Timberline Aquatics, Inc.

Memo

To:	Esther Vincent and Jennifer Stephenson, Northern Colorado Water Conservancy District.
From:	David E. Rees, Timberline Aquatics, Inc.
Date:	4/18/2019
Subject:	Results from the Colorado River Benthic Macroinvertebrate Biomonitoring Program, 2018.

Introduction

The structure and function of benthic macroinvertebrate communities in rivers and streams depends on the physical, chemical, and biological components of the associated ecosystem. Most macroinvertebrate taxa have a relatively long aquatic life-stage and limited mobility which results in a dependence on the surrounding environment for survival. These unique features provide an opportunity to monitor the influence of potential stressors at specific locations along the stream channel. Recent studies have emphasized the need for biological monitoring (biomonitoring) in order to evaluate water quality and the overall health of aquatic ecosystems (Barbour et al. 1999, Paul et al. 2005, Bonada et al. 2006).

Evolution and ecological processes have resulted in benthic macroinvertebrate taxa with specific adaptations to natural environmental conditions. Consequently, benthic communities have the ability to detect stress that ranges from local sources of pollution to watershed scale disturbances (Ward et al. 2002). Long-term biomonitoring studies are also essential when evaluating aquatic life in river systems with increasing water demands or changes in land-use practices (Likens and Lambert 1998, Voelz et al. 2005). The biomonitoring and analysis approach used for this study was intended to provide site-specific information describing the health of biological communities, while taking into account natural annual variability.

In the fall of 2018, the Colorado River was sampled for benthic macroinvertebrates at four locations with the intent to monitor potential changes in the health of the aquatic life in the vicinity of Windy Gap Reservoir. Results obtained from this study provided valuable information that could be used to evaluate potential changes in operations of Windy Gap Reservoir, and assess the effects of habitat improvement projects in this segment of the Colorado River. Results from data collected during the fall (September) of 2018 were the focus of this evaluation.

Study Area

Benthic macroinvertebrates were collected from four (4) sampling locations on the Colorado River during the fall of 2018 (Table 1, Figure 1). The most upstream site (CR-WGU) was on the Colorado River immediately upstream from Windy Gap Reservoir (Figure 1). Although this site receives potential influences from upstream reservoir operations (associated with Lake Granby) and some residential development, historical sampling results suggested that this segment of the Colorado River has maintained relatively healthy aquatic communities. Farther downstream, site CR-WGD was located on the Colorado River approximately 1.9 km downstream from Windy Gap Reservoir (Figure 1). This site has the potential to be influenced by aquatic conditions within the reservoir and Windy Gap Reservoir operations. Study sites CR-HSU and CR-WFU were both located even farther downstream on the Colorado River (13.0 km and 19.0 km, respectively) and these two sites were used to monitor the residual impacts from reservoir operations along with habitat improvement projects. Some confounding variables that may also influence the aquatic communities at the two most downstream sites (CR-HSU and CR-WFU) included runoff from an adjacent highway, and urban runoff associated with the Town of Hot Sulphur Springs.

Table 1. Site descriptions, coordinates, and elevations of sample sites on the West Slope sampled in 2018.

Site ID	Description	Latitude	Longitude	Elevation (m)
CR-WGU	Colorado River upstream of Windy Gap Reservoir	40.10045	-105.97248	2,401
CR-WGD	Colorado River downstream of Windy Gap Reservoir	40.10830	-106.00356	2,374
CR-HSU	Colorado River near Hot Sulphur Springs	40.07394	-106.10959	2,341
CR-WFU	Colorado River upstream of Williams Fork	40.04689	-106.14299	2,305

Methods

Stress-induced changes in macroinvertebrate community structure can be best ascertained through analysis of benthic data that has been collected using a standardized quantitative sampling methodology. The objective of this particular study required the collection of three (3) quantitative replicate samples from similar habitat at each station. All benthic macroinvertebrates from each quantitative sample were sorted and identified, and macroinvertebrate data were analyzed using a variety of individual metrics (including the MMI v3 and MMI v4). The following section provides a description of all analysis tools used in this study:

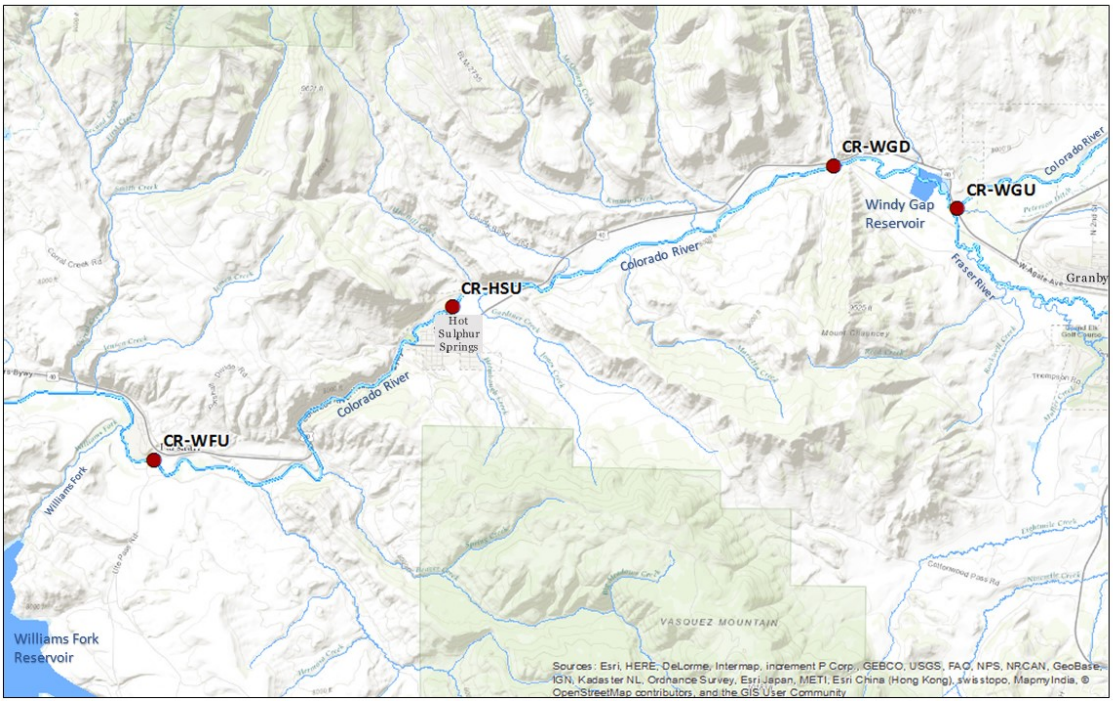

Figure 1. Map of study sites used for the Colorado River Biomonitoring Study.

The Multi-Metric Index (v3)

In the fall of 2010, the CDPHE published specific guidelines for benthic macroinvertebrate sampling and analysis to assist in the evaluation of aquatic life in the State of Colorado (Colorado Department of Public Health and Environment 2010). These guidelines described specific protocols for the analysis of benthic macroinvertebrate data using a Multi-Metric Index (MMI). The group of individual metrics used in MMI calculations depends on the location of the sampling site and corresponding Biotype (Mountains, Transitional, or Plains). All of the sites in this study area (on the Colorado River) were located in Biotype 1 (the Transitional Zone). In Biotype 1, the MMI provides a single score based on six equally weighted metrics. Each of the metrics used in the MMI produces a value that is adjusted to a scale from 1 to 100 based on the range of metric scores found at "reference sites" in the State of Colorado. The thresholds for MMI scores that determine 'attainment' or 'impairment' for aquatic life use in Biotype 1 are as follows:

Biotype	**Attainment Threshold**	**Impairment Threshold**
Transitional (Biotype 1)	52	42

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

Biotype	HBI	Diversity
Transitional (Biotype 1)	5.4	2.4

Shannon Diversity (Diversity): Diversity was used as an auxiliary metric for the MMI and as an independent metric in this study to evaluate changes in macroinvertebrate community structure. 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. The Diversity metric provides a measure of macroinvertebrate community balance.

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

An additional means of determining an 'attainment' or 'impairment' designation using the MMI (v3) involves the rapid decline of scores from high scoring waters. When MMI scores are available from multiple years at the same sampling location, and a large decline in scores occurs over the span of at least 12 months, a site will automatically be considered impaired for aquatic life use. The requirements for the allowable decline in MMI score for Biotype 1 are as follows:

Biotype	High Scoring Water (MMI score)	Allowable MMI Decline
Transitional (Biotype 1)	>64	-22

The Multi-Metric Index (v4)

In 2017, the MMI was recalibrated and updated to produce a new analysis tool - the MMI v4 (Colorado Department of Public Health and Environment 2017). This most recent version of the MMI was developed in the same way as the MMI v3, but provides a single index score based on

eight equally weighted metrics. In Biotype 1, these metrics include: EPT Taxa, Percent Non-Insect Individuals, Percent EPT Individuals (excluding Baetidae), Percent Coleoptera Individuals, Percent Intolerant Taxa, Percent Increaser Individuals (Mid-Elevation), Clinger Taxa, and Predator/Shredder Taxa. A detailed description of individual metrics and the development of the MMI (v4) can be found in the "Aquatic Life Use Attainment: Methodology to Determine Use Attainment for Rivers and Streams, Policy 10-1" (Colorado Department of Public Health and Environment 2017). Each of the metrics used in the MMI (v4) produces a score that is adjusted to a scale from 1 to 100 based on "reference sites" in the State of Colorado.

Thresholds for the MMI (v4) in Biotype 1 are as follows:

Biotype	**Attainment Threshold**	**Impairment Threshold**
Transitional (Biotype 1)	45.2	33.7

The MMI (v4) scores that fall between the thresholds for 'attainment' and 'impairment' are in the 'grey zone' and require further evaluation using the same two auxiliary metrics (Diversity and HBI) recommended in the MMI (v3). Calculations for these metrics have been previously described; however, thresholds have been adjusted for the new version of the MMI:

Biotype	**HBI**	**Diversity**
Transitional (Biotype 1)	5.8	2.1

Additional metrics used in the study:

In addition to the two MMI tools and their associated 'grey zone' metrics, several other individual metrics were applied in the analysis of macroinvertebrate data from the Colorado River in order to provide a more thorough evaluation of community structure and function. A description of these additional metrics is provided below:

Ephemeroptera Plecoptera Trichoptera (EPT Taxa): The design of this metric is based on the assumption that the orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are generally more sensitive to pollution than other benthic macroinvertebrate orders (Lenat 1988). The EPT metric is currently an important and widely used metric in many regions of the United States (Barbour et al. 1999). The EPT Taxa value is simply given as the total number of distinguishable taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera found at each station. This number will naturally vary among river systems, but it can be an excellent indicator of disturbance within a specific drainage. The EPT value is expected to decrease in response to a variety of stressors including nutrients (Wang et al. 2007).

Shannon Evenness (Evenness): Evenness values were used at all sites in this study to detect changes in macroinvertebrate community structure and balance. Evenness values range between 0.0 and 1.0, and lower values generally indicate greater stress. Values lower than 0.3 are considered indicative of organic pollution or other substantial perturbations (Ward et al. 2002).

Diversity and Taxa Index (DAT): The DAT index was used in this study to evaluate water quality based on benthic community structure and diversity. This metric is unique because it incorporates components of community diversity along with taxa richness. Calculated DAT values fall within a range of numbers that are correlated to a scale describing stream condition (Mangum 1986). The DAT scale (adjusted for Chironomids identified to the genus level) is as follows:

DAT Value	SCALE
24-35	Excellent
17-23	Good
11-16	Fair
0-10	Poor

Insect Taxa: Insect Taxa is an example of a metric that relies on community richness for detection of disturbances. The Insect Taxa value is reported as a total count of distinguishable insect taxa at each site. This metric is similar to the total taxa metric; however, the Insect Taxa metric measures the number of taxa in insect families exclusively, rather than the summation of insects and non-insects. In general, the Insect Taxa value is expected to decrease as water quality becomes more degraded (Weber 1973).

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

Percent Shredders and Scrapers: 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 comparison among sites within a specific study area.

Density: Macroinvertebrate abundance (Density) was reported as the mean number of macroinvertebrates per m^2 found at each study site. Density provides a means of measuring and comparing standing crop at each site and this metric provides an indication of productivity for the macroinvertebrate portion of the food web at each sampling location.

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

Results and Discussion

Benthic macroinvertebrates were collected on 19 September 2018 from four study sites on the upper Colorado River in order to evaluate aquatic conditions based on macroinvertebrate community structure and function. After macroinvertebrate samples were collected in the field using a quantitative (Hess) sampling technique, they were transported to the lab at Timberline Aquatics, Inc. where specimens were sorted, identified, and enumerated (Appendix A; Tables A1-A4). The previously described metrics and analysis tools (including versions 3 and 4 of the MMI) were applied to the macroinvertebrate data in order to provide a comprehensive assessment of aquatic conditions in the Colorado River study area (Tables 2-4). Results provided by select metrics (MMI v3 and v4, Diversity, HBI, and EPT) were also used to illustrate changes (or similarities) in community structure among sites (Figures 2-6). In general, results from 2018 indicated that benthic macroinvertebrate communities were relatively healthy throughout the study area, and detectable changes in aquatic conditions were minimal.

The most upstream sampling location on the Colorado River (CR-WGU) provided an opportunity to evaluate aquatic life upstream from Windy Gap Reservoir, while also producing reference information that could be compared throughout the remainder of the study area. Both versions of the MMI (v3 and v4), and most individual components the multi-metric tools, indicated that aquatic conditions were relatively healthy at site CR-WGU (Tables 2 and 3). While most of the individual metrics used in MMI calculations detected healthy community parameters, the Percent Non-Insect Taxa metric from the MMI v3, and the Percent Coleoptera metric in version 4, generated comparatively lower scores. The performance among individual metrics that was observed at site CR-WGU persisted throughout much of the study area suggesting that the influences on aquatic communities remained similar among sites (Tables 2 and 3). Despite some variability among individual metric values, both versions of the MMI indicated that site CR-WGU was in 'attainment' for aquatic life use. Other metrics used in this study generally supported the MMI by detecting healthy aquatic conditions at site CR-WGU (Table 4). The Evenness and DAT metrics suggested that the benthic community was well-balanced, and the EPT, Insect Taxa, and Percent EPT excluding Baetidae metrics detected a high proportion of sensitive taxa. When results from the MMI and select metrics were compared with historical results, most of the analysis tools showed that the aquatic community at site CR-WGU had remained similar (or improved based on Diversity values) since 2016 (Figures 2-6).

Most of the applied metrics suggested that aquatic life at site CR-WGD was similar (or slightly improved) when compared to the macroinvertebrate community structure at site CR-WGU (upstream from Windy Gap Reservoir). Both versions of the MMI produced scores that indicated 'attainment' for aquatic life use at site CR-WGD, and the score for the MMI v4 (80.4) was the highest in the study area (Tables 2 and 3). Despite potential influences from Windy Gap Reservoir, most of the component metrics used for MMI calculations produced similar scores upstream and downstream of the reservoir. Some of the slight improvements detected by the MMI v4 were due to an increase in sensitive species in the order Trichoptera. Other individual metrics showed that the macroinvertebrate community was well-balanced and maintained a variety of sensitive and specialized taxa (Table 4). A comparison with results from previous sampling events showed some improvement in community balance (Diversity) at site CR-WGD, while other metrics (EPT and HBI) detected a slight increase in stress during 2018 (Figures 2-6).

Table 2. Individual metrics and MMI (v3) scores from benthic macroinvertebrate samples collected at Northern Water sampling sites on the Colorado River on 19 September 2018. All metric scores are based on the MMI (v3) subsampling process. Scores associated with the MMI indicating impairment are provided in red.

Metric	Station ID			
	CR-WGU	CR-WGD	CR-HSU	CR-WFU
EP Taxa	88.5	79.5	81.5	83.8
% Chironomidae	80.9	76.4	93.4	99.0
% Sensitive Families	49.3	51.8	57.0	52.2
Predator/Shredder Taxa	71.4	85.7	42.9	64.3
Clinger Taxa	100.0	100.0	90.5	100.0
% Non-Insect Taxa	30.8	40.7	22.1	37.2
MMI	**70.2**	**72.3**	**64.6**	**72.7**
	Auxiliary Metrics			
Diversity	4.42	4.24	3.72	4.21
HBI	3.02	3.21	2.73	3.19

Table 3. Individual metrics and MMI (v4) scores from benthic macroinvertebrate samples collected at Northern Water sampling sites on the Colorado River on 19 September 2018. All metric scores are based on the MMI (v4) subsampling process. Scores associated with the MMI indicating impairment are provided in red.

Metric	Station ID			
	CR-WGU	CR-WGD	CR-HSU	CR-WFU
EPT Taxa	79.2	87.5	79.2	83.3
% Non-Insect Individuals	90.7	91.9	92.3	84.2
% EPT Individuals, no Baetidae	78.1	71.8	88.0	79.3
% Coleoptera Individuals	31.8	36.6	44.6	30.2
% Intolerant Taxa	75.3	80.1	74.5	89.0
% Increaser Individuals, Mid-Elevation	94.9	96.7	97.4	98.8
Clinger Taxa	76.9	100.0	76.9	100.0
Predator/Shredder Taxa	64.3	78.6	50.0	64.3
MMI	**73.9**	**80.4**	**75.4**	**78.6**
	Auxiliary Metrics			
Diversity	4.47	4.37	3.84	4.24
HBI	3.19	3.30	2.74	3.09
TIV (Sediment Region 2)	--	5.58	--	4.12

Table 4. Additional metrics and comparative values for macroinvertebrate samples collected from Northern Water sampling sites on the Colorado River on 19 September 2018. All additional metrics are based on full count Hess samples.

Metric	CR-WGU	CR-WGD	CR-HSU	CR-WFU
EPT	24	24	24	23
Evenness	0.797	0.739	0.709	0.788
DAT	32.4	34.9	31.4	27.9
Insect Taxa	37	42	37	37
Total Taxa	46	52	47	43
Percent Shredder+Scraper	27.05%	32.63%	38.85%	31.19%
Density of *Pteronarcys californica* (#/m^2)	0	0	0	225
Percent EPT excluding Baetidae	59.65%	51.72%	62.53%	57.55%
Density (mean #/m2)	5,802	6,213	6,155	3,853

Farther downstream at site CR-HSU, most of the analysis tools continued to demonstrate healthy macroinvertebrate community structure; however, some metrics detected a slight increase in stress compared to upstream study sites. Site CR-HSU was located approximately 13.0 km downstream from Windy Gap Reservoir, and while this location could be partially influenced by reservoir operations, there were also potential sources of stress associated with the adjacent highway and urban development near the Town of Hot Sulphur Springs. Components from both versions of the MMI responded to a slight decline in clinger taxa and predator/shredder taxa; however, both MMI scores continued to indicate 'attainment' for aquatic life use (Tables 2-3). The abundance of sensitive taxa (based on the EPT, Insect Taxa, and Percent EPT excluding Baetidae) and relatively high proportion of specialized feeding groups (Percent Shredder+Scraper) suggested that the aquatic community at site CR-HSU was healthy despite detectable changes in the fall of 2018 (Table 4). Although *Pteronarcys californica* had been previously observed at this site, this species was not collected during the fall of 2018. Most of the metric values from 2018 were similar to historical results; however, a slight decline in sensitive taxa (compared to previous years) may have been related to low flows that occurred during 2018 (Figures 2-6).

At the downstream boundary of the study area, site CR-WFU was positioned approximately 19.0 km from Windy Gap Reservoir and immediately upstream from the Williams Fork confluence. Results from the applied metrics suggested that the Colorado River continued to support healthy macroinvertebrate communities, and many of the MMI components detected slight improvements at site CR-WFU (Tables 2 and 3). Results from individual metrics that measure community balance (Diversity and Evenness) and metrics that measure the richness of sensitive taxa (EPT and Insect Taxa) showed relatively stable aquatic conditions compared to upstream study sites (Table 4). In general, spatial changes among macroinvertebrate communities have been relatively minor throughout the last three years (Figures 2-6). All study sites have supported healthy aquatic communities with little evidence of anthropogenic stressors.

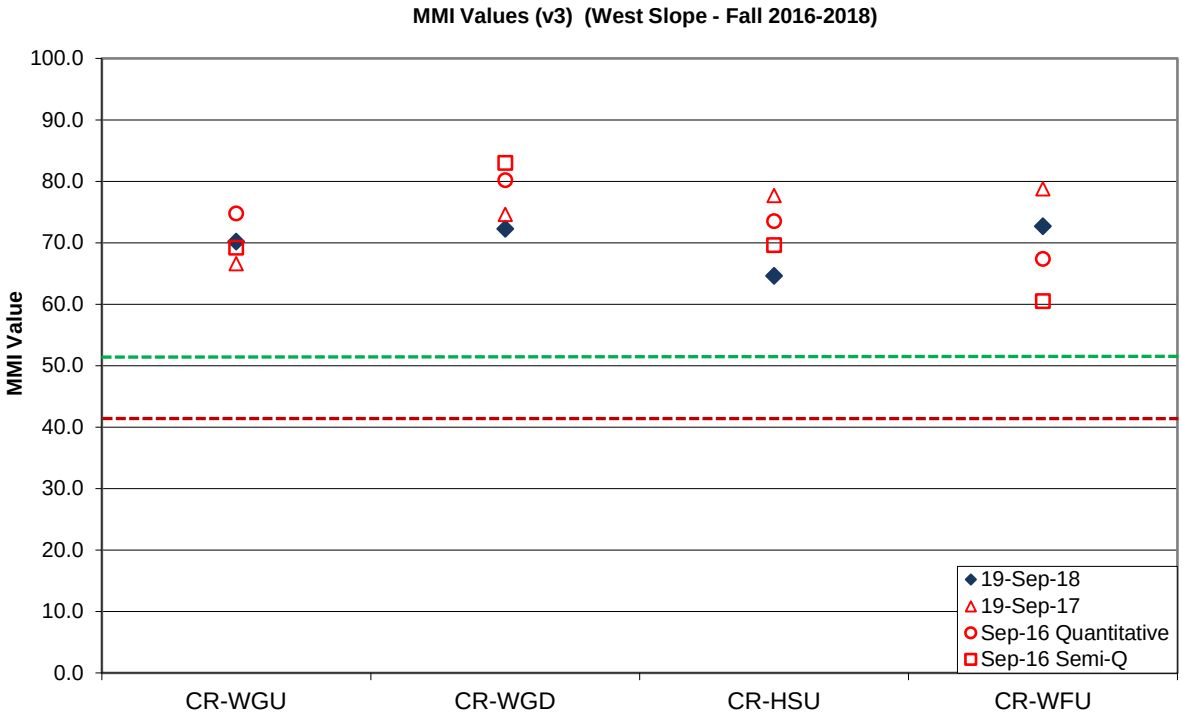

Figure 2. MMI (v3) scores for Colorado River study sites during the fall of 2016, 2017 and 2018. The green line indicates the attainment threshold and the red line indicates the impairment threshold for Biotype 1.

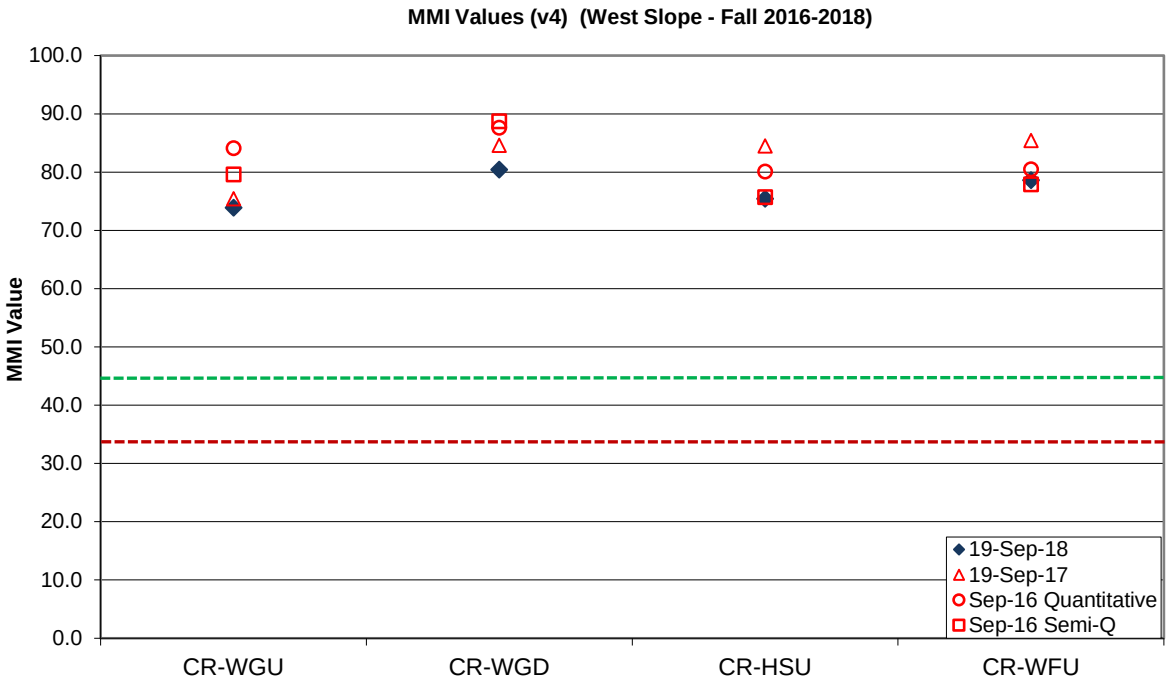

Figure 3. MMI (v4) scores for Colorado River study sites during the fall of 2016, 2017 and 2018. The green line indicates the attainment threshold and the red line indicates the impairment threshold for Biotype 1.

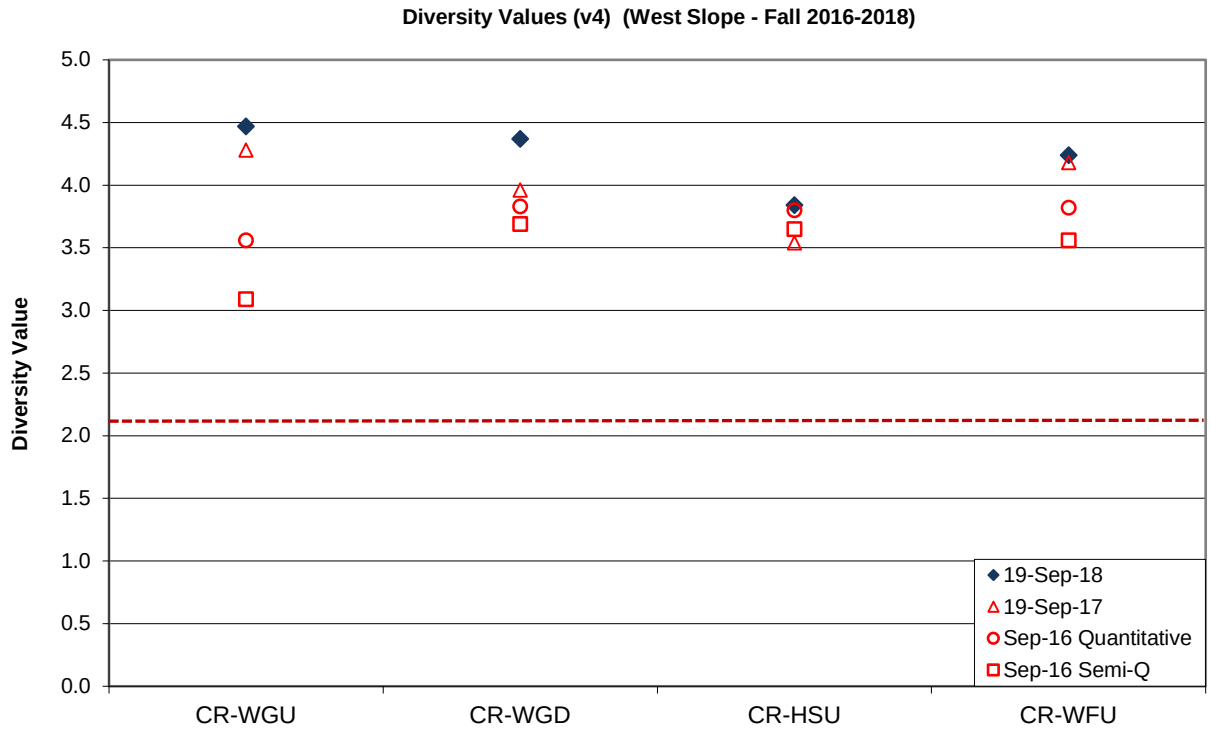

Figure 4. Diversity (v4) values for the Colorado River on the West Slope in fall 2016, 2017 and 2018. The red line indicates the impairment threshold for Biotype 1.

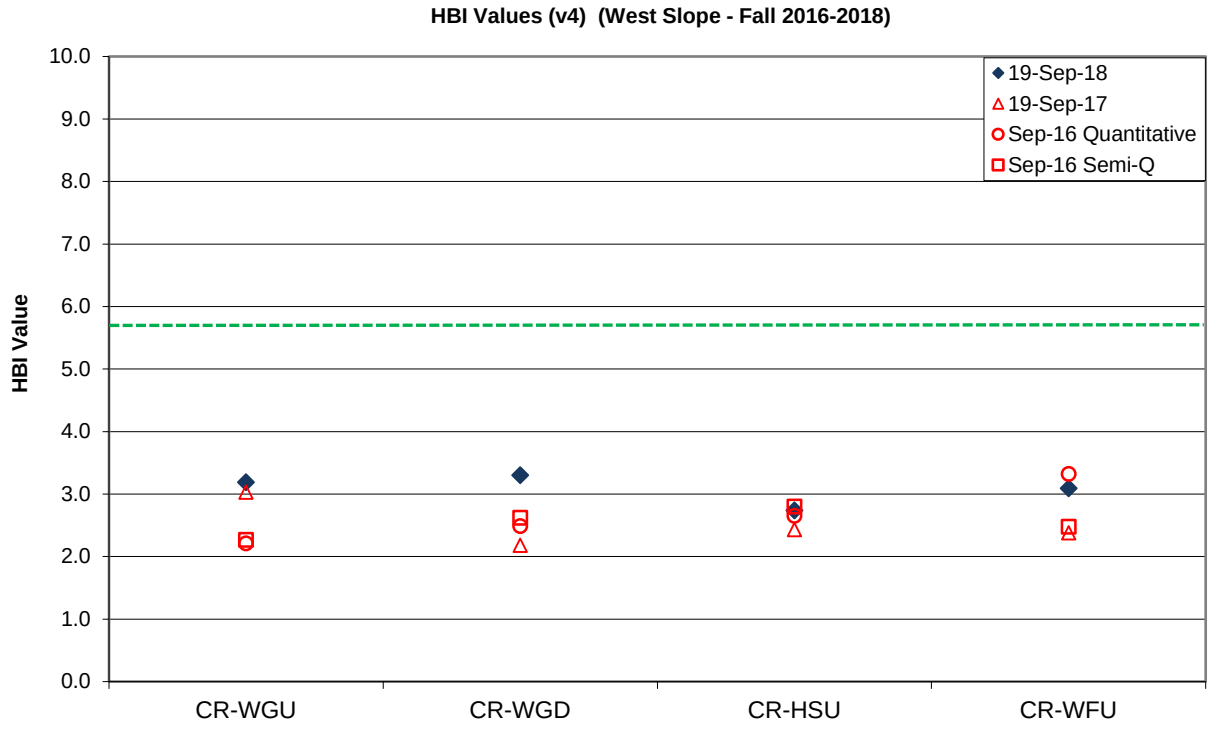

Figure 5. HBI (v4) values for the Colorado River on the West Slope in fall 2016, 2017 and 2018. Exceeding the green line indicates impairment for Biotype 1.

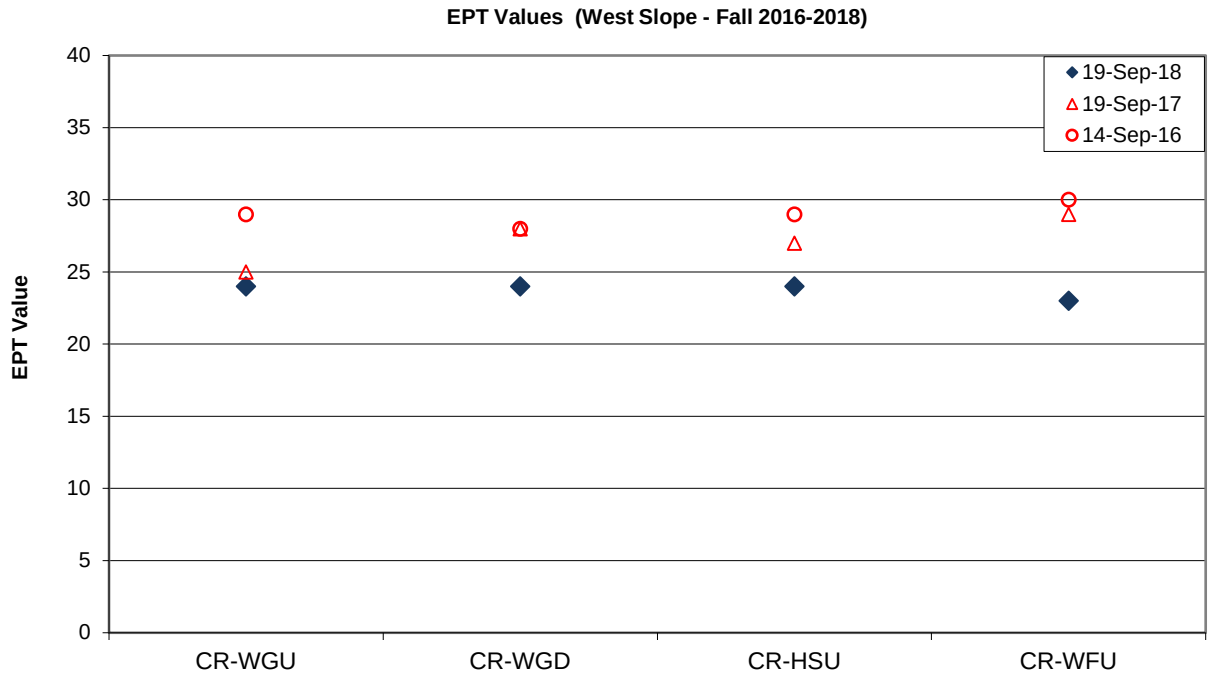

Figure 6. EPT values from quantitative sampling on the Colorado River during the fall of 2016, 2017 and 2018.

Benthic macroinvertebrates collected during the fall of 2018 were also organized into functional feeding groups in order to evaluate the ecological function of aquatic communities at each sampling location in the study area (Table 5, Figure 7). Healthy ecosystems typically support adequate representation from several feeding groups; however, it is common for certain groups (such as collector-gatherers) to be proportionally dominant. During the fall of 2018, all study sites supported a healthy balance among feeding groups. A slight decrease in collector-filterers and predators was observed in a downstream direction, while collector-gatherers and scrapers increased in the downstream portion of the study area (Table 5, Figure 7). Feeding groups that are considered specialized and sensitive to human impacts (shredders and scrapers) were found in relatively high proportions at all of the study sites. Minor shifts in the relative abundance of various feeding groups was likely influenced by gradual changes in the food resources that were occurring in a downstream direction.

The results from 2018 (and historical sampling events) have provided valuable baseline information that has consistently demonstrated healthy aquatic communities throughout this portion of the Colorado River. While most metrics agreed that aquatic communities were relatively healthy, each site exhibited minor variability in MMI scores and individual metric values. The spatial and temporal variability observed at each site can probably be attributed to annual fluctuations in aquatic conditions (flows, temperature, algal growth, etc.). Future sampling events will provide an assessment of any impacts from anthropogenic activities or habitat improvement projects that may occur in this study area.

Table 5. Relative abundance of functional feeding groups at study sites on the Colorado River during the fall of 2018.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
CR-WGU	23.51%	31.80%	8.48%	18.57%	17.64%	0.00%
CR-WGD	34.06%	25.95%	12.23%	20.40%	7.30%	0.06%
CR-HSU	37.15%	19.33%	13.60%	25.25%	4.41%	0.25%
CR-WFU	39.54%	21.73%	8.75%	22.43%	3.62%	3.92%

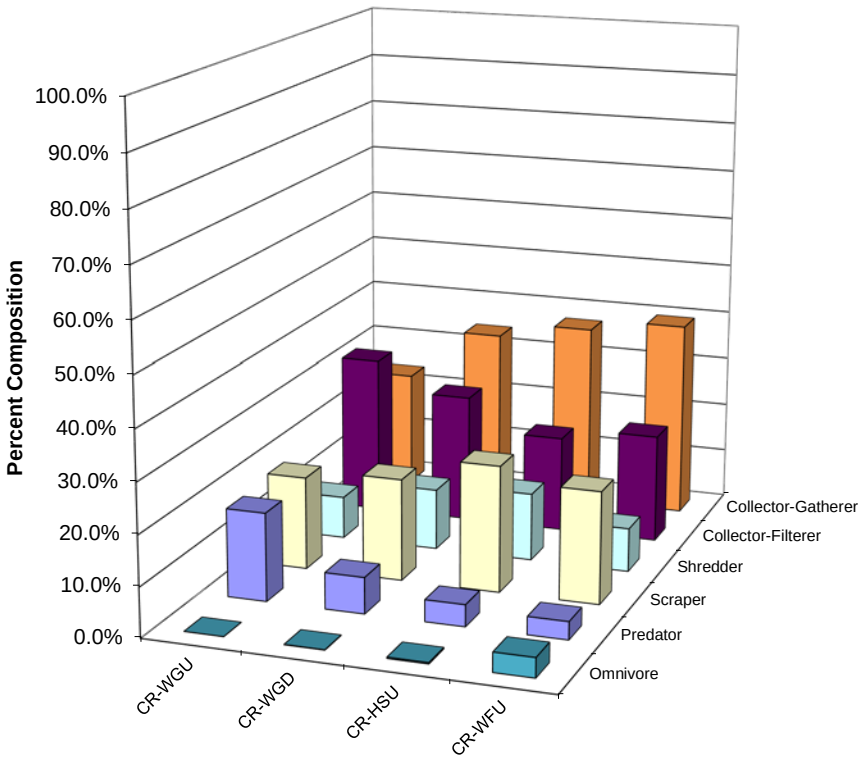

Figure 7: Percent composition of functional feeding groups collected on the Colorado River during the fall of 2018.

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Appendix A

Replicative Quantitative Samples – Fall 2018

Table A1: Macroinvertebrate data collected from West Slope at site CR-WGU on 19 Sept 2018.

Colorado River								
CR-WGU		Sample						
19 Sept. 2018	1	2	3		Mean	Count		HBI
Ephemeroptera								
Acentrella sp.	1		5		2.00	1		0.0160
Baetis flavistriga		1			0.33	1		0.0033
Baetis (*tricaudatus*)	16	9	17		14.00	1		0.1403
Diphetor hageni								
Attenella margarita								
Drunella grandis	9	3	1		4.33	1		0.0000
Ephemerella dorothea infrequens	44	42	27		37.67	1		0.0755
Epeorus sp.								
Rhithrogena sp.								
Tricorythodes explicatus			2		0.67	1		0.0053
Paraleptophlebia sp.	10	3	11		8.00	1		0.0321
Plecoptera								
Paracapnia angulata		9	9		6.00	1		0.0120
Chloroperlidae	54	27	77		52.67	1		0.1055
Sweltsa sp.			1		0.33	1		0.0007
Claassenia sabulosa	5	4	6		5.00	1		0.0301
Perlodidae (*Cultus* sp.)	16	8	11		11.67	1		0.0468
Isoperla sp.		3	1		1.33	1		0.0053
Isoperla fulva	2				0.67	1		0.0027
Skwala americana	1	1	1		1.00	1		0.0040
Pteronarcys californica								
Trichoptera								
Brachycentrus americanus	5	5	1		3.67	1		0.0073
Brachycentrus occidentalis	45	28	14		29.00	1		0.0581
Culoptila sp.								
Glossosoma sp.	38	20	31		29.67	1		0.0000
Protoptila sp.								
Helicopsyche borealis								
Arctopsyche grandis	41	22	9		24.00	1		0.0962
Cheumatopsyche sp.								
Hydropsyche cockerelli	89	25	46		53.33	1		0.4275
Hydropsyche oslari		2			0.67	1		0.0053
Lepidostoma sp.	54	19	8		27.00	1		0.2164
Ceraclea sp.		2			0.67	1		0.0067
Oecetis sp.								
Psychomyia flavida								
Rhyacophila coloradensis	1				0.33	1		0.0000

Table A1 cont.: Macroinvertebrate data collected from West Slope at site CR-WGU on 19 Sept 2018.

Diptera								
Chironomidae								
Cardiocladius sp.								
Cricotopus nostocicola	13	4	11		9.33	1		0.1309
Cricotopus/Orthocladius sp.	9	11	10		10.00	1		0.1202
Eukiefferiella sp.	15	12	19		15.33	1		0.2458
Micropsectra/Tanytarsus sp.								
Microtendipes sp.	21	25	1		15.67	1		0.1884
Pagastia sp.								
Parametriocnemus sp.	4		1		1.67	1		0.0167
Potthastia sp.	1				0.33	1		0.0027
Synorthocladius sp.								
Thienemannimyia group	5	2	1		2.67	1		0.0321
Tvetenia sp.	19	17	10		15.33	1		0.1536
Other Diptera								
Atherix pachypus								
Chelifera/Neoplasta sp.	6	4	4		4.67	1		0.0561
Hemerodromia sp.								
Wiedemannia sp.		1	1		0.67	1		0.0080
Maruina sp.								
Simulium sp.	6	9	82		32.33	1		0.3888
Antocha sp.	10	6	2		6.00	1		0.0361
Coleoptera								
Optioservus sp.	81	63	26		56.67	1		0.4542
Zaitzevia parvula								
Miscellaneous								
Atractides sp.			1		0.33	1		0.0053
Lebertia sp.	4	2			2.00	1		0.0321
Protzia sp.								
Sperchon sp.	8	1	3		4.00	1		0.0641
Caecidotea sp.	9		2		3.67	1		0.0588
Polycelis coronata								
Lymnaeidae								
Physa sp.	1	1	3		1.67	1		0.0267
Gyraulus sp.	1				0.33	1		0.0053
Pisidium sp.								
Crangonyx sp.	1				0.33	1		0.0027
Placobdella sp.								
Enchytraeidae								
Lumbricidae	1	2	1		1.33	1		0.0267
Tubificidae w/o hair chaetae								
Nematoda		2			0.67	1		0.0067
Totals	**646**	**395**	**456**		**499.00**	**46**		**3.36**

Table A2: Macroinvertebrate data collected from West Slope at site CR-WGD on 19 Sept 2018.

Colorado River								
CR-WGD		Sample						
19 Sept. 2018	1	2	3		Mean	Count		HBI
Ephemeroptera								
Acentrella sp.	3	2			1.67	1		0.0125
Baetis flavistriga								
Baetis (*tricaudatus*)	63	36	87		62.00	1		0.5802
Diphetor hageni			1		0.33	1		0.0031
Attenella margarita	1				0.33	1		0.0019
Drunella grandis	2		1		1.00	1		0.0000
Ephemerella dorothea infrequens	24	23	24		23.67	1		0.0443
Epeorus sp.	1	3	10		4.67	1		0.0000
Rhithrogena sp.								
Tricorythodes explicatus								
Paraleptophlebia sp.	8	8	4		6.67	1		0.0250
Plecoptera								
Paracapnia angulata								
Chloroperlidae	4	1			1.67	1		0.0031
Sweltsa sp.								
Claassenia sabulosa	3	5	8		5.33	1		0.0299
Perlodidae (*Cultus* sp.)	4	1	6		3.67	1		0.0137
Isoperla sp.	5	1	4		3.33	1		0.0125
Isoperla fulva								
Skwala americana								
Pteronarcys californica								
Trichoptera								
Brachycentrus americanus	53	32	40		41.67	1		0.0780
Brachycentrus occidentalis								
Culoptila sp.	6	21	23		16.67	1		0.0000
Glossosoma sp.	2				0.67	1		0.0000
Protoptila sp.	16	2	2		6.67	1		0.0125
Helicopsyche borealis			1		0.33	1		0.0019
Arctopsyche grandis	2	7	9		6.00	1		0.0225
Cheumatopsyche sp.								
Hydropsyche cockerelli	26	14	35		25.00	1		0.1871
Hydropsyche oslari	74	54	60		62.67	1		0.4691
Lepidostoma sp.	106	47	32		61.67	1		0.4616
Ceraclea sp.								
Oecetis sp.	1				0.33	1		0.0050
Psychomyia flavida		5	7		4.00	1		0.0150
Rhyacophila coloradensis	1				0.33	1		0.0000

Table A2 cont.: Macroinvertebrate data collected from West Slope at site CR-WGD on 19 Sept 2018.

Diptera								
Chironomidae								
Cardiocladius sp.								
Cricotopus nostocicola	8	1	2		3.67	1		0.0480
Cricotopus/Orthocladius sp.	39	15	28		27.33	1		0.3069
Eukiefferiella sp.	18	10	10		12.67	1		0.1896
Micropsectra/Tanytarsus sp.			3		1.00	1		0.0131
Microtendipes sp.		1			0.33	1		0.0037
Pagastia sp.	3		3		2.00	1		0.0037
Parametriocnemus sp.	3	1			1.33	1		0.0125
Potthastia sp.	1		1		0.67	1		0.0050
Synorthocladius sp.								
Thienemannimyia group	4	2	2		2.67	1		0.0299
Tvetenia sp.	45	17	24		28.67	1		0.2682
Other Diptera								
Atherix pachypus	3	1	1		1.67	1		0.0062
Chelifera/Neoplasta sp.	18	1	9		9.33	1		0.1048
Hemerodromia sp.	2				0.67	1		0.0075
Wiedemannia sp.	3				1.00	1		0.0112
Maruina sp.								
Simulium sp.	2		7		3.00	1		0.0337
Antocha sp.	4	3			2.33	1		0.0131
Coleoptera								
Optioservus sp.	112	57	58		75.67	1		0.5664
Zaitzevia parvula	9	2	1		4.00	1		0.0299
Miscellaneous								
Atractides sp.			1		0.33	1		0.0050
Lebertia sp.			1		0.33	1		0.0050
Protzia sp.	6	1	2		3.00	1		0.0449
Sperchon sp.	4	4	8		5.33	1		0.0799
Caecidotea sp.	2	2	4		2.67	1		0.0399
Polycelis coronata	1				0.33	1		0.0006
Lymnaeidae								
Physa sp.	3				1.00	1		0.0150
Gyraulus sp.	2	1	4		2.33	1		0.0349
Pisidium sp.								
Crangonyx sp.								
Placobdella sp.								
Enchytraeidae								
Lumbricidae		1			0.33	1		0.0062
Tubificidae w/o hair chaetae	1				0.33	1		0.0062
Nematoda								
Totals	**698**	**382**	**523**		**534.33**	**52**		**3.87**

Table A3: Macroinvertebrate data collected from West Slope at site CR-HSU on 19 Sept 2018.

Colorado River								
CR-HSU		Sample						
19 Sept. 2018	1	2	3		Mean	Count		HBI
Ephemeroptera								
Acentrella sp.	6	3	2		3.67	1		0.0277
Baetis flavistriga								
Baetis (*tricaudatus*)	47	41	42		43.33	1		0.4093
Diphetor hageni								
Attenella margarita								
Drunella grandis		3	4		2.33	1		0.0000
Ephemerella dorothea infrequens	95	124	39		86.00	1		0.1625
Epeorus sp.	7	12	4		7.67	1		0.0000
Rhithrogena sp.	1		1		0.67	1		0.0000
Tricorythodes explicatus								
Paraleptophlebia sp.	4	4	9		5.67	1		0.0214
Plecoptera								
Paracapnia angulata	1				0.33	1		0.0006
Chloroperlidae	1	1	6		2.67	1		0.0050
Sweltsa sp.								
Claassenia sabulosa	4	2			2.00	1		0.0113
Perlodidae (*Cultus* sp.)	1	1			0.67	1		0.0025
Isoperla sp.	1				0.33	1		0.0013
Isoperla fulva								
Skwala americana								
Pteronarcys californica								
Trichoptera								
Brachycentrus americanus	2	7	5		4.67	1		0.0088
Brachycentrus occidentalis								
Culoptila sp.	54	47	31		44.00	1		0.0000
Glossosoma sp.	2				0.67	1		0.0000
Protoptila sp.	8	1	6		5.00	1		0.0094
Helicopsyche borealis			1		0.33	1		0.0019
Arctopsyche grandis	3	1	1		1.67	1		0.0063
Cheumatopsyche sp.	4	4	8		5.33	1		0.0504
Hydropsyche cockerelli	11	29	21		20.33	1		0.1537
Hydropsyche oslari	53	81	64		66.00	1		0.4987
Lepidostoma sp.	68	74	72		71.33	1		0.5390
Ceraclea sp.								
Oecetis sp.		1	7		2.67	1		0.0403
Psychomyia flavida	1		1		0.67	1		0.0025
Rhyacophila coloradensis								

Table A3 cont.: Macroinvertebrate data collected from West Slope at site CR-HSU on 19 Sept 2018.

Diptera								
Chironomidae								
Cardiocladius sp.	3		1		1.33	1		0.0126
Cricotopus nostocicola			1		0.33	1		0.0044
Cricotopus/Orthocladius sp.	9	11	6		8.67	1		0.0982
Eukiefferiella sp.	18	20	16		18.00	1		0.2720
Micropsectra/Tanytarsus sp.	1		1		0.67	1		0.0088
Microtendipes sp.								
Pagastia sp.								
Parametriocnemus sp.	1	2	2		1.67	1		0.0157
Potthastia sp.								
Synorthocladius sp.	1				0.33	1		0.0013
Thienemannimyia group	1				0.33	1		0.0038
Tvetenia sp.	26	14	4		14.67	1		0.1385
Other Diptera								
Atherix pachypus								
Chelifera/Neoplasta sp.	1				0.33	1		0.0038
Hemerodromia sp.								
Wiedemannia sp.								
Maruina sp.								
Simulium sp.	8	3	2		4.33	1		0.0491
Antocha sp.								
Coleoptera								
Optioservus sp.	41	80	86		69.00	1		0.5214
Zaitzevia parvula	3	3	25		10.33	1		0.0781
Miscellaneous								
Atractides sp.								
Lebertia sp.			1		0.33	1		0.0050
Protzia sp.	2	3	8		4.33	1		0.0655
Sperchon sp.	6	6	13		8.33	1		0.1259
Caecidotea sp.								
Polycelis coronata	2		2		1.33	1		0.0025
Lymnaeidae	1				0.33	1		0.0050
Physa sp.	1	2	5		2.67	1		0.0403
Gyraulus sp.		1	2		1.00	1		0.0151
Pisidium sp.								
Crangonyx sp.								
Placobdella sp.								
Enchytraeidae	4	1			1.67	1		0.0315
Lumbricidae	1		1		0.67	1		0.0126
Tubificidae w/o hair chaetae			2		0.67	1		0.0126
Nematoda								
Totals	**504**	**582**	**502**		**529.33**	**47**		**3.48**

Table A4: Macroinvertebrate data collected from West Slope at site CR-WFU on 19 Sept 2018.

Colorado River								
CR-WFU		Sample						
19 Sept. 2018	1	2	3		Mean	Count		HBI
Ephemeroptera								
Acentrella sp.	1	4			1.67	1		0.0201
Baetis flavistriga								
Baetis (*tricaudatus*)	32	79	27		46.00	1		0.6942
Diphetor hageni								
Attenella margarita								
Drunella grandis		5	2		2.33	1		0.0000
Ephemerella dorothea infrequens	49	48	19		38.67	1		0.1167
Epeorus sp.	28	24			17.33	1		0.0000
Rhithrogena sp.	5	3	2		3.33	1		0.0000
Tricorythodes explicatus								
Paraleptophlebia sp.	19	16	5		13.33	1		0.0805
Plecoptera								
Paracapnia angulata		1			0.33	1		0.0010
Chloroperlidae		1	1		0.67	1		0.0020
Sweltsa sp.								
Claassenia sabulosa	3		10		4.33	1		0.0392
Perlodidae (*Cultus* sp.)		1	1		0.67	1		0.0040
Isoperla sp.								
Isoperla fulva								
Skwala americana								
Pteronarcys californica	12	24	22		19.33	1		0.0000
Trichoptera								
Brachycentrus americanus	1	4	1		2.00	1		0.0060
Brachycentrus occidentalis								
Culoptila sp.	8	4	12		8.00	1		0.0000
Glossosoma sp.	21	19	10		16.67	1		0.0000
Protoptila sp.	1	9	1		3.67	1		0.0111
Helicopsyche borealis								
Arctopsyche grandis		1			0.33	1		0.0020
Cheumatopsyche sp.	18	13	47		26.00	1		0.3924
Hydropsyche cockerelli	10	29	26		21.67	1		0.2616
Hydropsyche oslari	1	3	1		1.67	1		0.0201
Lepidostoma sp.	14	3	10		9.00	1		0.1087
Ceraclea sp.								
Oecetis sp.								
Psychomyia flavida		1			0.33	1		0.0020
Rhyacophila coloradensis		2	1		1.00	1		0.0000

Table A4 cont.: Macroinvertebrate data collected from West Slope at site CR-WFU on 19 Sept 2018.

Diptera								
Chironomidae								
Cardiocladius sp.	1	2			1.00	1		0.0151
Cricotopus nostocicola			1		0.33	1		0.0070
Cricotopus/Orthocladius sp.		2			0.67	1		0.0121
Eukiefferiella sp.	6	15	4		8.33	1		0.2012
Micropsectra/Tanytarsus sp.								
Microtendipes sp.								
Pagastia sp.		1			0.33	1		0.0010
Parametriocnemus sp.								
Potthastia sp.								
Synorthocladius sp.								
Thienemannimyia group	1	1	2		1.33	1		0.0241
Tvetenia sp.		1			0.33	1		0.0050
Other Diptera								
Atherix pachypus								
Chelifera/Neoplasta sp.		1			0.33	1		0.0060
Hemerodromia sp.		1	2		1.00	1		0.0181
Wiedemannia sp.								
Maruina sp.	2				0.67	1		0.0020
Simulium sp.	7	50	3		20.00	1		0.3622
Antocha sp.			1		0.33	1		0.0030
Coleoptera								
Optioservus sp.	8	20	39		22.33	1		0.2696
Zaitzevia parvula	10	14	26		16.67	1		0.2012
Miscellaneous								
Atractides sp.								
Lebertia sp.								
Protzia sp.								
Sperchon sp.		3	1		1.33	1		0.0322
Caecidotea sp.								
Polycelis coronata	6	27	6		13.00	1		0.0392
Lymnaeidae								
Physa sp.								
Gyraulus sp.								
Pisidium sp.			1		0.33	1		0.0080
Crangonyx sp.								
Placobdella sp.			1		0.33	1		0.0060
Enchytraeidae								
Lumbricidae		5	3		2.67	1		0.0805
Tubificidae w/o hair chaetae	2	3			1.67	1		0.0503
Nematoda								
Totals	**266**	**440**	**288**		**331.33**	**43**		**3.11**

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