

OGMCOAL - Crandall Canyon macro report attached

From: Steve Christensen
To: Ingrid Campbell; OGMCOAL
Date: 8/24/2011 9:20 AM
Subject: Crandall Canyon macro report attached
Attachments: final Sept 2010 sampling report macros report date aug 2011.pdf

fyi-

>>> "Marrelli, Dana" <dmarrelli@coalsource.com> 8/24/2011 9:17 AM >>>

Hello Steve,

Here is the macroinvertebrate report for Fall 2010.

Please let me know if you need anything else.

Thank you,

Dana

From: Karla Knoop [mailto:kknoop@jbrenv.com]
Sent: Monday, August 22, 2011 1:54 PM
To: Marrelli, Dana
Subject: macro report attached

Dana,

Attached is the Crandall Canyon Creek macroinvertebrate report for the samples that we took in September 2010. A hard copy was also mailed to you today.

Let me know if you have any questions.

Thanks for the opportunity to continue doing this work!

Karla

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Crandall Canyon Mine Macroinvertebrate Study September 2010

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Appendix 1 BugLab Report

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Crandall Canyon Mine Macroinvertebrate Study September 2010

1.0 Introduction

On September 24, 2010, JBR Environmental Consultants, Inc. (JBR) collected benthic macroinvertebrate samples from Crandall Creek, which is located near Huntington, Utah. The samples were collected both upstream and downstream of an underground coal mine operated by Genwal Resources, Inc. (Genwal) and permitted by the Utah Division of Oil, Gas and Mining (DOG M) through its coal mining program. The mine, known as the Crandall Canyon Mine, has been idle for several years. However, intercepted groundwater continues to discharge from the sealed portals and Crandall Creek is the receiving stream for the discharged water.

Beginning with the fall of 2009, JBR has sampled the creek's benthic macroinvertebrates twice yearly to determine whether or not the mine discharge is affecting Crandall Creek's aquatic community, and prepared biannual reports based upon the laboratory data (JBR 2010; JBR 2011). This report discusses the results from the September 24, 2010 sampling event. After giving some relevant background information, it describes the data collection and analysis methodology, provides the laboratory data, and discusses the study results to date.

1.1 Background

The Crandall Canyon Mine began discharging groundwater in late 1995, and did so more or less continuously for 12 years. During operations, groundwater entering the underground mine had to be collected and pumped to the surface to ensure safe working conditions. Except for some passive in-mine settling, this groundwater was not treated prior to being released to Crandall Creek. Its discharge was regulated by the Utah Division of Water Quality (DWQ) through the Utah Pollutant Discharge Elimination System (UPDES) permit program, and water quality limits were imposed to ensure that Crandall Creek and downstream water resources were protected. With very few exceptions, those permit limits were met during the 12 years of near-continuous pumped groundwater discharge.

Subsequent to mine closure in mid-2007 and without active pumping, groundwater discharge ceased. The UPDES permit continued to be in effect, and the "no discharge" status was reflected on the monthly discharge monitoring reports. However, after about three months with no discharge, groundwater unexpectedly began flowing out of the mine from beneath the portal seals. It has continued without interruption since that time.

While gravity-flow rates have been similar to the flow rates that prevailed during the operational pumping, water quality changed once the discharge resumed in early 2008 (JBR 2010). In particular, total iron concentrations increased by up to three orders of magnitude and exceeded the established UPDES permit limits. The iron-laden discharge also resulted in iron-stained streambed substrate along an approximate 3,000-foot reach of Crandall Creek immediately downstream of where the groundwater discharge enters the stream. In early 2010, Genwal began operating an iron treatment system, and total iron concentrations have consistently been kept at less than 1.0 mg/L since March 2010. However, the iron-stained substrate is still present.

Crandall Creek is a small perennial stream that drains a 2,500-acre watershed located within the bounds of the Manti-La Sal National Forest and conveys flow to Huntington Creek. Genwal's intercepted groundwater enters Crandall Creek approximately 1.5 miles upstream of the confluence of those two streams (Figure 1). Both Crandall Creek and Huntington Creek support aquatic resources, and Huntington Creek is a noted trout fishery. These fish rely in part upon a healthy and abundant macroinvertebrate community as a food source. The Utah Division of Wildlife Resources (DWR), in a 1995 letter to Genwal, indicated that Crandall Creek had a small resident cutthroat population and was also important spawning habitat for trout in Huntington Creek (Moretti 1995).

Iron is an essential element for both fish and the macroinvertebrates upon which they rely as a food source, as well as all other terrestrial and aquatic biota. However, in the aquatic environment, iron can be harmful or even toxic depending upon its chemical form and its concentration. Largely as a function of the water's pH and dissolved oxygen content, iron is typically present in either an insoluble ferric form or a soluble ferrous form. It can also be present as an integral component of individual sediment particles whose parent rock contains iron. While the chemistry of iron in water can be complex and is not fully discussed here, it is important to note a couple of key points. Commonly, iron found in groundwater is in the ferrous form, but when exposed to the atmosphere, this dissolved iron often oxidizes to the ferric form and then precipitates (Hem 1985). These iron precipitates can physically degrade aquatic habitat by covering bed substrate and organic matter; the covering can also reduce food sources for both fish and macroinvertebrates. The particulates (either from precipitates or fine sediments) can clog an organism's gills or filtering apparatus, and thereby hinder oxygen intake. Iron can also precipitate directly onto an organism's body, physically harming its body structure and function. In its soluble (dissolved) form, iron can also be toxic when ingested by aquatic life.

Taking all of these things into account, EPA has conservatively recommended a (nationwide) criterion (chronic) of 1.0 mg/L iron, as part of their published National Recommended Water Quality Criteria for the protection of aquatic life (EPA 2009). Following EPA's recommendation, Utah, in its Water Quality Standards given at U.A.C. R317-2-14, adopted a maximum dissolved iron criterion of 1.0 mg/L for all streams that are classed for aquatic wildlife beneficial uses.

DWQ set the Crandall Canyon Mine's UPDES permit limit at 1.0 mg/L total iron to provide protection at an even more conservative level than the stream standard without accounting for any dilution effects.

1.2 Purpose of Study

In 2009, due to ongoing elevated iron concentrations associated with Genwal's permitted groundwater discharge, the relevant regulatory (DWQ, DOGM) and management (U.S. Forest Service (USFS), DWR) agencies became concerned about the potential impacts of the discharge on aquatic life. In mid-August, 2009, DOGM issued a Citation for Non-Compliance (#10044) that required Genwal to engage a qualified biologist to collect macroinvertebrate samples from Crandall Creek twice each year (in June and September) and prepare comprehensive reports that describe and evaluate each study's results.

This report is intended to meet the ongoing DOGM requirements for the biannual sampling and reporting. Its purpose is to assess both the spatial and temporal variation in the macroinvertebrate community of Crandall Creek with the goal of determining what, if any, iron-caused impacts have occurred or are still occurring in that community.

In addition, study results can be used to assess the overall health of Crandall Creek. Because they are sensitive to water quality and respond quickly to stressors, including water pollutants, and also because they are fairly stationary within a given stream feature, benthic macroinvertebrates integrate variations in water quality or other habitat components (Davis et al. 2001). Numerous indices and metrics such as diversity, taxa ratios, richness, and the like can be calculated and used to assess the macroinvertebrate community at a given site in regard to its ability to tolerate environmental pollution. The presence or absence of a specific macroinvertebrate taxon can indicate a perturbation that may not have been captured by grab samples analyzed for specific water chemistry. Ideally, these repeat studies may provide insight on the general condition of Crandall Creek as well as the iron-specific impact (if any) of Genwal's discharge on the creek's aquatic community.

2.0 Previous Studies

Prior to the initiation of sampling in 2009 in response to the previously noted DOGM citation, Crandall Creek's macroinvertebrate community had been periodically assessed by others. In 1980, macroinvertebrate samples were collected at several locations along Crandall Creek before the mine start-up. A follow-up macroinvertebrate study was conducted in 1994, after several years of mine operations; at the time of sampling, groundwater had not been intercepted in a quantity sufficient to require surface discharge. In addition, the USFS samples benthic macroinvertebrates in Huntington Creek every five years. Brief descriptions of each of these other studies were given in a previous JBR report (JBR 2010).

To comply with DOGM Citation #10044, JBR collected macroinvertebrate samples in Crandall Creek in September 2009 (JBR 2010) and again in June 2010 (JBR 2011). During both of these studies, samples were collected at three locations. The uppermost sampling reach (CRANDUP-01) was upstream of any influence of the mine's groundwater discharge, thus serving as a reference reach. The middle reach (CRANDMD-02) included the area immediately downstream of the discharge location where flow mixing, aeration, and iron precipitation were occurring. The downstream reach (CRANDLWR-03) was a short distance upstream of the confluence with Huntington Creek, outside of the area with a visibly impacted substrate. During the September 2009 event, sample collection methodology was generally based upon the reach-wide, multi-habitat sample methodology outlined in the (EMAP) Field Operations Manual for Wadeable Streams (EPA 2001), modified as per discussions with the Manti-La Sal National Forest fisheries biologist. During the June 2010 sampling event, a set of targeted-riffle samples was added to the protocol.

Overall, the study results from the September 2009 and June 2010 sampling indicated that the Crandall Creek macroinvertebrate community downstream of the mine's discharge appeared to have been negatively impacted. However, both downstream reaches of the creek were still supporting a variety of macroinvertebrates, signifying that the iron-laden discharge had not completely decimated macroinvertebrate populations.

3.0 Site Locations and Descriptions

3.1 Site Locations

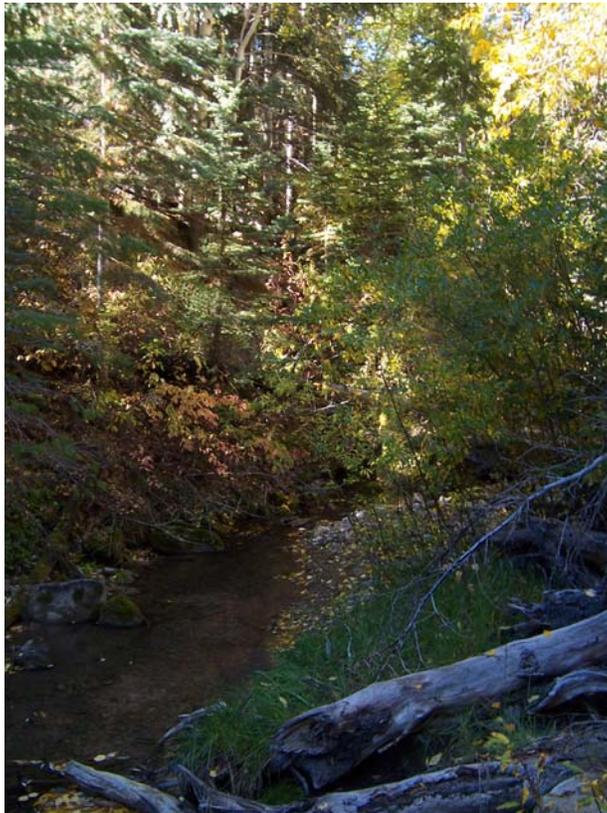
The September 2010 macroinvertebrate samples were collected at the same three sites that were sampled during the September 2009 and June 2010 sampling events (Figure 1). The uppermost site (CRANDUP-01) is near the upstream edge of the upper parking lot and outside of any influence of the mine's groundwater discharge. Its downstream endpoint is approximately 2 meters above the flow measurement flume and the reach extends upstream approximately 150 meters. The middle site (CRANDMD-02) includes the area immediately downstream of the discharge location where flow mixing and aeration are occurring, and where the iron previously precipitated. Its upstream endpoint (Transect K) is approximately 5 meters downstream of the discharge point, with the reach extending downstream approximately 150 meters. The downstream site (CRANDLWR-03) was chosen to be approximately 2 meters upstream of the mine road crossing near the confluence of Crandall Creek and Huntington Creek, and its reach extended upstream from that point approximately 150 meters.

As per EMAP protocol, during the September 2009 study 11 cross-section transects were established at regular intervals within each of these reaches, and were flagged and marked (JBR 2010). These same transects were used in the June 2010 and September 2010 studies.

3.2 Site Descriptions

The report that presented the 2009 study results (JBR 2010) described stream morphology, substrate, and riparian vegetation. During the June 2010 sampling, additional observations were made on bed substrate at each reach, in order to provide some context for variation in macroinvertebrate communities among the three reaches. Substrate at CRANDMD-02 is notable for iron-stained particles and the presence (seasonally) of filamentous algae. CRANDLWR-03 substrate is generally calcified and cemented in place.

September 2010 channel conditions were generally similar to those noted during the previous sampling events. Flow rates were substantially lower in September than in the previous June, as expected, since June rates reflected high snowmelt runoff. The following photos provide a visual description of the site conditions at the time of the September 2010 sampling.



CRANDUP-01 on September 24, 2010



CRANDMID-02 on September 24, 2010



CRANDMID-02 on September 24, 2010, close-up of iron precipitates and algae



CRANDLWR-03 on September 24, 2010

4.0 Methods

JBR collected two macroinvertebrate samples, a multi-habitat sample and a riffle sample, from each of the locations described above. Sample collection for the multi-habitat sample was the same as described in JBR (2010) and was based upon the reach-wide sample methodology outlined in the (EMAP) Field Operations Manual for Wadeable Streams (EPA 2001). The specific application of this sample methodology was modified as per discussions with the Manti-La Sal National Forest fisheries biologist who is responsible for USFS macroinvertebrate sampling on the Forest. Section 4.1.1 below describes the modified methodology. The riffle sample was collected following the EMAP targeted riffle sample methodology. Section 4.1.2 below describes the targeted riffle methodology.

The collected and preserved samples were then delivered to the National Aquatic Monitoring Center (the BugLab) in Logan, Utah for processing and taxonomic identification. The BugLab is a cooperative venture between the U.S. Bureau of Land Management (BLM) and Utah State University. It focuses on processing macroinvertebrate samples, and processes a large percentage of the samples collected on federal land in the western U.S. The DWQ Monitoring Manual (DWQ 2006) specifies that macroinvertebrate samples be processed by the BugLab. DWQ's methodology is described in Section 4.2., and the BugLab's complete report (Miller 2011) is attached as Appendix 1.

4.1 Sample Collection Methods

4.1.1 Modified Multi-Habitat Sample Collection

The EMAP methodology for the multi-habitat sample specifies that one macroinvertebrate subsample is taken at each of the eleven transects within the delineated reach. These subsamples are then combined into a composite sample. The sample location at the first transect is randomly selected using a six sided dice (i.e., sample is taken at a location 25, 50, or 75 percent of the distance from the channel's left edge depending upon the roll of the dice), with the sampling point at subsequent transects chosen systematically. However, the Manti-La Sal National Forest regularly collects only 4-5 macroinvertebrate subsamples within each reach, which are then combined into a single composite sample. The 4-5 subsamples are collected from as many habitat types as possible in order to sample the full range of habitat types present within the reach. In order to be more consistent with the methodology used by the Forest, the EMAP reach-wide, multi-habitat sample methodology was modified to only include five samples. However, to keep the modified methodology as similar to EMAP procedure as possible (which improves consistency and keeps the samples as replicable as possible), the five samples were collected at every other transect starting with Transect B, where possible.

As Crandall Creek is a narrow stream at all sites, and particularly CRANDUP-01, sample location at each transect was not chosen randomly or systematically, rather the site that was most suitable to sampling was chosen (i.e., the location that allowed placement of the sampler). All sampling was conducted using a 500-micron mesh D-frame kick net. The samples were collected in a downstream-to-upstream order to avoid including organisms dislodged from upstream samples.

For sampling transects the following procedures were utilized.

1. The kick net was quickly and securely positioned on the bottom of the channel with the opening facing upstream. Gaps between the frame and substrate were minimized.
2. The sample area was checked for heavy organisms, such as mussels and snails. Any such organisms were placed into the composite sample bucket. All substrate particles larger than golf balls and that were at least halfway into the sample area were picked up and rubbed with hands or a brush to dislodge organisms into the net. Particles that were more than halfway outside the sample area were pushed aside and not sampled. After particles were washed, they were placed outside of the sample area.
3. Starting at the upstream end of the sample area, the remaining substrate was kicked vigorously for 30 seconds. The water was allowed to clear before removing the net from the water column.

4. The net was lifted out of the water then quickly immersed several times to concentrate sample material in the end of net. Care was taken not to further disturb channel substrate with the net, or allow for organisms to escape.
5. The net was inverted into the composite bucket, which had been $\frac{1}{4}$ to $\frac{1}{2}$ filled with stream water. The net was inspected for clinging organisms and forceps were used to place these organisms into the bucket.
6. The net was rinsed in the stream before moving to the next transect.
7. The dominant substrate and habitat type were recorded on the field data sheet.

After sampling was completed at the five transects, the following procedures were employed to prepare a multi-habitat composite index sample to be sent to the lab.

1. The contents of the sample bucket were manually swirled to separate organisms from the sample material. The sample material was poured through a 300-micron mesh sieve and the inside of the bucket was inspected for organisms. Organisms were rinsed off any large objects (rocks, organics, etc.) with a spray bottle filled with stream water before discarding the objects. Additional serial bucket rinses were employed until no remaining organisms were noted in the sample bucket.
2. Using the spray bottle, the sample material inside the sieve was rinsed to one side and transferred into the sample container using as little water as possible. The sieve was carefully examined for clinging organisms and these were placed into the sample bottle using forceps.
3. The sample container was completely filled with 95-percent ethanol so that the final concentration was between 75 and 90 percent. The container was slowly tipped horizontally and rotated to allow complete mixing of the ethanol and sample.
4. Sample containers were labeled with the information listed below. A duplicate of this label was written on ethanol-safe paper and placed inside of the container. Samples were then delivered to the BugLab for analysis.
 - * Type of Sample (e.g., multi-habitat or riffle)
 - * Stream Name
 - * Site I.D.
 - * Forest (Manti-La Sal National Forest)
 - * Date and Time of Collection
 - * Number of Jars

4.1.2 Targeted Riffle Sample Collection

The EMAP methodology for the targeted riffle sample specifies that eight macroinvertebrate subsamples be taken within available riffle macrohabitat units within the delineated reach. These subsamples are then combined into a composite targeted riffle sample. The sample locations are identified by surveying the delineated reach prior to sampling to visually estimate the number and area of riffle units. If the reach contains more than one distinct riffle macrohabitat unit but less than eight, the eight sampling points are allocated among the units to spread the effort throughout the reach as much as possible, with it possible to collect more than one kick sample from a single riffle unit. If the number of riffle macrohabitat units is greater than eight, one or more habitats is skipped at random. Within each riffle unit, EMAP specifies that the sample locations be chosen at random from nine equal quadrats (visually estimated). However, as already noted, Crandall Creek is a narrow stream at all sites, and particularly CRANDUP-01. As a result, the riffle samples from each macrohabitat unit were not chosen randomly, rather the site that was most suitable to sampling was chosen (i.e., the location that allowed placement of the sampler). The samples were collected in a downstream-to-upstream order to avoid including organisms dislodged from upstream samples.

Once locations were chosen, samples were collected and composited following the same procedures outlined for the modified multi-habitat sample.

4.2 Analysis Methods

As noted above, the BugLab identified the taxa represented in the macroinvertebrate samples that JBR collected. The lab processed the samples using methods similar to those recommended by the United States Geological Survey (Cuffney et al 1993, as referenced in Miller 2011). For samples containing fewer than 600 organisms, 100 percent of the sample material was processed, and for samples where more than 600 organisms were present per sample, a sub-sampling procedure was used. Generally, organisms were removed under a dissecting microscope at 10-30 power and separated into taxonomic orders. Organisms were then identified to a lower taxonomic level (family, genus, and/or species, as feasible). Once identified and counted, samples were placed in 20-ml glass scintillation vials with polypropylene lids in 70% ethanol, given a catalog number, and retained. The results report (Miller 2011) includes a complete list of taxa and the number of organisms by taxa (see Appendix 1).

The BugLab also provided data summaries and calculated various indices and metrics (Miller 2011), many of which will be discussed in the results discussion. These include: abundance, total taxa richness, EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa richness, Ephemeroptera taxa richness, Plecoptera taxa richness, Trichoptera taxa richness, percent EPT abundance, percent Ephemeroptera abundance, percent Chironomidae abundance, Intolerant taxa richness, percent tolerant organisms, Hilsenhoff Biotic Index, percent contribution of the dominant taxon, clinger taxa richness, percent clinger abundance, percent collector-filterer abundance, and percent scraper abundance. Definitions/descriptions of these individual

metrics and their usefulness are provided below and are taken almost verbatim from the BugLab's data report (Miller 2011). More detail and references for how calculations were made are also given in their report, which can be found in Appendix 1.

Taxa richness - Richness is a component and estimate of community structure and stream health based on the number of distinct taxa. Taxa richness normally decreases with decreasing water quality. In some situations organic enrichment can cause an increase in the number of pollution tolerant taxa. Taxa richness was calculated for operational taxonomic units (OTUs) and the number of unique genera, and families. The values for OTUs may be overestimates of the true taxa richness at a site if individuals were the same taxon as those identified to lower taxonomic levels or they may be underestimates of the true taxa richness if multiple taxa were present within a larger taxonomic grouping but were not identified. All individuals within all samples were generally identified similarly, so that comparisons in operational taxonomic richness among samples within this dataset are appropriate, but comparisons to other data sets may not. Comparisons to other datasets should be made at the genera or family level.

Abundance - The abundance, density, or number of aquatic macroinvertebrates per unit area is an indicator of habitat availability and fish food abundance. Abundance may be reduced or increased depending on the type of impact or pollutant. Increased organic enrichment typically causes large increases in abundance of pollution tolerant taxa. High flows, increases in fine sediment, or the presence of toxic substances normally cause a decrease in invertebrate abundance. Invertebrate abundance is presented as the number of individuals per square meter for quantitative samples and the number of individuals collected in each sample for qualitative samples.

EPT - A summary of the taxonomic richness and abundance within the insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT). These orders are commonly considered sensitive to pollution (Karr and Chu 1998, as referenced in Miller 2011).

Percent contribution of the dominant family or taxon - An assemblage largely dominated (>50%) by a single taxon or several taxa from the same family suggests environmental stress. Habitat conditions likely limit the number of taxa that can occur at the site.

Shannon Diversity Index - Ecological diversity is a measure of community structure defined by the relationship between the number of distinct taxa and their relative abundances. The Shannon Diversity Index was calculated for each sampling location for which there were a sufficient number of individuals and taxa collected to perform the calculations.

Evenness - Evenness is a measure of the distribution of taxa within a community. Value ranges from 0-1 and approach zero as a single taxa becomes more dominant.

Clinger taxa - The number of clinger taxa have been found by Karr and Chu (1998, as referenced in Miller 2011) to respond negatively to human disturbance. These taxa typically

cling to the tops of rocks and are thought to be reduced by sedimentation or abundant algal growths.

Long-lived taxa - The number of long-lived taxa was calculated as the number of taxa collected that typically have 2-3 year life cycles. Disturbances and water quality and habitat impairment typically reduces the number of long-lived taxa (Karr and Chu 1998, as referenced in Miller 2011).

Biotic indices - Biotic indices use the indicator taxa concept. Taxa are assigned water quality tolerance values based on their tolerance to pollution. Scores are typically weighted by taxa relative abundance. In the US, the most commonly used biotic index is the Hilsenhoff Biotic Index (Hilsenhoff 1987 and 1988, as referenced in Miller 2011). The USFS and BLM throughout the western U.S. have also frequently used the USFS Community Tolerance Quotient.

Hilsenhoff Biotic Index - The Hilsenhoff Biotic Index (HBI) summarizes the overall pollution tolerances of the taxa collected. This index has been used to detect nutrient enrichment, high sediment loads, low dissolved oxygen, and thermal impacts. It is best at detecting organic pollution. Families were assigned an index value from 0 (taxa normally found only in high quality unpolluted water) to 10 (taxa found only in severely polluted waters). Family level values were taken from Hilsenhoff (1987 and 1988, as referenced in Miller 2011) and a family level HBI was calculated for each sampling location for which there were a sufficient number of individuals and taxa collected to perform the calculations. Sampling locations with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 polluted. Rather than using mean HBI values for a sample, taxon HBI values can also be used to determine the number of pollution intolerant and tolerant taxa occurring at a site. In this report, taxa with HBI values ≤ 2 were considered intolerant clean water taxa and taxa with HBI values ≥ 8 were considered pollution tolerant taxa. The number of tolerant and intolerant taxa and the abundances of tolerant and intolerant taxa were calculated for each sampling location.

USFS community tolerant quotient - Taxa are assigned a tolerant quotient from 2 (taxa found only in high quality unpolluted water) to 108 (taxa found in severely polluted waters). The dominance weighted community tolerance quotient (CTQd) was calculated. Values can vary from about 20 to 100, in general the lower the value the better the water quality.

Functional feeding group measures - A common classification scheme for aquatic macroinvertebrates is to categorize them by feeding acquisition mechanisms. Categories are based on food particle size and food location, e.g., suspended in the water column, deposited in sediments, leaf litter, or live prey. This classification system reflects the major source of the resource, either within the stream itself or from riparian or upland areas and the primary location, either erosional or depositional habitats. The number of taxa and individuals of the following feeding groups were calculated for each sampling location.

Shredders - Shredders use both living vascular hydrophytes and decomposing vascular plant tissue - coarse particulate organic matter. Shredders are sensitive to changes in riparian vegetation. Shredders can be good indicators of toxicants that adhere to organic matter.

Scrapers - Scrapers feed on periphyton - attached algae and associated material. Scraper populations increase with increasing abundance of diatoms and can decrease as filamentous algae, mosses, and vascular plants increase, often in response to increases in nitrogen and phosphorus. Scrapers decrease in relative abundance in response to sedimentation and higher levels of organic pollution or nutrient enrichment.

Collector-filterers - Collector-filterers feed on suspended fine particulate organic matter. Collector-filterers are sensitive to toxicants in the water column and to pollutants that adhere to organic matter.

Collector-gatherers - Collector-gatherers feed on deposited fine particulate organic matter. Collector-gatherers are sensitive to deposited toxicants.

Predators - Predators feed on living animal tissue. Predators typically make up about 25% of the assemblage in stream environments and 50% of the assemblage in still-water environments.

Unknown feeding group - This category includes taxa that are highly variable, parasites, and those that for which the primary feeding mode is currently unknown.

In addition, JBR used the BugLab's data set to calculate several other metrics that various literature sources consistently indicate as being potentially useful for macroinvertebrate analysis, particularly in regard to potential metals pollution. These are described below.

Ratio of Specialist Feeders to Generalist Feeders - Specialist feeders include shredders and scrapers and generalist feeders include filterers and gatherers. Generalists are typically more tolerant to environmental stressors, so their proportion often increases in response to degraded water quality or stream habitat. This ratio has been used successfully to assess impacts from mining (Mize and Deacon 2002).

Ratio of EPT to Chironomidae - Ideally, communities have a near-even distribution among all four of these major groups. The Chironimid Family, in general, is more tolerant than most of the taxa in the Ephemeroptera, Plecoptera, and Trichoptera orders (Barbour et al 1999). Therefore, this ratio can indicate environmental stress when it shows disproportionate numbers of Chironomidae (Davis et al 2001).

Percent *Baetis*, Hydropsychidae, and Orthocladinae; Ratio of *Baetis* to all Ephemeroptera – These two similar measures express the documented higher tolerances of *Baetis*, Hydropsychidae, and Orthocladinae, than other members of their families. Mize and Deacon (2002) among others have used the presence of these taxa when assessing environmental

conditions specific to mining (some studies have found the opposite conclusion with *Baetis*; however, the majority appear to consider it one of the more tolerant of the mayflies).

Percent Heptageniidae, Chloroperlidae, and *Rhyacophila*; Ratio of Heptageniidae to all Ephemeroptera – Similarly to the above-noted tolerant taxa, Heptageniidae, Chloroperlidae, and *Rhyacophila* were considered by Mize and Deacon (2002) when assessing elevated trace metals impacts. Heptageniidae, Chloroperlidae, and *Rhyacophila* were chosen due to their apparent sensitivity to such elements, thus their absence can indicate poor water quality. Many other authors have associated a lack of Heptageniidae organisms, in particular, with heavy metals pollution (i.e. Kiffney and Clements 1994).

As with analysis of any set of macroinvertebrate data, multiple metrics and their predicted response to perturbations (as given by EPA (2009a) and others in the scientific community) will be relied upon to make a finding of impact or nonimpact in regard to Genwal's groundwater discharge and Crandall Creek. Whether looking at data from an individual sample, comparing data from different sites for a spatial assessment, or examining temporal changes, no one metric can ever be presumed to tell the whole story. First, there is typically some natural variability in community makeup, so reliance on a single metric can be misleading. Further, some metrics are better at ascertaining specific conditions than others (i.e., organic pollution versus metals pollution). For these reasons, most researchers use a variety of metrics and would expect to see similar indications in several of them before making a conclusion regarding impact to a given site. In contrast, there is some redundancy among metrics because they use at least some of the same data. EPA (Barbour et al 1999) and others have developed techniques for combining various metrics into a single index, and also for ranking sites based upon individual metrics in a way that a potentially impacted site can be compared to reference sites (known to be unimpacted). In this study, the low number of sample sites, lack of replicates, and inadequate information on historical baseline make these techniques impossible or impractical to use. Further, the natural variability of any of one these metrics is not known, so it is difficult to determine whether a difference between sites as shown by one metric is due to degraded conditions or simply a reflection of natural variability. While a data set conducive to statistical handling (assigning confidence limits, assessing significance, etc.) would be ideal, and may be available as sampling continues in the future, those types of data do not currently exist.

Instead, individual metrics were calculated for each site and graphed to provide an easy visual means of comparison (Appendix 2). Although some metrics are not independent of each other, there was a specific intent to choose metrics that are of different types (i.e., tolerance as measured by CTQd, community composition as measured by EPT abundance, feeding mechanism as measured by specialist-to-generalist ratio), as recommended by EPA (Barbour et al 1999). Metrics that would be expected to decrease as site conditions worsen (i.e., richness) are shown in blue and those that would be expected to increase as site conditions worsen (i.e.,

HBI) are shown in green, further facilitating visual interpretation. Comparisons between CRANDUP-01 and CRANDMD-02, across matrices, allow an assessment of whether conditions are degraded below Genwal's discharge. The presumption is that if multiple matrices indicate the same trend (i.e., impact), there is a greater likelihood that there is a degradation between sites as a result of mine discharge. Similarly, comparisons between CRANDMD-02 and CRANDLWR-03 can be made to assess whether there is a spatial limit to the degradation (recovered conditions downstream).

5.0 Results and Discussion

The laboratory results report that was prepared by the BugLab (Miller 2011) is provided in full as Appendix 1. That report includes the raw data (taxonomic lists of organisms that were sampled, counts, etc.) as well as numerous tables giving various metrics and indices that the lab calculated based upon the data. The BugLab's report (Miller 2011) does not discuss or interpret the study results. This section focuses on those tasks, beginning with a brief summary of the data and a general discussion of the results.

A total of 45 operational taxonomic units (OTUs) were identified in the 6-sample set, which is fewer than either of the previous sampling events. At 26, the number of families was similar as the previously reported 28, but the number of genera was substantially lower (23, compared with 33 in fall 2009 and 46 in spring 2010). However, total abundance was 1,266 (average organisms per square meter over the 6-sample set), which is much greater than previously reported (523 in June 2010 and 660 in September 2009). These variations can be caused by flow conditions, time of year, macroinvertebrate life cycles, and environmental degradation.

All of the insect orders most commonly found in macroinvertebrate communities (Coleoptera, Diptera, Ephemeroptera, Plecoptera, and Tricoptera) as well as individuals from some non-insect classes were represented in both sample sets. Perhaps notable, however, is that there were a higher percentage of non-insects compared to previous sampling and Ephemeroptera represented a much smaller percentage than previously (see the first graph in Appendix 2 – Percent Predominant Taxonomic Groups). This, combined with the large proportion of members of the order Diptera at all sites, continues to show that none of the three Crandall Creek sites is in optimum condition. CTQd, which can range from about 20 in the best quality streams up to about 100 in the poorest, was between 76 and 97 in the Crandall Creek September 2010 samples, which also indicates a stream that is providing less than ideal aquatic habitat, and is overall slightly worse than in the previous sampling events.

Although Crandall Creek as a whole may provide less-than-ideal habitat, all of the sites had at least a somewhat diverse assemblage of taxa, and all supported at least some taxa that are considered intolerant to pollution or other habitat alterations. Knowing that (1) Crandall Creek overall has an aquatic community that is not optimum, and (2) in spite of Genwal's previous iron-laden discharge, the creek is still supporting aquatic life provides a useful context for the

remainder of the results discussion. Those two things being said, by most of the metrics discussed below, there continues to be a less healthy macroinvertebrate community at both CRANDMD-02 and CRANDLWR-03, which are downstream of the discharge, than at CRANDUP-01, which is upstream of the discharge.

Habitat differences among the three sites (described briefly above in Section 3.2) could be at least partially reflected in the results and their interpretation. For example, CRANDUP-01 and CRANDLWR-03 have similar substrate size compositions, but at the latter much of the substrate is embedded and cemented. This lack of interstitial spaces results in poor physical habitat for macroinvertebrates at CRANDLWR-03. Therefore, the site comparisons in Section 5.2 must consider that habitat is degraded at this site due to characteristics unrelated to any that have potentially occurred due to the discharges of iron-laden water. Additionally, the substrate at CRANDMD-02 is similar to that at the other two sites, but proportionally has more graveled riffle reaches than the other two sites. These features generally offer the best physical habitat for macroinvertebrates, but at CRANDMD-02, much of this high-quality substrate is now iron-stained and covered filamentous algae. Seasonal differences, primarily reflected in the flow rate, could also have a bearing on the results interpretation.

5.1 Comparison of Targeted Riffle and Multi-Habitat Samples

As with the September 2009 and June 2010 analyses, numerous metrics and indices have been calculated and graphed for the September 2010 samples. These graphs are included in Appendix 2. They provide a visual means to determine whether there were differences between the samples collected from targeted riffle sites and those collected from the multi-habitat sites. (Data are still insufficient to determine statistical significance of any noted differences.)

One of the reasons that the first study report (JBR 2010) recommended that targeted riffle samples should be collected along with the multi-habitat ones during future monitoring events was based upon the observation that habitat types varied somewhat between each reach. It was felt that the spatial data comparison would be more robust using the results of targeted riffle sampling. In addition, Utah's DWQ monitoring program calls for macroinvertebrate samples to be collected using only a targeted riffle method (DWQ 2006). Collecting targeted riffle samples in Crandall Creek, as well as continuing to collect multi-habitat samples, would allow a broader means of data interpretation in the future, as the data set grows.

In June 2010, for sites CRANDMD-02 and CRANDLWR-03, differences between the targeted riffle and the multi-habitat samples were generally fairly small, but at CRANDUP-01, more often than not, there were larger differences between these two sample types. In September 2010, however, this did not appear to be the case. Instead, no clear relationships were evident between the two sample types at any of the sites.

For the remainder of this report, the targeted riffle sample results will be used for the discussion of spatial variation (Section 5.2) and the multi-habitat sample results will be used for the discussion of temporal variation (Section 5.3). In the first instance, using targeted riffles eliminates some of the potential bias due to varying substrate characteristics among the sites. In the second instance, because multi-habitat samples are the only ones for which we have like-season (fall) data in more than one year, they are the most appropriate means of temporal comparisons.

5.2 Spatial Variation in Macroinvertebrate Community

As noted above, numerous metrics and indices based upon the September 2010 sampling at CRANDUP-01, CRANDMD-02, and CRANDLWR-03 have been calculated and graphed. These graphs are included in Appendix 2 and provide a visual aid for analyzing the spatial variation in the macroinvertebrate community along Crandall Creek. As noted above in Section 5.1, only the targeted riffle samples will be used for the spatial comparisons. CRANDUP-01 is upstream of any potential impact from Genwal's discharge, CRANDMD-02 is immediately below the discharge where impacts would presumably be the greatest, and CRANDLWR-03 is further downstream where impacts could presumably be either similar to those seen at CRANDMD-02 or reduced, thus indicating a spatial limit to the impact.

Out of the 20 metrics graphed in Appendix 2, 80 percent (16) of the targeted riffle sample results indicate a decline in macroinvertebrate community health between CRANDUP-01 and CRANDMD-02. This is the same percentage as was noted in the June 2010 samples (JBR 2011). Despite the limitations of the data (as outlined in Section 4.2), the fact that such a high percentage of the metrics showed the same trend between these two sites substantiates a finding of difference and increases the likelihood that the difference is not simply due to natural variation.

The 16 metrics that indicate a decline in the aquatic community between sites CRANDUP-01 and CRANDMD-02 encompass a range of tolerance, community composition, diversity, and feeding group metrics. Both the CTQd Index, which is a weighted community tolerance index, and Shannon's Diversity Index, which is a measure of variety in the macroinvertebrate community, indicated significantly poorer conditions at CRANDMD-02 than at CRANDUP-01. Several metrics assessing various taxa (Chironomids, *Baetis*, Hydropsychidae, and Orthocladiinae) that can withstand poor water quality showed a higher relative abundance of those organisms at CRANDMD-02 than at CRANDUP-01, supporting the contention of degraded conditions at the former. These include several metrics assessing taxa sensitive to poor water quality (Heptageniidae, Chloroperidae, and *Rhyacophila*, specifically, and all EPT taxa generally). Of specific note are the marked differences between CRANDUP-01 and CRANDMD-02 in the "Percent EPT", "EPT:Chironomids", and "Percent Heptageniidae, Chloroperidae, & *Rhyacophila*" graphs in Appendix 2. Based generally upon the number and variety of metrics that indicate at least some level of decline in the macroinvertebrate community between these

two sites, and specifically upon the three above-noted metrics, the macroinvertebrate community at CRANDMD-02 has most likely been impacted by Genwal's discharge.

Similarly, based upon almost all of the various targeted riffle sample metrics (Appendix 2), CRANDUP-01 has a healthier macroinvertebrate community than does CRANDLWR-03, seemingly indicating that CRANDLWR-03 has also been subject to some type of perturbation. In some cases, the graphs show better conditions immediately below the discharge (CRANDMD-02) than further downstream (CRANDLWR-03) and in some cases show the opposite. Overall, analysis of the targeted riffle samples shows that CRANDUP-01 is in better health than the other two sites. As mentioned in Section 5.0, the poor condition of the macroinvertebrate community at CRANDLWR-03 may be due to poorer physical habitat conditions (i.e. embeddedness and cementation) at this site.

5.3 Temporal Variation in Macroinvertebrate Community

As previously mentioned, macroinvertebrate studies were conducted in Crandall Creek in 1980 and 1994. However, those data are of limited use for temporal comparisons due to unknowns in either sampling locations and/or collection methodology. Instead, the three sets of multi-habitat data (from September 2009, June 2010, and September 2011) are examined herein to assess temporal variation. Although the sample sites and methodology are the same for these three sets, the June 2010 data was collected during a time of much higher stream flows and in a different phase of some macroinvertebrate life cycles than the other two data sets.

Examining the multi-habitat sample metric graphs (Appendix 2) that show September 2009, June 2010, and September 2011 data indicates that CRANDUP-01 had poorer macroinvertebrate conditions in June than in either of the two September sampling events, (as reflected in 16 out of the 20 metrics). This likely reflects stream flows and seasonal differences at the time of sampling. A comparison between the two fall-season sample sets shows that, while some metrics were better in 2010 than in 2009, CRANDUP-01 macroinvertebrate conditions overall appear to be similar in the two fall seasons.

At CRANDMD-02, however, the most recent September sampling showed conditions were either worse than or essentially the same as either of the two previous sampling events; only one metric out of 20 indicated a slight improvement in September 2010. Comparing the two fall data sets, no metrics shows any marked improvement in September 2010; all were either similar or showed poorer conditions. Thus, the data do not indicate that macroinvertebrate habitat had begun to improve at this site, even though the water quality treatment plant had been operating effectively for several months at the time of September 2010 sampling.

The overall trend in CRANDLWR-03 data is more mixed, with a few metrics showing improvement and more declining or similar over time (based on both the three data sets and the two fall data sets).

6.0 Recommendations for Future Study

JBR recommends that future sampling events use the same methodology and equipment as was used in 2010. Samples should include both a multi-habitat sample at each site and a targeted riffle sample at each site. Further, the next study report should refine the use of the metrics; either certain metrics should be eliminated (based upon an assessment of their usefulness in these particular environments) and/or a statistical analysis should be attempted if sufficient data are available.

7.0 Summary and Conclusions

In September 2010, benthic macroinvertebrate samples were collected from three reaches of Crandall Creek. One reach was located upstream of Genwal's Crandall Canyon Mine groundwater discharge while the other two reaches were located downstream of the discharge. One of the primary goals of the study was to determine whether the previously elevated iron concentrations have impacted Crandall Creek's macroinvertebrate population. Macroinvertebrate community composition at these three reaches was determined by taxonomic identification of the organisms collected during the June sampling, and numerous indices and metrics were calculated for ease in interpreting results.

Overall, the study results indicate that the Crandall Creek macroinvertebrate community immediately downstream of the mine discharge continues to show negative impacts of the mine water discharge. Attributing the degradation directly to the previously elevated iron in Genwal's groundwater discharge continues to be problematic, as was discussed in the previous study reports (JBR 2010; JBR 2011). Further, although the discharge water is no longer iron-laden, the stream bed within the CRANDMD-02 reach continues to be visibly altered by iron precipitates and by algal growth. Although the furthest downstream reach of Crandall Creek (CRANDLWR-03) also has a degraded macroinvertebrate community, its poor substrate condition (embedded and cemented) is likely a contributing (if not dominating) factor affecting macroinvertebrate community health at that site. However, both downstream reaches of the creek are still supporting a variety of macroinvertebrates, indicating that the past iron-laden discharge has not completely eliminated macroinvertebrate habitat.

8.0 References

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APPENDIX 1

BUGLAB REPORT

Aquatic Invertebrate Report For Samples Collected By JBR Environmental Consultants - Sandy, UT

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21 July 2011

Sampling Locations

Table 1. Sampling site locations

Station	Location	Latitude	Longitude	Elevation (meters)
CRANDLWR-03	Crandall Creek, Lower, Emery County, UT	39.464	-111.1460	2363
CRANDMD-02	Crandall Creek, Middle, Emery County, UT	39.460	-111.1650	2384
CRANDUP-01	Crandall Creek, Upstream, Emery County, UT	39.460	-111.1680	2389

Methods

Field sampling

Samples were collected on September 24, 2010 (Table 2). Aquatic invertebrates were collected quantitatively and qualitatively from reachwide habitats with a Kick Net

Laboratory methods

General procedures for processing invertebrate samples were similar to those recommended by the United States Geological Survey (Cuffney et al. 1993) and are described in greater detail and rationalized in Vinson and Hawkins (1996). Samples were sub-sampled if the sample appeared to contain more than 600 organisms. Sub-samples were obtained by pouring the sample into an appropriate diameter 500 micron sieve, floating this material by placing the sieve within an enamel pan partially filled with water and leveling the material within the sieve. The sieve was then removed from the water pan and the material within the sieve was divided into two equal parts. One half of the sieve was then randomly chosen to be processed and the other half set aside. The sieve was then placed back in the enamel pan and the material in the sieve again leveled and split in half. This process was repeated until approximately 600 organisms remained in one-half of the sieve. This material was placed into a Petri dish and all organisms were removed under a dissecting microscope at 10-30 power. Additional sub-samples were taken until at least 600 organisms were removed. All organisms within a sub-sample were removed, and separated into taxonomic Orders. When the sorting of the sub-samples was completed, the entire sample was spread throughout a large white enamel pan and searched for 10 minutes to remove any taxa that might not have been picked up during the initial sample sorting process. The objective of this "big/rare" search was to provide a more complete taxa list by finding rarer taxa that may have been excluded during the sub-sampling process. These rarer bugs were placed into a separate vial and the data entered separately from the bugs removed during the sub-sampling process. All the organisms removed during the sorting process were then identified using appropriate identification keys (see literature cited list for list of taxonomic resources used). Once the data had been entered into a computer and checked, the unsorted portion of the sample was discarded. The identified portion of the sample was placed in a 20 ml glass scintillation vial with polypropylene lids in 70% ethanol, given a catalog number, and retained. In this report, metrics were calculated using data from the sub-sampled and big/rare portions of the sample. Abundance data are presented as the estimated number of individuals per square meter for quantitative samples and the estimated number per sample for qualitative samples.

Table 2. Field comments and laboratory processing information.

Sample	Station	Sampling Date	Habitat Sampled	Sampling Method	Sampling Area Sqmts	% of sample processed	Number of individuals identified
146221	CRANDLWR-03	09/24/2010	Reachwide	Kick Net	0.47	100	292
146222	CRANDLWR-03	09/24/2010	Targeted Riffle	Kick Net	0.74	100	365
146219	CRANDMD-02	09/24/2010	Reachwide	Kick Net	0.47	100	439
146220	CRANDMD-02	09/24/2010	Targeted Riffle	Kick Net	0.74	56	674
146217	CRANDUP-01	09/24/2010	Reachwide	Kick Net	0.47	56	767
146218	CRANDUP-01	09/24/2010	Targeted Riffle	Kick Net	0.74	100	765

Data summarization

A number of metrics or ecological summaries can be calculated from an aquatic invertebrate sample. A summary and description of commonly used metrics is available in Barbour et al. (1999, <http://www.epa.gov/owow/monitoring/rbp/index.html#Table%20of%20Contents>) and Karr and Chu (1998). Both of these publications suggest use of the following metrics for assessing the health of aquatic invertebrate assemblages: Total taxa richness, EPT taxa richness, Ephemeroptera taxa richness, Plecoptera taxa richness, Trichoptera taxa richness, % EPT abundance, % Ephemeroptera abundance, % Chironomidae abundance, Intolerant taxa richness, % tolerant organisms, Hilsenhoff Biotic Index, % contribution of the dominant taxon, clinger taxa richness, % clinger abundance, % collector-filterer abundance, and the % scraper abundance. Assessments are best made by comparing samples to samples collected similarly at reference sites or from samples collected prior to impacts or management actions at a location. In this report, the following metrics were calculated for each sample.

Taxa richness - Richness is a component and estimate of community structure and stream health based on the number of distinct taxa. Taxa richness normally decreases with decreasing water quality. In some situations organic enrichment can cause an increase in the number of pollution tolerant taxa. Taxa richness was calculated for operational taxonomic units (OTUs) and the number of unique genera, and families. The values for operational taxonomic units may be overestimates of the true taxa richness at a site if individuals were the same taxon as those identified to lower taxonomic levels or they may be underestimates of the true taxa richness if multiple taxa were present within a larger taxonomic grouping but were not identified. All individuals within all samples were generally identified similarly, so that comparisons in operational taxonomic richness among samples within this dataset are appropriate, but comparisons to other data sets may not. Comparisons to other datasets should be made at the genera or family level.

Abundance - The abundance, density, or number of aquatic macroinvertebrates per unit area is an indicator of habitat availability and fish food abundance. Abundance may be reduced or increased depending on the type of impact or pollutant. Increased organic enrichment typically causes large increases in abundance of pollution tolerant taxa. High flows, increases in fine sediment, or the presence of toxic substances normally cause a decrease in invertebrate abundance. Invertebrate abundance is presented as the number of individuals per square meter for quantitative samples and the number of individuals collected in each sample for qualitative samples.

EPT - A summary of the taxonomic richness and abundance within the insect Orders Ephemeroptera, Plecoptera, and Trichoptera (EPT). These orders are commonly considered sensitive to pollution (Karr and Chu 1998).

Percent contribution of the dominant family or taxon - An assemblage largely dominated (>50%) by a single taxon or several taxa from the same family suggests environmental stress. Habitat conditions likely limit the number of taxa that can occur at the site.

Shannon diversity index - Ecological diversity is a measure of community structure defined by the relationship between the number of distinct taxa and their relative abundances. The Shannon diversity index was calculated for each sampling location for which there were a sufficient number of individuals and taxa collected to perform the calculations. The calculations were made following Ludwig and Reynolds (1988, equation 8.9, page 92).

Evenness - Evenness is a measure of the distribution of taxa within a community. The evenness index used in this report was calculated following Ludwig and Reynolds (1988, equation 8.15, page 94). Value ranges from 0-1 and approach zero as a single taxa becomes more dominant.

Clinger taxa - The number of clinger taxa have been found by Karr and Chu (1998) to respond negatively to human disturbance. Clinger taxa were determined using information in Merritt et al. (2008). These taxa typically cling to the tops of rocks and are thought to be reduced by sedimentation or abundant algal growths.

Long-live taxa - The number of long-lived taxa was calculated the number of taxa collected that typically have 2-3 year life cycles. Disturbances and water quality and habitat impairment typically reduces the number of long-lived taxa Karr and Chu (1998). Life-cycle length determinations were based on information in Merritt et al. (2008).

Biotic indices - Biotic indices use the indicator taxa concept. Taxa are assigned water quality tolerance values based on their tolerance to pollution. Scores are typically weighted by taxa relative abundance. In the United States the most

commonly used biotic index is the Hilsenhoff Biotic Index (Hilsenhoff 1987, Hilsenhoff 1988). The USFS and BLM throughout the western United States have also frequently used the USFS Community Tolerance Quotient.

Hilsenhoff biotic index - The Hilsenhoff Biotic Index (HBI) summarizes the overall pollution tolerances of the taxa collected. This index has been used to detect nutrient enrichment, high sediment loads, low dissolved oxygen, and thermal impacts. It is best at detecting organic pollution. Families were assigned an index value from 0- taxa normally found only in high quality unpolluted water, to 10- taxa found only in severely polluted waters. Family level values were taken from Hilsenhoff (1987, 1988) and a family level HBI was calculated for each sampling location for which there were a sufficient number of individuals and taxa collected to perform the calculations. Sampling locations with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 polluted. Rather than using mean HBI values for a sample, taxon HBI values can also be used to determine the number of pollution intolerant and tolerant taxa occurring at a site. In this report, taxa with HBI values ≤ 2 were considered intolerant clean water taxa and taxa with HBI values ≥ 8 were considered pollution tolerant taxa. The number of tolerant and intolerant taxa and the abundances of tolerant and intolerant taxa were calculated for each sampling location.

USFS community tolerant quotient - Taxa are assigned a tolerant quotient (TQ) from 2 - taxa found only in high quality unpolluted water, to 108 - taxa found in severely polluted waters. TQ values were developed by Winget and Mangum (1979). The dominance weighted community tolerance quotient (CTQd) was calculated. Values can vary from about 20 to 100, in general the lower the value the better the water quality.

Functional feeding group measures - A common classification scheme for aquatic macroinvertebrates is to categorize them by feeding acquisition mechanisms. Categories are based on food particle size and food location, e.g., suspended in the water column, deposited in sediments, leaf litter, or live prey. This classification system reflects the major source of the resource, either within the stream itself or from riparian or upland areas and the primary location, either erosional or depositional habitats. The number of taxa and individuals of the following feeding groups were calculated for each sampling location. Functional feeding group designations were from Merritt et al. (2008).

Shredders - Shredders use both living vascular hydrophytes and decomposing vascular plant tissue - coarse particulate organic matter. Shredders are sensitive to changes in riparian vegetation. Shredders can be good indicators of toxicants that adhere to organic matter.

Scrapers - Scrapers feed on periphyton - attached algae and associated material. Scraper populations increase with increasing abundance of diatoms and can decrease as filamentous algae, mosses, and vascular plants increase, often in response to increases in nitrogen and phosphorus. Scrapers decrease in relative abundance in response to sedimentation and higher levels of organic pollution or nutrient enrichment.

Collector-filterers - Collector-filterers feed on suspended fine particulate organic matter. Collector-filterers are sensitive to toxicants in the water column and to pollutants that adhere to organic matter.

Collector-gatherers - Collector-gatherers feed on deposited fine particulate organic matter. Collector-gatherers are sensitive to deposited toxicants.

Predators - Predators feed on living animal tissue. Predators typically make up about 25% of the assemblage in stream environments and 50% of the assemblage in still-water environments.

Unknown feeding group - This category includes taxa that are highly variable, parasites, and those that for which the primary feeding mode is currently unknown.

Results

Abundance data and taxa richness are reported as the estimated number of individuals per square meter for quantitative samples and the number per sample for qualitative samples. NC = Not calculated. * = unable to calculate. EPT = totals for the insect orders, Ephemeroptera, Plecoptera, Trichoptera. QL = qualitative sample.

Sample	Sampling date	Station	Total abundance	EPT abundance	Dominant family	% contribution dominant family
146217	09/24/2010	CRANDUP-01	2892	738	Psychodidae	38.07
146218	09/24/2010	CRANDUP-01	1034	272	Psychodidae	27.08
146219	09/24/2010	CRANDMD-02	944	69	Chironomidae	43.54
146220	09/24/2010	CRANDMD-02	1610	80	Chironomidae	53.11
146221	09/24/2010	CRANDLWR-03	628	30		25.96
146222	09/24/2010	CRANDLWR-03	493	39	Sperchonidae	43.41
Mean			1266.8	204.7		38.53

Diversity indices

Sample	Sampling Date	Station	Total taxa richness	Total genera richness	Total family richness	EPT taxa richness	Shannon diversity index	Evenness
146217	09/24/2010	CRANDUP-01	45	21	26	19	2.620	0.690
146218	09/24/2010	CRANDUP-01	40	16	29	13	2.630	0.710
146219	09/24/2010	CRANDMD-02	29	18	19	8	2.340	0.690
146220	09/24/2010	CRANDMD-02	36	21	20	11	1.930	0.540
146221	09/24/2010	CRANDLWR-03	24	12	13	7	2.200	0.690
146222	09/24/2010	CRANDLWR-03	25	15	16	7	1.700	0.530
Mean			33.2	17.2	20.5	10.8	2.240	0.640

Genera richness by major taxonomic group.

Sample	Sampling Date	Station	Coleoptera	Diptera	Ephemeroptera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Crustacea	Mollusca
146217	09/24/2010	CRANDUP-01	2	19	6	0	0	0	8	5	1	0	1
146218	09/24/2010	CRANDUP-01	6	14	3	0	0	1	6	4	0	0	0
146219	09/24/2010	CRANDMD-02	1	14	1	0	0	0	4	3	1	0	1
146220	09/24/2010	CRANDMD-02	2	16	1	0	0	0	4	6	1	0	1
146221	09/24/2010	CRANDLWR-0	2	9	2	0	0	0	2	3	1	0	1
146222	09/24/2010	CRANDLWR-0	3	10	1	0	0	0	5	1	0	0	0
Mean			2.7	13.7	2.3	0.0	0.0	0.2	4.8	3.7	0.7	0.0	0.7

Total abundance by major taxonomic group.

Sample	Sampling Date	Station	Coleoptera	Diptera	Ephemeroptera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Crustacea	Mollusca
146217	09/24/2010	CRANDUP-01	11	1902	134	0	0	0	411	194	19	0	34
146218	09/24/2010	CRANDUP-01	22	501	45	0	0	3	70	157	0	0	0
146219	09/24/2010	CRANDMD-02	28	531	2	0	0	0	49	17	37	0	174
146220	09/24/2010	CRANDMD-02	33	1068	10	0	0	0	41	29	89	0	29
146221	09/24/2010	CRANDLWR-03	6	196	9	0	0	0	11	11	114	0	30
146222	09/24/2010	CRANDLWR-03	8	168	12	0	0	0	26	1	0	0	0
Mean			18.0	727.7	35.3	0.0	0.0	0.5	101.3	68.2	43.2	0.0	44.5

Biotic Indices

Sample	Sampling date	Station	Hilsenhoff Biotic Index		USFS Community CTQd
			Index	Indication	
146217	09/24/2010	CRANDUP-01	5.86	Fairly significant organic pollution	76
146218	09/24/2010	CRANDUP-01	4.31	Possible slight organic pollution	77
146219	09/24/2010	CRANDMD-02	3.58	Possible slight organic pollution	92
146220	09/24/2010	CRANDMD-02	4.13	Possible slight organic pollution	93
146221	09/24/2010	CRANDLWR-03	1.91	No apparent organic pollution	97
146222	09/24/2010	CRANDLWR-03	2.25	No apparent organic pollution	96
Mean			3.67		88.5

Taxa richness and relative abundance values with respect to tolerance or intolerance to pollution were based on the Hilsenhoff Biotic Index (HBI). Intolerant taxa have HBI score ≤ 2 . Tolerant taxa have a HBI score ≥ 8 . Data are presented as estimated count per square meter for quantitative samples and total number per sample for qualitative samples.

Sample	Sampling date	Station	Intolerant taxa				Tolerant Taxa			
			Richness	Abundance	Richness	Abundance	Richness	Abundance		
146217	09/24/2010	CRANDUP-01	10	(22)	513	(18)	1	(2)	1101	(38)
146218	09/24/2010	CRANDUP-01	10	(25)	201	(19)	2	(5)	282	(27)
146219	09/24/2010	CRANDMD-02	5	(17)	56	(6)	0	(0)	0	(0)
146220	09/24/2010	CRANDMD-02	7	(19)	51	(3)	1	(3)	2	(0)
146221	09/24/2010	CRANDLWR-0	1	(4)	2	(0)	0	(0)	0	(0)
146222	09/24/2010	CRANDLWR-0	4	(16)	24	(5)	0	(0)	0	(0)
Mean			6.2	(17)	141.2	(9)	0.7	(2)	230.8	(11)

Functional feeding groups

Taxa richness by functional feeding group. The percent of the total is shown in parentheses.

Sample	Sampling date	Station	Shredders		Scrapers		Collector-filterers		Collector-gatherers		Predators		Unknown	
146217	09/24/2010	CRANDUP-01	8	(18)	1	(2)	4	(9)	12	(27)	16	(36)	4	(9)
146218	09/24/2010	CRANDUP-01	7	(18)	0	(0)	3	(8)	9	(23)	17	(43)	4	(10)
146219	09/24/2010	CRANDMD-02	3	(10)	0	(0)	2	(7)	7	(24)	14	(48)	3	(10)
146220	09/24/2010	CRANDMD-02	4	(11)	0	(0)	4	(11)	8	(22)	17	(47)	3	(8)
146221	09/24/2010	CRANDLWR-0	2	(8)	0	(0)	5	(21)	5	(21)	9	(38)	3	(13)
146222	09/24/2010	CRANDLWR-0	1	(4)	1	(4)	2	(8)	5	(20)	12	(48)	2	(8)
Mean			4.2	(12)	0.3	(1)	3.3	(11)	7.7	(23)	14.2	(43)	3.2	(10)

Invertebrate abundance by functional feed group. The percent of the total is shown in parentheses.

Sample	Sampling date	Station	Shredders		Scrapers		Collector-filterers		Collector-gatherers		Predators		Unknown	
146217	09/24/2010	CRANDUP-01	399	(14)	19	(1)	80	(3)	1536	(53)	797	(28)	61	(2)
146218	09/24/2010	CRANDUP-01	95	(9)	0	(0)	9	(1)	459	(44)	438	(42)	32	(3)
146219	09/24/2010	CRANDMD-02	17	(2)	0	(0)	176	(19)	387	(41)	329	(35)	34	(4)
146220	09/24/2010	CRANDMD-02	20	(1)	0	(0)	36	(2)	968	(60)	551	(34)	35	(2)
146221	09/24/2010	CRANDLWR-0	13	(2)	0	(0)	47	(7)	269	(43)	284	(45)	15	(2)
146222	09/24/2010	CRANDLWR-0	1	(0)	3	(1)	7	(1)	164	(33)	311	(63)	5	(1)
Mean			90.8	(5)	3.7	(0)	59.2	(6)	630.5	(46)	451.7	(41)	30.3	(2)

The 10 metrics thought to be most responsive to human induced disturbance (Karr and Chu 1998).

Sample	Sampling Date	Station	Total taxa	Ephemeroptera taxa	Plecoptera taxa	Trichoptera taxa	Long-lived taxa	Intolerant taxa	Clinger taxa	% tolerant individuals	% contribution dominant taxon	% predators
146217	09/24/2010	CRANDUP-01	45	2	4	3	3	10	11	38.07	38.07	27.56
146218	09/24/2010	CRANDUP-01	40	0	3	2	7	10	9	27.27	27.08	42.36
146219	09/24/2010	CRANDMD-02	29	1	3	1	1	5	6	0.00	32.31	34.85
146220	09/24/2010	CRANDMD-02	36	1	3	4	4	7	11	0.12	51.18	34.22
146221	09/24/2010	CRANDLWR-03	24	1	0	1	2	1	4	0.00	25.00	45.22
146222	09/24/2010	CRANDLWR-03	25	1	2	0	3	4	6	0.00	42.19	63.08
Mean			33.2	1.0	2.5	1.8	3.3	6.2	7.8	10.91	35.97	41.22

Taxonomic list and counts for 6 samples collected on September 24, 2010. Count is the total number of individuals identified and retained. Samples heading refers to the number of samples containing that taxon.

Order	Family	Subfamily/Genus/Species	Samples	Count
Phylum: Annelida				
Class: Clitellata	SubClass: Oligochaeta		4	112
Phylum: Arthropoda				
Class: Arachnida	SubClass: Acari			
Trombidiformes			4	31
Trombidiformes	Arrenuridae	Arrenurus	4	8
Trombidiformes	Hydryphantidae		1	2
Trombidiformes	Hygrobatidae		1	1
Trombidiformes	Lebertiidae	Lebertia	6	327
Trombidiformes	Mideopsidae	Mideopsis	1	1
Trombidiformes	Sperchonidae		1	117
Trombidiformes	Sperchonidae	Sperchon	5	230
Trombidiformes	Sperchonidae	Sperchonopsis	1	4
Trombidiformes	Torrenticolidae		1	2
Class: Insecta	SubClass: Pterygota			
Coleoptera	Amphizoidae	Amphizoa	1	3
Coleoptera	Dryopidae		1	1
Coleoptera	Dryopidae	Helichus	1	2
Coleoptera	Elmidae		1	2
Coleoptera	Elmidae	Narpus concolor	5	30
Coleoptera	Elmidae	Optioservus	1	2
Coleoptera	Elmidae	Optioservus quadrimaculatus	5	10
Coleoptera	Hydrophilidae	Hydrophilinae Hydrophilini Hydrobius	1	5
Diptera			2	18
Diptera	Ceratopogonidae		4	18
Diptera	Ceratopogonidae	Ceratopogoninae Sphaeromiini Probezia	5	36
Diptera	Chironomidae		6	24
Diptera	Chironomidae	Chironominae	2	36
Diptera	Chironomidae	Orthoclaadiinae	6	801
Diptera	Chironomidae	Tanypodinae	2	100
Diptera	Dixidae	Dixa	1	1
Diptera	Empididae		3	18
Diptera	Empididae	Clinocera	1	1
Diptera	Empididae	Hemerodromiinae Hemerodromiini	1	2
Diptera	Empididae	Hemerodromiinae Hemerodromiini Chelifera	2	23
Diptera	Empididae	Neoplasta	4	20
Diptera	Empididae	Wiedemannia	1	1
Diptera	Muscidae		4	87
Diptera	Psychodidae	Pericoma	3	496
Diptera	Ptychopteridae		1	1
Diptera	Simuliidae		2	5
Diptera	Simuliidae	Simuliinae Simuliini Simulium	4	9
Diptera	Simuliidae	Simuliinae Simuliini Simulium	2	3
Diptera	Stratiomyidae		1	2
Diptera	Stratiomyidae		1	1
Diptera	Stratiomyidae	Caloparyphus	3	3

Diptera	Stratiomyidae	Euparyphus	4	8
Diptera	Tabanidae		2	2
Diptera	Tipulidae		2	6
Diptera	Tipulidae	Dicranota	4	7
Diptera	Tipulidae	Hexatoma	1	4
Diptera	Tipulidae	Limoniinae Eriopterini Ormosia	1	6
Diptera	Tipulidae	Limoniinae Hexatomini Limnophila	2	10
Diptera	Tipulidae	Pedicia	1	1
Diptera	Tipulidae	Tipulinae Tipula	4	34
Ephemeroptera	Baetidae		3	23
Ephemeroptera	Baetidae	Baetis	5	30
Ephemeroptera	Ephemerellidae		2	11
Ephemeroptera	Heptageniidae		1	5
Ephemeroptera	Heptageniidae	Rhithrogena	1	1
Ephemeroptera	Leptophlebiidae		2	16
Odonata	Coenagrionidae		1	2
Plecoptera			2	13
Plecoptera			1	1
Plecoptera	Capniidae	Capniinae	3	30
Plecoptera	Chloroperlidae	Chloroperlinae	1	1
Plecoptera	Chloroperlidae	Sweltsa	1	1
Plecoptera	Nemouridae		2	15
Plecoptera	Nemouridae	Zapada	1	3
Plecoptera	Nemouridae	Zapada	3	17
Plecoptera	Nemouridae	Zapada cinctipes	2	33
Plecoptera	Perlodidae		5	87
Plecoptera	Perlodidae	Isoperlinae Isoperla	4	9
Plecoptera	Perlodidae	Megarcys signata	3	16
Plecoptera	Pteronarcyidae	Pteronarcyinae Pteronarcellini Pteronarcella	1	1
Trichoptera			1	1
Trichoptera	Hydropsychidae		5	13
Trichoptera	Hydropsychidae	Arctopsychinae Arctopsyche grandis	1	1
Trichoptera	Hydropsychidae	Arctopsychinae Parapsyche	1	3
Trichoptera	Hydropsychidae	Hydropsychinae Hydropsyche	1	2
Trichoptera	Limnephilidae		5	58
Trichoptera	Limnephilidae	Limnephilinae Limnephilini Hesperophylax	1	2
Trichoptera	Rhyacophilidae	Rhyacophila	3	20
Trichoptera	Rhyacophilidae	Rhyacophila vagrita group	1	1
Trichoptera	Rhyacophilidae	Rhyacophila vofixa group	3	93
Phylum: Mollusca				
Class: Bivalvia	SubClass: Heterodonta			
Veneroida	Pisidiidae	Pisidiinae Pisidium	4	116
Phylum: Nemata				
Class:	SubClass:		2	3

Total: OTU Taxa: **83** Genera: **45** Families: **37** Individuals: **3302**

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Taxa Lists for Individual Samples

Taxonomic list and densities of aquatic invertebrates identified and retained from a sample collected September 24, 2010 at station CRANDUP-01, Crandall Creek, Upstream, Emery county, Utah. The sample was collected from reachwide habitat using a Kick Net. The total area sampled was 0.465 square meters. The percentage of the sample that was identified and retained was 56% of the collected sample. A total of 767 individuals were removed, identified and retained. The sample identification number is 146217. OTU=operational taxonomic unit. Notes - identification to genus or species was not supported because: I - immature organisms, D- damaged organisms, M - poor slide mount, G - gender, U - indistinct characters or distribution, R - retained in our reference collection.

Order	Family	Subfamily/Genus/Species	Life Stage	Density	Notes
Phylum: Annelida					
Class: Clitellata		SubClass: Oligochaeta		adult	19.12
Phylum: Arthropoda					
Class: Arachnida		SubClass: Acari			
Trombidiformes	Hygrobatidae		adult	3.82	U
Trombidiformes	Lebertiidae	Lebertia	adult	156.75	
Trombidiformes	Sperchonidae	Sperchon	adult	26.76	
Class: Insecta		SubClass: Pterygota			
Coleoptera	Dryopidae	Helichus	adult	7.65	
Coleoptera	Elmidae	Optioservus quadrimaculatus	adult	3.82	
Diptera			larvae	15.29	I,D,U
Diptera	Ceratopogonidae		larvae	11.47	I,D
Diptera	Ceratopogonidae	Ceratopogoninae Sphaeromiini Probezia	larvae	26.76	
Diptera	Chironomidae		pupae	22.94	
Diptera	Chironomidae	Chironominae	larvae	69.30	
Diptera	Chironomidae	Orthoclaadiinae	larvae	182.32	
Diptera	Chironomidae	Tanypodinae	larvae	262.13	
Diptera	Empididae	Hemerodromiinae Hemerodromiini	larvae	7.65	
Diptera	Empididae	Wiedemannia	larvae	3.82	
Diptera	Muscidae		larvae	35.36	
Diptera	Psychodidae	Pericoma	larvae	1101.08	
Diptera	Ptychopteridae		larvae	3.82	D
Diptera	Simuliidae	Simuliinae Simuliini Simulium	larvae	11.47	
Diptera	Tabanidae		larvae	3.82	U
Diptera	Tipulidae	Dicranota	larvae	7.65	
Diptera	Tipulidae	Limoniinae Eriopterini Ormosia	larvae	22.94	
Diptera	Tipulidae	Limoniinae Hexatomini Limnophila	larvae	23.42	
Diptera	Tipulidae	Pedicia	larvae	3.82	
Diptera	Tipulidae	Tipulinae Tipula	larvae	86.74	
Ephemeroptera	Baetidae		larvae	19.12	I,D
Ephemeroptera	Baetidae	Baetis	larvae	53.52	
Ephemeroptera	Ephemerellidae		larvae	11.47	I,D
Ephemeroptera	Heptageniidae		larvae	19.12	D
Ephemeroptera	Heptageniidae	Rhithrogena	larvae	3.82	
Ephemeroptera	Leptophlebiidae		larvae	26.76	D
Plecoptera			larvae	34.41	I,D
Plecoptera	Capniidae	Capniinae	larvae	78.61	I,D
Plecoptera	Nemouridae		larvae	19.12	I,D
Plecoptera	Nemouridae	Zapada	larvae	11.47	I,D
Plecoptera	Nemouridae	Zapada	larvae	30.59	
Plecoptera	Nemouridae	Zapada cinctipes	larvae	110.87	
Plecoptera	Perlodidae		larvae	105.38	I,D
Plecoptera	Perlodidae	Megarcys signata	larvae	20.07	
Trichoptera	Hydropsychidae		larvae	22.94	I,D
Trichoptera	Hydropsychidae	Arctopsychinae Parapsyche	larvae	11.47	
Trichoptera	Limnephilidae		larvae	26.76	I,D

Trichoptera	Limnephilidae	Limnephilinae	Limnephilini	Hesperophylax	larvae	7.65
Trichoptera	Rhyacophilidae	Rhyacophila	vofixa group		larvae	98.21
Phylum: Mollusca						
Class: Bivalvia		SubClass: Heterodonta				
Veneroida	Pisidiidae	Pisidiinae	Pisidium		adult	34.41
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Total:	OTU Taxa:	45	Genera:	23	Families:	26
						2892.23
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Taxonomic list and densities of aquatic invertebrates identified and retained from a sample collected September 24, 2010 at station CRANDUP-01, Crandall Creek, Upstream, Emery county, Utah. The sample was collected from targeted riffle habitat using a Kick Net. The total area sampled was 0.740 square meters. The percentage of the sample that was identified and retained was 100% of the collected sample. A total of 765 individuals were removed, identified and retained. The sample identification number is 146218. OTU=operational taxonomic unit. Notes - identification to genus or species was not supported because: I - immature organisms, D- damaged organisms, M - poor slide mount, G - gender, U - indistinct characters or distribution, R - retained in our reference collection.

Order	Family	Subfamily/Genus/Species	Life Stage	Density	Notes
Phylum: Arthropoda					
Class: Arachnida		SubClass: Acari			
	Trombidiformes		adult	12.16	U
	Trombidiformes	Hydryphantidae	adult	2.70	U
	Trombidiformes	Lebertiidae Lebertia	adult	59.46	
	Trombidiformes	Mideopsidae Mideopsis	adult	1.35	
	Trombidiformes	Sperchonidae	adult	158.11	U
	Trombidiformes	Torrenticolidae	adult	2.70	U
Class: Insecta		SubClass: Pterygota			
	Coleoptera	Amphizoidae Amphizoa	larvae	4.05	
	Coleoptera	Dryopidae	adult	1.35	D,U
	Coleoptera	Elmidae	adult	2.70	D,U
	Coleoptera	Elmidae Narpus concolor	larvae	1.35	
	Coleoptera	Elmidae Optioservus quadrimaculatus	adult	5.41	
	Coleoptera	Hydrophilidae Hydrophilinae Hydrophilini Hydrobius	adult	6.76	
	Diptera		larvae	9.46	U
	Diptera	Ceratopogonidae	larvae	13.51	U
	Diptera	Ceratopogonidae Ceratopogoninae Sphaeromiini Probezzia	larvae	9.46	
	Diptera	Chironomidae	pupae	1.35	U
	Diptera	Chironomidae Orthocladiinae	larvae	124.32	
	Diptera	Dixidae Dixia	larvae	1.35	
	Diptera	Empididae	larvae	18.92	U
	Diptera	Empididae Neoplasta	larvae	12.16	
	Diptera	Muscidae	larvae	1.35	U
	Diptera	Psychodidae Pericoma	larvae	279.73	
	Diptera	Simuliidae	larvae	2.70	I
	Diptera	Simuliidae Simuliinae Simuliini Simulium	pupae	2.70	
	Diptera	Stratiomyidae Euparyphus	larvae	5.41	
	Diptera	Tipulidae Tipulinae Tipula	larvae	9.46	
	Ephemeroptera	Baetidae	larvae	21.62	D,U
	Ephemeroptera	Ephemerellidae	larvae	10.81	I,D
	Ephemeroptera	Leptophlebiidae	larvae	12.16	D
	Odonata	Coenagrionidae	larvae	2.70	U
	Plecoptera	Capniidae Capniinae	larvae	10.81	U
	Plecoptera	Nemouridae	larvae	13.51	D,U
	Plecoptera	Nemouridae Zapada	larvae	9.46	
	Plecoptera	Nemouridae Zapada cinctipes	larvae	5.41	
	Plecoptera	Perlodidae	larvae	29.73	I,D,U
	Plecoptera	Perlodidae Isoperlinae Isoperla	larvae	1.35	
	Trichoptera	Hydropsychidae	larvae	4.05	I
	Trichoptera	Limnephilidae	larvae	44.59	D,U
	Trichoptera	Rhyacophilidae Rhyacophila	larvae	20.27	U
	Trichoptera	Rhyacophilidae Rhyacophila vofixa group	larvae	87.84	
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Total:	OTU Taxa: 40	Genera: 18	Families: 29	1033.78	

Taxonomic list and densities of aquatic invertebrates identified and retained from a sample collected September 24, 2010 at station CRANDMD-02, Crandall Creek, Middle, Emery county, Utah. The sample was collected from reachwide habitat using a Kick Net. The total area sampled was 0.465 square meters. The percentage of the sample that was identified and retained was 100% of the collected sample. A total of 439 individuals were removed, identified and retained. The sample identification number is 146219. OTU=operational taxonomic unit. Notes - identification to genus or species was not supported because: I - immature organisms, D- damaged organisms, M - poor slide mount, G - gender, U - indistinct characters or distribution, R - retained in our reference collection.

Order	Family	Subfamily/Genus/Species	Life Stage	Density	Notes
Phylum: Annelida					
Class: Clitellata					
SubClass: Oligochaeta					
			adult	36.56	
Phylum: Arthropoda					
Class: Arachnida					
SubClass: Acari					
Trombidiformes	Arrenuridae	Arrenurus	adult	6.45	
Trombidiformes	Lebertiidae	Lebertia	adult	79.57	
Trombidiformes	Sperchonidae	Sperchon	adult	15.05	
Class: Insecta					
SubClass: Pterygota					
Coleoptera	Elmidae	Narpus concolor	larvae	27.96	
Diptera	Ceratopogonidae	Ceratopogoninae Sphaeromiini Probezziia	larvae	23.66	
Diptera	Chironomidae		pupae	2.15	
Diptera	Chironomidae	Chironominae	larvae	36.56	
Diptera	Chironomidae	Orthocladiinae	larvae	305.38	
Diptera	Chironomidae	Tanypodinae	larvae	66.67	
Diptera	Empididae	Clinocera	larvae	2.15	
Diptera	Empididae	Hemerodromiinae Hemerodromiini Chelifera	larvae	10.75	
Diptera	Muscidae		larvae	64.52	
Diptera	Simuliidae	Simuliinae Simuliini Simulium	larvae	2.15	
Diptera	Stratiomyidae	Caloparyphus	larvae	2.15	
Diptera	Stratiomyidae	Euparyphus	larvae	2.15	
Diptera	Tabanidae		larvae	2.15	I
Diptera	Tipulidae	Limoniinae Hexatomini Limnophila	larvae	6.45	
Diptera	Tipulidae	Tipulinae Tipula	larvae	4.30	
Ephemeroptera	Baetidae	Baetis	larvae	2.15	
Plecoptera	Nemouridae	Zapada	larvae	4.30	
Plecoptera	Perlodidae		larvae	30.11	I
Plecoptera	Perlodidae	Isoperlinae Isoperla	larvae	4.30	
Plecoptera	Perlodidae	Megarcys signata	larvae	10.75	
Trichoptera			pupae	2.15	U
Trichoptera	Limnephilidae		larvae	8.60	I
Trichoptera	Rhyacophilidae	Rhyacophila	larvae	6.45	I,U
Phylum: Mollusca					
Class: Bivalvia					
SubClass: Heterodonta					
Veneroida	Pisidiidae	Pisidiinae Pisidium	adult	174.19	
Phylum: Nemata					
Class:					
SubClass:					
			adult	4.30	
Total:	OTU Taxa: 29	Genera: 18	Families: 19	944.09	

Taxonomic list and densities of aquatic invertebrates identified and retained from a sample collected September 24, 2010 at station CRANDMD-02, Crandall Creek, Middle, Emery county, Utah. The sample was collected from targeted riffle habitat using a Kick Net. The total area sampled was 0.740 square meters. The percentage of the sample that was identified and retained was 56% of the collected sample. A total of 674 individuals were removed, identified and retained. The sample identification number is 146220. OTU=operational taxonomic unit. Notes - identification to genus or species was not supported because: I - immature organisms, D- damaged organisms, M - poor slide mount, G - gender, U - indistinct characters or distribution, R - retained in our reference collection.

Order	Family	Subfamily/Genus/Species	Life Stage	Density	Notes
Phylum: Annelida					
Class: Clitellata					
SubClass: Oligochaeta					
			adult	88.89	
Phylum: Arthropoda					
Class: Arachnida					
SubClass: Acari					
			adult	7.21	U
	Arrenuridae	Arrenurus	adult	4.80	
	Lebertiidae	Lebertia	adult	209.01	
	Sperchonidae	Sperchon	adult	88.89	
Class: Insecta					
SubClass: Pterygota					
Coleoptera	Elmidae	Narpus concolor	larvae	30.18	
Coleoptera	Elmidae	Optioservus quadrimaculatus	adult	2.40	
Diptera	Ceratopogonidae		larvae	7.21	I
Diptera	Ceratopogonidae	Ceratopogoninae Sphaeromiini Probezzia	larvae	24.02	
Diptera	Chironomidae		pupae	31.23	
Diptera	Chironomidae	Orthoclaadiinae	larvae	824.02	
Diptera	Empididae		larvae	2.40	D
Diptera	Empididae	Hemerodromiinae Hemerodromiini Chelifera	larvae	43.24	
Diptera	Empididae	Neoplasta	larvae	9.61	
Diptera	Muscidae		larvae	102.85	
Diptera	Psychodidae	Pericoma	larvae	2.40	
Diptera	Simuliidae	Simuliinae Simuliini Simulium	larvae	2.40	
Diptera	Stratiomyidae		larvae	4.80	I
Diptera	Stratiomyidae	Caloparyphus	larvae	2.40	
Diptera	Stratiomyidae	Euparyphus	larvae	4.80	
Diptera	Tipulidae		larvae	2.40	I
Diptera	Tipulidae	Dicranota	larvae	2.40	
Diptera	Tipulidae	Tipulinae Tipula	larvae	1.35	
Ephemeroptera	Baetidae	Baetis	larvae	9.61	
Plecoptera	Perlodidae		larvae	19.22	I
Plecoptera	Perlodidae	Isoperlinae Isoperla	larvae	12.01	
Plecoptera	Perlodidae	Megarcys signata	larvae	8.56	
Plecoptera	Pteronarcyidae	Pteronarcyinae Pteronarcellini Pteronarcella badia	larvae	1.35	
Trichoptera	Hydropsychidae		larvae	2.40	I
Trichoptera	Hydropsychidae	Arctopsychinae Arctopsyche grandis	larvae	2.40	
Trichoptera	Limnephilidae		larvae	14.41	I
Trichoptera	Rhyacophilidae	Rhyacophila	larvae	4.80	I
Trichoptera	Rhyacophilidae	Rhyacophila vagrita group	larvae	2.40	
Trichoptera	Rhyacophilidae	Rhyacophila vofixa group	larvae	2.40	
Phylum: Mollusca					
Class: Bivalvia					
SubClass: Heterodonta					
	Veneroida	Pisidiidae	Pisidiinae Pisidium	adult	28.83
Phylum: Nemata					
Class:					
SubClass:					
			adult	2.40	

Total: OTU Taxa: **36**

Genera: **23**

Families: **20**

1609.76

Taxonomic list and densities of aquatic invertebrates identified and retained from a sample collected September 24, 2010 at station CRANDLWR-03, Crandall Creek, Lower, Emery county, Utah. The sample was collected from reachwide habitat using a Kick Net. The total area sampled was 0.465 square meters. The percentage of the sample that was identified and retained was 100% of the collected sample. A total of 292 individuals were removed, identified and retained. The sample identification number is 146221. OTU=operational taxonomic unit. Notes - identification to genus or species was not supported because: I - immature organisms, D- damaged organisms, M - poor slide mount, G - gender, U - indistinct characters or distribution, R - retained in our reference collection.

Order	Family	Subfamily/Genus/Species	Life Stage	Density	Notes
Phylum: Annelida					
Class: Clitellata					
SubClass: Oligochaeta					
			adult	113.98	
Phylum: Arthropoda					
Class: Arachnida					
SubClass: Acari					
			adult	38.71	I,D
	Arrenuridae	Arrenurus	adult	2.15	
	Lebertiidae	Lebertia	adult	156.99	
	Sperchonidae	Sperchon	adult	53.76	
Class: Insecta					
SubClass: Pterygota					
Coleoptera	Elmidae	Narpus concolor	larvae	4.30	
Coleoptera	Elmidae	Optioservus quadrimaculatus	adult	2.15	
Diptera	Chironomidae		pupae	2.15	
Diptera	Chironomidae	Orthocladiinae	larvae	144.09	
Diptera	Empididae		pupae	3.23	
Diptera	Empididae	Neoplasta	larvae	8.60	
Diptera	Simuliidae		pupae	6.45	D
Diptera	Simuliidae	Simuliinae Simuliini Simulium	pupae	2.15	
Diptera	Tipulidae		larvae	10.75	I,D
Diptera	Tipulidae	Dicranota	larvae	6.45	
Diptera	Tipulidae	Hexatoma	larvae	8.60	
Ephemeroptera	Baetidae		larvae	4.30	
Ephemeroptera	Baetidae	Baetis	larvae	4.30	
Plecoptera			larvae	8.60	I,D
Plecoptera			larvae	2.15	
Trichoptera	Hydropsychidae		larvae	4.30	I,D
Trichoptera	Hydropsychidae	Hydropsychinae Hydropsyche	larvae	4.30	
Trichoptera	Limnephilidae		larvae	2.15	I
Phylum: Mollusca					
Class: Bivalvia					
SubClass: Heterodonta					
Veneroida	Pisidiidae	Pisidiinae Pisidium	adult	30.11	
Total:	OTU Taxa: 24	Genera: 12	Families: 13	627.96	

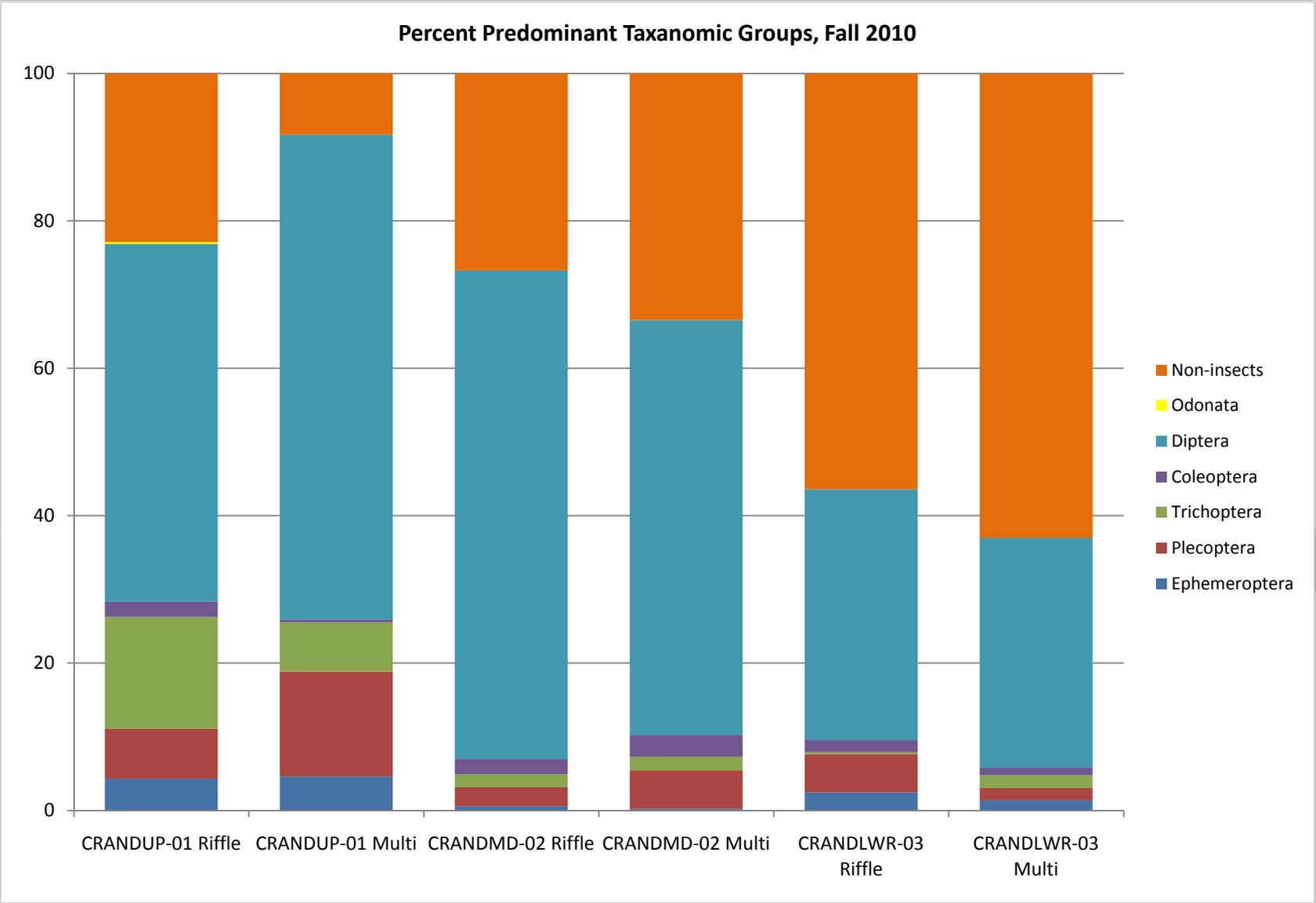
Taxonomic list and densities of aquatic invertebrates identified and retained from a sample collected September 24, 2010 at station CRANDLWR-03, Crandall Creek, Lower, Emery county, Utah. The sample was collected from targeted riffle habitat using a Kick Net. The total area sampled was 0.740 square meters. The percentage of the sample that was identified and retained was 100% of the collected sample. A total of 365 individuals were removed, identified and retained. The sample identification number is 146222. OTU=operational taxonomic unit. Notes - identification to genus or species was not supported because: I - immature organisms, D- damaged organisms, M - poor slide mount, G - gender, U - indistinct characters or distribution, R - retained in our reference collection.

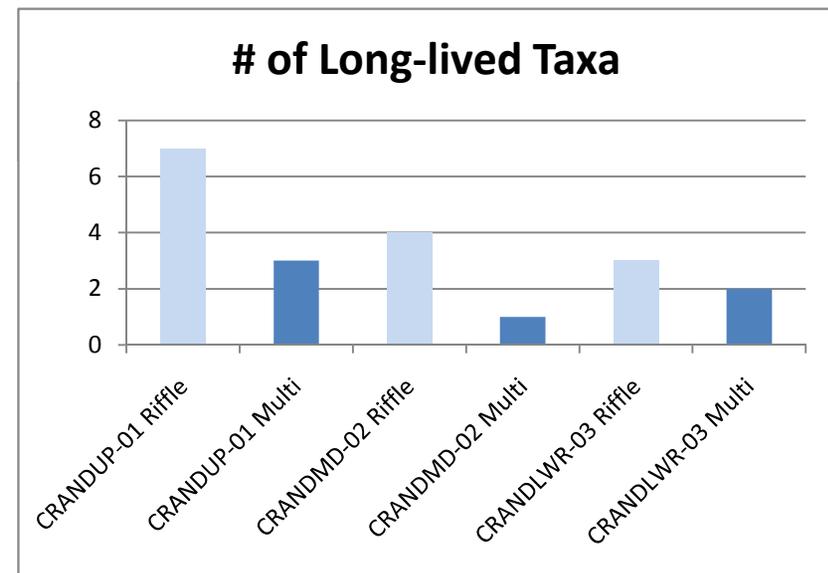
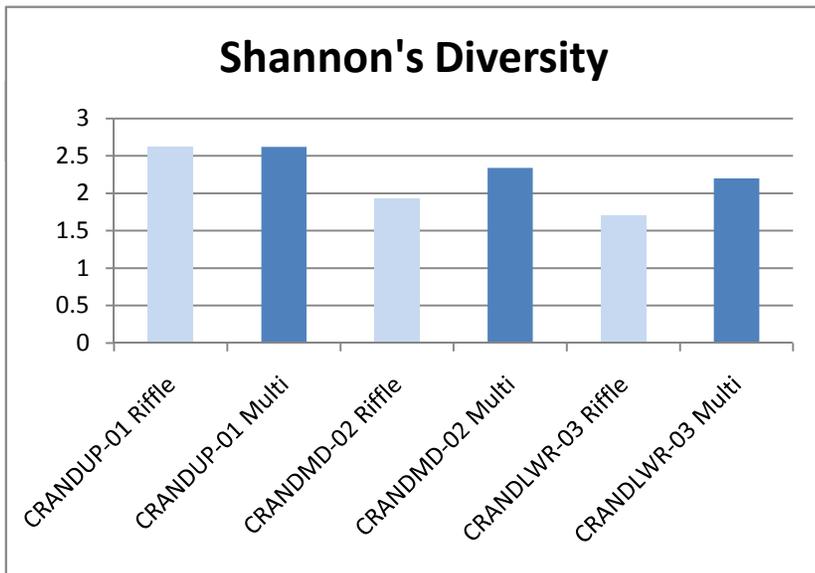
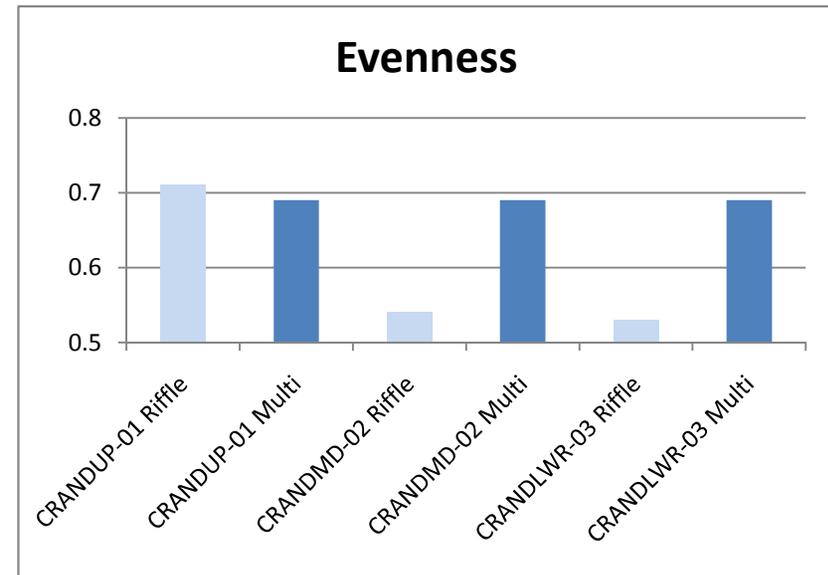
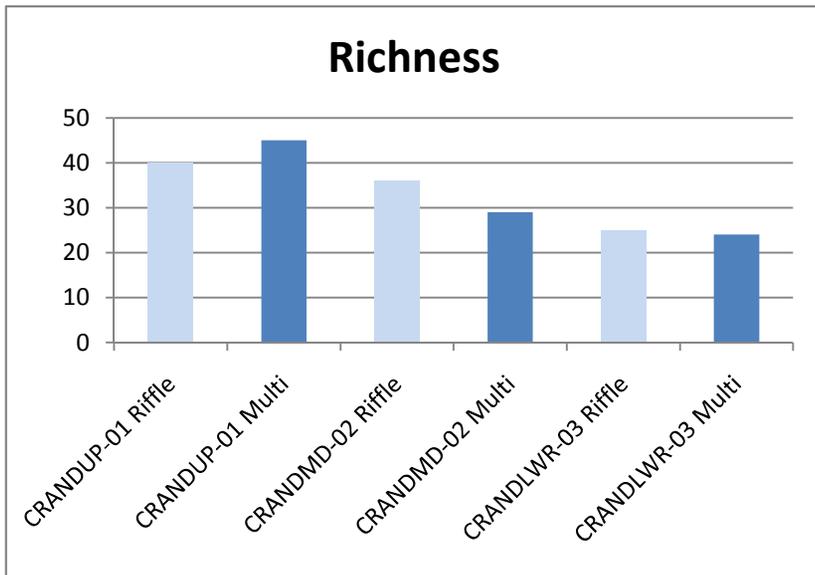
Order	Family	Subfamily/Genus/Species	Life Stage	Density	Notes
Phylum: Arthropoda					
Class: Arachnida		SubClass: Acari			
	Trombidiformes		adult	1.35	U
	Trombidiformes	Arrenuridae Arrenurus	adult	2.70	
	Trombidiformes	Lebertiidae Lebertia	adult	60.81	
	Trombidiformes	Sperchonidae Sperchon	adult	208.11	
	Trombidiformes	Sperchonidae Sperchonopsis	adult	2.70	
Class: Insecta		SubClass: Pterygota			
	Coleoptera	Elmidae Narpus concolor	larvae	1.35	
	Coleoptera	Elmidae Optioservus	larvae	2.70	
	Coleoptera	Elmidae Optioservus quadrimaculatus	adult	4.05	
	Diptera	Ceratopogonidae	larvae	2.70	D
	Diptera	Ceratopogonidae Ceratopogoninae Sphaeromiini Probezia	larvae	1.35	
	Diptera	Chironomidae	pupae	2.70	
	Diptera	Chironomidae Orthocladiinae	larvae	145.95	
	Diptera	Empididae Neoplasta	larvae	4.05	
	Diptera	Simuliidae Simuliinae Simuliini Simulium	larvae	5.41	
	Diptera	Stratiomyidae	larvae	1.35	I
	Diptera	Stratiomyidae Caloparyphus	larvae	1.35	
	Diptera	Stratiomyidae Euparyphus	larvae	1.35	
	Diptera	Tipulidae Dicranota	larvae	1.35	
	Ephemeroptera	Baetidae Baetis	larvae	12.16	
	Plecoptera	Capniidae Capniinae	larvae	1.35	I
	Plecoptera	Chloroperlidae Chloroperlinae	larvae	1.35	I,D
	Plecoptera	Chloroperlidae Sweltsa	larvae	1.35	
	Plecoptera	Perlodidae	larvae	20.27	I,D
	Plecoptera	Perlodidae Isoperlinae Isoperla	larvae	1.35	
	Trichoptera	Hydropsychidae	larvae	1.35	I
<hr/>					
Total:	OTU Taxa: 25	Genera: 16	Families: 16	493.24	

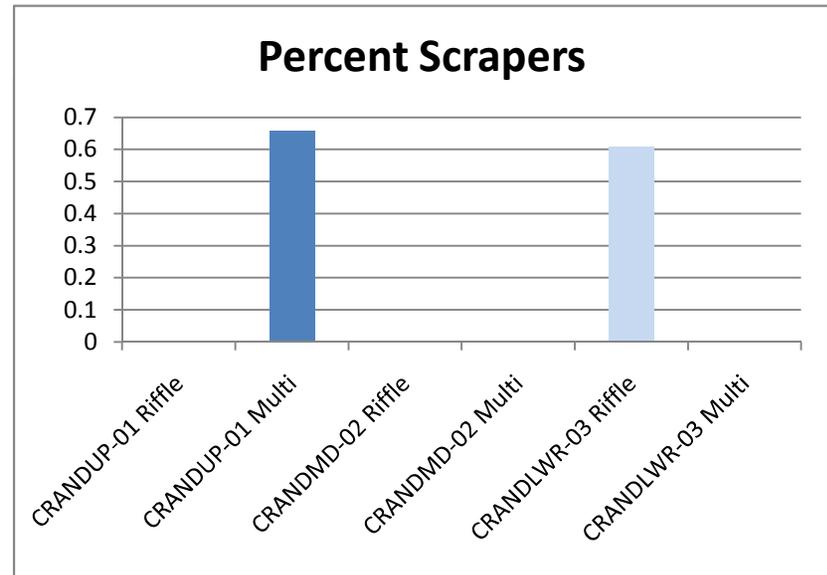
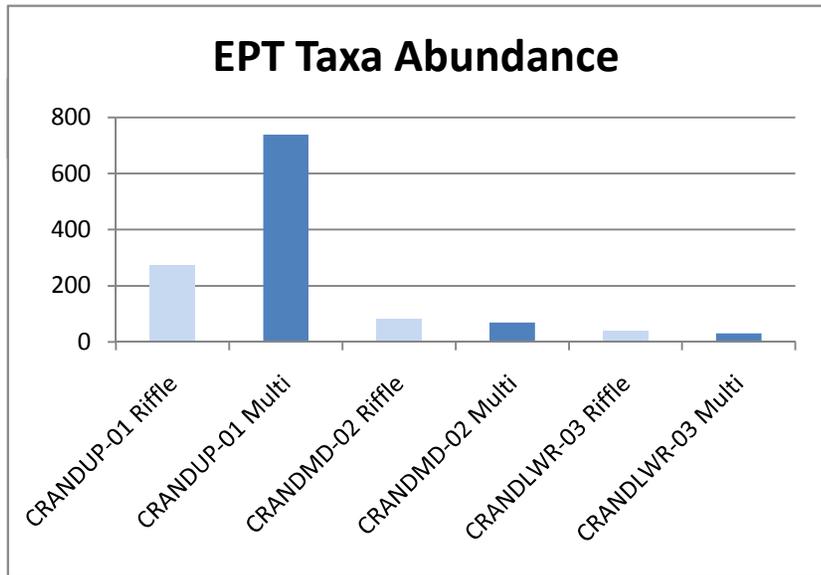
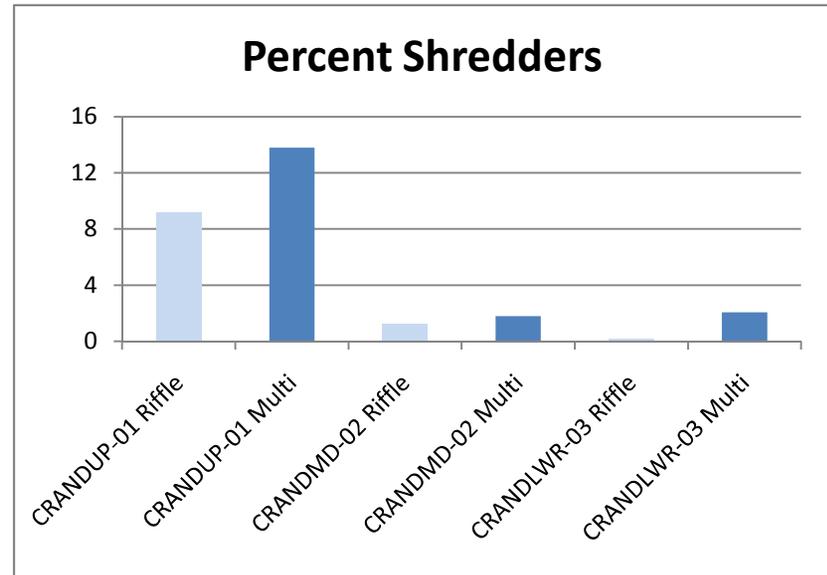
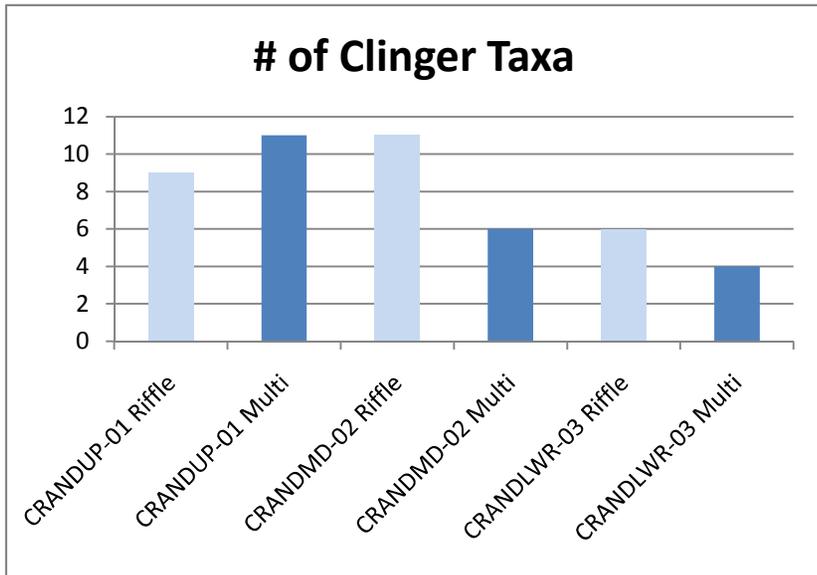
APPENDIX 2
MACROINVERTEBRATE METRICS

Notes:

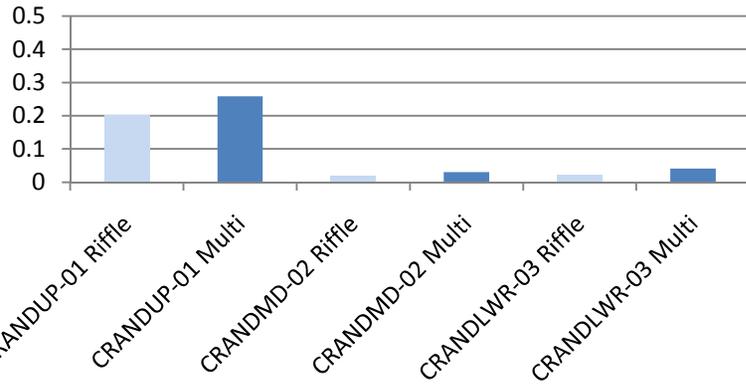
1. Most metrics were calculated by the National Aquatic Monitoring Center's BugLab and included in their July 21, 2011 report on the September 24, 2010 Crandall Creek samples. Remaining metrics were calculated by JBR Environmental Consultants using data contained in the BugLab's report.
2. Samples designated on the graphs as 1, 2, and 3 represent sample sites CRANDUP-01, CRANDMD-02, and CRANDLWR-03, respectively. Multi refers to samples collected using the reach-wide, multi-habitat method. Riffle refers to samples collected using the target riffle habitat method.
3. Graphs shown with blue bars represent metrics for which a decrease would be expected to occur with a decline in stream health. Graphs shown with green bars represent metrics for which an increase would be expected to occur with a decline in stream health.



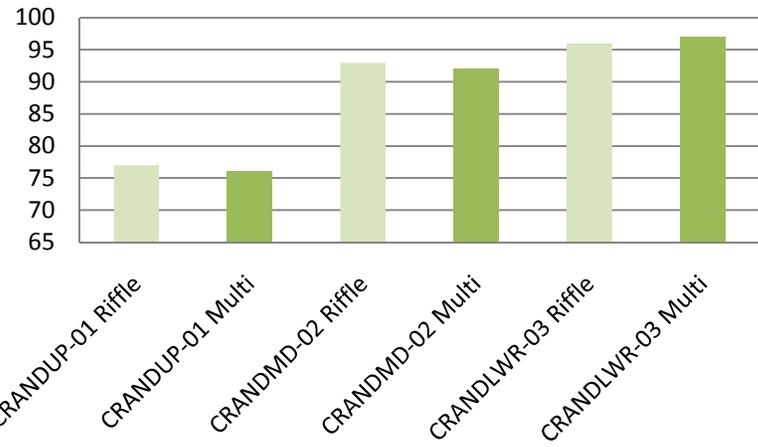




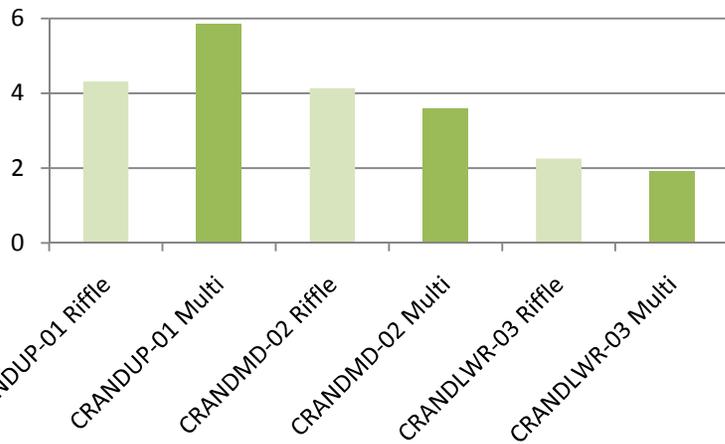
Specialist Feeders:Generalist Feeders



CTQd



HBI



Percent EPT

