
Density				**1,859**
% Non-Insect				**1.89%**
% Shredder/Scraper				**53.78%**
Taxa Richness				**33**
# Ephemeroptera Taxa				**6**
# Plecoptera Taxa				**8**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**47.48%**
% Plectopera individuals				**5.46%**
% Trichoptera individuals				**34.24%**
Percent Chironomidae				**7.14%**
Percent Tolerant Organisms				**5.88%**
# Intolerant Taxa				**21**

Table C10. Macroinvertebrate data collected from site LBR on 6 November 2020.

Blue River				
LBR		Sample		
6 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.	1			**4**
Baetis tricaudatus	90	153	131	**1450**
Drunella doddsii				
Drunella grandis	7	8	10	**97**
Ephemerella dorothea infrequens	4	10	15	**113**
Cinygmula sp.				
Epeorus sp.				
Epeorus longimanus	5	3	3	**43**
Rhithrogena sp.	1		2	**12**
Paraleptophlebia sp.	3	2	29	**132**
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.			1	**4**
Paraleuctra sp.				
Prostoia besametsa				
Zapada cinctipes	1	1	3	**20**
Zapada oregonensis group				
Claassenia sabulosa			1	**4**
Hesperoperla pacifica	1			**4**
Perlodidae			2	**8**
Diura knowltoni				
Isoperla fulva	3	7	6	**63**
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus	7	5	14	**101**
Brachycentrus occidentalis				
Micrasema bactro	1			**4**
Glossosoma sp.	22	17	167	**799**
Arctopsyche grandis	24	40	55	**462**
Hydropsyche cockerelli	37	48	107	**745**
Lepidostoma sp.	7	11	26	**171**
Rhyacophila coloradensis		4	3	**28**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	8	3	5	**63**
Diamesa sp.				
Eukiefferiella sp.	2	4	12	**70**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.		2	5	**28**
Microtendipes sp.				
Pagastia sp.	5	16	22	**167**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.			2	**8**
Synorthocladius sp.			1	**4**
Thienemannimyia genus group	1	1	4	**24**
Tvetenia sp.	1			**4**

Table C10. cont. Macroinvertebrate data collected from site LBR on 6 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.		4	2	**24**
Antocha sp.	1	3	2	**24**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus		2		**8**
Optioservus sp.	34	29	46	**423**
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.			5	**20**
Torrenticola sp.			1	**4**
Polycelis coronata	24	42	75	**547**
Enchytraeidae				
Nematoda				
Totals	**290**	**415**	**757**	**5682**
Shannon Weaver Diversity				**3.55**
Calculated Evenness				**0.691**
EPT				**20**
% EPT				**75.10%**
Density				**5,682**
% Non-Insect				**10.05%**
% Shredder/Scraper				**27.63%**
Taxa Richness				**35**
# Ephemeroptera Taxa				**7**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**32.63%**
% Plectopera individuals				**1.78%**
% Trichoptera individuals				**40.70%**
Percent Chironomidae				**6.43%**
Percent Tolerant Organisms				**2.12%**
# Intolerant Taxa				**21**

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APPENDIX E

Periphyton Sampling

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SWQC Fall Periphyton Sampling Report

Submitted: December 16, 2020
Amended for BR-IWMP: August 2, 2021

Submitted by:
Tanner Banks, Project Manager | Trout Unlimited

Background

Discussions about the root cause for a declining gold medal fishery, and ultimately, the deterioration of ecological function of the Blue River have been ongoing since 2015. To identify the cause for such declines, an initial phase of an Integrated Water Management Plan (IWMP) would collate historic data and fund field sampling according to metrics agreed upon by IWMP managers and stakeholder groups. Due to unforeseen costs to complete Phase 1 objectives, periphyton sampling was postponed until more funding could be pursued. At the request of Summit Water Quality Committee (SWQC), Trout Unlimited completed an initial round of periphyton sampling at all but one IWMP study site. This report summarizes the results from that sampling event.

With Blue Valley Ranch (BVR) recently proposing a nutrient enhancement study downstream of Green Mountain Reservoir (IWMP Reach LBR), it was an opportune time to collect periphyton at the Upper Blue and Middle Blue sites (IWMP Reach 1 and 2). Even in the event the BVR proposed study is not undertaken, the data collected by BVR since 2019 provide valuable background information that can be used to inform comparisons with periphyton collected this October in the Middle Blue River. The BVR study is focused on understanding the effect of phosphorus on benthic algae (periphyton), and more specifically *Didymosphenia geminata* (Didymo), a filamentous diatom that can invade and alter the ecological function of lotic ecosystems (Rost & Fritsen 2014). One concern of practitioners is that these invasive Didymo algae blooms often take place in oligotrophic streams, and particularly, in streams that lack dissolved phosphorus. This deficiency in phosphorus may be part of what's causing the occurrence of Didymo below Green Mountain Reservoir. Comparatively, the Middle Blue is also oligotrophic, but colonization's of Didymo are much less severe and therefore may serve as control reach should the BVR study commence.

Ultimately, benthic algae samples will identify differences and similarities between the two Blue River reaches that can be used to inform future management decisions. Data collation in conjunction with the BVR nutrient study will provide quantified data for whether nutrient enhancement could be useful on the Middle Blue (Reach 2), and if so, whether it would be an effective management tool for restoring ecological function. This periphyton sampling was also intended to serve as continued foundational data to be used in determining root causes for the decline of Blue River ecological function.

Sampling

This benthic algae field sampling did not adhere to WQCD stream chlorophyll sampling protocols. Instead, a more rigorous sampling approach was used to coincide with the methods set forth by BVR. This alternative sampling methodology is comparable to the WQCD approach but is tailored for repeatability. The quantitative strength of this sampling was not compromised, rather its use provides for more direct comparisons with ongoing sampling on the Blue River downstream of Green Mountain Reservoir. Importantly, the Blue River IWMP macroinvertebrate sample site locations were used in this study to enable a better understanding of all potential factors affecting the Middle Blue River stream ecology.

Upon approval by the SWQC, Trout Unlimited completed the periphyton sampling on October 6th, 2020. Eight Middle Blue and one Upper Blue IWMP study sites (Figure 1) were sampled according to the agreement between SWQC and Trout Unlimited. This task was completed with the assistance of the BVR staff to ensure comparability of results from the two field sampling initiatives and so field work could be completed in a single day. Immediately following the completion of field work, samples were shipped overnight to EnviroScience in Stow, Ohio for laboratory analysis.

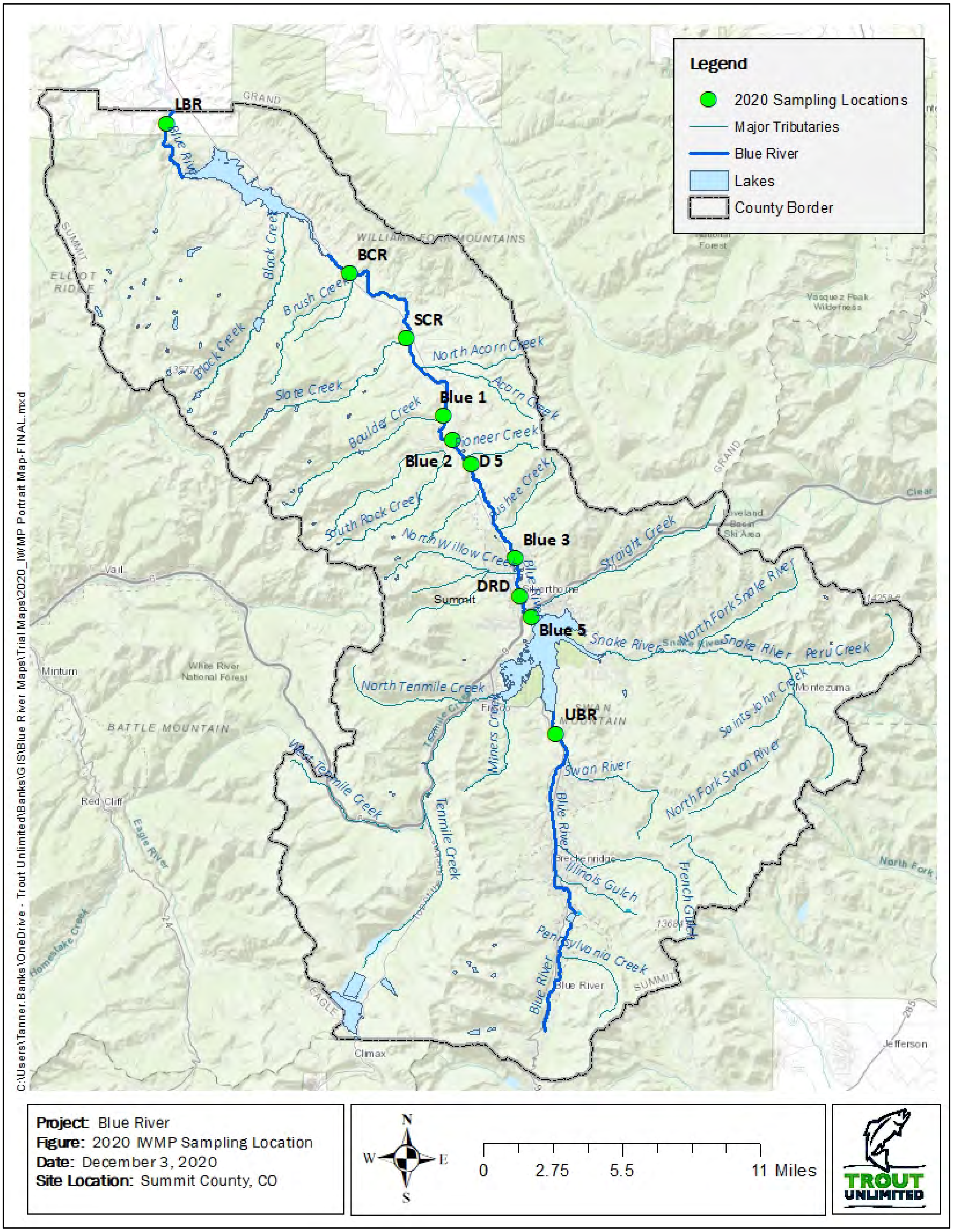
Methods

At each site, a total of eight small to large cobble with an estimated range of 60 - 180 mm were collected from a single riffle/run segment. Of the eight sample rocks, four were collected as replicates to quantify spatial variability. The section of the rock exposed to surface water and to be scraped for benthic algae is referred to as the "standing crop". Over a small plastic tub, the standing crop margin is scraped and brushed to dislodge benthic algae and organic matter. The organic-laden stream water is then consolidated within the small tub, bottled and labeled for lab analysis. Following the scrapes, aluminum foil was placed over the top each rock and cut to fit the total area scraped; the foil is used to determine surface area to quantify the mass per unit area of each subsample.

EnviroScience received the periphyton samples on October 7th, and subsequently completed the lab analysis for Ash-free dry weight (AFDW) and chlorophyll a (Chl-*a*). The AFDW is a general quantification of the total organic mass using oxidation methods for total organic mass of a sample; AFDW does not differentiate the type of organics. Chl-*a* is commonly measured using spectrophotometry, which is a pigment analysis that identifies the abundance of benthic algae (Steinman et. al 2006). The advantage of a pigment analysis compared to AFDW is its ability to differentiate algal biomass from organics such as detritus or fungi (Steinman et al. 2006). The results of the top rock scrapes and subsequent lab results are presented in Table 1.

At site *Blue-5*, only two rocks at the upstream and downstream locations were used to due to the abundant biomass of aquatic algae and mosses. Chain of custody paperwork was completed for each sample to catalogue and verify collection parameters and field sampling notes, which is attached as *Appendix 1*.

Figure 1. 2020 site locations according the Blue River IWMP.



Data

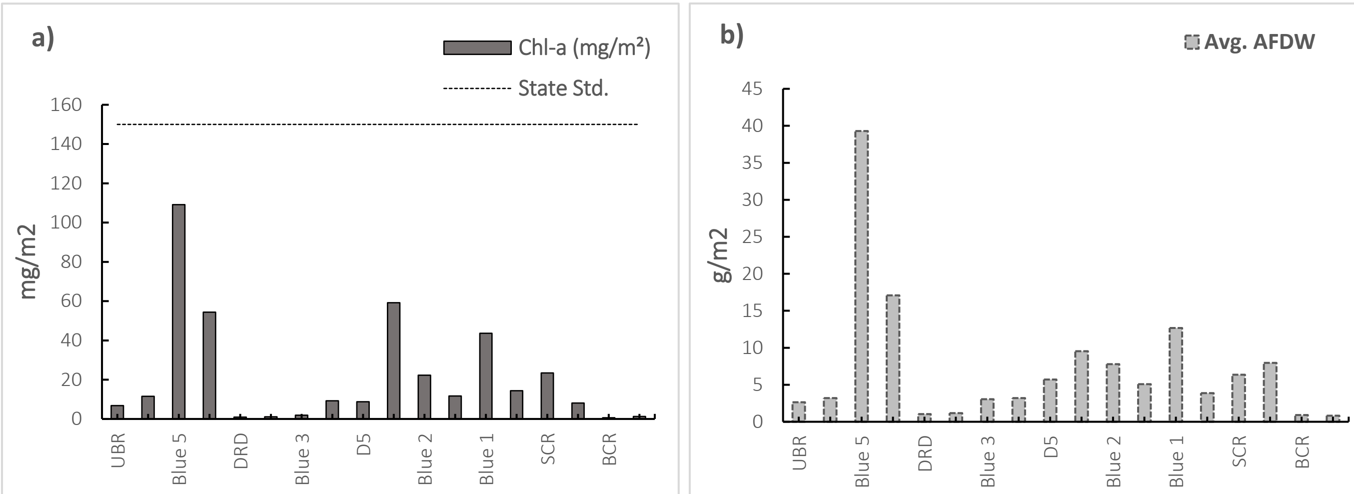
During the periphyton field sampling, several sites displayed healthy colonization's of periphyton, while other sites appeared relatively void of any primary productivity. After completing the field work, it was apparent at that time that the longitudinal distribution of periphyton communities in the Blue River are spatially, highly variable. Each of the IWMP sample sites is represented by two periphyton subsamples; an upstream (US) and a downstream (DS) site, the DS is considered the subsample control.

Table 1. Shows all sites according to the IWMP nomenclature with lab results by site and subsample. Chlorophyll *a* concentrations are reported as milligrams of Chl-a per square meter (mg/m^2) and ash-free dry mass are reported as grams of AFDW per square meter (g/m^2).

IWMP Site Name	Site Notes	Lat , Long	Sample ID	AVG AFDW (mg/L)	AVG AFDW (g/m²)	Initial Sample Volume (mL)
UBR	Historic FS Site - Above Swan Mtn Rd	39.56627, -106.04929	TR-UBR_US	331	2.6339	438
			TR-UBR_DS	501	3.1970	373
Blue 5	Historic FS Site - Above Straight Cr	39.62604, -106.06712	TR-Blue-5_US	1240	39.2885	565
			TR-Blue-5_DS	1320	17.0766	780
DRD	Dillon Ranger Station	39.63626, -106.07526	TR-DRD-US	237	1.0419	270
			TR-DRD-DS	246	1.1692	245
Blue 3	Historic FS Site - Below Willow Cr	39.65606, -106.07747	TR-Blue-3_US	295	3.0611	315
			TR-Blue-3_DS	473	3.2044	432
D5	Historic FS Site - Pioneer Cr	39.70523, -106.11146	TR-D5_US	493	5.7019	474
			TR-D5_DS	639	9.5370	579
Blue 2	Historic FS Site - Campground	39.72716, -106.13264	TR-Blue-2_US	516	7.7812	804
			TR-Blue-2_DS	367	5.0858	480
Blue 1	Historic FS Site - Below Boulder Cr	39.74358, -106.13282	TR-Blue-1_US	504	12.6698	542
			TR-Blue-1_DS	425	3.8766	497
SCR	Above Slate Cr	39.78226, -106.16085	TR-SCR_US	541	6.3688	503
			TR-SCR_DS	408	7.9604	743
BCR	Below Brush Cr	39.82165, -106.20679	TR-BCR_US	111	0.9069	430
			TR-BCR_DS	80	0.8132	411

Table 1 and Figures 2a-b support the field observations described above. The highest algal biomass measured as Chl-a was located at Blue 5 at 109.13 mg/m^2, compared to the least abundant sample, BCR at 0.653 mg/m^2. AFDW mass per unit area results are similar to Chl-a concentrations with the most abundance observed at Blue 5 (39.28 g/m^2) and least at the BCR control site (0.813 g/m^2). Lewis and McCutchin (2016) explain, annual abundances of Chl-a is affected by several factors including but limited to runoff and anchor ice, which can lead to spatial and temporal variability. These factors are important because it may help explain some of the variability presented in this report. While abiotic factors likely have a more significant impact on biota in high alpine environments, data from grab samples lack spatial and temporal representation and therefore may not allow for this generalization in this specific context. Annual sampling events throughout all seasons should continue to provide a more statistically confident representation of abiotic and biotic interactions.

Figure 2a. Depicts Chlorophyll-a concentrations at each IWMP sample site compared to the current State Chl-a threshold for cold water rivers and streams. **Figure 2b.** Depicts the average ash free dry weight (AFDW), which is the total biomass of benthic algae scraped from the upstream and downstream locations at each site.



Based on the results illustrated in Figure 2a – b, site Blue 5 displayed significantly higher concentrations of Chl-a and AFDW than all other 2020 sample sites. This finding has been documented from data collected and presented by in Lewis et. al (2012, 2016) in SWQC annual reports. Neither the 2016 or 2012 Lewis and McCutchan reports explicitly recognize high concentrations of Chl-a or the causation, but rather explains the unlikelihood of exceedances of the Chl-a standard at any site in the Blue River Watershed. Based on the 2020 data, concentrations of Chl-a at Blue-5 approach State Chl-a thresholds, but do not exceed them. Field observations at the time of collection noted the increase in biomass of benthic algae, filamentous algae, and aquatic mosses.

The 2016 and 2020 sampling events carried out by Lewis et. al, as well as this Trout Unlimited study reveal that Chl-a concentrations immediately downstream of Dillon Dam are significantly higher than those observed in the Upper Blue River before the inlet into Dillon Reservoir (Figure 3). The 2020 results also reveal that Chl-a concentrations at sites north of Silverthorne down to SCR have reasonable concentrations of Chl-a. Referencing Figure 2b, the total algal biomass is more consistent and can be interpreted that the abundance of forage for benthic macroinvertebrates increases as you move downstream from site DRD.

Figure 3. Compares Chlorophyll a concentrations from 2012, 2016, and 2020 below Dillon Dam (DD) and above Dillon Reservoir (DR). The sampling locations are not identical across all years, but GPS locations confirm that during all years, samples collected from the DR site are taken upstream of the water treatment plant and the DD site is within 0.30 miles of the Dillon Dam tailrace.

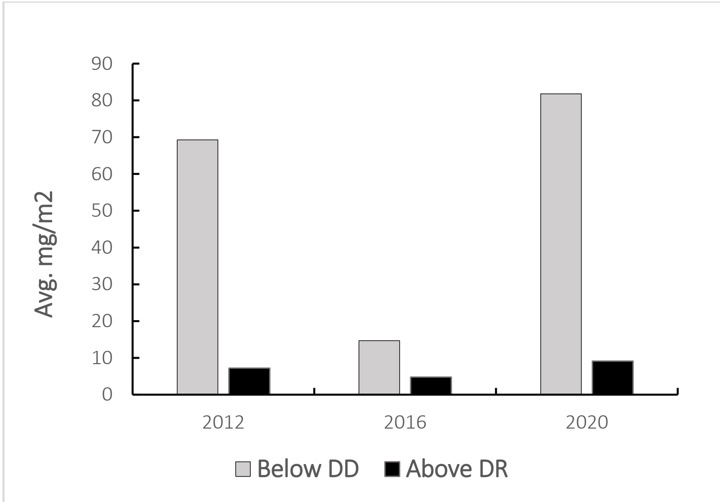
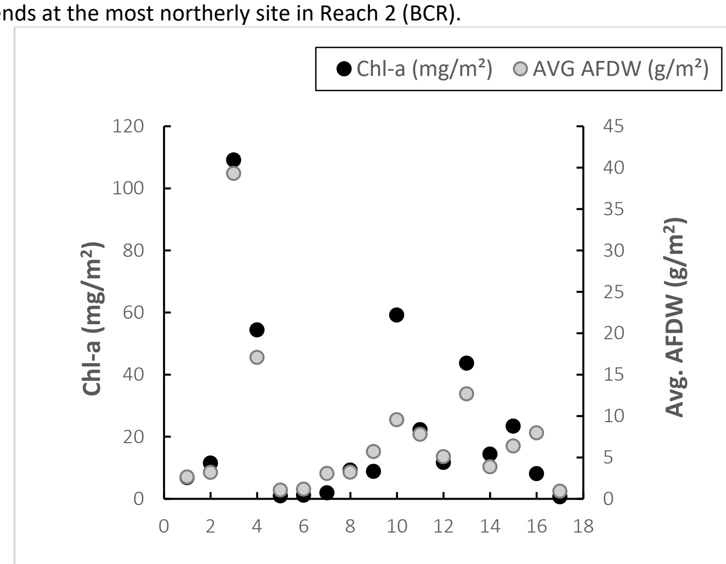


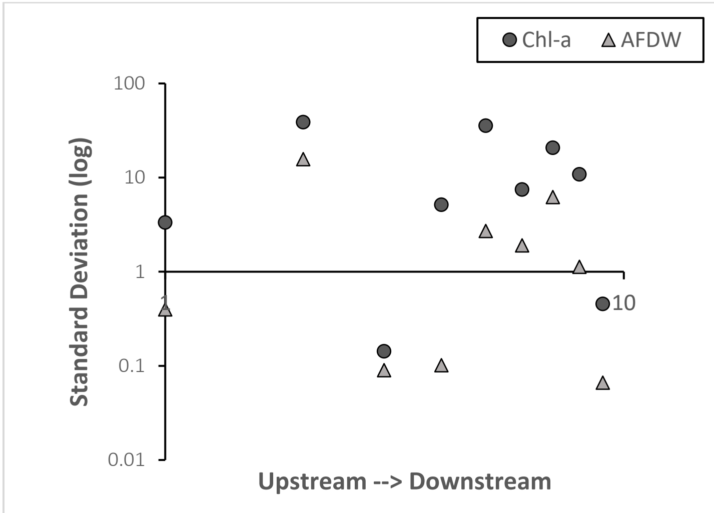
Figure 4. Illustrates periphyton abundance as chlorophyll-a in mg/m^2 as the primary y-axis compared to the average ash-free dry weight (AFDW) in g/m^2 as the secondary axis. The x-axis is represented by the sample number, which starts at the most southerly site (UBR) and ends at the most northerly site in Reach 2 (BCR).



X-axis: 1-2 (UBR); 3-4 (Blue 5); 5-6 (DRD); 7-8 (Blue 3); 9-10 (D5); 11-12 (Blue 2); 13-14 (Blue-1); 15-16 (SCR); 16-17 (BCR)

The similarity between Chl-a and AFDW that is illustrated in Figure 4 reveals that there is not a large amount of fungi, bacteria, or detritus in the Blue River. This relationship can be partially explained in the sampling methods and the removal of clung particulates and caddis retreats from the standing crop area prior to scraping. This removal may have inadvertently removed biological communities that colonize woody particulates and/or caddis retreats symbiotically. This field sampling is worth noting, but it is not believed that the step to remove such debris and detritus altered results in a significant manner. Figure 5 illustrates that that longitudinally, Chl-a and AFDW are closely correlated and the samples were not comprised of significant amounts of detritus or non-pigment producing plant matter; D5 appearing to be the only site that does not reflect that pattern (Figure 4 & 5).

Figure 5. Denotes the standard variation between all the upstream and downstream top rock samples at each site across all nine IWMP sample sites on a logarithmic scale. It does not represent differences found between sites. The figure represents the variability found between top rock samples (y-axis) at each of the respective sites (x-axis).



Conclusions and Recommendations

The lack of regional precipitation from late winter through typical monsoonal months is a potential variable impacting the results of this seasonal study. Due to the draught-like conditions throughout the Blue River and Upper Colorado watersheds, drinking water impoundments such as Dillon Reservoir and Green Mountain Reservoir maximized their water storage resulting in less than typical reservoir releases. Future sampling events should seek to increase the frequency of sampling to explain seasonal variability that is often observed below each reservoir.

The fall sampling effort was extremely useful in that it provided practitioners and stakeholders with more baseline data for Reach 2. Although the sampling was not identical to the original proposal by TU to BREW and IWMP members, this sampling does provide useful data on Reach 2. For a one-time grab sample, September through October is the most meaningful time to represent one growing season (WQCD). For a more comprehensive representation of the potential shifts in benthic algae assemblages, more frequent sampling events should be considered.

Most importantly, the results of this study should be combined with chemical and biological data collected prior to, or as part of the IWMP. Historic water chemistry data from the Blue River should be referenced in conjunction with benthic algae samples as well as all relevant species assemblages of benthic macroinvertebrates. Any future benthic algae study plans should include methods to quantify temporal variability as well as determine whether spatial variability of the 2020 samples was a stochastic event. The temporal component should be accounted for by completing seasonal top rock scrapes along with the benthic macroinvertebrate samplings (spring, summer, fall). Site Blue 5 should be resampled according to the sampling protocols set forth in 2020 to determine whether this site consistently supports increased primary productivity, and more specifically, what factors may be causing the current conditions. Should continued empirical studies takes place on the Blue River, an emphasis should be given on the necessity to continue this work through several consecutive years. As seen in this dataset, there may be several abiotic and biotic variables impacting individual grab samples, making annual replication paramount for well-informed management actions.

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Steinman et al. (2006) Biomass and Pigments of Benthic Algae. Methods of Stream Ecology: Second Edition, Edited by F. Richard Hauer and Gary A. Lamberti, Ch. 17, 357-368.

Colorado Water Quality Control Division (WQCD), Standard Operating Procedures for the Collection of Streams Periphyton Samples.

William M. Lewis and James H. McCutchan (2012), Evaluation and Interpretation of Multi-Metric Index (MMI) Information on Invertebrate Communities of the Blur River below the Dillon Reservoir Dam, Summit County, Colorado, Rpt. 337.

William M. Lewis and James H McCutchan (2013), Results of a Field Survey of Benthic Chlorophyll Abundance and its Possible Relationship to Nutrient Concentrations for Streams within and Just Below the Lake Dillon Watershed, Rpt. 328.

William M. Lewis and James H McCutchan and Jennifer Roberson (2016), Chlorophyll and Nutrient Concentrations for Selected Sites in the Lake Dillon Watershed, Rpt. 378.

Appendix 1. Blue River Chlorophyll *a* and ash-free dry weight EnviroScience chain of custody (CoC) forms.

EnviroScience
Excellence in Any Environment

5070 Stow Road Stow, OH 44224
Phone: 330-688-0111 Ext. 282
Fax: 330-688-3858
Email: ecotoxicologylab@enviroscienceinc.com

Purchase Order Number:

Project ID #:

SAMPLE SUBMISSION AND CHAIN OF CUSTODY FORM

Report to:	Tanner Banks	Invoice to:	Tanner Banks	Client:	Blue Valley Ranch
Company:	Trout Unlimited	Company:	Trout Unlimited	Contact:	Brian Rose
Address:	620 Main St, STE 9	Address:	620 Main St, STE 9	Email:	brian.rose@[illegible].com
	Frisco, CO 80443		Frisco, CO 80443	Phone:	970-531-6223
Phone:	970-390-9492	Phone:	970-390-9492		
Email:	tanner.banks@tu.org	Email:	tanner.banks@tu.org		

Laboratory No. (Lab Use Only)	Sample ID	Site ID	Date	Time	HAB Screening	Algal Toxin Analysis	Algae Test 1	Algae Test 2	Algae Test 3	Ash-Free Dry Weight	ATP Analysis	Carbon Analysis	Chl. a	Volume of Container	Number of Containers
	TR-BCR-01	Middle Blue	11/6/20	9:00											
	TR-BCR-Control			"											
	TR-SCR-01			11:30											
	TR-SCR-Control			"											
	TR-BlueR-01			10:50											
	TR-BlueR-Control			"											

Requested custom analyses (Target parameters if required):

Total Number of Containers

Preservative(s) Used:
On ice at 4°C
Glutaraldehyde
Formalin
Other:

EnviroScience Use Only
Sample Receipt Evaluation
Received Time / Lab Receipt
Lab Notation / Approved Conditions
Sample Temperature: °C
(If preserved by cooling on ice at 4°C)
Condition of Container(s)

Relinquished by	Received by	Date	Time	Shipping Information		Sample collector signature:
Tanner Banks				Date Shipped	11/6/20	
	[illegible]	11/7/20		Method Shipped	overnight (UPS)	

EnviroScience
Excellence in Any Environment

[illegible] Stow Road, Stow, OH 44224
Phone: [illegible]
Fax: [illegible]
Email: [illegible]

SAMPLE SUBMISSION AND CHAIN OF CUSTODY FORM

Purchase Order Number:
Project ID #:

Report to:	Tanner Banks
Company:	Trout Unlimited
Address:	620 Main St, STE 9
	Frisco, CO 80443
Phone:	970-390-9492
Email:	tanner.banks@TU.org

Invoice to:	Tanner Banks
Company:	Trout Unlimited
Address:	620 Main st, STE 9
	Frisco, CO 80443
Phone:	970-390-9492
Email:	tanner.banks@TU.org

(Leave blank if same as reporting)

Client:	Blue Valley Ranch
Contact:	Brian Rose
Email:	brian.rose@[illegible] .com
Phone:	970-531-6229

(Leave blank if same as reporting)

Laboratory No. (Lab Use Only)	Sample ID	Site ID	Date	Time	HAB Screening	Algal Toxin Analysis	Algae level 1	Algae level 2	Algae level 3	Ash-Free Dry Weight	ATP Analysis	Diatom Analysis	Chl-a	Volume of Containers	Number of Containers
	TR-Blue-2_01	middle Blue	10/6/20	11:22											
	TR-Blue-2_Control														
	TR-D-5_01			11:56											
	TR-D-5_Control														

Requested turn to analysis (if a rush analysis is required):

Total Number of Containers:

Preservative(s) Used:	
Chilled at 4°C:	
Glutaraldehyde:	
Formalin:	
Other:	

EnviroScience Use Only	
Sample Receipt Evaluation	
[illegible]	[illegible]
[illegible]	[illegible]
Sample Temperature:	
(If preserved by cooling on ice at 4°C)	
Condition of Container(s)	

Relinquished by	Received by	Date	Time	Shipping Information	
Tanner Banks				Date Shipped	10/6/20
	[illegible]	[illegible]		Method Shipped	UPS overnight

Sample collector signature: [illegible]

EnviroScience
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SAMPLE SUBMISSION AND CHAIN OF CUSTODY FORM

Purchase Order Number:	
Project ID #:	

Report to:	Tanner Banks	Invoice to:	Tanner Banks	Client:	Blue Valley Ranch
Company:	Trout Unlimited	Company:	Trout Unlimited	Contact:	Brian Pope
Address:	620 Main st, STE 9	Address:	" "	Email:	brian.pope@jasgrp.com
	Frisco, CO 80443			Phone:	970-531-6223
Phone:	970-390-5492	Phone:			
Email:	tanner.banks@TU.org	Email:			

Laboratory No. (Lab Use Only)	Sample ID	Site ID	Date	Time	Requested Analyses	Chl. a	Volume of Containers	Number of Containers
		Middle Blue						
	TR-Blue3_01		10/6/20	12:25				
	TR-Blue3_Control			" "				
	TR-DRD_01			12:57				
	TR-DRD_Control							

Requested toxins to analyze (if algal toxin analysis is required):

Total Number of Containers

Preservative(s) Used:	
On ice at 4°C:	
Glutaraldehyde:	
Formalin:	
Other:	

EnviroScience Use Only
Sample Receipt Evaluation

Sample Temperature: °C
(If preserved by cooling on ice at 4°C)
Condition of Container(s)

Relinquished by	Received by	Date	Time	Shipping Information
Tanner Banks				Date Shipped: 10/6/20
				Method Shipped: UPS OVERNIGHT

Sample collector signature:

EnviroScience
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SAMPLE SUBMISSION AND CHAIN OF CUSTODY FORM

5070 Stow Road, Stow, OH 44224
Phone: 330-688-0111 Ext. 282
Fax: 330-688-3256
Email: [illegible]

Purchase Order Number:
Project ID #:

Report to:	Tanner Banks
Company:	Trout Unlimited
Address:	620 Main St, STE 9
	Frisco, CO 80443
Phone:	970-390-9492
Email:	Tanner.Banks@TU.org

Invoice to:	Tanner Banks
Company:	Trout Unlimited
Address:	"
Phone:	
Email:	

(Leave blank if same as reporting)

Client:	Blue Valley Ranch
Contact:	Brian Rose
Email:	[illegible]
Phone:	970-531-6823

(Leave blank if same as reporting)

Laboratory No. (Lab Use Only)	Sample ID	Site ID	Date	Time	[illegible]	Algal Toxin Analysis	Algae Test 1	Algae Test 2	Algae Test 3	Ash-Free Dry Weight	[illegible]	Diatom Analysis	Chl-a	Volume of Collection	Number of Containers
	TR-Blue5_01	(Middle River)	10/6/20	1:21											
	TR-Blue5_Control														
	TR-UBR_01	(Upper River)		2:03											
	TR-UBR_Control														

Requested toxins to analyze (if algal toxin analysis is required):

Total Number of Containers:

Preservative(s) Used:	
On ice at 4°C:	
Glutaraldehyde:	
Formalin:	
Other:	

EnviroScience Use Only	
Sample Receipt Evaluation	
[illegible]	Lab Aliquots
[illegible]	[illegible]
Sample Temperature	°C
(If preserved by cooling on ice at 4°C)	
Condition of Container(s)	

Relinquished by	Received by	Date	Time	Shipping Information	
Tanner Banks				Date Shipped	10/7/20
	[illegible]	10/8/20		Method Shipped	UPS OVERNIGHT

Sample collector signature: [illegible]

APPENDIX F

Blue River Fishery

Summary Report on the

The Blue River Fishery Status and the Influence of Water Temperature on the Blue River Fishery

August 2021

Prepared For:
Tetra Tech Inc.

Prepared By:
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Fort Collins, Colorado 80526

Executive Summary

The Blue River fishery below Dillon Reservoir has been under special regulation management since 1983. These regulations were implemented to increase both numbers and biomass of fish in the Blue River. By the late 1980's the fishery had reached it maximum production of quality fish, and since then has shown a downward trend and currently the fishery is at than 50% or less of what was seen after the implementation of the regulations. Most recent estimates show the Blue River supports approximately 1000 fish per mile which is significantly less than reference streams like the Taylor River (5000 fish/mile) and the Fryingpan (8000 fish/mile). The Blue River has been shown to have the slowest growth rates of studied rivers in Colorado. A 4+ year old brown trout in the Blue River is more than and inch smaller than fish of similar age in other Colorado Rivers.

Cold water temperatures coming out of Dillon Reservoir contributes to the declining fishery by limiting growth, reproduction and recruitment of brown trout. Cold temperatures also have been found to limit aquatic invertebrates which are the main food source for the fish in the Blue River. Temperatures for optimal growth of brown trout (11-18^0 C) were only seen in 2020 in the lower few miles above Green Mountain Reservoir and only in late summer.

Blue River fish populations also seems to fluctuate more than other rivers in Colorado. Habitat availability at different flow levels has been found to impact year class strength on the Blue River. This may be due to stream channel changes due to years of altered flows and the lack of lateral connection to critical habitat at higher flows. In 2020 the reservoir spill created an increase in stream temperatures of 6.6^0 C (4.8^0-11.4^0 C), in 48 hours, which is considerable when compared to conditions on the Blue River above Dillon which changed 1.2^0 C (7.7^0-8.9^{0}C) over the same time period. Rapid increases temperature during the spill events may create temperature shock as well as limit habitat for brown trout fry and invertebrates.

Future work on the Blue River fishery should include continued year-round monitoring of water temperature in both the mainstem Blue River and a few select tributaries. Habitat assessment to determine the need for restoration projects to improve lateral connectivity and overall habitat for all life stages at anticipated flows. And all projects should be measured for success by standardized fish sampling and creel census, with the goal of returning the Blue River to the Gold Medal Status it once had.

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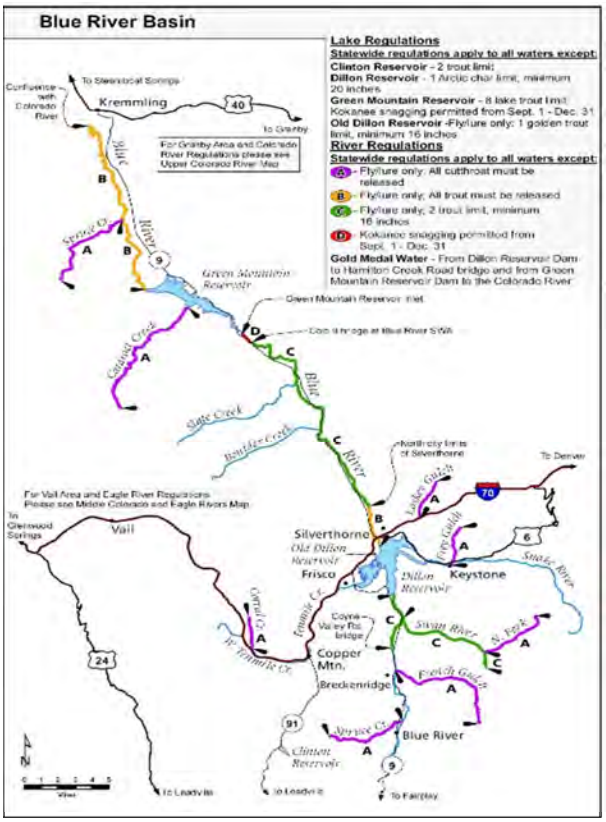
Introduction

In 2016 Colorado Parks and Wildlife's designation of Gold Medal status was removed from the portion of the Blue River between Hamilton Creek Road and Green Mountain Reservoir . A Gold Medal fishery must be able to produce a minimum of 12 "quality trout" (14+ inches) per acre and 60 pounds of trout standing stock per acre. However, this portion of the Blue River has not met Gold Medal criteria for many years prior. The purpose of this summary report is to inform decision makers on existing data, studies and information that provide insight on the declining fishery in the Blue River below Dillon Reservoir. This report will also review the temperature data collected in 2020 and review how temperature continues to influence the fishery in the Blue River.

Review of Data on Blue River Fish Populations

Fisheries data from Colorado Parks and Wildlife databases were reviewed along with older documents associated with the environmental review for Two Fork (Chadwick and Associates 1986). The majority of these historical data sets are for the Blue River between Dillon Reservoir and Green Mountain Reservoir, and for the purpose of this document will be the focus of the following discussion.



Beginning in 1983 the Blue River between Dillon and Green Mountain Reservoirs was placed under a 2-trout creel limit with a catch and release restriction on all brown trout under 35cm (14 in). These regulations were implemented initially to increase the trout biomass and fish quality (Nehring 1987). Nehring postulated that angler activity removed the younger, faster growing fish under standard regulations and so the protections to a larger size kept those faster growing fish in the river longer. Current fishing regulations (Figure 2) include catch and release fishing from Dillon Reservoir downstream within the city limits of Silverthorne and downstream of Green Mountain Reservoir to the Colorado River. Two additional areas, downstream of Silverthorne to Green Mountain Reservoir and upstream of Dillon Reservoir to Summit County Road 3 (Coyne Valley Bridge) and the Swan River are managed with a fly and lure, 2 trout over 16-inch regulation.

Figure 1. Current fishing regulation map for the Blue River Drainage (CPW 2020 Regulation Brochure).

Rainbow trout in the Blue River are maintained by stocking on most years with both catchable trout (>9 inches) and sub-catchable (<9 inches) sized fish. A stocking strategy has been difficult to determine for the biologist because survival and recruitment have been erratic and unpredictable. Sub-catchable rainbows stocked have not shown consistent survival between years. It is felt this is due to heavy predations by brown trout or mortality due to the fish not thriving after stocking due to cold water and fluctuating flows (Ewert, personal communication). Recent years excess brood fish (>14 inches) have been utilized for stocking and success has been limited. During low flows, brood fish that are stocked do not disperse throughout the river. They appear to remain in, or close to, the locations that they were stocked for the entire season (Ewert, personal communication), Nehring (1991) found similar sedentary nature of stocked rainbow trout on the Fryingpan River. This increases their vulnerability to angler and lessens the probability of survival long term. From 1992 to 1999 no rainbow trout were stocked into the Blue River due to hatchery rainbow trout availability because of whirling disease. Little fish sampling was completed during this time period, so no results are available to know the impact to the fishery.

Brown trout are managed as a wild trout fishery and make up the majority of the numbers and biomass of trout throughout the Blue River. Nehring (1987) found implementation of special regulations in 1983, increased population biomass and numbers of brown trout over 30 and 35 cm (12 and 15 inches). He felt after 4 years of special regulations the Blue River had reached maximum production of quality trout, and that 35 cm (14 inches) was about the maximum size that most brown trout could achieve in the Blue River. Nehring cited cold water temperatures in the Blue River due to hypolimnion releases from Dillon Dam led to slow growth rates for brown trout. However strong year classes were seen in years of drought with increased growth rates of young of the year brown trout. Nehring (1987) found that the larger average sizes in the first year of life carried through in subsequent years for that cohort's life span in the stream. This is evident after the drought of 2002-2003 where lower fish per mile created higher biomass of brown trout (Figure 3), or higher biomass was created by bigger fish from the 2003-year class.

Following the initial success of special regulations in the late 1980's brown trout numbers per acre and biomass have trended down and currently are at or less than 50% of the numbers per acre and biomass what was seen after the implementation of the special regulations (Figure 2 and 3). Recent surveys of trout populations in reach 2 of the Blue River between Lake Dillon and Green Mountain Reservoir have continued to show low growth rates and lower body condition that was documented in the fishery inventories which began in the mid-1980's (Nehring 1987).

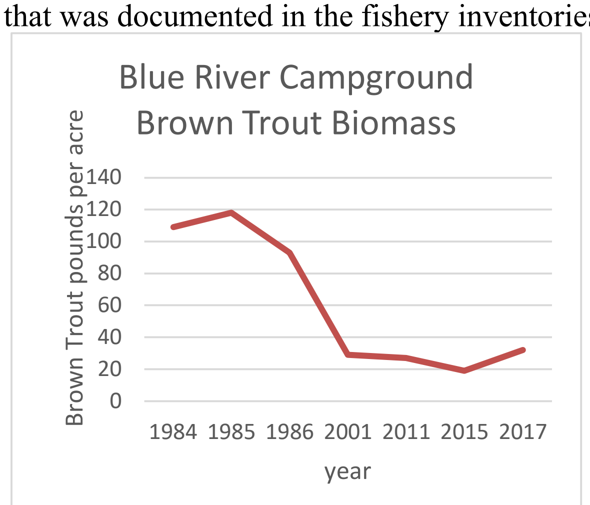


Figure 2.Brown Trout Biomass (lb./A) at Blue Campground 1984-2017

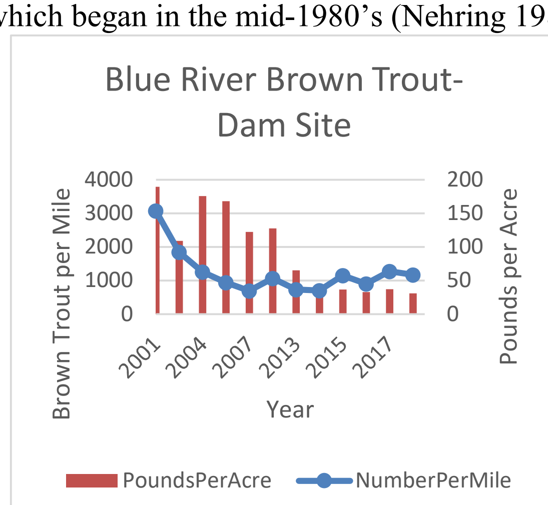


Figure 3.Brown trout per mile and Biomass downstream of Dillon Dam.

. .

Conditions in the Blue River, 1.5 miles downstream of the reservoir, at the Forest Service Ranger Station did not meet Gold medal standards in recent surveys, however there was a relatively consistent brown trout biomass seen in four occasions, sampled in 2004, 2005, 2008 and 2014. Rainbow estimates have been more variable; however, the differences can be directly attributed to stocking strategies in effect at the time.

The Blue River adjacent to the USFS Blue River Campground has been surveyed multiple times over the past decade and since 2011 this segment has not met the biological criteria for a Gold Medal designation. Reasons for the lack of productivity on this reach of the Blue are not fully understood. There are some areas with obvious physical habitat shortcomings particularly when Dillon releases are less than 100 cfs, but it is likely not the only limiting factor given the extremely slow trout growth in the surveyed populations here, which suggests aquatic invertebrate productivity limitations (Rees 2021).

Chadwick and Associates (1986) found that a positive tailwater effect on the fishery was not seen below the Dillon Reservoir, as no increase in bio-productivity was evident. Some of the most productive fisheries are in tailwaters below dams due to constant temperatures and ample food supply from macro invertebrates and items like amphipods (scuds) coming out of the associated reservoir. These factors allow faster growth, superior fish condition and overall survival.

Comparison to Other Colorado River Systems

Additional analysis was completed comparing the Blue River fishery over time to similar rivers in Colorado that are regulated by large reservoirs upstream which have hypolimnetic releases and similar fisheries management and regulations. Rivers which were utilized were the Fryingpan River below Reudi Reservoir, and the Taylor River below Taylor Reservoir. Both these rivers have wild brown trout populations with rainbow populations which are dependent on stocking.

All these rivers have been stocked with catchable and sub-catchable size rainbow trout since 1980 (Table 1). Statewide stocking rainbow trout in tailrace fisheries is quite common, due to factors limiting rainbow trout reproduction and recruitment. In addition to the Blue River, Fryingpan River and Taylor River other tailrace fisheries like the Dream Stream (below Spinney Mtn Res.) and Cheeseman Canyon on the South Platte are stocked with fingerling rainbow trout because seasonal flows and/or cold-water temperatures hinder successful rainbow spawning. Unlike the Blue River these other tailrace rivers have developed rainbow trout fisheries by stocking subcatchable fish. Whirling disease limited statewide stocking of rainbows in the 1990's.

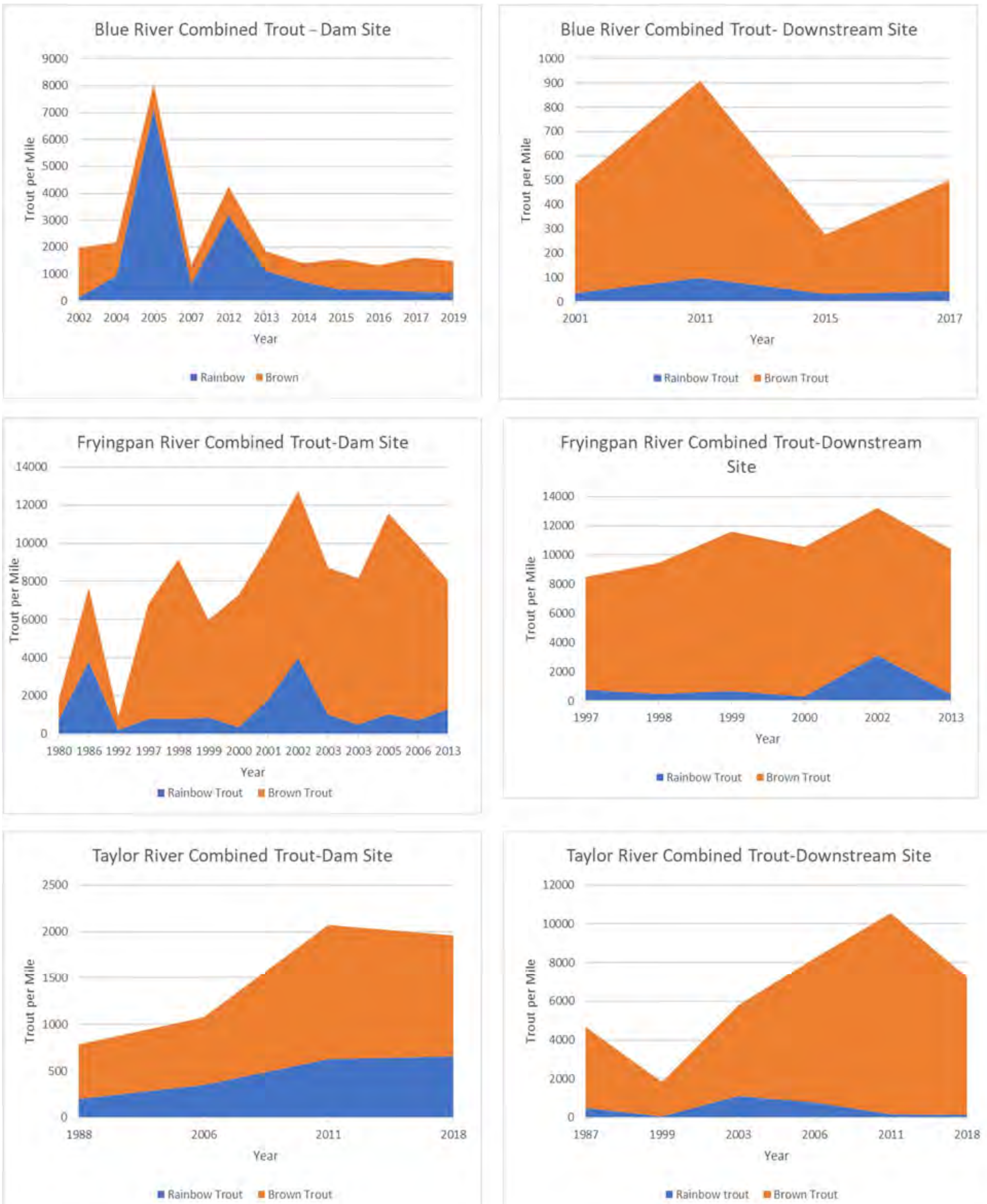
Sampling of these rivers over the past nearly 40 years has been completed for many different objectives. These include standardized population sampling, stocking evaluations, research on whirling disease and water development projects. The sampling approach is not always the same and sampling technique and data collected differs between rivers and biologists. Different data collection approach can limit the comparisons but trends in fish populations provide some insight into what is occurring in the fishery.

Table 1. Stocking summary for the Blue River, Fryingpan River, Taylor River for the period of 1980-2019

River				
		Blue	**Fryingpan**	**Taylor**
Catchables	**Years Stocked**	**26**	**8**	**25**
	Total Stocked	**130,159**	**12,224**	**179,851**
	Average/Year	**5,006**	**1528**	**7,419**
	Maximum	**30,767**	**5999**	**25,899**
	Minimum	**507**	**22**	**1,800**
		Blue	**Fryingpan**	**Taylor**
Sub-catchable				
	Years Stocked	**25**	**32**	**32**
	Total Stocked	**814,151**	**736,481**	**220,218**
	Average/ Year	**32,556**	**24,549**	**7,274**
	Maximum	**61,815**	**48,061**	**27,630**
	Minimum	**1,564**	**5,005**	**833**

Fisheries data was filtered for sampling dates that reported results for fish-per-mile and biomass. Sites that were directly associated with the dam and a site downstream a few miles were utilized for comparison. Looking at trends for fish-per-mile and biomass are more insightful than comparing individual results between rivers. In all three rivers brown trout make up the majority of the numbers and biomass in each river. The Blue River has significantly fewer trout per mile than the Fryingpan or Taylor Rivers at both the dam sites and downstream sites (Figure 4). Population trends on both the Fryingpan and Taylor show an upward trend in fish-per-mile over the last twenty years, whereas the Blue River shows a static to slightly decreasing trend for the number of fish (Figure 4). Brown trout populations on the Blue River do not appear to have the recruitment and survival of fish, the other river seem to have evidenced by the lower fish per mile. Altered flows below reservoirs have been shown to narrow natural channels and decrease connectivity with the lateral flood plain which can limit habitat for all life stages in peak flow events or other times of year (Schmutz and Moog 2018). Chadwick and Associates (1986) showed in the Blue River brown trout adults, juvenile and fry have approximately 40-50% loss of available habitat during the summer peak flows. Downstream sites on the Blue River available juvenile and adult habitat decreases by about 40% during high flow periods. Fry habitat seems to be the limiting habitat type during the peak summer flows or spill events from Dillon Reservoir.

Figure 4.Fish-per-mile for the Blue, Fryingpan and Taylor Rivers for approximately the last twenty years. Information is for sampling locations associated with respective upstream dams and sites less than 10 miles downstream. (CPW Aquatic Database)



Fish populations numbers on the Blue River fluctuate more than is what has been evident in the Fryingpan and Taylor Rivers. Cold water release temperatures and fluctuation in flows from Dillon Reservoir limits not only growth but also limits spawning success and recruitment of trout (Nehring 1987, Ewert, CPW personal communication) Nehring (1987) found in May when Dillon Reservoir releases are held below 500 cfs year class strength for age 2+ fish is much stronger when compared against same age cohorts when flows exceed 1000 cfs, correlating to habitat availability at different flows. Growth of the Brown Trout in the Blue River was found to be some of the slowest among rivers in Colorado. Nehring (1987) found that age 4+ brown trout in the Blue River averages 28 cm (10 in.) which was more than an inch smaller than Brown Trout from other rivers (Table 2).

Table 2. Back-calculated size of age 4+ Brown Trout from select rivers in Colorado studied by Nehring in 1987.

River	Size at Age 4+
Blue River	28 cm (10 in)
Fryingpan River	32 cm (12.7 in)
Colorado River	37 cm (15 in)
Gunnison R / Almont	32 cm (12.6 in)

When compared directly to the Fryingpan River in 1986, Brown Trout in the Blue River were consistently smaller in size than the same age Brown Trout in the Fryingpan River. Growth rate differences increased each year of age and by age 5+ was found to be 7 cm (2.8 in) (Table 3) (Nehring 1987). This difference could be influenced by river elevation and habitat availability.

Table 3. Back calculated lengths (cm) of trout from Blue and Fryingpan Rivers (Table 4, Nehring, 1987).

Table 4. Back calculated lengths (cm) of trout from Blue and Fryingpan Rivers , 1986 (Nehring 1987)

Year Class	N	Age Class	L_C	S.E.	L_1	S.E.	L_2	S.E.	L_3	S.E.	L_4	S.E.	L_5	S.E.	L_6	S.E.	L_6
Blue River browns - November 1986																	
1985	40	1+	15.3	0.39	7.44	0.33											
1984	20	2+	21.2	0.40	6.47	0.40	14.6	0.49									
1983	30	3+	26.8	0.10	6.66	0.30	13.4	0.53	20.9	0.63							
1982	24	4+	31.8	0.55	6.86	0.28	14.6	0.56	21.5	0.68	27.9	0.54					
1981	15	5+	35.1	0.83	8.46	0.61	16.3	0.99	22.5	1.15	28.0	1.02	32.6	0.89			
1980	9	6+	36.6	0.44	6.84	0.39	13.7	0.72	21.4	0.87	27.2	0.98	30.9	0.83	34.2	0.65	
1979	1	7+	39.0		8.82		19.1		24.3		28.0		31.0		34.8		36.7

Year Class	N	Age Class	L_C	S.E.	L_1	S.E.	L_2	S.E.	L_3	S.E.	L_4	S.E.	L_5	S.E.	L_6	S.E.	L_6
Fryingpan River brown - Fall 1986																	
1985	27	1+	14.8	0.35	7.23	0.30											
1984	37	2+	20.9	0.47	6.85	0.26	14.2	0.36									
1983	41	3+	28.6	0.57	8.03	0.29	15.8	0.39	23.2	0.45							
1982	36	4+	35.1	0.61	8.02	0.26	16.7	0.52	24.3	0.61	30.8	0.54					
1981	15	5+	40.6	0.97	7.74	0.38	16.6	0.69	24.7	0.82	31.6	1.05	37.6	0.96			
1980	4	6+	45.8	3.82	8.12	1.42	19.2	1.51	28.8	2.57	34.6	2.34	39.7	3.60	43.1	3.82	

L_c • Length at time of collection L_1 • back-calculated length at year y_1

The Fryingpan and Taylor Rivers also have the addition of *Mysis* shrimp entrained through the outlet structures into the river. Nehring (1991) found that when pluses of mysids are entrained through the outlets and into the Fryingpan and Taylor Rivers, growth rates and body conditions of the downstream trout populations appeared to increase dramatically with the addition of this new food source within the first mile below the dam. Mysids were abundant in collections made in Dillon Reservoir from 1981-1984. Anecdotal information is that mysids were entrained to the outlet and were utilized by fish in the Blue River in the mid 1980's but have not continued as has been seen in the Fryingpan and Taylor Rivers. This may be due to o Mysis density within each reservoir and the operational release patterns and flows creating entrainment from the reservoirs. Dillon Reservoir's mysid population appears to be decreasing due to an aging reservoir and the introduction of Arctic Char (Hansen, CPW, personal communication).

Influence of Temperature on the Fishery in the Blue River

Water temperature essentially influences ecosystem function and aquatic diversity, because all life stages of fish and aquatic invertebrates are intricately linked to the thermal regime of a given environment. Water temperature is perhaps the single most important environmental parameter for fish (Magnusen et al 1979). Ambient water temperature drives fish survival (Brinkman et al 2013), behavior (Cook and Bergersen 1988, Rogers 1998), growth (Selong et al. 2001, Bear et al. 2007, Brinkman et al. 2013) and also is known to define the range a fish can occupy (Dunham et al. 2003, de la Hoz Franco and Budy 2005) Recently most temperature research has been associated with rising temperatures and the potential impact to river dwelling fish (Ficke et al. 2007, Wenger et al. 2011, Zeigler et al. 2019, Roberts et al. 2013), with less research on the impacts of cold water on fish habitat and fish populations (Coleman and Fausch 2007a, Coleman and Fausch 2007b, Mullner and Hubert 2005, Simpkins and Hubert 2000, Brown et al 2011). Temperature requirements of different life stages of brown trout have been studied by numerous researchers. (Raleigh et. al 1986, Elliot and Hurley 1999, Elliot and Elliot 2010).

Study Area

In 2020 temperature loggers were monitored at 8 locations between Dillon and Green Mountain Reservoir. These temperature monitoring stations are a combination of temperature loggers installed by Trout Unlimited (TU) in 2020 and loggers previously installed by the US Forest Service (USFS). Sites were selected based on a combination of factors including locations relative to tributaries, access and previous USFS temperature monitoring sites. Sampling sites also included one location upstream from Dillon Reservoir, and one sampling location downstream from Green Mountain Reservoir. The upstream site was selected as a reference location not impacted by Dillon Reservoir (DR.). For the purpose of this report the upstream site and six sites between Dillon and Green Mountain Reservoirs were used for analysis (Table 4). All sites sampled for various purposes is shown in Figure 5. temperature logger data for Sites SCR and Blue 2, were not used in this report due to data availability or sampling dates.

Table 4. Coordinates and elevation for temperature sampling sites 2020.

Site	Description	Latitude	Longitude	Elevation (m)	Miles from Dillon Dam
UBR	Immediately upstream of DR	39.56651	-106.04884	2773	-
Blue 5	Immediately downstream of DR	39.62601	-106.06658	2684	0.4
DRD	At Dillon Ranger District in Silverthorne	39.63651	-106.07419	2675	1.4
Blue 3	Downstream of Bald Eagle Drive	39.65595	-106.07685	2647	2.9
D5	Upstream of County Road 1870	39.70545	-106.11062	2596	7.3
Blue 2	Downstream of Blue River Campground	39.72713	-106.1321	2575	9.6
Blue 1	Downstream of Boulder Creek	39.74336	-10613196	2558	11.0
BCR	Upstream of GMR at Blue River State Wildlife Area	39.8217	-106.20584	2443	20.1

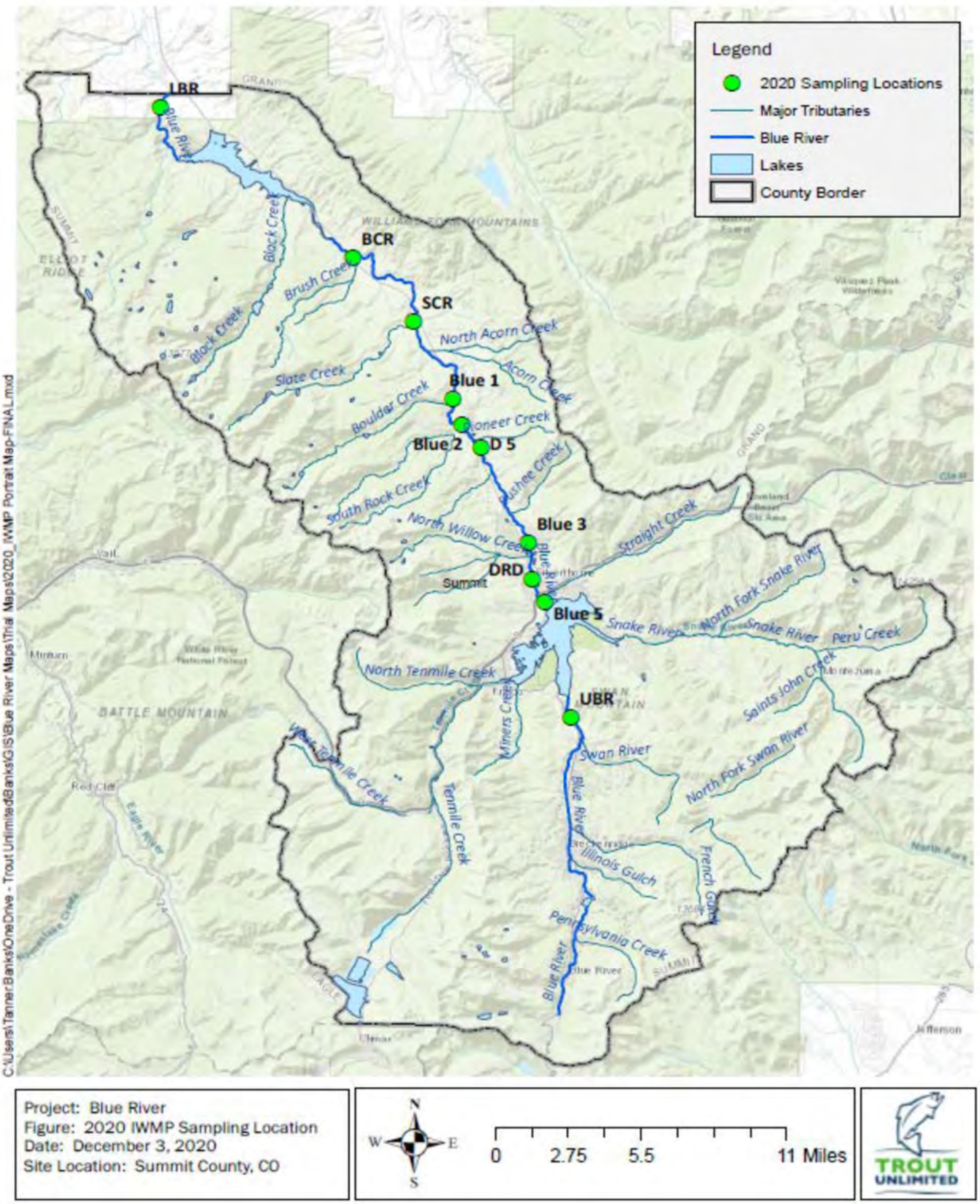


Figure 5. Map of the study sites used for temperature, macroinvertebrates and periphyton in 2020.

Methods

Onset HOBO Water Temperature Pro v2 (Onset Corporation, Bourne, MA, USA) data loggers were deployed at samplings sites in the spring of 2020. The data loggers were set to record water temperature every hour and data loggers were downloaded in late fall, and the information exported to files that could be analyzed by WaTSS 3.0 a water summary software developed by Colorado Parks and Wildlife. (Rogers K. B. 2015).

Hourly temperatures were analyzed into several temperature statistics. Daily temperature metrics were calculated from hourly daily temperatures. Monthly, growing season (May 1 to Oct 31) and comparative annual statistics (when available) were all calculated from daily metrics. Further analysis and graphics were completed in Microsoft Excel (2021). Several temperature metrics were calculated in consideration of aquatic biota. The 30-day average temperature (M30AT)was calculated as a measurement of potential fish production. The maximum weekly temperature (MWMT) was calculated as a prediction of fish population persistence, survival of brown trout is expected when maximum weekly temperature is <29^0 C. Degree day increases for each station was calculated for each site for the growing season of May 1 to October 31, providing insight into both emergence and growth. A Daily Temperature Unit is equal to 1^0F above freezing (32^0F) for a 24 period. For example, if the average daily water temperature for the first day of incubation 49^0F, it would equal to 17 DTU (49^0-32^0) (Piper 1983) Optimal growth range for adult brown trout was found to occur between 11^0 C and 19^0 C, with spawning occurring in the fall as day length shortens and temperatures decrease to <9^0 C (Range 2-13^0 C) and growth to 1-year from 7^0 to 15^0 C (Raleigh et.al 1986).

Results for the 2020 Temperature Sampling Season

Temperature varied between sites and seasons. Overall, in 2020 average hourly water temperatures ranged from an absolute minimum of -0.10^0 C (site B1) in January to an absolute maximum of 15.4^0 C (site B5) in July. Reservoir spill events are the only flow change to the Blue River that had any impact on downstream temperature. For example, at Blue 5 2020 hourly water temperature changes occurred June 17-19 with an increase of 13.5^0 C (0.56^0 C/ hour) and again on July 4-10 with a decrease of 19.9^0 C (-0.28^0 C/hour), coinciding with the increasing and decreasing discharge associated with the surface releases from Dillon Reservoir. The surface release associated with a spill event increased overall maximum water temperature as well as daily average water temperature at all sites, diminishing downstream (Table 5).

Mean average water temperature from May through October increased with distance downstream from Dillon Reservoir (Table 5). The influence of the bottom release reservoir can be seen throughout the May-October time frame, outside the spill event, at all sites down to Site Blue 1. All show a loss in stream temperature after the spill event. Only Site BCR appears to maintain an increased temperature post spill event (Figure 6). Temperatures downstream of Dillon Reservoir do not recover to the temperature seen above the reservoir at the reference site until Site B1 which is over 11 miles downstream of the reservoir (Table 5, Figure 6).

Average rates of warming in the Blue River, downstream of Dillon Reservoir, were 0.18^0 C/mile in the growing season of 2020 ranging from 0.04 and $0{,}32^0$ C, and 0.04^0 C/mile across a year for the river segment from Blue 3 to Blue 1 (Table 6).

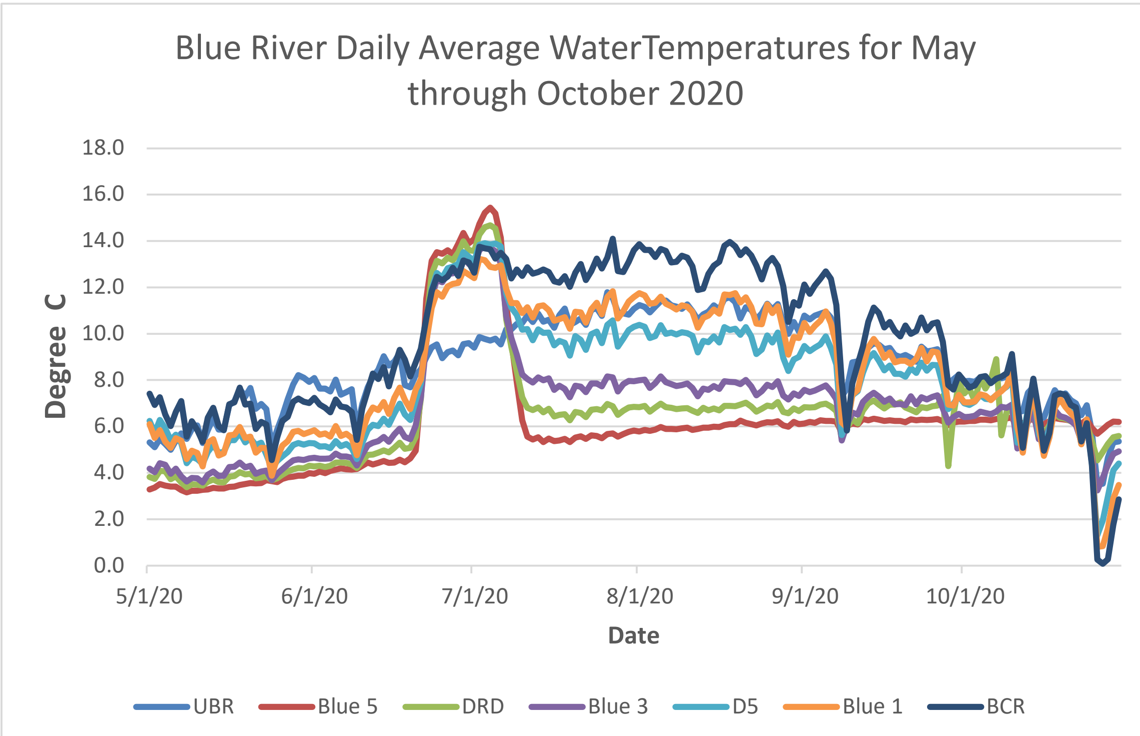
Table 5. Mean and maximum water temperatures (^{0}C) for May to October 2020, by site for the Blue River.

Site	Mean Temperature (±95%CI)	Maximum Temperature
UBR	8.7 (0.28)	11.8
Blue 5	6.1 (0.38)	15.4
DRD	6.5 (0.36)	14.7
Blue 3	6.9 (0.34)	13.8
D5	8.0 (0.37)	13.9
Blue 1	8.4 (0.40)	13.2
BCR	9.6 (0.46)	14.1

Table 6. Comparison of change in temperature per mile between sites on the Blue River during the designated growing season May through October.

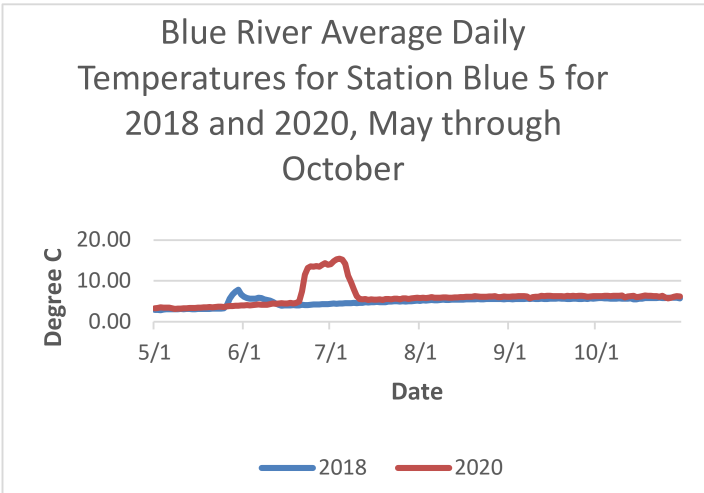
Location	Reach Length (mile)	Δ C^0/Mile ±95% confidence limits Growing Season May through October	Year 11/19 to 10/20
Blue 5 to DRD	1.1	0.04 ±0.01	
DRD to Blue 3	1.5	0.21 ±0.07	
Blue 3 to D5	4.4	0.26 ±0.03	
D5 to Blue 1	3.7	0.11 ±0.03	
Blue 1 to BCR	9.1	0.32 ±0.03	
Blue 5 to BCR	19.8	0.18 ±0.02	
Blue 3 to Blue 1	8.1		0.04 ±0.02

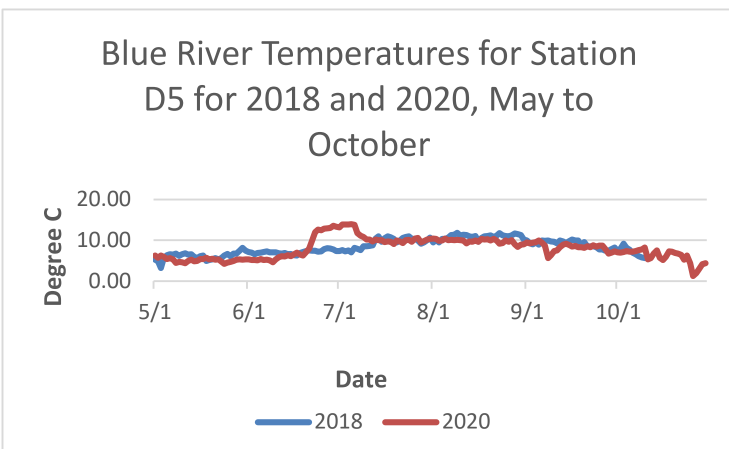
Figure 6. Blue River daily average water temperatures for May through October 2020 by site.

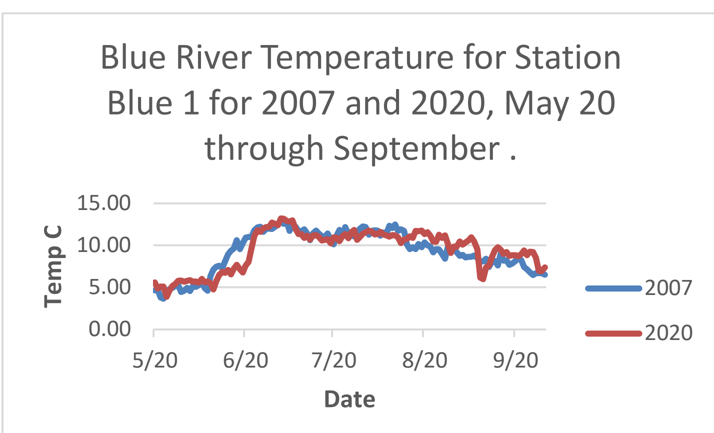


Water temperatures did not differ notably between years at any one site (Figure 7), for data available. What was observed is that average daily temperature does show more variation, moving downstream, with apparent ice formation in late October or early November at all sites. This is most likely due to solar warming and addition of tributary streams entering the Blue River. Tributary streams could also buffer loss of temperature as the river cooled after a spill event from the reservoir (Figure 6). Only the most downstream site maintained similar temperature readings seen during the remainder of the summer.

Figure 7. Comparison of daily average temperatures for three Blue River sites May through October, from different years.

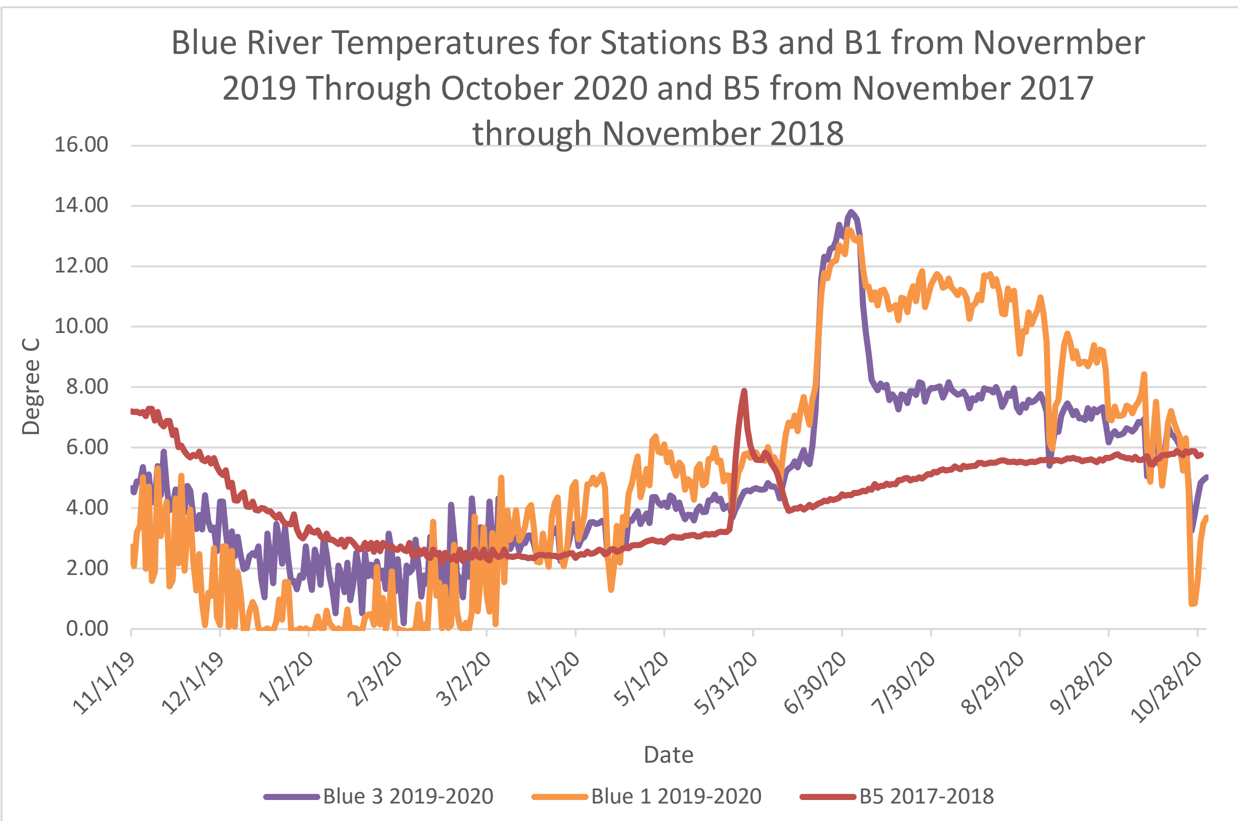






Hypolimnetic release reservoirs, like Dillon Reservoir, alter the natural temperature regimes downstream resulting in warmer-than-natural winter water temperatures (Figure 8). Warmer winter water extends downstream approximately 3 miles (Blue 3) below the reservoir, however the reverse is true in the remainder of the year, where you see colder temperatures due to the influence of the hypolimnetic release (Figure 8).

***Figure 8. Yearlong daily average water temperature for Sites B5, B3 and B1, showing the warmer than natural winter flow and colder than normal summer flows below Dillon Reservoir due to the hypolimnetic release*.**



Biological Temperature Metrics

Figure 9 shows 2020 Blue River average daily temperatures with highlighted optimal adult growth range, growth during the first year of life and spawning range for brown trout. Temperatures seen in the Blue River in 2020 meet the criteria for adult growth in the Upper Blue River (UBR) and the lower two stations (Blue 1 and BCR) from approximately July-August and showed better temperatures for successful hatching and recruitment of browns in the Blue River. Stream temperatures in 2020 seem to potentially limit growth of brown trout in the Blue River.

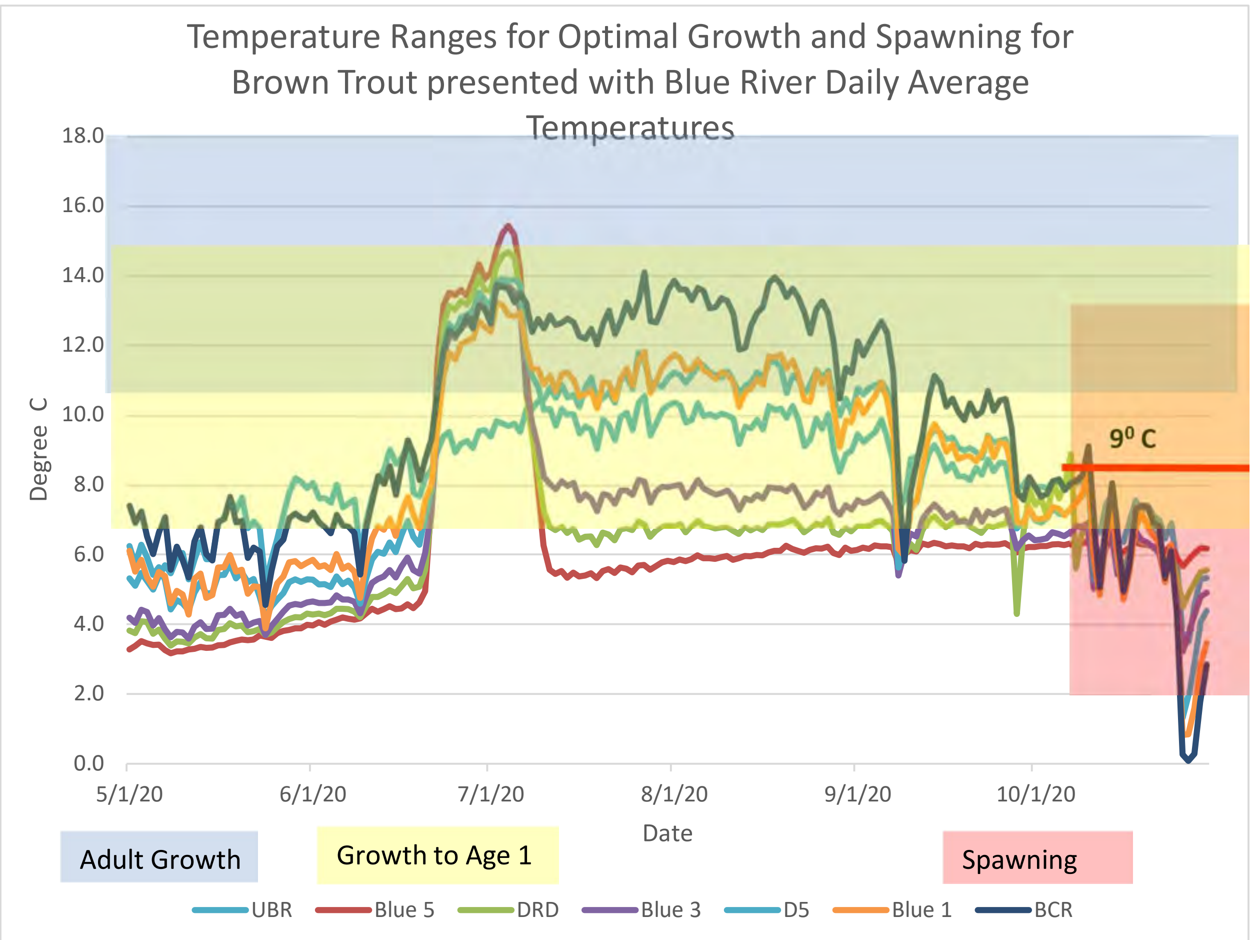


Figure 9. Blue River average daily temperature with growth and spawning temperature requirements and known range of dates those temperatures are needed for adult growth, growth to age 1 and spawning. Temperature ranges from Raleigh et. al 1986.

The M30AT tended to increase downstream, but the MWAT showed a general decrease moving downstream showing the influence of the reservoir spill (Table 8). M30AT ranged from 10.2^0 C to 13.2^0 C, and MWMT ranged from 14.8^0 C and 17.3^0 C. Temperatures never approach critical levels (27^0C) with respect to survival for brown trout. Other than the Upper Blue River (UBR) these values are influenced by the spill event from Dillon Reservoir in 2020. The increase in temperature caused by the release of surface water from Dillon Reservoir influences these temperature metrics to increase over what would be seen in years without a reservoir spill.

Table 7 Summary of the fish-temperature metrics for the Blue River. (M30AT = maximum 30-day average temperature, MWMT = maximum weekly mean maximum temperature). Accumulated Degree Day values include the influence of the Dillon Reservoir spill seen in 2020. All values summarize May 1 to October 31, 2020. *not influenced by reservoir spill

	Temperature Metric		
Site	**MWMT**	**M30AT**	**Degree Days**
UBR	14.8	11.1	1606*
Blue 5	15.7	10.2	1128
DRD	15.7	10.4	1209
Blue 3	15.5	10.5	1260
D5	16.8	11.5	1462
Blue 1	16.2	11.6	1546
BCR	17.3	13.2	1766

Degree days increased moving downstream from Dillon Dam. The hypolimnetic releases have an impact on degree days values down to below Blue 1. If the degree day production during the spill event is accounted for at each site, on average a reduction 259-degree days would be reduced at all sites downstream of Dillon Reservoir. With Site BCR maintaining stream temperature after the spill event the increase to Degree Days is less than would be seen at upstream sites. At the CPW Mount Shavano Hatchery brown trout eggs hatch at 760-degree days, but fry do not swim up from hatching until approximately they have gained 1440-degree days (Bryan Johnson, CPW, personal communication). Showing that in portions of the Blue River recruitment of brown trout fry could be limited due to temperature (Table 7).

Summary and Recommendations

After special regulation management was instituted on the Blue River in 1983, limiting harvest and tackle restrictions, the brown trout population expanded in both number and biomass until

1987, when it was shown to have reached the maximum production potential of quality size fish (35 cm,14-in). The Blue River was also shown to have the slowest growth rates when compared to other Colorado Rivers where wild fish populations were being studied. Overtime quality size fish numbers decreased until the Gold Medal fishery designation was removed in 2016.

The hypolimnetic releases from Dillon Reservoir alter the natural flow and temperature regime downstream in all seasons of the year. Non winter seasons have colder than normal temperatures which do not rebound to temperatures found above the reservoir until approximately 11 miles downstream. This impacts not only fish production in both growth and reproduction, but also has been shown to depress macroinvertebrate health (Reese, 2021). Wild brown trout populations below other hypolimnetic release reservoirs in Colorado have not shown the decline in recent years that has been seen on the Blue River. Reservoir productivity of the upstream reservoir impacts the downstream fishery. In this case all the rivers compared, (Blue River, Taylor River, Fryingpan River) all had special regulation management put into place at the same general time (early 1980's) and all had similar response of expanding trout number and biomass. The Blue River is the only one to show a general decline in the fishery since the early 2000's. These streams differ in that the upstream reservoirs have different purposes and need for water delivery which could potentially influence downstream river productivity. Both the Taylor and the Fryingpan only deliver water to downstream users, whereas Dillon Reservoir delivers water to East Slope (Denver) via the Roberts Tunnel in addition to the Blue River.

Water temperature downstream of Dillon Reservoir are having a negative impact all life stages of the brown trout fishery. Cold temperatures are limiting growth and reproduction but seems to have the largest impact on the growth of adult brown trout. In 2020,only the Blue River stream reach below Boulder Creek (Blue 1 and BCR) provided water temperatures during the summer in the optimal temperatures for adult brown trout growth. Rapid changes in temperature and flow associated with the reservoir spill may negatively impact both fry and juvenile brown trout. In general, slow changes in temperature or flow within the natural range of variability are needed to avoid negative impact on juvenile salmonids (Brown et al, 2011) . If acceptable ramping rates could be developed with the onset and ending of a spill event of Dillon Dam, downstream fisheries would benefit. Given the importance of stream temperature to aquatic organisms (Bear et al. 2007, Ziegler et al. 2013) and the relative ease with which the data can be collected, long-term year-round temperature monitoring seems like a logical way to track conditions in the Blue River. Monitoring the yearlong temperatures in some key tributaries will be useful to determine the influence of tributary temperature on the Blue River between Dillon and Green Mountain Reservoirs.

In addition to altering downstream temperature, reservoirs can alter downstream channel configuration and complexity that was seen prior to reservoir construction. These changes often result in over width channels and the loss of deep pool habitat, nursery areas and overall habitat for all life stages in various time of the year. In addition, changes to sediment supply and occurrence of cobble habitat which provides critical fish habitat is altered below reservoirs. Habitat quality assessments and availability need to be completed to determine if channel alterations could improve the overall fishery of the Blue River.

To determine if projects or changes to the Blue River system have and effect on the quality of the fishery some measurement tool must be used to measure success. Statistically valid creel census should be completed both before and after changes are made to measure the success of a project.

If the goal is to return the Blue River to Gold Medal Fishery status, then angler satisfaction as well as standard fish population sampling must be completed to verify success.

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APPENDIX G

Stream Assessments

APPENDIX G

BLUE RIVER STREAM ASSESSMENT

G.1. PURPOSE

A preliminary stream assessment for the Blue River in Summit County, Colorado was conducted for the purpose of rating functional ecological conditions of the river to develop a basis for understanding the key physical characteristics of the river and associated aquatic health. This information will support the formulation of restoration opportunities and/or needs for further study and create a baseline for future assessments and evaluations. Several studies and assessments concurrently underway or proposed for subsequent phases of the BRIWMP will be folded into this assessment in future phases. It is anticipated that this assessment may be updated in conjunction with these additional assessments, possibly resulting in modified ratings or scores.

Section G2 presents the assessment methodology and defines the variables used to perform the assessment. Section G3 summarizes the assessments by reach and section G4 provides an assessment summary by variables. Section G5 provides a summary of data sources.

G.2. METHODOLOGY

This assessment utilizes the framework outlined in the Functional Assessment of Colorado Streams (FACStream) version 1.0 (Beardsley et al. 2015). FACStream is a reach-scale functional assessment tool that rates functional conditions of a stream using the level of departure from a reference reach. A reference reach is defined as a river segment that represents a stable channel within a particular valley morphology, generally in an unimpacted condition. FACStream uses ten ecological variables and can be employed as a reconnaissance (Level 1), routine (Level 2), or intensive (Level 3) effort.

- Level 1 relies on the documentation of observable factors
- Level 2 routine assessment includes observable factors and review of existing information
- Level 3 includes observable factors, review of existing information, and the use of predictive models to further document the degree of impairment and loss of function

The Blue River Stream Assessment can generally be categorized as a Level ”1 to 2” assessment utilizing observable factors and to the extent practical, existing available reports and data.

A desktop analysis of existing available information collected and/or developed for the draft BRIWMP, including hydrologic analysis, aerial imagery, channel profile information, water quality, land use, watershed conditions (including pine beetle impacts), presence of channel obstructions and hydraulic controls, was conducted to inform this evaluation.

Field assessments were conducted in the fall of 2020. Observations and assessments generally follow the guidance outlined in FACStream to qualitatively assess the ten stream health variables summarized in Table G-1.

Table G-1. FACStream Variables

Scale	Variable		Metrics
Watershed	V_{hyd}	Flow Regime	Peak flow, base flow, rate of change
	V_{sed}	Sediment Regime	Land and channel erosion; transport through the reach
	V_{chem}	Water Quality	Temperature, nutrients, metals, others
Riparian	V_{con}	Floodplain Connectivity	Extent of lateral flooding and duration
	V_{veg}	Riparian Vegetation	Vegetation banks and overbanks, diversity, connectivity
	V_{deb}	Debris	Large wood, soil and duff, organic matter
Stream	V_{morph}	Stream Morphology	channel planform/dimensions, profile
	V_{stab}	Stability	channel stability and ability to recover
	V_{str}	Physical Structure	Bank and bed structures (rock and wood) supporting aquatic life
	V_{bio}	Biotic Structure	Macroinvertebrates, fishery

These ten variables are assessed and rated on a report card grading scale relative to the degree of functional impairment or deviation from the reference standard (Table G-2). Details on the scoring guidelines can be found in the FACStream 1.0 (Beardsley et al. 2015).

Table G-2. FACStream Scoring: Degree of Deviation from Reference Reach

Scores	
A	Negligible
B	Mild
C	Significant
D	Severe
F	Profound or unsustainable

FACStream indicates the reference standard should be thought of as "the river in its state of natural dynamic equilibrium or 'optimal' functioning river system, likely present prior to settlement in or around the 1800s." The use of a reference standard establishes a consistent benchmark against which to measure the different FACStream scores and provides a consistent definition of reference standard to enable universal scoring guidelines. FACStream utilizes three stream classification systems: Rosgen Stream Classification, Stream Evolution Model Classification, and Montgomery-Buffington Classification.

> *Selecting the appropriate reference standard when doing a FACStream assessment begins with defining the reference morphological type of the assessment reach. On many reaches, the stream type may have been altered either by direct human manipulation or by channel evolution following some anthropogenic disturbance. Because of these changes, selecting the appropriate reference stream type requires some knowledge about local history and general trends in stream evolution. FACStream provides some basic guidance following the principle that certain stream types naturally occur in certain process domains (Beardsley et al. 2015).*

For purposes of conducting this stream assessment, the use of the term ”reference reach” will be limited to a general understanding of what undisturbed conditions might be for the Blue River. Based on guidance outlined in FACStream, and a general understanding and familiarity of the watershed. An overall reference standard could generally be described as a meandering single thread channel with wide floodplains, unconfined or partially confined valleys, pool-riffle bed formation consisting primarily of cobble and gravels, and a relatively moderate to dense riparian vegetated corridor. This reference standard diverges in the upstream headwater region of Reach 1 where the river begins as a steep, cobble, and confined single thread channel that follows the centerline of the valley bottom, into a flatter, braided channel with a wetlands complex and beaver habitat. These reference reaches would have no local water use, transbasin diversions or water impoundments.

G.3. REACHES

The project reach is defined as the main stem of the Blue River from the headwaters region at Hoosier Pass to the confluence with the Colorado River, estimated to be approximately 60 miles of river corridor. Assessments are conducted in each of the three main project reaches shown in Figure G-1. The major reaches are further divided into subreaches as documented in the assessment and defined in the following sections of this appendix. Tributaries are not assessed in this phase of the BRIWMP, but may be added at a later time.

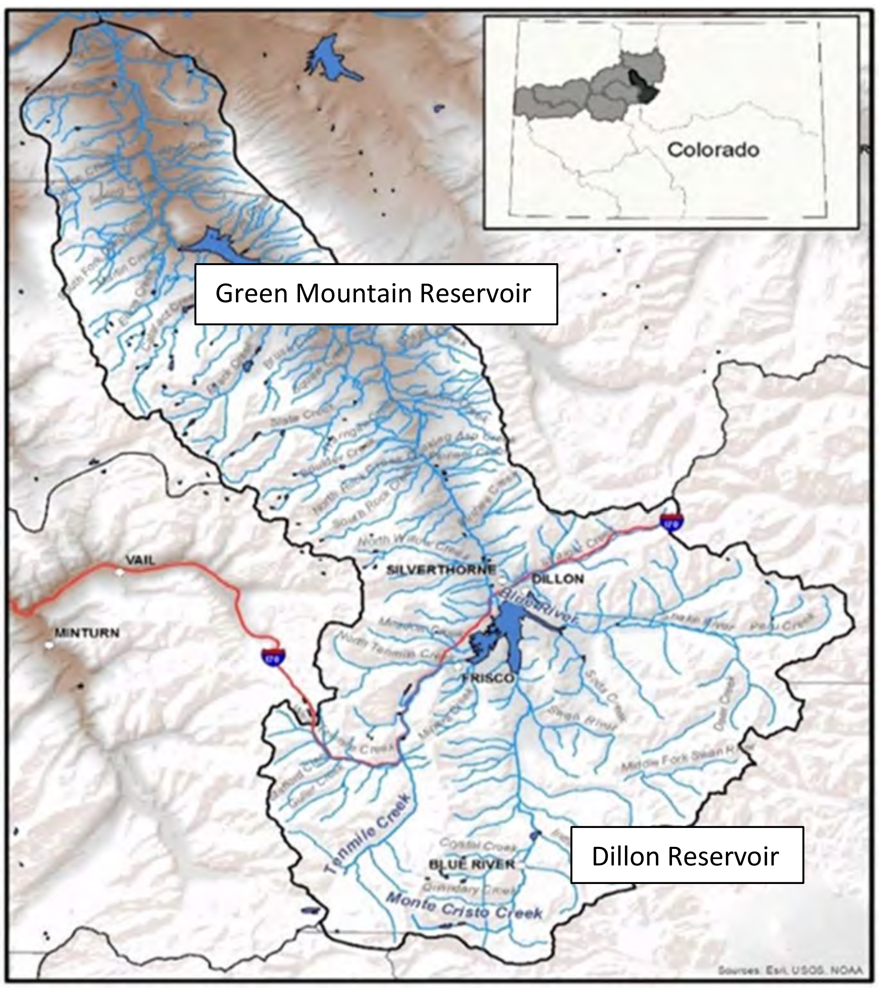

Figure G-1. Blue River Watershed.

Reach 1

Reach 1 is approximately 16.6 miles long and extends from Hoosier Pass on the Continental Divide to Dillon Reservoir. For purposes of this assessment, Reach 1 is further subdivided into four subreaches to represent the changing morphology and starkly different settings, in terms of river form, urban development, and historic disturbance from mining activities which have been significant in this Reach (Figure G-2). The assessment does not include Dillon Reservoir, nor tributaries to the reservoir or main stem of the Blue River.

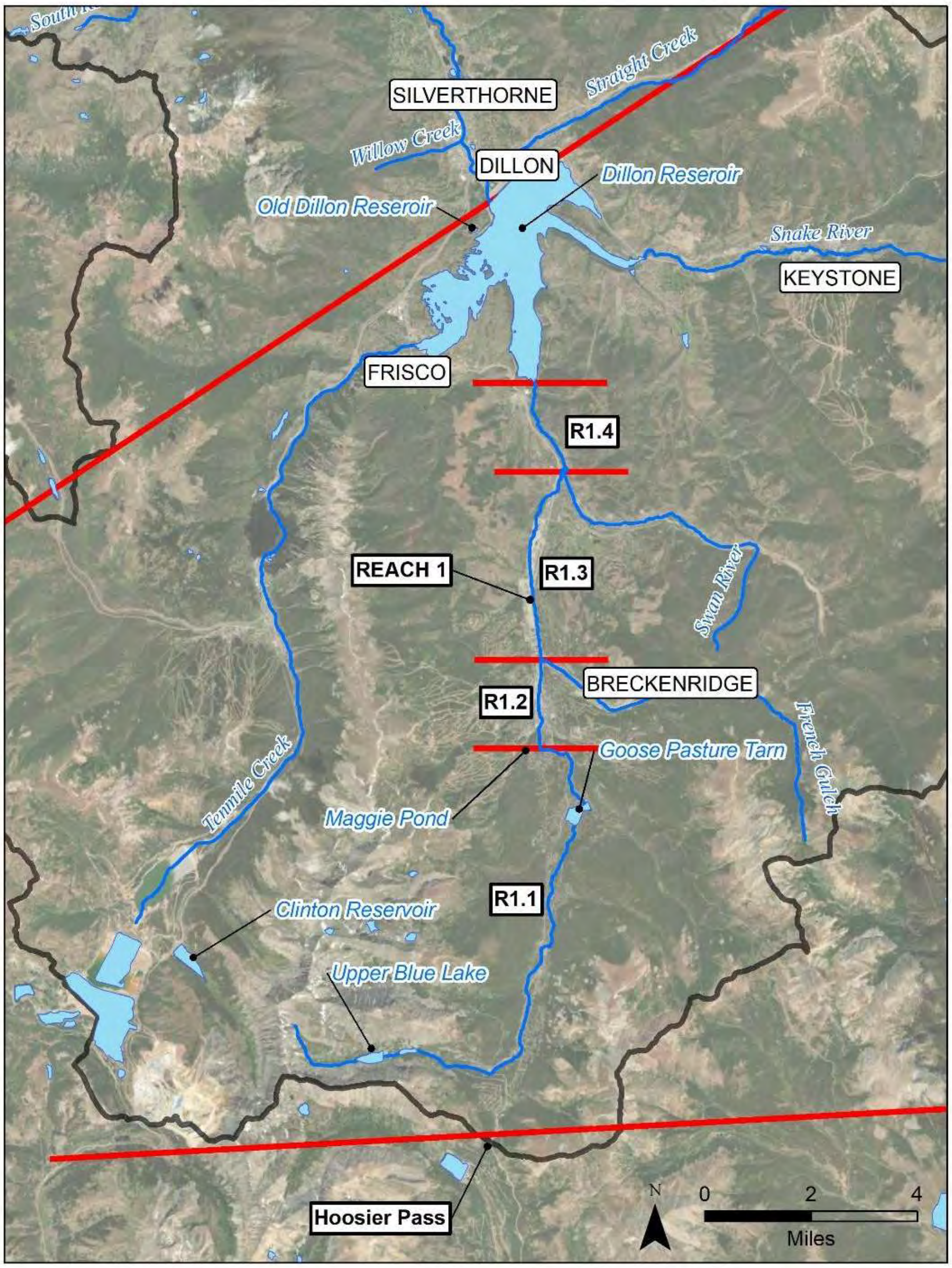

Figure G-2. Reach 1 Subreaches.

Blue River Reach 1.1-Headwaters to Maggie Pond in Breckenridge

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	B	Mild	Reach R1.1 begins at the Continental Divide. The Continental-Hoosier transbasin diversion is located in this reach. Transbasin diversions and local mmunicpal uses may affect flow. Increases to transbasin diversions are anticipated. There are several small mine sites. This reach is listed on the 303(d) list for macroinvertebrates and arsenic, both with a low priority. Impacts from winter maintenance (sanding) along US Hwy 9 were observed.
	V_{sed}	Sediment Regime	A-	Negligible/mild	
	V_{chem}	Water Quality	B	Mild	
Riparian	V_{con}	Floodplain Connectivity	A	Negligible	There are three significant wetland areas located along this reach. There is some encroachment but overall the wetlands are relatively undisturbed and have signs of beaver activity; bank overtopping and saturation of overbanks appear to be frequent as evident by extensive footprint of wetlands. Goose Pasture Tarn, an online dam likely creates additional backwater, sustaining a wetlands upstream of the reservoir. Wood is present.
	V_{veg}	Riparian Vegetation	A	Negligible	
	V_{deb}	Debris	A-	Negligible/mild	
Stream	V_{morph}	Stream Morphology	A-	Negligible/mild	Some encroachment along the river, more notably near Breckenridge. There are several stream crossings and one online dam and reservoir serving the Town of Breckenridge (Goose Pasture Tarn).
	V_{stab}	Stability	A	Negligible	
	V_{str}	Physical Structure	A-	Negligible/mild	
	V_{bio}	Biotic Structure	B+	Mild/negligible	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Overall Reach 1.1 has hydrologic impacts from transbasin diversions and winter maintenance activities along the highway, one online dam and encroachment from rural development, however, overall impacts are relatively minor, particularly compared to downstream reaches.
0.80			A-	Negligible/mild	

Blue River Reach 1.2-Maggie Pond in Breckenridge to French Gulch Confluence

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	B-	Mild/significant	Transbasin diversions impact hydrology in this reach, and increases are anticipated; snowmaking and naturally occurring late season flows result in low flows in early winter. This reach is on the 303(d) list for macroinvertebrates, zinc, aquatic life, arsenic, manganese and zinc, all with a low priority. Water quality vaults in the Town of Breckenridge collect and reduce sediment within Town. Illinois Gulch, a tributary along this subreach includes several mines that likely contribute inorganic contaminants; urban environment encroaches on riparian corridor.
	V_{sed}	Sediment Regime	A-	Negligible/mild	
	V_{chem}	Water Quality	B-	Mild/significant	
Riparian	V_{con}	Floodplain Connectivity	B-	Mild/significant	Restoration has been implemented through the urban corridor by Town of Breckenridge in phases over the past 20 years. Corridor is urbanized with landscaping along the banks that includes plantings, trails and multiple river crossings. Some crossings are likely impediments to fish passage.
	V_{veg}	Riparian Vegetation	C	Significant	
	V_{deb}	Debris	C-	Significant/severe	
Stream	V_{morph}	Stream Morphology	C+	Significant/mild	This subreach is highly urbanized, with encroachments and channel alterations in an urban-park setting. Much of this reach has walkways and pedestrian crossings and is very popular with tourists. Channel appears stable and well armored.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B-	Mild/significant	
	V_{bio}	Biotic Structure	C	Significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 1.2 was significantly impacted by mining and more recently reconstructed and urbanized. Generally this is a relatively straight reach within a confined urban setting. Flows regimes are affected by transbasin diversions and local municipal uses.
0.62			B-	Mild/significant	

Blue River Reach 1.3-French Gulch Confluence to Swan River Confluence

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	B	Mild	Transbasin diversions and local municipal uses affect flows in this reach and increases are anticipated. Pump back at new water treatment plant may improve base flows in the river. Reach currently on the 303(d) list for cadmium, manganese, nitrite, zinc , arsenic, with highest levels detected between French Gulch and County Road 3; likely source is Wellington Oro mine where work is being undertaken to improve water quality in a cooperative effort with EPA, County, Town of Breck and land developer.
	V_{sed}	Sediment Regime	B	Mild	
	V_{chem}	Water Quality	C	Significant	
Riparian	V_{con}	Floodplain Connectivity	C+	Significant/mild	This reach was significantly impacted by dredge boat mining, with excavations to depths up to 60 feet and widths up to 1,200 feet to the river and floodplain. Restoration has been or is being implemented in phases by various parties (Town of Breck, Summit County, private landowners) beginning in the 1980's; some are currently in progress. Swan River, a major tributary to the Blue River was also heavily impacted by dredge boat mining and is also in various stages of restoration.
	V_{veg}	Riparian Vegetation	C	Significant	
	V_{deb}	Debris	D	Severe	
Stream	V_{morph}	Stream Morphology	C	Significant	As noted extensive restoration has been implemented ; Step pools and a kayak park downstream of French Gulch may be creating fish passage barriers. Physical structure and biotic structure should improve with time but are not anticipated to be optimal for many decades. CPW fish surveys indicate a healthy fishery in the lower reaches, a poor fishery in the upstream reach and an overall trend showing a decline for the entire reach. Reach is listed provisional for macroinvertebrates.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	C	Significant	
	V_{bio}	Biotic Structure	C	Significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 1.3 is undergoing significant restoration efforts for both riverine and aquatic habitat as well as water quality improvements. Without these restoration efforts this reach would be rated as 'F or Profound.'
0.56			C+	Significant/mild	


Blue River Reach 1.4-Swan River Confluence to Dillon Reservoir

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	B-	Mild/significant	Transbasin diversions and local municipal uses affect flows in this reach and increases are anticipated. Flows from Swan River, a major tributary located at the upstream end of this reach, ameliorate flow conditions. This reach is currently on 303(d) list for zinc (H) and arsenic (L), and macroinvertebrates.
	V_{sed}	Sediment Regime	A-	Negligible/mild	
	V_{chem}	Water Quality	C	Significant	
Riparian	V_{con}	Floodplain Connectivity	B-	Mild/significant	This reach was not impacted by dredge boat mining and landownership is large acreage, privately owned. Consequently there has been minor to moderate disturbance to floodplain overbanks. Riparian corridor is present, although somewhat disturbed from urban encroachment.
	V_{veg}	Riparian Vegetation	B-	Mild/significant	
	V_{deb}	Debris	C+	Significant/mild	
Stream	V_{morph}	Stream Morphology	B-	Mild/significant	Overall channel morphology has some impacts from development and channel alterations and crossings. Fish surveys conducted by CPW show decline in fishery since 2011 (CPW 2018). Sampling in 2020 indicate MMI scores between 'attainment' and 'impairment.' Water temperature trends indicate an unexpected drop in surface water temperatures between Swan River confluence and Dillon Reservoir.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B	Mild	
	V_{bio}	Biotic Structure	B-	Mild/significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 1.4 is located below the confluence with the Swan River which likely ameliorates low flow conditions. This reach was also not disturbed by dredge boat mining and a riparian corridor is present. Fishery is in decline and MMI scores are between 'attainment' and 'impairment.'
0.64			B-	Mild/significant	

Reach 2

Reach 2 is approximately 27.5 miles long from the outlet at Dillon Reservoir to the inlet of Green Mountain Reservoir. Three subreaches are used to characterize Reach 2 representing the urbanized area immediately downstream of Dillon Reservoir in Silverthorne, the confined valley area of the Blue River to approximately mid-way to Green Mountain Reservoir, and the lower half of the valley near Green Mountain Reservoir (Figure G-3). This assessment does not include Green Mountain Reservoir, nor tributaries to the reservoir or main stem of the Blue River.

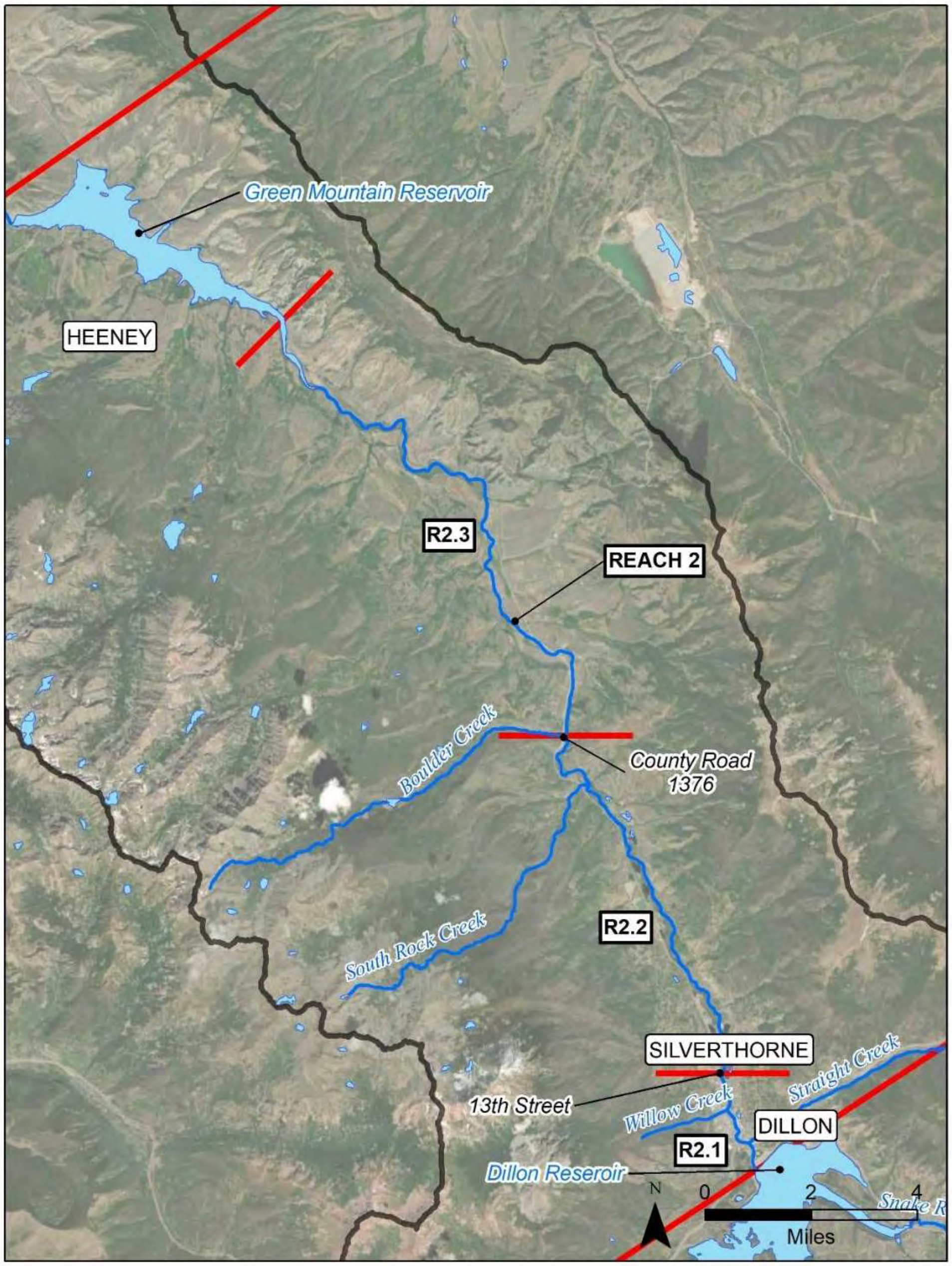

Figure G-3. Reach 2 Subreaches.

Blue River Reach 2.1-Dillon Reservoir (DR) outlet to 13th Street in Silverthorne

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	C	Significant	Transbasin diversion and flow operations from Dillon Reservoir impact flow releases reducing overall volumes and spring time peaks; transbasin diversion are anticipated to increase. Monitoring of surface water indicate average monthly temperatures below narrative standards recommended by USFWS for adult brown trout and 'growth to age 1' brown trout for all months monitored (April through October). In 2020 the Town of Silverthorne initiated a water quality sampling program to assess stormwater/snowmelt runoff.
	V_{sed}	Sediment Regime	C	Significant	
	V_{chem}	Water Quality	C-	Significant/severe	
Riparian	V_{con}	Floodplain Connectivity	C	Significant	Review of 1954 aerial mapping indicates this channel alignment and adjacent riparian fringe has not changed significantly in spite of the significant urban encroachment and development adjacent to the river. Flow alterations may be dimensioning habitat availability in the side channels and floodplain overbanks thereby not optimal for supporting aquatic life and other natural functions.
	V_{veg}	Riparian Vegetation	B	Mild	
	V_{deb}	Debris	C-	Significant/severe	
Stream	V_{morph}	Stream Morphology	B	Mild	Overall channel morphology is impacted by development and encroachment, channel alterations and crossings. The overbanks along the first mile are heavily developed with commercial land uses. Flow alterations are likely diminishing habitat availability in the overbanks. Portions of the channel has retained a narrow band of riparian and forested growth.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B-	Mild/significant	
	V_{bio}	Biotic Structure	D	Severe	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 2.1 spans the first 2 miles below Dillon Reservoir and includes sample sites Blue 5 and DRD. Average monthly water temperatures at these sites were suboptimal from April through October; MMI scores for 2020 macroinvertebrate failed to reach attainment in spring, summer and fall; and fish surveys conducted by CPW report slow growth in the brown trout fishery. Overall channel morphology has some impacts from development, encroachment, channel alterations and crossings and flow alterations are likely diminishing habitat availability.
0.54			C	Significant	

Blue River Reach 2.2-13th Street in Silverthorne to Boulder Creek at County Road 1376

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	C+	Significant/mild	Transbasin diversion and flow operations from Dillon Reservoir impact flow releases, although some amelioration may be occurring from tributaries. Transbasin diversion are anticipated to increase. Average monthly water temperatures were below narrative standards recommended by USFWS for adult brown trout for all months monitored (April through October) and for 'growth to age 1' for April through July.
	V_{sed}	Sediment Regime	B	Mild	
	V_{chem}	Water Quality	B	Mild	
Riparian	V_{con}	Floodplain Connectivity	B	Mild	Review of 1954 aerial mapping indicates this channel alignment is relatively stable and has not changed significantly, although there is evidence of vegetation encroachment likely due to lower flows since 1954 with the construction of DR. Flow alterations may be diminishing habitat conditions and not optimal for supporting aquatic life and other natural functions.
	V_{veg}	Riparian Vegetation	B	Mild	
	V_{deb}	Debris	B	Mild	
Stream	V_{morph}	Stream Morphology	B	Mild	Review of 1954 aerial mapping indicates this channel alignment is relatively stable and has not changed significantly, although there is evidence of vegetation encroachment likely do to lower flows since 1954 with the construction of DR. Overbank floodplain impacts exist from gravel mining. MMI scores for 2020 macroinvertebrate varied with sample site Blue 3 consistently impaired while D5 between impaired and attainment. Fish surveys conducted by CPW report slow growth in the brown trout fishery. Flow alterations are likely diminishing habitat availability.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B	Mild	
	V_{bio}	Biotic Structure	C	Significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 2.2 spans miles 2 to 11 below Dillon Reservoir to the confluence with Boulder and Pebble Creek and includes sample sites Blue 3 and D5. Average monthly water temperatures at these sites were suboptimal from April through October; MMI scores for 2020 macroinvertebrate varied with sample site Blue 3 consistently impaired while D5 between impaired and attainment. Fish surveys conducted by CPW report slow growth in the brown trout fishery. Flow alterations are likely diminishing habitat availability.
0.66			B	Mild	

Blue River Reach 2.3-Boulder Creek at County Road 1376 to Green Mountain Reservoir					
FACStream Summary					**Notes**
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	B	Mild	Transbasin diversion and flow operations from Dillon Reservoir impact flow releases, with some amelioration from tributaries. Transbasin diversion are anticipated to increase. Average monthly water temperatures were below narrative standards recommended by USFWS for adult brown trout and for 'growth to age 1' for April through June.
	V_{sed}	Sediment Regime	B	Mild	
	V_{chem}	Water Quality	B+	Mild/negligible	
Riparian	V_{con}	Floodplain Connectivity	B	Mild	There is evidence of land use encroachment from agriculture, resulting in a lower sinuosity, loss of side channels and a reduction in riparian vegetation density and lateral extent. Flow alterations may be diminishing habitat conditions and not optimal for supporting aquatic life and other natural functions. Diversions for irrigiation are present which may impact fish passage.
	V_{veg}	Riparian Vegetation	C	Significant	
	V_{deb}	Debris	B	Mild	
Stream	V_{morph}	Stream Morphology	B	Mild	Review of 1954 aerial mapping indicates this channel alignment is relatively stable and has not changed significantly, although there is evidence of vegetation encroachment likely do to lower flows since 1954 with the construction of DR. Flow alterations may be diminishing habitat conditions and not optimal for supporting aquatic life and other natural functions. MMI scores for 2020 macroinvertebrate sampling generally indicate attainment to slightly impaired in spring, summer and fall.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B	Mild	
	V_{bio}	Biotic Structure	B-	Mild/significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 2.3 spans the downstream half of the reach between Dillon and Green Mountain Reservoir and generally depicts a downstream recovery in both temperatures and macroinvertebrates. Average monthly water temperatures show a general increase but remain suboptimal from April through June; MMI scores for 2020 macroinvertebrate generally show attainment. Development is outside of the historically active floodplain, although there is agricultural impacts including loss of riparian vegetation and the presence of fish passage impediments.
0.70			B	Mild	

Reach 3

Reach 3 is approximately 16 miles long and extends from the Green Mountain Reservoir outlet to the confluence with the Colorado River (Figure G-4). Much of this reach is in private ownership, held by Blue Valley Ranch (BVR) and extensively managed for aquatic habitat and agricultural land use. Most of this reach is in Grand County and was studied in preparation of the Grand County Stream Management Plan (GCSMP) which is referenced and relied on, along with updated data from BVR, for information used in this stream assessment.

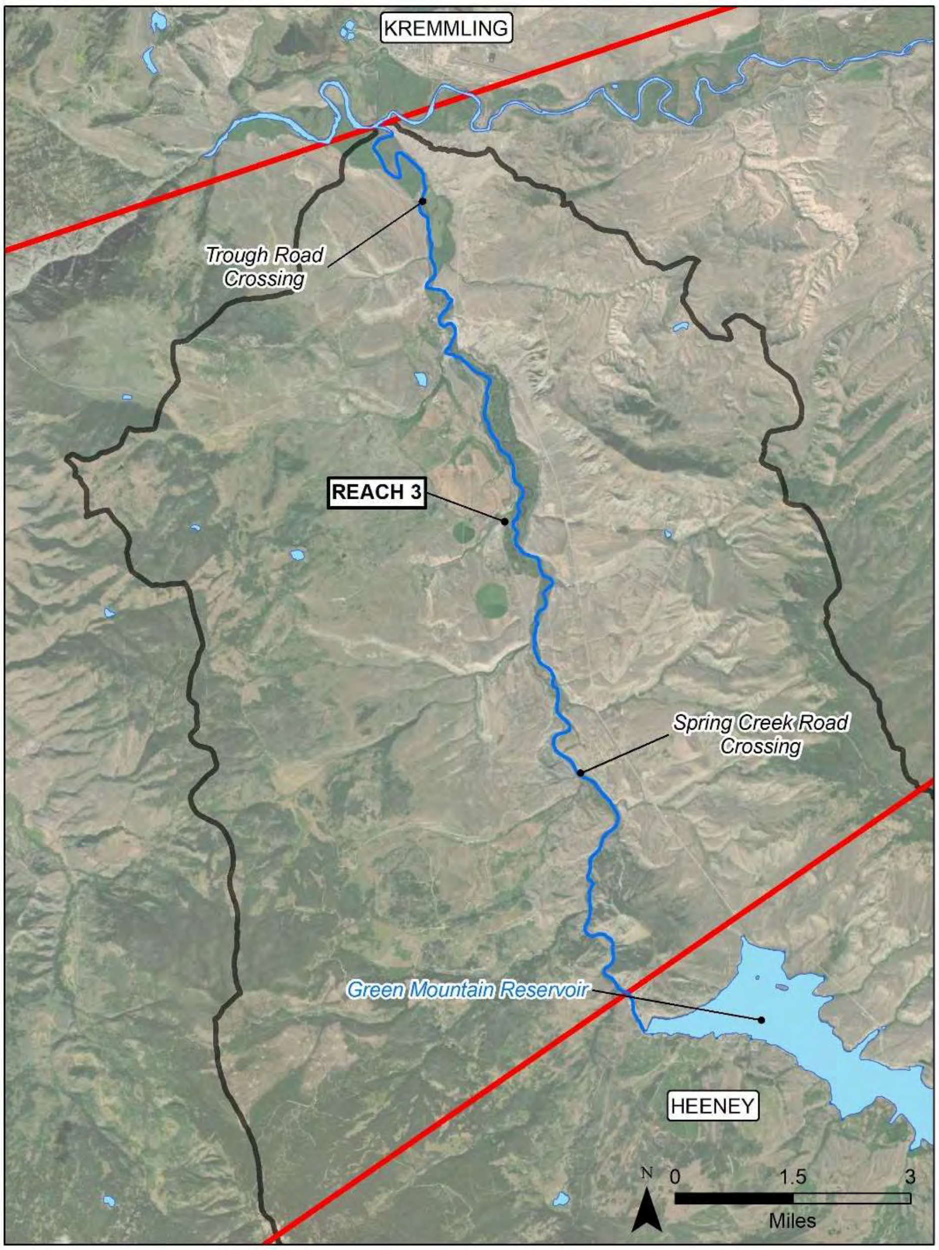

Figure G-4. Reach 3 Subreach.

Blue River Reach 3-Green Mountain Reservoir to confluence with Blue River					
FACStream Summary					**Notes**
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	C	Significant	Rapid flow changes from GMR particularly in the late fall have impacted spawning habitat with high flows in early fall support create spawning habitat in side channels and along the banks of the main channel, but later left dry due to rapid and significant flow reductions (GCSMP 2010).
	V_{sed}	Sediment Regime	B	Mild	
	V_{chem}	Water Quality	B	Mild	
Riparian	V_{con}	Floodplain Connectivity	B	Mild	Generally riparian corridor appears well vegetated along banks with well established cottonwood galleries. Overbanks are in agricultural production with some areas managed for wildlife habitat. There is a lack of debris (wood) in the lower portions of this reach.
	V_{veg}	Riparian Vegetation	A	Negligible	
	V_{deb}	Debris	B	Mild	
Stream	V_{morph}	Stream Morphology	B	Mild	Below GMR and above Trough Road there appears to be many structures in the river (v-shaped weirs, deflectors, jetties) likely installed to stabilize the river and support irrigation diversions. These may impede fish passage.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B	Mild	
	V_{bio}	Biotic Structure	B-	Mild/significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 3 is located between GMR and the Colorado River. While this reach is the benefactor of ample flow releases from GMR, the timing and rate of flow changes may be hampering the aquatic life in this reach.
0.64			B	Mild	

G.4. SUMMARY OF RESULTS BY VARIABLE

Much of the information, data, and reporting referenced in this Stream Assessment report is derived from the studies cited in the main body of the report and appended documents. This includes CPW fish surveys (cited), macroinvertebrate sampling by Timberline (Appendix D), Periphyton sampling by TU (Appendix E) Blue River Fishery Review by Ksqrdfish Aquatics (Appendix F) and water quality and temperature (Appendix C). Additional data sources are also identified in the following descriptions and Section G.5. of the appendix.

Flow Regime

The Blue River is generally a snowmelt driven system, with peak flows typically occurring in late spring and early summer and often lasting for multiple days or weeks. Snowmelt runoff will typically dominate flows until early summer as river flows begin to drop off. Changes to total annual volume and peak flows, including bankfull discharge and floods, are most relevant to channel stability, riparian vegetation, and floodplain functions. Impacts to base flows are most relevant to stream habitat and water quality. Alterations to natural patterns of flow variability, including the frequency and timing of peaks, fluctuations, and rates of change, are particularly important to fish, insects and other biota that have life history strategies tied to predictable flow rates at specific times of the season (Beardsley et al. 2015).

The Blue River watershed is impacted by transbasin diversions which occur in several locations, including a diversion in the headwaters of Reach 1 and in Dillon Reservoir at the upstream end of Reach 2. These diversions often occur during peak runoff but can affect both peak flows and base flows. Current estimates indicate annual flow depletions from transbasin diversions can be significant. In the 2012 Blue River Water Quality Management Plan prepared by the Northwest Colorado Council of Governments (NWCCOG) they note:

> *In 2009, 71,436.5 acre-feet of water were diverted to the eastern slope from the Blue River watershed [2009 Annual Report, Division 5 Water Resources]. To put this in perspective, in the 2000 water year 150,576 acre-feet of water flowed past the USGS gage 0.3 miles below Green Mountain dam [USGS 2000 Water Resources Data, Colorado Volume 2]. The trans-basin water diversions, therefore account for approximately 40% of the total stream flow in the Blue River watershed. (NWCCOG 2012).*

Changes in flow regime in Reach 3 is impacted by releases from Green Mountain Reservoir, which makes releases for downstream water uses late in the summer or fall resulting in an unnaturally high flow regime in the fall. Based on the scoring guidelines provided in FACStream, these factors can result in a rating of a severe impairment for total volume of flow and high to very high ecological risks to the Blue River.

Information developed through the Flow Evaluation Tool and Analysis & Technical Update provided by the Colorado Water Plan (CWP 2019) indicates future water demands, combined with climate-impacted conditions, will likely result in peak flows moving earlier in the year, with April through August flows decreasing and possible mis-matches between peak flow timing and species' needs. The *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* scenarios developed in the Flow Evaluation Tool indicate that mid- and late-summer flows may be reduced by 60 to 70 percent, creating high risk to fish from loss of habitat. In addition, downstream from major reservoirs, diminished peak flows could create risk for riparian/wetland vegetation and fish habitat if sediment is not flushed (CWP 2019).

Additional information will be collected in subsequent phases of analysis to assess habitat suitability for selected fish species and age groups, likely brown trout, including quantitative analysis and prediction of suitable physical habitat for chosen species and life stages under different river flow scenarios. This assessment will be based on field measurements, hydraulic calibration, and species physical habitat preferences (depth, velocity, and substrate).

Sediment Regime

Overall, the sediment regime in the main stem of the Blue River scored in the negligible to mild range of impairment, indicating little observable or documented modifications from reference standards. There are two exceptions. The first is in Reach 2.1 downstream of the Dillon Reservoir dam where a lack of fine material as well as lack of small gravels and cobbles in the channel is observed and likely a result of the impoundment from the dam. The second is in Reach 1.3 located between the Swan River confluence and French Gulch where dredge boat mining has resulted in a reduction in fine sediment, gravel, and small cobble within the channel and adjacent floodplain. In Reach 1.1, there is some evidence of sand accumulation south of Breckenridge, possibly indicating impacts from the placement of traction sand on Highway 9 in the winter. Data collection in Phase 2, particularly for habitat suitability and associated field observations, will provide an opportunity to further the understanding of sediment regime in all three reaches. Excess sediment was not observed in the other reaches.

Water Quality and Temperature

Review of water quality data indicate a presence of inorganics and toxins in all reaches, with some exceedances in Reach 1, likely the result of underlying geology, as well as historic hard rock mining along several of the tributaries.

Temperature regime is a critical abiotic habitat factor that often limits what types of organisms inhabit a reach. It is a direct determinant of biotic structure and physicochemical processes such as metabolic rates. Impacts typically manifest at the extremes (high temperatures in summer or extended freezing in winter) (Beardsley et al. 2015).

Review of temperature data indicate the Blue River has little to no warm temperature standard exceedances but can often be very cold, dropping below narrative standards established by the USFWS for support of brown trout (Raleigh et al, 1986). In the summer of 2020, continuous temperature loggers were installed along the Blue River to complement the temperature loggers already in place and being monitored by the USFS. The data indicate values below cold water narrative standards. See Appendix B for further discussion on cold water narrative standards and impacts on the fishery.

Floodplain Connectivity

Floodplain connectivity describes the degree to which water accesses and hydrates the floodplain. Reach 1.1 upstream of the town of Breckenridge, has the lowest degree of impairment ,impairment, with increasing impairment moving downstream. Reach 1.1 has minor development encroaching on the floodplain and several wetland complexes where access and hydration are abundant. Floodplain connectivity in Reaches 1.2 and 1.3 is rated with a significant impairment due to urban development and the historic dredge boat mining. Dredge boat mining destroyed the original river channel and surrounding floodplain as the dredge boats extracted the alluvium and sifted through the material for gold. What remained of the river was a straight, trapezoidal channel which only conveyed flow during snowmelt run-off. Additionally, the dredge tailings, devoid of vegetation, fine sediment and boulders, were highly mobile resulting in very unstable riverbed and banks. Restoration has been in progress since the mid-1980s including the urban corridors through Breckenridge (McMillen et. al. 2013). By necessity due to dense development in the town of Breckenridge, the urban corridors have reduced floodplain connectivity (Figure G-5). Reach 1.3 is also in the process of being restored to improve this and other riparian and stream functions and conditions. Without the restoration efforts, the impacts to floodplain connectivity in Reaches 1.2 and 1.3 would be rated as "Profound." Reach 1.4 has mild impairments due to large acreage residential development.

Reach 2 has had fewer floodplain connectivity impacts from mining, but instead has impairment due to reduced flow regimes. This is evident by the change in riparian vegetation density, which has increased over the past 60 years, likely due to lack of overbank flows since the time Dillon Reservoir was constructed in 1963 (Figure G-6).

Figure G-5. Urban Development along the Blue River, Breckenridge (top photo) and photo of dredge boat in operation immediately north of Breckenridge (1938) (bottom photo).

Figure G-6. 1954 aerial photo (left) and 2020 aerial photo (right) showing increases in vegetation density on channel banks and bars.

Reach 3, downstream of Green Mountain Reservoir, is located within a largely rural agricultural setting. Land ownership includes several privately held properties, ranches, and the USFS. Floodplain encroachment is typically limited to agricultural impacts; however, floodplain connectivity is likely reduced due to reservoir operations.

Riparian Vegetation

The degree of impairment for riparian vegetation in Reach 1 generally follows the same pattern as the floodplain connectivity, with negligible impairments in the upper watershed (Reach 1.1) and profound impacts in the urban corridor (Reach 1.2) and where dredge boat mining has occurred (Reach 1.3). Ratings reflect ongoing restoration efforts. Within Reach 2 and outside of the urbanized areas (Reach 2.1), the riparian vegetation impairment is rated as "mild;" however, in this case, the vegetation has become heavier along the channel corridor, likely due to the reduction of overbank flows which would have, in a unaltered system, scoured and mobilized the material in the overbanks thereby maintaining a less dense riparian corridor. In portions of Reach 2.3, impacts to the riparian corridor are rated as "significant" due primarily to agricultural land use that includes the removal of riparian vegetation along the channel corridor. Reach 3, downstream of Green Mountain Reservoir, is located within a largely rural agricultural setting with relatively minor impacts . Land ownership includes several privately held properties and ranches which are managed to maintain and improve riparian vegetation. The portion of the Blue River within USFS land is near the outlet of Green Mountain Reservoir and is heavily wooded, steep, and relatively undisturbed except for changes in flow regime from reservoir operations. The riparian vegetation and cottonwood galleries are abundant.

Stream Morphology

Stream morphology rates the degree of departure from the reference condition, which includes planform, channel dimensions, and longitudinal profile. Based on guidance outlined in FACStream, and a broad understanding and familiarity with the watershed, an overall reference standard could generally be described as a meandering single thread channel with wide floodplains, unconfined or partially confined valleys, pool-riffle bed formation consisting primarily of cobble and gravels, and a relatively dense riparian vegetated corridor. The reference reach would have no local water use, transbasin diversions or water impoundments.

This variable is affected by anthropogenic impacts and flows. Here again, Reach 1.2 and 1.3 scored a significantly higher departure from the reference reach due to anthropogenic impacts (urbanization and dredge boat mining) while the other reaches rated as having a "mild" degree of impairment as a result of anthropogenic impacts. Changes in flow regime due to transbasin diversions have occurred in all three reaches.

Stability

Stability evaluates the probability that the stream will maintain its geomorphic structure over time based on the dynamic balance between sediment supply and transport. This measurement also encompasses the ability of the system to recover after a large disturbance such as a large flood, wildfire, or mass erosion event. Primary factors include its ability to move and adjust as well as the potential for riparian vegetation communities to recover. For the Blue River mainstem, all reaches rated as having a "mild" departure from the reference reach, indicating that despite the changes that have occurred in the recent past, the mainstem has retained its resiliency and ability to rebound from disturbance in most locations with the exception of Reaches 1.2 and 1.3 which were significantly impacted by dredge boat mining.

Physical Structure

Physical Structure rates the degree to which characteristic patterns of structural heterogeneity are altered as depicted by the processes of erosion, scour, and deposition that shape the form of bed, banks, and substrate. Biological drivers such as riparian vegetation, wood, and beavers may have an impact on physical structure and diversity. For the Blue River mainstem reaches 1.4, all of 2, and all of 3, are rated as having a "mild" departure from the reference reach. Reaches 1.2 and 1.3 are rated as "mild" to "significant" departure reflecting the urbanization and dredge boat mining impacts. Restoration of these reaches have typically been linear, with little sinuosity or channel meandering due to existing and proposed encroachments including such things as the downtown corridor of Breckenridge, urban encroachment, and Highway 9.

Biotic Structure

Biotic structure is the biological component of the natural infrastructure of a stream, and the main subject of stream ecology. As noted in FACStream, this variable is difficult to assess accurately in routine assessments because few simple, rapid indicators exist. For purposes of this assessment the biotic structure included consideration of CPW fish surveys and 2020 macroinvertebrate monitoring. The CPW fish surveys indicate a healthy but declining fishery in Reach 1, and a poor and declining fishery in Reach 2. Macroinvertebrate monitoring results in the form of MMI scores indicate less than optimal conditions in Reach 1, impairment in the upstream section of Reach 2, and attainment in the lower reaches of Reach 2 and all of Reach 3.

Channel Habitat Assessment, Reach 3

In 2010, the Blue River from the confluence of the Colorado River to the Grand-Summit County line was assessed for the Grand County Stream Management Plan (GCSMP) (Reach 3). The analysis and data generated for the GCSMP is presented herein with permission of Grand County and reported on for the purposes of the BRIWMP this Stream Assessment. (Tetra Tech et al. 2010).

Flow recommendations developed in the GCSMP and adopted for Reach 3 were developed using the PHABSIM (Physical Habitat Simulation) system (Bovee 1997; USGS 2001). Spawning habitat availability was also evaluated using water depth and velocity suitability curves for brown and rainbow trout, assuming a substrate preference for gravel (less than 3.0-inch diameter).

Five sites were selected for analysis as described below.

1. One site was established downstream of County Road 10 in 2007. This site is within the upstream reaches of the Blue Valley Ranch property.
2. One site was established in 2008 downstream of Trough Road at the old highway bridge on San Toy Land Company property. The site is referred to in this report as the "spawning site."
3. Three additional sites were established in 2009, all within the Blue Valley Ranch property and are referred to as the upper, middle, and lower sites.

Flow recommendations developed from this analysis are as follows:

- 200 to 300 cubic feet per second (cfs), April 1 through September 30
- 200 to 300 cfs, October 1 through March 31
- Flushing flow - at least 1150 cfs for a 3-day duration with a frequency of 1 in 2 years during the late May to late June period.

Note that current instream flows for this reach are 60 cfs from May 1-July 15 and 85 cfs for the remainder of the year. These values are closer to the values assessed for the Two Forks Aquatic Baseline and in the

Nehring Federal Reports state PHABSIM recommendations are for a minimum of 50 and optimum of 100. Further analysis and assessment may be required to review the differing results.

Both the 1985 Chadwick and Associates report and the GCSMP note that rapid changes in streamflow (ramping) could adversely affect aquatic life, including fish. Rapidly rising streamflows could potentially re-locate fish and other aquatic life downstream into less favorable habitats, while rapidly declining flows can strand fish and other aquatic life in temporary habitats ultimately leading to desiccation and death (Reiser et al. 2008). Also, flow reductions during important life cycle events such as spawning can lead to drying of incubating eggs in redds and immobile fry attempting to emerge from the inter-gravel environment. The latter problem was observed on the Blue River through the BVR and downstream below the Trough Road. While the magnitude of the effects of rapid streamflow fluctuations on the Blue River trout population and other aquatic life is not well defined, additional study, evaluation, and discussion of this potential issue is recommended. To the extent possible, flows should be maintained at a fairly constant rate within the recommended target flow range during the trout spawning and incubation period to lessen or prevent the loss of developing trout embryos. This includes the late summer and early fall seasons of September through October during which flows from Green Mountain Reservoir have often been used to supplement downstream water requirements.

G.5. DATA SOURCES AND EXISTING STUDIES

The following is a brief summary of several existing studies referenced in preparation of the stream assessments.

G.5.1. Channel Habitat Assessments Upstream of Dillon Reservoir

A cursory review of existing studies and assessments for the establishment of instream flows upstream of Dillon Reservoir was conducted by Bill Miller of Miller Ecological on behalf of Summit County in 2019/2020. It is our understanding that Mr. Miller located several R2Cross studies conducted in the 1980s to establish the minimum instream flows in the Blue River upstream of Dillon Reservoir; two additional hydraulic simulations completed in the reach downstream of the Swan River; and an R2Cross model upstream of the confluence with the Swan River and upstream of the highway bridge. Minimum flows specified by CWCB for each section of the river are based on the R2Cross model results in combination with a water availability analysis. The supportive data for each minimum flow appropriation includes the R2Cross data sets and model output, and hydrologic analysis. The R2Cross data and hydrologic analysis appeared to be used in combination to set the minimum flow recommendations used by the Colorado Water Conservation Board to establish instream flows.

R2Cross does not inform on seasonal flow requirements, flushing flows for habitat maintenance, nor are the data sets helpful for assessing impacts of restoration projects, operational changes, and/or changes in trans-basin diversions. For this level of assessment, a more robust study and assessment is required. A summary of current instream flows for the study reach is provided in Table G3.

Table G-3. CWCB Instream Flows

Blue River Minimum Instream Flows		Minimum Flows, cfs									
Reach	Segment description	summer cfs	date	fall/winter cfs	date	fall/winter cfs	date	fall/winter cfs	date	fall/winter cfs	date
1	To Hwy 9 near Fredonia	2	all year								
1	Hwy 9 near Fredonia to Goose Pasture Tarn	5	5/1-9/30	3	10/1-4/30						
1	Swan River confluence upstream 1 mile to pond	20	5/1-10/31	10	11/1-4/30						
1	Swan River to Dillon Reservoir inlet	32	5/1-10/31	16	11/1-4/30						
2	Dillon Reservoir outlet to Straight Creek	50	all year								
2	Straight Creek to Willow Creek	55	5/1-7/31	52	8/1-9/30	50	10/1-4/30				
2	Willow Creek to Rock Creek	75	4/1-9/30	58	10/1-3/31						
2	Rock Creek to Boulder Creek	115	5/1-8/31	90	9/1-9/30	78	10/1-10/31	67	11/1-3/31	90	4/1-4/30
2	Boulder Creek to Slate Creek	125	5/1-8/31	90	9/1-10/31	70	11/1-2/29	78	3/1-3/31	90	4/1-4/30
2	Slate Creek to GMR inlet	125	5/1-9/30	90	10/1-4/30	85	12/1-2/29	90	3/1-4/29		
3	GMR outlet to Colorado River	60	5/1-7/15	85	7/16-4/29						

G.5.2. Channel Habitat Assessment Metropolitan Denver Water Supply Systemwide/Site-Specific Environmental Impact Statement (1986)

Instream Flow Incremental Methodology (IFIM) is a method for determining the relationship between stream flows and fish habitat. An IFIM was completed in association with the Aquatic Baseline Metropolitan Denver Water Supply Systemwide/Site-Specific Environmental Impact Statement in 1986 (Chadwick and Associates). Four IFIM sites (Table G-4) were assessed, three by Chadwick and Associates (1985) and one by the Colorado Division of Wildlife (1983). Two sites were located downstream of Dillon Reservoir and two were completed downstream of Green Mountain Reservoir.

Table G-4. IFIM Sites

Station	Sampled By	Latitude	Longitude
Blue River I	Chadwick 1985	39° 42’10”	106° 06’ 23”
Blue River II	CDOW 1983	39° 45’ 14”	106° 07’ 51”
Blue River III	Chadwick 1985	39° 45’ 23”	106° 20’ 39”
Blue River IV	Chadwick 1985	39° 58’ 05”	106° 23’ 25”

The four segments used for the IFIM analysis were selected based on a combination of discharge, slope, and geomorphology (Chadwick and Associates 1986).

River segments are presented below:

Blue River I extends from the base of Dillon Reservoir to the confluence with Rock Creek and represents 10.4 km (6.5 mi). This coincides with the BRIWMP Reach 1 and portions of Reach 2.

Blue River II extends from Rock Creek to the inlet of Green Mountain Reservoir and represents 21.6 km (13.5 mi) This overlaps with the BRIWMP Reach 2 and all of Reach 3.

Blue River III extends from the base of Green Mountain Reservoir to the confluence of Spring Creek and represents 6.1 km (3.8 mi). This coincides with the BRIWMP Reach 3.

Blue River IV extends from Spring Creek to the confluences of the Colorado River and represents 17.6 km (11.0 mi). This site was completed before the channel restoration efforts on the Blue Valley Ranch were implemented. This coincides with the BRIWMP Reach 3.

In the IFIM study, brown trout was the species of interest in the Blue River. The suitability of use curves were from Raleigh et al. (1984b). The brown trout spawning criteria was modified using data collected in the fall of 1985.

G.5.3. Other Data Sources

Colorado Department of Natural Resources. Colorado Water Plan Technical Update (CWP). 2019. Water Conservation Board. Available at: https://dnrftp.state.co.us/#/CWCB/Technical%20Update%20to%20Water%20Plan/1.%20Technical%20Update%20Documentation/

Colorado Parks and Wildlife. 2020. Fishing Regulations Brochure. Colorado Parks and Wildlife.

Northwest Colorado Council of Governments (NWCCOG). 2012. Regional Water Quality Management Plan. At: http://nwccog.org/programs/watershed-services/

McMillen, LLC, Tetra Tech. 2013. Blue River Section 206 Aquatic Ecosystem Restoration, Breckenridge, Colorado. Appendix B. Engineering Report.

Tetra Tech, HabiTech, Inc. and Walsh Aquatics, Inc., 2010. Draft report, Stream Management Plan, Phase 3, Grand County, Colorado. Prepared for Grand County, CO with support from Denver Water and Northern Colorado Water Conservancy District. Hot Sulphur Springs, CO. August.

Site assessments were conducted in the fall of 2020 which included photo documentation and pebble counts.

Google earth was utilized to estimate valley lengths, slopes.

1954 aerial imagery was utilized to compare riparian conditions with current conditions in Reach 2 (Grand County, CO, Bureau of Land Management, Esri, HERE, Garmin, INCREMENT P, Intermap, USGS, METI/NASA, EPA, USDA | USGS The National Map: Imagery | Trout Unlimited).