GENWAL™
RESOURCES, INC.

P.O. Box 910, East Carbon, Utah 84520 794 North "C" Canyon Rd, East Carbon, Utah 84520
Telephone (435) 888-4000 Fax (435) 888-4002

Utah Division of Oil, Gas & Mining
Utah Coal Program
1594 West North Temple, Suite 1210
P.O. Box 145801
Salt Lake City, UT 84114-5801

March 11, 2020

Attn: Steve Christensen
Permit Supervisor

Re: Genwal Resources, Inc. C/015/032
C20-001 Annual Report

Dear Mr. Christensen,

Please find attached all the information needed to complete the Annual Report for 2019.

If you have any questions or problems with this change, please feel free to call me directly at 435-888-4026.

____
Karin Madsen
Environmental Permitting Engineer
UtahAmerican Energy, Inc.

APPLICATION FOR PERMIT PROCESSING

Permit Change ☐	New Permit ☐	Renewal ☐	Transfer ☐	Exploration ☐	Bond Release ☐	Permit Number: ACT/015/032
Title of Proposal: C20-001 2019 Annual Report						Mine: Crandall Canyon Mine
						Permittee: Genwal Resources, Inc.

Description, include reason for application and timing required to implement

Instructions: *If you answer yes to any of the first 8 questions (gray), submit the application to the Salt Lake Office. Otherwise, you may submit it to your reclamation*

☐ Yes	☐ No	1. Change in the size of the Permit Area? _____ acres Disturbed Area? _____ acres ☐ increase ☐ decrease.
☐ Yes	☐ No	2. Is the application submitted as a result of a Division Order? DO #
☐ Yes	☐ No	3. Does application include operations outside a previously identified Cumulative Hydrologic Impact Area?
☐ Yes	☐ No	4. Does application include operations in hydrologic basins other than as currently approved?
☐ Yes	☐ No	5. Does application result from cancellation, reduction or increase of insurance or reclamation bond?
☐ Yes	☐ No	6. Does the application require or include public notice/publication?
☐ Yes	☐ No	7. Does the application require or include ownership, control, right-of-entry, or compliance information?
☐ Yes	☐ No	8. Is proposed activity within 100 feet of a public road or cemetery or 300 feet of an occupied dwelling?
☐ Yes	☐ No	9. Is the application submitted as a result of a Violation?
☐ Yes	☐ No	10. Is the application submitted as a result of other laws or regulations or policies? Explain: Annual Report
☐ Yes	☐ No	11. Does the application affect the surface landowner or change the post mining land use?
☐ Yes	☐ No	12. Does the application require or include underground design or mine sequence and timing? (Modification of R2P2?)
☐ Yes	☐ No	13. Does the application require or include collection and reporting of any baseline information?
☐ Yes	☐ No	14. Could the application have any effect on wildlife or vegetation outside the current disturbed area?
☐ Yes	☐ No	15. Does application require or include soil removal, storage or placement?
☐ Yes	☐ No	16. Does the application require or include vegetation monitoring, removal or revegetation activities?
☐ Yes	☐ No	17. Does the application require or include construction, modification, or removal of surface facilities?
☐ Yes	☐ No	18. Does the application require or include water monitoring, sediment or drainage control measures?
☐ Yes	☐ No	19. Does the application require or include certified designs, maps, or calculations?
☐ Yes	☐ No	20. Does the application require or include subsidence control or monitoring?
☐ Yes	☐ No	21. Have reclamation costs for bonding been provided for?
☐ Yes	☐ No	22. Does application involve a perennial stream, a stream buffer zone or discharges to a stream?
☐ Yes	☐ No	23. Does the application affect permits issued by other agencies or permits issued to other entities?

X Attach 1 complete digital copy of the application and maps.

I hereby certify that I am a responsible official of the applicant and that the information contained in this application is true and correct to the best of my information and belief in all respects with the laws of Utah in reference to commitments, undertakings, and obligations, herein.

[signature] Karin Madsen - Environmental Permitting Eng.- 3-11-2020
Signed - Name - Position - Date

Subscribed and sworn to before me this 11 day of March, 20 20.

[signature] Notary Public

My Commission Expires: 1/9, 20 23
Attest: STATE OF Utah
COUNTY OF Carbon

STACY M HEADLEY
NOTARY PUBLIC
STATE OF UTAH
COMMISSION # 703969
COMM. EXP. 01/09/2023

Received by Oil, Gas & Mining

ASSIGNED TRACKING NUMBER

Application for Permit Processing
Detailed Schedule of Changes to the MRP

C20-001 2019 Annual Report

Permit Number: ACT/015/032

Mine: Crandall Canyon Mine

Permittee: Genwal Resources, Inc.

Provide a detailed listing of all changes to the mining and reclamation plan which will be required as a result of this proposed permit application. Individually list all maps and drawings which are to be added, replaced, or removed from the plan. Include changes of the table of contents, section of the plan, pages, or other information as needed to specifically locate, identify and revise the existing mining and reclamation plan. **Include page, section and drawing numbers as part of the description.**

			DESCRIPTION OF MAP, TEXT, OR MATERIALS TO BE CHANGED
☐ ADD	☐ REPLACE	☐ REMOVE	2019 Annual Report
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	

Any other specific or special instructions required for insertion of this proposal into the Mining and Reclamation Plan?

2019 ANNUAL REPORT

Submit the completed document and any additional information identified to the Division by March 31, 2020.

GENERAL INFORMATION

Company Name	Genwal Resources Inc.	Mine Name	Crandall Canyon Mine
Permit Number	C/015/0032	Permit Expiration Date	5-13-23
Operator Name	Genwal Resources	Phone Number	+1 (435) 888-4000
Mailing Address	PO Box 910	Email	kmadsen@coalsource.com
City	East Carbon		
State	UT	Zip Code	84520

		DOGM File Location or Annual Report Location
Excess Spoil Piles	☐ Required ☒ Not Required	
Refuse Piles	☐ Required ☐ Not Required	
Impoundments	☒ Required ☐ Not Required	Sediment pond annual certifications are included.
Other:		

OPERATOR COMMENTS

REVIEWER COMMENTS ☐ Met Requirements ☐ Did Not Meet Requirements

COMMITMENTS AND CONDITIONS

The Permittee is responsible for ensuring annual technical commitments in the Mining and Reclamation Plan and conditions accepted with the permit are completed throughout the year. The Division has identified these commitments below and has provided space for you to report what you have done during the past year for each commitment. If additional written response is required, it should be filed as an attachment to this report.

Title: MACROINVERTEBRATE SAMPLING

Objective: To monitor macroinvertebrate populations in Crandall Creek
Frequency: Spring and Fall beginning in 2009
Status: Annually
Reports: Submit surveys in annual report
Citation: Chapter 3, page 3-17

OPERATOR COMMENTS

Macro-invertibrate study completed by EIS for the Spring and Fall of 2019. Reports included.

REVIEWER COMMENTS ☐ Met Requirements ☐ Did Not Meet Requirements

Title: SUBSIDENCE MONITORING

Objective: To determine subsidence effects from mining. Please provide a map that shows the locations of the monitoring points to compare variations due to mining.
Frequency: Annually
Status: Ongoing
Reports: Submit surveyed monitoring data and map to Division annually
Citation: Chapter 5, Section 5.25.14, page 5-25

OPERATOR COMMENTS

Subsidence monitoring completed by Ware Surveying. Report included.

REVIEWER COMMENTS ☐ Met Requirements ☐ Did Not Meet Requirements

Title: BURMA POND INFORMATION/SAMPLING

Objective: Provide report of accumulated depth of sludge in the Burma Evaporation Pond. Grab samples to obtained every five years or when 7.5" of solid waste has been deposited. Grab Samples to be analyzed for all RCRA metals.
Frequency: Annually or at five year intervals. (First report was submitted with the 2016 annual report.)
Status: Ongoing
Reports: Include in Annual Report
Citation: Appendix 7-66, page 7

OPERATOR COMMENTS

Sampling was completed by Mt Nebo in 2016. Will sample Burma again in 2021.

REVIEWER COMMENTS ☐ Met Requirements ☐ Did Not Meet Requirements

FUTURE COMMITMENTS AND CONDITIONS

The following commitments are not required for the current annual report year, but will be required by the permittee in the future as indicated by the "status" field. These commitments are included for information only, and do not currently require action. If you feel that the commitment is no longer relevant or needs to be revised, please contact the Division.

Title: RECLAMATION OF CULVERT

Objective: To reclaim part of the culvert section of the stream which provided habitat to the cutthroat trout population. And enhancement of the stream below the mine discharge point due to the impact on the stream habitat and aquatic wildlife that occurred because of the iron-laden water discharge.
Frequency: Once during reclamation.
Status: To be done during reclamation.
Reports: Submitted to the Division upon project completion.
Citation: Chapter 3, page 3-16

Title: RAPTOR SURVEYS

Objective: To monitor raptor activity and nesting within and adjacent to the permit area.
Frequency: Every three years, or annually if a.) UDWR recommends it, b.) it will not unduly harass raptors, or c.) it if is prudent to insure raptor safety and/or habitat. Raptor surveys are not required if the mine is not active AND no significant activity is taking place.
Status: Surveys required prior to installation of any discharge treatment facilities or prior to reclamation work.
Reports: Annual Report
Citation: Chapter 3, page 3-17

REPORTING OF OTHER TECHNICAL DATA

Please list other technical data or information that was not included in the form above, but is required under the approved plan, which must be periodically submitted to the Division.

Please list attachments:

REVIEWER COMMENTS ☐ Met Requirements ☐ Did Not Meet Requirements

MAPS

Copies of mine maps, current and up-to-date, are to be provided to the Division as an attachment to this report in accordance with the requirements of R645-301-525.240. The map copies shall be made in accordance with 30 CFR 75.1200 as required by MSHA. Mine maps are not considered confidential.

Map Name	Map Number	Included		Confidential	
		Yes	No	Yes	No
Annual Subsidence Map	Not Required	☐	☒	☐	☒
Mine Map	Included	☒	☐	☐	☒
		☐	☐	☐	☐
		☐	☐	☐	☐
		☐	☐	☐	☐

REVIEWER COMMENTS ☐ Met Requirements ☐ Did Not Meet Requirements

Crandall Canyon Mine Macroinvertebrate Study Fall 2019

March 2020

Prepared By:
EIS Environmental & Engineering Consulting
31 North Main Street * Helper, Utah 84526
Office – (435) 472-3814 * Toll free – (800) 641-2927 * Fax – (435) 472-8780
eisec@preciscom.net * www.EISenviro.com

Table of Contents

1.0 Introduction **1**

1.1 Background 1

2.0 Site locations and Description **2**

3.0 Methods **4**

3.1 Multi-Habitat Samples 4

3.2 Riffle Habitat Samples 5

3.3 Composite Sample Preparation 6

3.4 Sample Analysis 6

4.0 Results and Discussion **11**

4.1 Comparison of Targeted Riffle and Multi-habitat Samples 13

4.2 Spatial Variation in Macroinvertebrate Community 14

4.3 Temporal Variation in Macroinvertebrate Community 14

Conclusion **15**

References **16**

Authors **17**

Appendix A BugLab Report

Appendix B Macroinvertebrate Metrics Fall 2019 Data

Appendix C Macroinvertebrate Metrics Fall 2009-Fall 2019 Data

Appendix D Macroinvertebrate Metrics Fall 2009-Fall 2019 Averaged Data

Taxa Lists for Individual Samples

Appendix E Raw Data From USU Bug Lab

1.0 INTRODUCTION

EIS Environmental & Engineering Consulting (EIS) collected benthic macroinvertebrate samples from Crandall Creek on August 22, 2019. The creek is located near Huntington, Utah. From 2009 to 2012, the creek was sampled by JBR Environmental Consultants, Inc. (JBR). Samples were collected from three different reaches of Crandall Creek. These three reaches were located directly upstream of the Crandall Canyon mine (CRANDUP-01), in the middle reach (CRANDMD-02) which is immediately downstream of the mine's discharge location, and a lower reach (CRANDLWR-03) located at the end of the creek before the confluence of Crandall Creek and Huntington Creek. Each reach was 150 meters long.

UtahAmerican Energy, Inc. (UEI) hired EIS to sample Crandall Creek's benthic macroinvertebrates and evaluate the subsequent data to determine whether the mine's discharge is affecting the creeks aquatic community and to what degree. EIS was provided with the data collected by JBR since September 2009 for use in discussing the trends and comparisons by The National Aquatic Monitoring Center (BugLab). Starting with the September 2011 dataset, the BugLab began reporting the richness-based metrics off of standardized results. This generally results in a lesser value for these metrics when compared to data prior to this change in calculation methodology. Therefore there were some discrepancies within the data provided by the BugLab and what JBR had reported prior to 2011 due to the lab switching to a standardized fixed count which allows for better comparison between samples. The attached tables, charts, and graphs (Appendices A-C) were all computed with the revised historical data (personal communication with BugLab July 26th, 2013).

As stated in previous JBR reports, there were some changes to the sampling methodology and these changes were implemented in 2010. EIS also followed the new methodology that was addressed in JBR's June 2010 report (JBR 2010). This report is intended to continue to meet the Utah Division of Oil, Gas, and Mining (DOGM) for the biannual sampling and reporting.

1.1 Background

The Crandall Canyon Mine began discharging ground water in 1995 and continued until the mine was closed in 2007. The discharged water flowed into Crandall Creek with little or no treatment. The discharge was monitored for pollutants and limits were established by the Utah Division of Water Quality (UDWQ) and permitted through the Utah Pollution Discharge Elimination System. Without actively pumping out water from the mine after the closure, water began flowing from beneath the portal seals. The water contained higher concentrations of iron than permitted and flowed into the creek. The mine began iron treatments in 2010 and has reduced the concentration of iron in the discharged water to the limit set by UDWQ.

In 2009, DOGM required the mine to contract a qualified biologist to sample macroinvertebrates in Crandall Creek twice yearly (Spring and Fall) to monitor water quality and provide reports documenting the survey results. The first seven surveys were completed by JBR (JBR 2012). They included surveys from the Fall of 2009 until the Fall of 2012. EIS has since completed two surveys a year (Spring and Fall) starting in the Spring of 2013. This report provides the results of the Fall survey of 2019. The samples were collected August 22, 2019. The samples were then shipped to the BugLab in Logan, Utah for processing, as per UDWQ requirements.

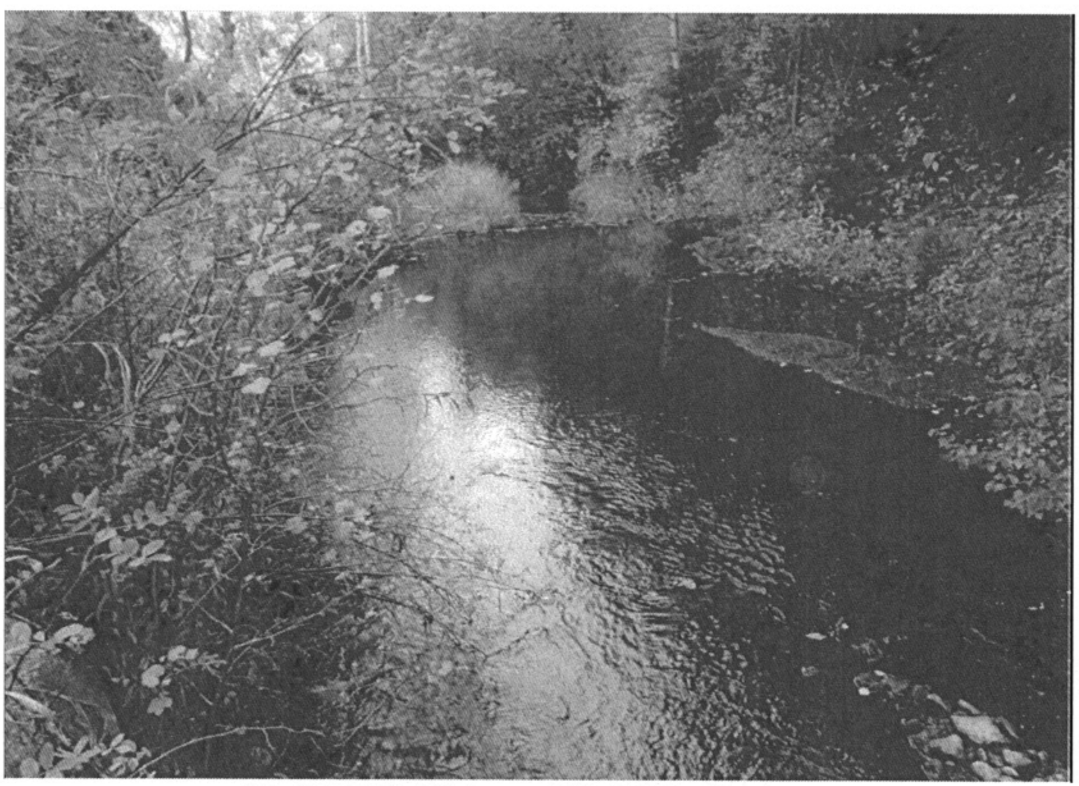
2.0 SITE LOCATIONS AND DESCRIPTION

The 3 reaches sampled are the same as previous surveys (JBR 2012). The downstream transect for the CRANDUP-01 reach is approximately 6 feet (2 meters) upstream from the flow measurement flume west of the mine site and extends approximately 500 feet (150 meters) upstream. Crandall Creek in this reach is narrow with dense riparian vegetation at the stream banks. The width of the creek in this reach is generally less than 3 feet (1 meter), except for various riffle-pools and beaver ponds. Substrate within this reach ranges from gravel to cobble. This reach has more riffle habitat than the other reaches and appeared to have a faster flow velocity. There were areas above the beaver dams with finer sediment substrate.

The upstream transect in the reach CRANDMD-02 is located approximately 16 feet (5 meters) downstream from the mine's discharge culvert and extends approximately 500 feet (150 meters) downstream. This reach has more open area between vegetation than the other reaches and the creek is wider than the CRANDUP-01 reach. There are several beaver dams and areas above the dams with fine sediment deposits. Substrate was generally fine to gravel sized rock.

The downstream transect in the CRANDLWR-03 reach is approximately 6 feet (2 meters) upstream from where the mine access road crosses the creek and extends approximately 500 feet (150 meters) upstream. Substrate was generally bedrock or fine sediment and gravel. The vegetation is denser along the stream banks than CRANDMD-02 and less dense than the stream bank in CRANDUP-01. The creek in the CRANDLWR-03 reach has a lower gradient and stream velocity than the other reaches.

CRANDUP-01 August 22, 2019 – Upstream



CRANDMD-02 August 22, 2019 – Upstream

CRANDLWR-03 August 22, 2019 - Upstream

3.0 METHODS

The methods used for the survey are described by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program Field Operations Manual (EMAP 2006) and were modified as in previous sampling (JBR 2010). Representative samples were collected from multiple kick net samples throughout each reach to create a composite sample of each survey type, multi-habitat and riffle, for each reach.

One person would collect samples using a kick net, and another person would time the collection. A 1-foot wide D-frame kick net with 500-micron mesh was used to collect one sample from each location (transect or riffle). The net was placed securely on the stream bottom to close gaps along the bottom of the net and to prevent macroinvertebrates from passing under the net. While the net was held firmly with the opening facing upstream, a quadrat was visually estimated to be 1 net width wide and 1 net width long, approximately 1 foot squared, upstream of the positioned net. The quadrat was checked for larger organisms, such as snails. Loose rocks that were golf ball-sized or larger within the quadrat or at least half way within the quadrat were picked up and scrubbed to dislodge organisms so they were washed into the net. After scrubbing, the rocks were placed outside of the quadrat. Starting with the upstream end of the quadrat, the upper 1.5 to 2 inches (4 to 5 centimeters) of the substrate within the quadrat was kicked using feet and toes to dislodge organisms for 30 seconds. After the 30 seconds of kicking, the net was pulled out of the water and partially immersed in the stream to remove fine sediments and collect organisms at the bottom of the net. The net was then inverted and emptied into the appropriate composite sample bucket, i.e., multi-habitat or riffle. The net was then inspected to find clinging organisms. The organisms were removed by using a squirt bottle and forceps and deposited in the bucket. Large objects in the bucket were inspected and organisms were removed from the object before discarding the object. The bucket was then sealed with a lid. The net was rinsed before collecting the next sample.

Riffle samples were collected in conjunction with the multi-habitat samples to minimize the number of passes within the stream. The samples from each type were carefully placed in the correct sample container, multi-habitat or riffle, to avoid contaminating the samples.

3.1 Multi-Habitat Samples

Each reach was divided by 11 transects located approximately 50 feet (15 meters) apart to distribute samples throughout habitat types. If the flagging marking the transect line from previous studies remained, that transect was used for sampling. When flagging was not present, the transect was located by using a measuring tape to measure 50 feet from the adjacent transect. The EMAP methods describe collecting samples at each of the 11 cross-section transects, A through K, at assigned locations left, center, and right across the creek. In order to provide comparative data to previous macroinvertebrate studies conducted by the Manti-La Sal National Forest and by previous surveys (JBR 2012), only 5 samples were collected and each sample location was not chosen randomly or systematically. Instead, the samples were collected at every other transect starting with transect B at the site that most suitable for the placement of the kick net as done in previous surveys. Sample locations were located as close to each transect as possible. Samples from the 5 locations were combined into a single composite sample bucket labeled "multi-habitat." At each sampling transect the dominant substrate and habitat type was recorded on the sample collection form. Samples were collected from downstream transects to upstream transects.

3.2 Riffle Habitat Samples

Eight riffle samples were collected from each of the 3 reaches using the methods form the EMAP manual. Before sampling, the total number and area of riffle microhabitat was estimated for each reach. If the reach contained more than 1 riffle microhabitat but less than 8, the 8 sample locations were spread throughout the reach as much as possible with more than 1 sample collected from a single riffle unit. If the reach contained more than 8 riffle units, 1 or more units were skipped at random to spread the sampling locations throughout the reach. Samples were collected from downstream to upstream units in the order they were encountered. Since Crandall Creek is narrow, the riffle sampling locations within a unit were not chosen randomly, but were chosen by the most suitable location for kick net placement as done in previous surveys (JBR 2012). The 8 samples were combined into a single composite sample bucket labeled "riffle."

3.3 Composite Sample Preparation

The contents from each composite bucket for each reach (multi-habitat or riffle) were poured through a 300-micron sieve into a bucket. The composite bucket was inspected for organisms and rinsed using a squirt bottle filled with stream water. The composite bucket contents were again poured through the sieve. Large objects such as sticks, rocks, or plant material were inspected and any clinging organisms were dislodged using the squirt bottle over the sieve. The squirt bottle was used to rinse the material in the sieve to one side and then into a sample jar using as little water as possible. Remaining organisms on the sieve were then transferred to the jar using a squirt bottle filled with 95% ethanol to rinse the sieve into the jar or by using forceps. Additional jars were used if the contents filled over two-thirds of the sample jar, as instructed by the BugLab. If multiple jars were used, the jar number and total number of jars in the sample were recorded on the jar and the sample collection form. The sample jar was filled with 95% ethanol so that the final ethanol concentration was between 75 and 90%. A waterproof label with stream ID, date, sample type, reach ID, and number of kick net samples collected was placed in the jar. The lid was placed on the jar and the jar was slowly tipped to a horizontal position and gently rotated to mix the contents with the ethanol solution. The jar was then sealed with tape and labeled with sample information taped to the outside of the jar. This procedure was repeated for each Multi-habitat and Riffle composite sample for each of the 3 reaches for a total of 6 samples from the creek.

3.4 Sample Analysis

The samples were shipped to the BugLab for identification of taxa within the samples. The BugLab generally uses subsampling to collect approximately 600 individual organisms and sort them by major taxonomic orders. Collection and sorting is completed using a 7x or greater dissecting scope. Once the subsample has been sorted by major taxonomic orders, a "big/rare" search is completed using the entire sample to identify taxa that may have been missed in the subsample. Qualified taxonomists then identify the collected organisms to the lowest taxa possible (family, genus, and species if possible) without fixed slides. The laboratory results were prepared by the BugLab (Armstrong, Miller 2018) and are used in Appendices A-D and in the Taxa Lists. This data includes standardized and raw data used for the tables and graphs. In 2011, the began using a newly revised output format, which includes richness-based metrics standardized to Operational Taxonomic Units (OTU) and a fixed count of 300 for more accurate comparison between samples. The fixed count or standard rarefaction count was changed to 400 in 2017, and back to 300 for the Spring 2018 data. Fixed count for this sample data was 400. The data from previous surveys has been obtained from the BugLab in a standardized format in order to compare metrics between surveys since previous studies did not include standardized data. The BugLab provided summaries and calculated many different indices and metrics. The findings are discussed further in the results; more detail and reference for how the calculations were made are also in Appendix A along with the corresponding tables.

Additional comparisons from the BugLab's data have been calculated for comparison with previous studies (JBR 2012). These different comparisons may be used to relate the species composition to the water quality of the creek. Graphs of these comparisons are included in Appendices B, C, and D. Some of these graphs include a breakdown of predominant taxonomic groups, graphs of the different diversity and biotic indices, abundances, total taxa richness, EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa richness, individual taxa richness, Tolerant and Intolerant taxa richness, percent richness, Hilsenhoff Biotic Index, different functional feeding group richnesses, and abundances. As mentioned in previous reports, no one metrics can be used to explain the potential influences the mine may have on the creek. Multiple metrics were used as in previous years to compare data from site to site and year to year. Descriptions of why these values are beneficial are below and have been taken directly out of the Bug Labs report (Judson and Miller 2013)

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 according to Standard Taxonomic Effort (see NAMC website), 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 Judson and Miller 2010).

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 single taxa becomes more dominant.

Clinger taxa- The number of clinger taxa have been found by Karr and Chu (1998, as referenced in Judson and Miller 2010) 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 Judson and Miller 2010).

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 Judson and Miller 2010). 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 Judson and Miller 2010) 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 2-8 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, EIS used the BugLab's data set to calculate several other metrics that JBR also indicated being potentially useful for macroinvertebrate analysis. 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.

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 *Rhyacophia* 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).

The Ratio of Specialist Feeders to Generalist Feeders shows the ratio of stress tolerant species, generalists, to less tolerant specialized feeders. The Ratio of Ephemeroptera, Plecoptera, and Trichoptera orders (EPT) to Chironomidae shows the more tolerant Chironomidae species abundance to the less tolerant EPT species. The Percent *Baetis*, Hydropsychidae, and Orthocladinae and the Ratio of *Baetis* to all Ephemeroptera are used to show the relative abundance of the stress tolerant *Baetis* mayflies. The Percent Heptageniidae, Chloroperlidae, and *Rhacophila* show these taxa percentages to other species as they are more sensitive to trace minerals.

4.0 RESULTS & DISCUSSION

The results prepared by the BugLab (Armstrong, Miller 2019) are incorporated into the tables of the following appendices A-E. As with assessment, multiple metrics and datasets should be relied upon to make a finding of whether any impact or nonimpact has occurred between the mine's groundwater discharge and Crandall Creek. Numerous metrics should be used in evaluating what may be happening in the creek. In this study, the natural variability of any of these metrics is not known due to limited number of samples sites, absence of replicates, and partial historical baseline information. Therefore, it is difficult to determine whether there is an impact between sites from analyzing only one metric. This section and its associated appendices will review these metrics within this season's individual sample, spatially among each reach and habitat type, and any temporal changes since 2009. In the appendices, a blue colored graph is used when an increase in values indicate a more desirable habitat. A green colored graph is used when the lower the number, or a decline, specifies a healthier steam. Data is compared from the reference reach (CRANDUP-01) to the other two reaches. Additionally, a comparison between the middle reach directly below the mine (CRANDMD-02) and the lowest reach (CRANDLWR-03) can be made to assess the spatial limit and overall condition. The metrics evaluated include the various measurement types recommended by EPA (Barbour et al 1999). They include tolerance indices (HBI, CTQd), diversity (Shannon's), community composition (% EPT), and functional feeding groups (Percent Scraper/Shredders).

Appendix A of the report includes a summarization of the raw and standardized data for the samples collected in September 2018. The following Appendices (B-D) graph the previously mentioned matrices to show a visual comparison. Appendix B begins with a graph showing the distribution of the dominate orders within each reach and sample type (Figure 1b) as well as the numerical values (Table 1b). It is followed by numerous graphs that represent the Fall 2018 sample set and show a visual comparison of potential differences between the habitat types as well as spatial variation (Figures 2b-24b). The graphs of Appendix C include all the data gathered since Fall 2009 for temporal comparison among all the samples. They are differentiated by the multi-habitat and target riffle samples for further comparison (Figures 1c-23c). The graphs in Appendix D also contain data since the Fall of 2009; however the values from both the multi-habitats and riffle habitats sample were combined to obtain an average value assess any potential overall trends throughout the years (Figures 24c-42c).

A total of 6 operational taxonomic units (OTU) were identified in the Fall 2018 sample set. There were 31 families and 42 genera present. Most of the insect orders most commonly found in macroinvertebrate communities were found in each reach, orders Diptera, Ephemeroptera, and Trichoptera. The common order Veneroida was not found in the middle reach riffle habitat sample. Non-insect invertebrates were also identified in all samples, but was most plentiful in the lower riffle habitat.

The dominate family in the upper reach was Chironomidae, and in lower reach was Baetidae, while the middle riffle habitat was Baetidae and middle multi habitat was Pisidiidae. In the middle reach riffle habitat the order of non-insects made up 90 percent of the sample, while in the middle multi habitat the order Ephemeroptera was the most common at 32 percent. In the upper reach, Diptera outnumbered all orders at 63 percent in the multi-habitat and 70 percent in the riffle habitat. In the lower reach the dominate macroinvertebrate order in both habitats was Ephemeroptera (Figure 1b and Table 1b). A dominance of any single order or taxon greater than 50 percent suggests environmental stress, which exhibited in all reaches except for the middle riffle habitat.

The orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) are commonly considered sensitive to pollution and fluctuation in their abundance can be an indicator of stream health (Karr & Chu 1999). In the upper reach, the orders EPT made up less than 30 percent (Figure 9b). In the middle reach directly below the mine, EPT percentages were at less than 10 percent of abundance in multi-habitat and but over 50 percent in the riffle samples. In the lower reach, EPT was between much higher at over 80 percent in the two habitat types (Figure 9b).

Although Crandall Creek as a whole continues to provide less than ideal habitat for a macroinvertebrate community, all of the samples contained at least one distinct taxon that is considered to be intolerant to pollution. The middle reach had the highest number of intolerant taxa in both habitat types with 3 distinct taxa in the multi-habitat and 8 in the riffle habitat. The upper reach had 1distinct intolerant taxa in the multi-habitat and 3 in the riffle habitat. The lower reach had 3 distinct intolerant taxa in the multi-habitat and 1 in the riffle (Figure 14b). The upper multi-habitat had 16 unique taxa in both habitats, based off the standardized data. The middle reach multi-habitat had 19 distinct taxa and the riffle sample had 21. The richness in the lower reach multi-habitat was 17 and was 15 in the riffle habitat (Figure 2b). The number of distinct taxa appears to be fluctuating within all reaches and both habitat types year to year; more data is likely required to find a real discernible trend. These same results were found when evaluating many of the other metrics.

As with previous years, the differences in overall habitat among the three reaches likely influence the result of this study. The upper most reach and the lowest reach have similar substrate size compositions, which was largely bedrock overlaid with larger rocks. The lowest reach had a much more cemented substrate. The lack of interstitial spaces results in poorer habitat conditions for macroinvertebrates (Mize and Deacon 2002). These two reaches were narrower than the middle reach as well as more of a vegetative overstory. It is also important to note the changes in the stream morphology of Crandall Creek when comparing data from previous years. The colonization of beaver and subsequent dams are continuing to change the creek, mainly in the middle reach. The catastrophic impacts to Huntington Creek from major flooding resulting from a major wildfire in 2012 in the upper drainage areas should also be considered. The high flows have directly impacted macroinvertebrate populations in Huntington Creek, which are sources for movement into Crandall Creek. In 2018, conditions could have been impacted by severe drought conditions and a controlled burn that led to a wildfire on the South side of Crandall Canyon. Therefore, the spatial comparisons discussed further should consider that there may be an indication of degradation that may be due to these physical attributes, to some extent. In 2018-2019 the snow pack was 200% greater than normal in Crandall Canyon; the subsequent flows scoured the creek bed and resulted in fewer macroinvertebrates.

4.1 Comparison of Targeted Riffle and Multi-Habitat Samples

As with the prior years' analyses (JBR 2010; 2011a; 2011b) and the data provided by the BugLab for 2012 (no report of their findings was provided to EIS), all the indices and metrics have been calculated and graphed in the appendices. In 2010, JBR recommended that the targeted riffle samples be collected based upon the observation that habitat types varied. It is also in Utah's DWQ monitoring program that all samples be collected using only a targeted riffle method (DWQ 2006). EIS continued to collect both riffle and multi-habitat sample to allow for a more comprehensive data interpretation for the future.

The graphs in Appendix B display the differences between the two habitats within this dataset (June 2018). Appendix C graphs each habitat type since Fall of 2009. The richness in the riffle-habitat upper reach had a slightly lower value than the multi. In the middle reach the multi-habitat was slightly higher than that of the riffle-habitat. The lowest reach showed richness values of less than 20 (Figure 2c). The pattern found in the Shannon's Diversity values show that the middle reach riffle habitat is the highest at 2.351177(Figure 3b). The evenness in the upper multi and riffle habitats were 0.72 and 0.53, respectively. In the middle reach the multi-habitat was 0.39 and the riffle was 0.77, and in the lower reach the evenness was 0.39 and 0.52, respectively (Figure 4b).

The abundance in the upper reach was 704 in the multi-habitat and 468 in the riffle. In the middle reach multi-habitat it was 798 and 1695 in the riffle and in the lower reach it was 1461 and 1071, respectively (Figure 5b). The HBI, which a lower value indicates less pollution, was 3.74 in the upper reach multi-habitat and 5.136 in the riffle. It was 0.466 and 3.48 in the middle reach, respectively. In the lowest reach, the HBI was 3.84 in the multi-habitat and 4.22 in the riffle (Figure 6b). The middle reach tends to show less pollution than the upper reach that may have experienced significant impacts from the wildfire that occurred in June 2018. The CTQd, which a lower the value indicates higher quality unpolluted water as well, was 97 in the upper reach multi-habitat and 94 in the riffle. In the middle reach these values were 102 in the multi-habitat and 74 in the riffle habitat. In the lower reach the multi-habitat was 80 and the riffle was at 87 (Figure 7b). Appendices A and B have more specific detail on all the values found and metrics graphed for visual comparison. While addressing any trends or spatial differences, both the riffle and multi-habitat results were averaged and this value was then used (Appendix D).

4.2 Spatial Variation in Macroinvertebrate Community

As mentioned in earlier parts of this report, there were 3 different reaches sampled in Crandall Creek. CRANDUP-01 (upper) is upstream of any potential impact from the mine's discharge, CRANDMD-02 (middle) is immediately below the discharge, and CRNDLWR-03 (lower) is further downstream. Averages between the two habitat types (multi and riffle) were used in the following results to gauge whether any spatial variation is present.

The average richness, or number of distinct taxa, in the upper reach and lower reaches was found to be 16, and in the middle reach the average was 16.6875 (Figure 1d). The average evenness value was 0.624 in the upper reach, 0.428 in the middle reach and 0.453 in the lower reach (Figure 2d). The average Shannon's Diversity in the upper reach was 1.73, in the middle reach it was 1.21, and in the lower reach it was 1.25 (Figure 3d). The average abundance of individuals was 396 in the upper reach, 755 in the middle reach and 871 in the lower reach (Figure 4d). The HBI, which the lower the value indicates less pollution in the stream ranging from 0-10, was found to be 4.43 in the upper reach, 5.28 in the middle reach and 4.03 in the lower reach (Figure 5d). The CTQd, which a lower value also indicates higher quality unpolluted water, ranges from 2 to 108. The CTQd was found as 95.5 in the upper reach, 95.12 in the middle reach and 83.5 in the lower reach (Figure 6d). Overall, it appears that the quality of water in the middle reach has improved compared to the upper reach, which should not be affected by the mine discharge. During the field work of gathering the macroinvertebrates, Mel Coonrod noted that the health and condition of the upper reach was possibly greatly impacted by the Trail Mountain Fire that occurred in June 2018.

4.3 Temporal Variation in Macroinvertebrate Community

EIS was able to obtain the standardized data from the BugLab dating back to 2009 to assess any temporal variations. The graphs in Appendices C and D provide a visual means to examine the temporal variation within the creek. In all reaches, the data fluctuates from year to year. A trendline was added to the averaged overall data in Appendix D to assist in observing any overall trends.

The upper reach, which should not be impacted by the mine's discharge, has great variability within each metric. For example the average richness in Fall 2009 was found to be 24, and since it has gone up and down year to year with no real pattern. This sample set produced a richness value of 16. The evenness values were around 0.74 in 2009, dropped down to .65 in Fall 2010, increased to around 0.77 from 2012-2013, and dropped to 0.62 this sample. Similar variability is present within all the metrics.

The middle reach also has this variation occurring throughout the years. The averaged richness value in the Fall 2009 and Spring 2010 sample set was found to be 22. It fluctuated to a low of 13.5 in the Spring of 2013, then back up to 21.5 in the Fall of 2013. In 2017 it was found to be at 16.25 distinct taxa. This sample it went up to 16.6875. The evenness has also fluctuated throughout the years. In the earlier samples, it was found to be around .60 to .73. It has dropped down to a 0.34 in Spring of 2012, went back up to 0.78 in the Fall of 2013. It has dropped to 0.42877 this sample set. Throughout the years, the reach directly below the mine has shown signs of decline. The Fall 2018 samples, however, show richness and evenness to be leveling off and almost equal to that of the 2017 samples.

The lowest reach has shown signs of variable conditions. As with the other two reaches, the numbers have also fluctuated throughout years. In Fall of 2009 the richness was found to be 18, it dropped to 11 in Spring of 2011, went up to 21.5 in the Fall of 2013. There were 16 distinct taxa found this sample, which is an improvement from 2017. The evenness in 2009 was 0.74, has gone up and down and is currently at 0.4535. Refer to Appendix D for further results.

5.0 CONCLUSION

The samples for the 2018 Spring Macroinvertebrate Study were collected on September 21st , 2018 from each of the three reaches of Crandall Creek. The upper reach is located upstream from the mine and is should not be influenced from ground water discharge from the mine, therefore it is considered as a reference of how conditions should be. The middle and lower reaches are below the mine water discharge. The objective of the survey was to collect macroinvertebrate samples as indicators of water quality in Crandall Creek. The samples collected were sorted and identified to the lowest taxa possible by the BugLab. Abundances of taxa and community composition relationships from the samples are provided to assess the water quality of Crandall Creek.

The survey results show variability among all the sampled reaches and generally show reduced habitat quality and less than optimal conditions in all sampled locations. It does appear that the upper reach has decreased in quality standards over the past year, and that the lower reach has improved since 2009. In the middle reach, the overall quality seems to be lower than the other two reaches, based on most indicators. The data for all three reaches fluctuate from year to year and season to season. It is important to note that the substrate and habitat differs greatly between reaches and should be taken into consideration in the results. The changes in stream morphology due to increased beaver dams in the middle reach and upper reach should also be considered, along with heavy precipitation in 2017, and drought conditions in 2018. The controlled burn turned wildfire, Trail Mountain Fire, that occurred in the early summer of 2018 could have possibly impacted the health and abundance of macroinvertebrates of the upper reach of Crandall Creek.

In 2018-2019 winter resulted in a 200% increase in snow pack resulting in heavier than normal runoff. The creek channel was scoured. During the spring the macroinvertebrates declined and there was still evidence during the fall surveying period.

There appears to be no correlation in macroinvertebrates and water quality (mine discharge) as indicated in appendix B,C, and D from 2009 through 2018. The actual laboratory findings for the fall sample period are included in Appendix E.

The results are not included in appendix A-D, but are stand along for the August 22, 2019 survey.

REFERENCES

Barbour, M.T. et al., 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish. EPA 841-B-99-002*, US Environmental Protection Agency, Office of Water, Washington, DC, http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm.

Division of Water Quality (DWQ). 2006. Utah Division of Water Quality Monitoring Manual.

Environmental Protection Agency. 2006. Environmental Monitoring and Assessment Program-Surface Waters Western Pilot Study: Field Operation Manual for Wadeable Streams. EPA/620/R-06/003. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

Karr, J.R. & E. W. Chu. 1999. *Restoring life in running waters: better biological monitoring*, Island Press.

Kiffney, P. M. & W. H. Clements. 1994. Effects of heavy metals on a macroinvertebrate assemblage from a Rocky Mountain stream in experimental microcosms. Journal of the North American Benthological Society. *13*(4) pp. 511-523

JBR Environmental Consultants, Inc. (JBR). 2010. Crandall Canyon Mine Macroinvertebrate Study September 2009. Prepared for Genwal Resources, Inc. January 27, 2010.

JBR Environmental Consultants, Inc. (JBR). 2011a. Crandall Canyon Mine Macroinvertebrate Study June 2010. Prepared for Genwal Resources, Inc. January 17, 2011.

JBR Environmental Consultants, Inc. (JBR). 2011b. Crandall Canyon Mine Macroinvertebrate Study September 2011. Prepared for Genwal Resources, Inc. August 22, 2011.

JBR Environmental Consultants, Inc. (JBR). 2012. Crandall Canyon Mine Macroinvertebrate Study September 2011. Prepared for Genwal Resources, Inc. Oct 2012.

Miller, S. and S. Judson. 2011. Macroinvertebrate Sample Processing and Reporting Methodologies of the National Aquatic Monitoring Center. National Aquatic Monitoring Center <www.usu.edu/buglab/> Accessed 31 Jul 2013.

Miller, S. and T. Armstrong. 2018. Aquatic Invertebrate Report for Samples Collected by EIS. Report prepared October 2018. U.S. Bureau of Land Management, National Aquatic Monitoring Center, Department of Watershed Sciences, Utah State University.

Mize, S.V., and Deacon, J.R. 2002. Relations of benthic macroinvertebrates to concentration of trace elements in water, streambed sediment, and transplanted bryophytes and stream habitat conditions in nonmining and mining areas of the Upper Colorado River Basin, Colorado, 1995-98. U.S. Geological Survey Water-Resources Investigation.

Report prepared and reviewed by:

Melvin Coonrod, CEO/Owner EIS

Mel has post graduate work in Ecology, an M.S. in Silviculture, and a B.S. in Zoology from Utah State University. He is the owner/CEO of EIS Environmental & Engineering Consulting.

Molly Hocanson, Biological and Natural Resource Specialist

Molly has a B.S. in Natural Resource Management from Utah State University. She has a number of years working for EIS Environmental & Engineering Consulting as a Biological Technician and the U.S. Forest Service.

Davie Stokes

Davie has a BS degree in Biology from Utah State University and has worked for EIS for a number of years before joining the NRCS.

APPENDIX A

BUGLAB REPORT

Report prepared for:

Customer contact:	Mel Coonrod
Customer:	EIS Environmental and Engineering Consulting
Customer Address :	31 N Main Street
Customer City, State, Zip:	Helper UT 84526
Customer Phone:	435-472-3814
Customer Email:	eisec@preciscom.net

Report prepared by:
Trip Armstrong: 760.709.1210 / trip.armstrong@usu.edu
Scott Miller: 435.797.2612 / scott.miller@usu.edu

BLM/USU National Aquatic Monitoring Center (NAMC)
Department of Watershed Sciences (WATS) - Utah State University
5210 Old Main Hill Logan, UT 84322-5210
http://www.usu.edu/buglab/

October 2018

Table 1a. Sampling site locations

Station	Location	Latitude	Longitude	Elevation (meters)
CRANDUP-01	Crandall Creek, Lower, Emery County, UT	39.459722	-111.16778	2363
CRANDMD-02	Crandall Creek, Middle, Emery County, UT	39.460278	-111.16528	2384
CRANDLWR-03	Crandall Creek, Upstream, Emery County, UT	39.463611	-111.14639	2389

Table 2a. Field comments and laboratory processing information

Sample ID	Station	Collection Date	Habitat Sampled	Collection Method	Area sampled (m^2)	% of Sample Processed	Number of individuals identified
167923	CRANDUP-01	9/21/2018	Reachwide	Kick net	0.46	100	324
167924	CRANDUP-01	9/21/2018	Targeted Riffle	Kick net	0.74	100	346
167925	CRANDMD-02	9/21/2018	Reachwide	Kick net	0.46	100	367
167926	CRANDMD-02	9/21/2018	Targeted Riffle	Kick net	0.74	50	626
167927	CRANDLWR-03	9/21/2018	Reachwide	Kick net	0.46	100	672
167928	CRANDLWR-03	9/21/2018	Targeted Riffle	Kick net	0.74	96.88	763

Results

The following data is based off of the estimated number of individuals per square meter for quantitative samples and the estimated number per sample for qualitative samples.

Table 3a. Total Abundance, EPT Abundance, Dominant Family, Percent Contribution

Sample ID	Collection Date	Station	Total Abundance	EPT Abundance	Dominant Family	% Contribution dominant family
167923	9/21/2018	CRANDUP-01 Multi	704	12	Chironomidae	23.30
167924	9/21/2018	CRANDUP-01 Riffle	468	111	Chironomidae	56.84
167925	9/21/2018	CRANDMD-02 Multi	798	12	Psidiidae	32.21
167926	9/21/2018	CRANDMD-02 Riffle	1695	909	Baetidae	27.85
167927	9/21/2018	CRANDLWR-03 Multi	1461	616	Baetidae	37.65
167928	9/21/2018	CRANDLWR-03 Riffle	1071	891	Baetidae	72.18
Mean			1032.8	425.2		41.67

Diversity Indices

Table 4a. Richness totals for taxa, genera, families, and EPT based off of raw qualitative data

Sample ID	Collection Date	Station	Total taxa richness	Total genera richness	Total family richness	EPT taxa richness
167923	9/21/2018	CRANDUP-01 Multi	22	13	13	4
167924	9/21/2018	CRANDUP-01 Riffle	22	14	17	7
167925	9/21/2018	CRANDMD-02 Multi	25	16	18	6
167926	9/21/2018	CRANDMD-02 Riffle	42	28	26	19
167927	9/21/2018	CRANDLWR-03 Multi	28	20	20	12
167928	9/21/2018	CRANDLWR-03 Riffle	28	16	17	14
Mean			27.8	17.8	18.5	10.3333

Table 5a. Diversity indices based on standardized OTU

Sample ID	Collection Date	Station	Total taxa richness	EPT taxa richness	Shannon diversity index	Evenness
167923	9/21/2018	CRANDUP-01 Multi	16	3	1.9965	0.720085
167924	9/21/2018	CRANDUP-01 Riffle	16	5	1.465716	0.528645
167925	9/21/2018	CRANDMD-02 Multi	19	5	1.139908	0.387139
167926	9/21/2018	CRANDMD-02 Riffle	21	11	2.351177	0.772265
167927	9/21/2018	CRANDLWR-03 Multi	17	7	1.096469	0.387005
167928	9/21/2018	CRANDLWR-03 Riffle	15	5	1.408285	0.520036
Mean			17.33333	6	1.576342	0.552529

Table 6a. Genera richness by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemeroptera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
167923	9/21/2018	CRANDUP-01 Multi	1	10	1	0	0	0	1	2	1	0	1
167924	9/21/2018	CRANDUP-01 Riffle	1	9	2	0	0	0	2	3	1	0	1
167925	9/21/2018	CRANDMD-02 Multi	3	8	3	0	0	0	2	1	1	0	1
167926	9/21/2018	CRANDMD-02 Riffle	1	15	6	0	0	0	5	8	0	0	0
167927	9/21/2018	CRANDLWR-03 Multi	0	10	3	0	0	0	3	6	1	0	1
167928	9/21/2018	CRANDLWR-03 Riffle	0	10	3	0	0	0	4	7	1	0	1
Mean			1.0	10.3	3.0	0.0	0.0	0.0	2.8	4.5	0.8	0.0	0.8

Table 7a. Total Abundance by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemeroptera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
167923	9/21/2018	CRANDUP-01 Multi	4	446	11	0	0	0	2	13	11	0	13
167924	9/21/2018	CRANDUP-01 Riffle	3	326	96	0	0	0	5	9	4	0	3
167925	9/21/2018	CRANDMD-02 Multi	7	48	15	0	0	0	9	2	30	0	559
167926	9/21/2018	CRANDMD-02 Riffle	5	485	536	0	0	0	205	168	0	0	0
167927	9/21/2018	CRANDLWR-03 Multi	0	59	1224	0	0	0	24	91	37	0	13
167928	9/21/2018	CRANDLWR-03 Riffle	0	165	781	0	0	0	15	95	8	0	4
Mean			3	255	444	0	0	0	43.5	63.1	15.1	0.0	98.6

Biotic Indices

Table 8a. Hilsenhoff Biotic Index and CTQd

Sample ID	Collection Date	Station	Hilsenhoff Biotic Index Index	Indication	USFS Community CTQd
167923	9/21/2018	CRANDUP-01 Multi	3.74	Potential slight organic pollution	97
167924	9/21/2018	CRANDUP-01 Riffle	5.136667	Some organic pollution	94
167925	9/21/2018	CRANDMD-02 Multi	0.466667	No apparent organic pollution	102
167926	9/21/2018	CRANDMD-02 Riffle	3.48	Potential slight organic pollution	74
167927	9/21/2018	CRANDLWR-03 Multi	3.843333	Potential slight organic pollution	80
167928	9/21/2018	CRANDLWR-03 Riffle	4.22	Some organic pollution	87
Mean			3.481111		89.00

Table 9a. Intolerant taxa richness and abundance values and percentages.

			Intolerant Taxa				Tolerant Taxa			
Sample ID	Collection Date	Station	Richness	Percent	Abundance	Percent	Richness	Percent	Abundance	Percent
167923	9/21/2018	CRANDUP-01 Multi	1	6	0	0	0	0	0	0
167924	9/21/2018	CRANDUP-01 Riffle	3	19	0	0	0	0	0	0
167925	9/21/2018	CRANDMD-02 Multi	3	16	0	0	1	5	0	0
167926	9/21/2018	CRANDMD-02 Riffle	8	38	0	0	1	5	0	0
167927	9/21/2018	CRANDLWR-03 Multi	3	18	0	0	0	0	0	0
167928	9/21/2018	CRANDLWR-03 Riffle	1	7	0	0	1	7	0	0
Mean			3.2	17	0.0	0	0.5	3	0.0	0

Functional Feeding Groups

Table 10a. Taxa richness by functional feeding groups

Sample ID	Collection Date	Station	Shredders		Scrapers		Collector-filterers		Collector-gatherers		Predators		Unknown	
			Richness	Percent	Richness	Percent	Richness	Percent	Richness	Percent	Richness	Percent	Richness	Percent
167923	9/21/2018	CRANDUP-01 Multi	0	0	0	0	1	6	1	6	8	50	6	38
167924	9/21/2018	CRANDUP-01 Riffle	0	0	1	6	2	13	2	13	8	50	3	19
167925	9/21/2018	CRANDMD-02 Multi	2	11	1	5	1	5	1	5	6	32	8	42
167926	9/21/2018	CRANDMD-02 Riffle	2	10	0	0	2	10	2	10	7	33	8	38
167927	9/21/2018	CRANDLWR-03 Multi	2	12	0	0	3	18	3	18	6	35	3	18
167928	9/21/2018	CRANDLWR-03 Riffle	3	20	0	0	3	20	3	20	3	20	3	20
Mean			1.5	8.6	0.3	1.9	2.0	11.9	2.0	11.9	6.3	36.7	5.2	29.0

Table 11a. Taxa abundance by functional feeding group

Sample ID	Collection Date	Station	Shredders		Scrapers		Collector-filterers		Collector-gatherers		Predators		Unknown	
			Abundance	Percent	Abundance	Percent	Abundance	Percent	Abundance	Percent	Abundance	Percent	Abundance	Percent
167923	9/21/2018	CRANDUP-01 Multi	4	1	0	0	6	2	95	29	218	67	1	0
167924	9/21/2018	CRANDUP-01 Riffle	1	0	1	0	8	2	365	78	89	19	4	1
167925	9/21/2018	CRANDMD-02 Multi	2	1	1	0	257	70	30	8	76	21	1	0
167926	9/21/2018	CRANDMD-02 Riffle	89	5	51	3	95	6	862	51	592	35	6	0
167927	9/21/2018	CRANDLWR-03 Multi	30	4	0	0	30	4	592	88	19	3	1	0
167928	9/21/2018	CRANDLWR-03 Riffle	53	5	0	0	116	11	846	79	56	5	0	0
Mean			29.8	2.8	8.8	0.6	85.3	15.7	465.0	55.6	175.0	25.0	2.2	0.3

Data summarization

Compositional changes in macroinvertebrate assemblages are most frequently used to quantify freshwater ecosystem responses to anthropogenic disturbances (Bonada et al. 2006). Common approaches range from the computation and evaluation of individual metrics characterizing the composition, richness, function or tolerance of invertebrate assemblages to complex multivariate analyses and statistical modelling that aims to predict assemblage composition in the absence of impairment (e.g., RIVPAVS or O/E) (V. H. Resh et al. 1993; Wright et al. 2000; Merritt et al. 2008). Regardless of the analytical approach, determinations of biological condition are generally achieved by comparing the deviation of macroinvertebrate metrics or assemblages composition at test sites (i.e., sampled sites) to that of reference or minimally impacted conditions. The NAMC's output for macroinvertebrate samples aims to support both (multi-) metric and multivariate approaches.

Related fields in Excel Output:

[Fixed Count]

The number of resampled organisms to a fixed count of 300 (unless otherwise requested). If the number of sub-sampled organisms ([Split Count]) was less than the fixed count, the fixed count will be less than the target of 300 and should approximate the [Split Count] but may be slightly lower due to taxa omitted during OTU standardization.

Richness metrics

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 according to Standard Taxonomic Effort (see Appendix 1 or NAMC website), 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.

Related fields in Excel Output:

[Richness]

The number of unique taxa at the lowest possible taxonomic resolution (typically genus or species).

[# of EPT Taxa]

The taxonomic richness for the insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT). These orders are commonly considered sensitive to pollution (Karr & Chu 1999). This is reported along with the accompanying density metric, [Abundance of EPT Taxa].

[Shannon's Diversity]

The Shannon-Wiener diversity function is a measure of community structure and heterogeneity defined by the relationship between the number of distinct taxa and their relative abundances. The Shannon's diversity index is noted to weight rare species slightly more heavily than the Simpson's diversity index (Krebs 1999). The calculation is made as follows:

-Σ([Relative Abundance]taxa*ln([Relative Abundance]taxa)) after Ludwig and Reynolds (1988, equation 8.9, page 92):

[Simpson's Diversity]

The Simpson's diversity index is a measure of community structure and heterogeneity defined by the relationship between the number of distinct taxa and their relative abundances. The Simpson's diversity index is noted to weight common species slightly more heavily than the Shannon's diversity index (Krebs 1999). The calculation is provided in the common form as follows:

1 - [Simpson's Diversity] = 1 - Σ([Relative Abundance]taxa)2

after Ludwig and Reynolds (1988, equation 8.6, page 91):

Modified to the complement of the Simpson's probability measure as shown in Krebs (1999, equation12.28, page 443).

[Evenness]

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. The evenness index used in this report was calculated as: [Shannon's Diversity]/ln([Richness]) following Ludwig and Reynolds (1988, equation 8.11, page 93).

Dominance metrics

Metrics used to characterize the absolute or proportional abundance of individual taxa within a sampled assemblage. An assemblage largely dominated (>50%) by a single taxon or several taxa from the same family suggests environmental stress.

Related fields in Excel Output:

[Dominant Family]

The taxonomic family with the highest abundance per sample. The name of this family is given to provide information about the life history and pollution tolerance of the dominant taxa.

[Abundance of Dominant Family]

The density of the most abundant family. This number should be compared to the total abundance for the sample to determine what percent of the total abundance is comprised by the dominant family. An assemblage dominated (e.g., >50%) by a single family suggests environmental stress; although the specific dominant family needs to be considered. For example, dominance by Chironomidae, Hydropsychidae, Baetidae, or Leptohyphidae frequently suggest impaired conditions, while other families within the orders Coleoptera, Ephemeroptera, Plecoptera or Trichoptera may suggest otherwise. Dominance of the macroinvertebrate assemblage by a few taxa can also be evaluated with the Evenness metric.

[Dominant Taxa]

The taxa (usually identified to genus) with the highest abundance in a sample. The name of this taxa is given to provide information about the life history and pollution tolerance of the dominant taxa.

[Abundance of Dominant Taxa]

The density of the numerically dominant taxon. This number should be compared to the total abundance for the sample to determine what percent of the total abundance is comprised by the dominant taxa. An assemblage largely dominated (e.g., >50%) by a single taxon suggests environmental stress. This can also be evaluated in conjunction with the Eveness metric.

Tolerance (Biotic) Indices

Taxa are assigned values based on their tolerance to a single or multiple pollutants (e.g., nutrients, temperature, fine sediment). Pollution tolerance scores are typically weighted by taxa relative abundance and summed among all observed taxa. In the United States the most commonly used biotic index is the Hilsenhoff Biotic Index developed for organic matter enrichment (Hilsenhoff 1987; 1988). The USFS and BLM throughout the western United States have also historically used the USFS Community Tolerance Quotient (Winget & Mangum 1979).

Related fields in Excel Output:

[Hilsenhoff Biotic Index]

The Hilsenhoff Biotic Index (HBI) was originally developed to quantify the tolerance of macroinvertebrate assemblages to organic pollution, but this index has been used to detect nutrient enrichment, fine sediment loading, low dissolved oxygen, and thermal impacts. Families are assigned an index value from 0 (taxa normally found only in unpolluted water) to 10 (taxa found only in severely polluted waters). following Hilsenhoff (1987; 1988) and a family level HBI is calculated using the below equation.Sampling locations with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 polluted. The HBI is calculated as:

$$\Sigma([Abundance]taxa*[Tolerance]taxa)/[Abundance]Total$$

following the equation presented in Hilsenhoff (1988)

[# of Intolerant Taxa]

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 our report, taxa with HBI values < 2 were considered 'intolerant', clean water taxa (Vinson unpublished). The provided value is the richness (count) of taxa with HBI values < 2.

[Abundance of Intolerant Taxa]

The abundance of taxa with HBI values < 2, which were considered to be 'intolerant', clean water taxa in this report (Vinson unpublished).

[# of Tolerant Taxa]

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 our report, taxa with HBI values > 8 were considered pollution 'tolerant' taxa (Vinson unpublished). The provided value is the richness (count) of taxa with HBI values > 8.

[Abundance of Tolerant Taxa]

The abundance of taxa with HBI values > 8, which were considered to be pollution 'tolerant' taxa in this report (Vinson unpublished).

[USFS Community Tolerance Quotient (d)]

Taxa are assigned a tolerant quotient (TQ) from 2 (taxa found only in high quality, unpolluted waters) to 108 (taxa only found in severely polluted waters) following Winget and Mangum (1979). A dominance weighted community tolerance quotient (CTQd) is calculated according to the equation below where values can range from 20 to 100, with lower values indicating better water quality.

$$\Sigma([Tolerance\ Quotient] * \log([Abundance]taxa))/\Sigma \log([Abundance]taxa)$$

Functional Feeding Groups and Traits

Aquatic macroinvertebrates can be categorized by mode of feeding, adaptations to local habitat conditions, time to complete a life cycle, and other life history traits. Such classification schemes attempt to understand how individuals interact with local environmental conditions, with specific emphasis on the functional role of macroinvertebrate assemblages within aquatic ecosystems.

One of the most population classification schemes is functional feeding groups (FFG), which classify individuals based on their morpho-behavioral adaptations for food acquisition (e.g., scraping, piercing, net building); recognizing that all macroinvertebrates exhibit some degree of omnivory. The richness and relative abundance of different FFGs indicate the dependency of observed macroinvertebrate assemblages on different food resources and thus the trophic basis for secondary production. For example, the ratio of scrapers to shredders indicates the degree to which the local macroinvertebrate assemblage depends on instream algal production versus inputs of terrestrial leaf litter.

Functional feeding group designations are derived from Merritt et al (2008). Taxa are not included that are highly variable in their food habits, are parasites, or their primary feeding mode is currently unknown.

Related fields in Excel Output:

Functional feeding group measures

[# of Shredder Taxa] & [Shredder Abundance]

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

[#of Scraper Taxa] & [Scraper Abundance]

Scrapers feed on periphyton (i.e., attached algae) and associated material. Scraper populations increase with increasing abundance of diatoms and can decrease as filamentous algae, mossesor 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.

[# of Collector-filterer Taxa] & [Collector-filterer Abundance]

Collector-filterers feed on suspended fine particulate organic matter and often construct fixed retreats or have morpho-behavioral adaptation for filtering particles. Collector-filterers are sensitive highly mobile substrate condition, the quantity of fine particulate organic matter and pollutants that adhere to organic matter.

[# of Collector-gatherer Taxa] & [Collector-gatherer Abundance]

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

[# of Predator Taxa] & [Predator Abundance]

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.

Life History Trait measures

[# of Clinger Taxa]

Clingers typically have behavioral (e.g., fixed retreat construction including rock ballasts, silk production) or morphological (e.g., modified gill structures, long curved claws, crochet hooks) adaptations for attachment to the tops of rocks or wood surfaces. Clingers have been found to respond negatively to fine sediment loading or abundant algal growth (Karr & Chu 1999). Clinger taxa were determined using information in Merritt et al. (2008).

[# of Long-lived Taxa]

Taxa that take two or more years to complete their life cycle are considered to be long-lived. Macroinvertebrates with such protracted life cycles are considered good bioindicators since their presence indicates the maintenance of certain water quality or habitat conditions; the number of long-lived taxa typically decreases in response to degraded water quality of physical conditions (Karr & Chu 1999). The classification of long-lived taxa was based on life cycles greater than two years following Merritt et al. (2008).

Taxa Richness and Abundance

For taxa groups that are indicators of water quality or that are commonly used in multimetric indices, richness and abundance within that taxa are given.

[# of ** Taxa]

The richness (count of unique taxa) within each specified group.

[Abundance of ** Taxa]

The abundance, density, or number of aquatic macroinvertebrates of the indicated group per unit area. 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. Abundance 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.

Literature Cited

Barbour, M.T. et al., 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish. EPA 841-B-99-002*, US Environmental Protection Agency, Office of Water, Washington, DC, http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm.

Bonada, N. et al., 2006. Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. *Annual review of entomology*.

Cuffney, T. F et al., 1993. *Methods for collecting benthic invertebrate samples as part of the National Water-Quality Assessment Program*, US Geological Survey.

Cuffney, T. F., Bilger, M.D. & A.M. Haigler. 2007. Ambiguous taxa: effects on the characterization and interpretation of invertebrate assemblages. *Journal of the North American Benthological Society*, 26(2), pp.286–307.

Hilsenhoff, W.L., 1987. An improved biotic index of organic stream pollution. *Great Lakes Entomologist*, 20(1), pp.31–40.

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

Karr, J.R. & E. W. Chu. 1999. *Restoring life in running waters: better biological monitoring*, Island Press.

Krebs, C.J., 1999. *Ecological methodology*, Benjamin/Cummings.

Ludwig, J.A. & J. F. Reynolds. 1988. *Statistical ecology: a primer on methods and computing*, Wiley-Interscience,http://books.google.com/books?hl=en&lr=&id=sNsRYBixkpcC&oi=fnd&pg=PA3&dq=ludwig+and+reynolds+1988.

Merritt, R.W., K. W. Cummins, & M. B. Berg. 2008. *An Introduction to the Aquatic Insects of North America* 4th ed., Kendall Hunt Publishing.

Moulton, S. et al., 2000. *Methods of analysis by the US Geological Survey National Water Quality Laboratory-processing, taxonomy, and quality control of benthic macroinvertebrate samples*, US Geological Survey.

Resh, V.H., J.K. Jackson, & D. M. Rosenberg. 1993. *Freshwater biomonitoring and benthic macroinvertebrates*, New York: Chapman and Hall.

Vinson, M.R. & C. P. Hawkins. 1996. Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams. *Journal of the North American Benthological Society*, 15(3), pp.392–399.

Winget, R.N. & F. A. Mangum. 1979. *Biotic condition index: integrated biological, physical, and chemical stream parameters for management*, US Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT.

Wright, J.F., D. W. Sutcliffe, & M. T. Furse. 2000. *Assessing the Biological Quality of Fresh Waters: RIVPACS and Other Techniques*, Freshwater Biological Assn.

APPENDIX B

MACROINVERTEBRATE METRICS FALL 2018

Figure 1b. Percent Predominant Taxonomic Groups Fall 2018 Samples

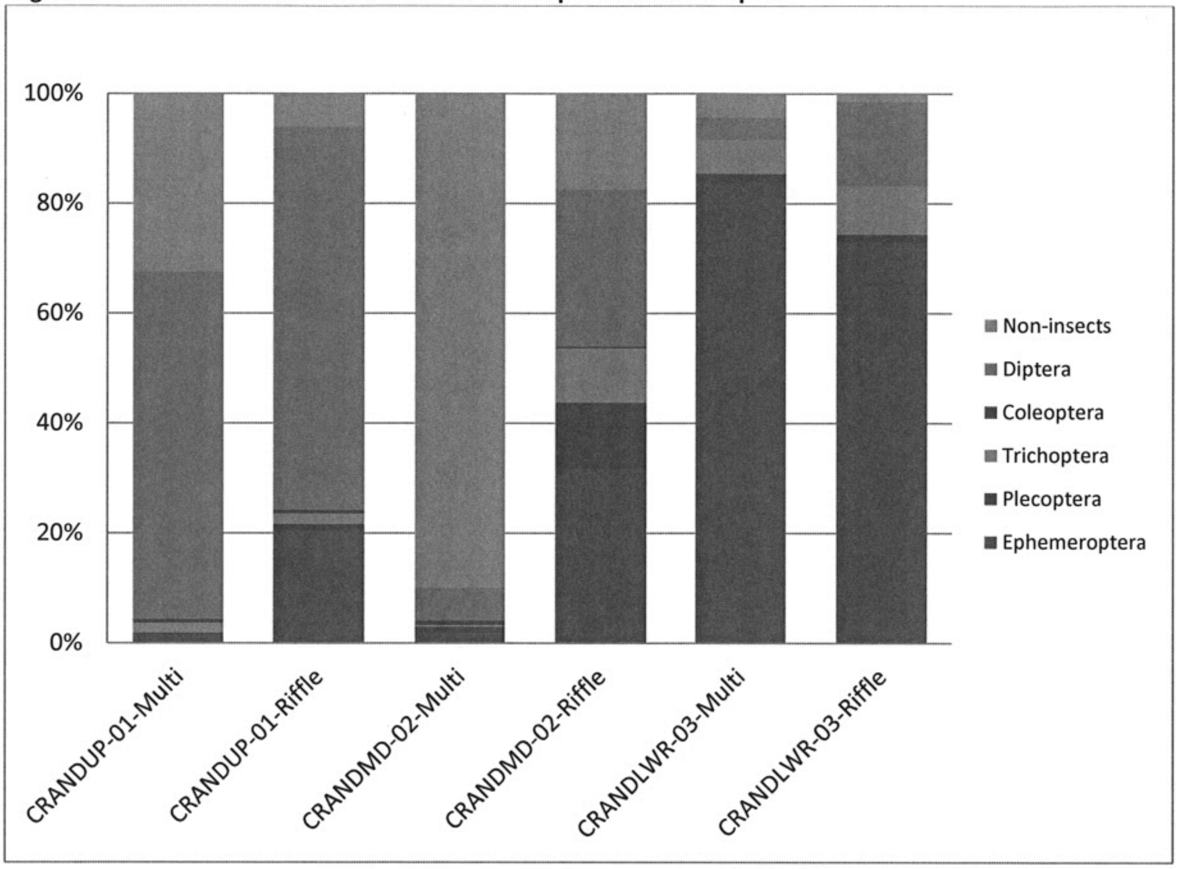


Table 1b. Percent Predominant Taxonomic Groups in the Fall 2018 Samples

	CRANDUP-01-Multi	CRANDUP-01-Riffle	CRANDMD-02-Multi	CRANDMD-02-Riffle	CRANDLWR-03-Multi	CRANDLWR-03-Riffle
Non-insects	32	6	90	17	4	1
Diptera	63	70	6	29	4	15
Coleoptera	0.6	0.6	0.8	0.3	0.0	0.0
Trichoptera	2	2	0	10	6	9
Plecoptera	0	1	1	12	2	1
Ephemeroptera	2	21	2	32	84	73

Figure 2b. Richness

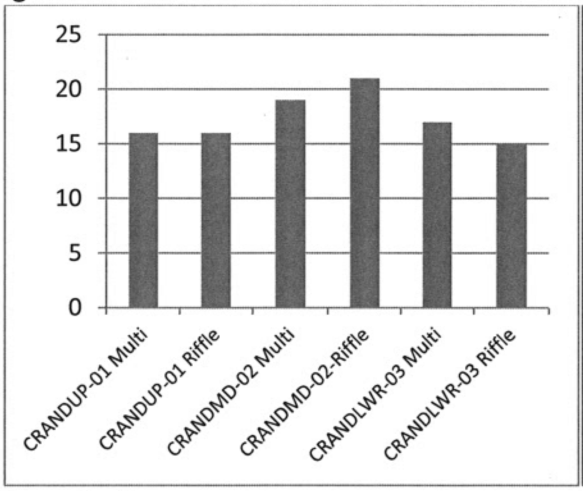


Figure 3b. Shannon's Diversity

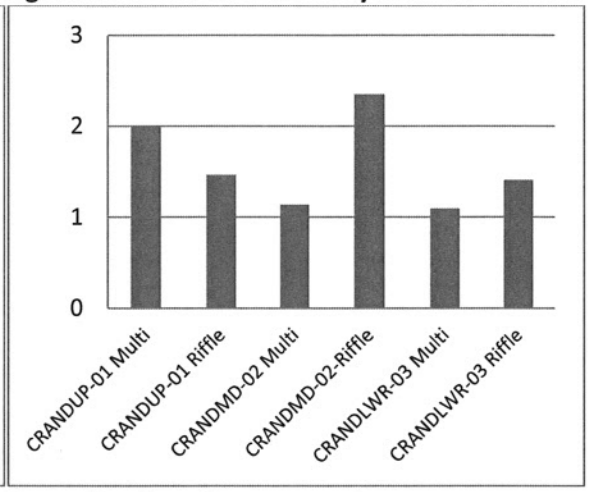


Figure 4b. Evenness

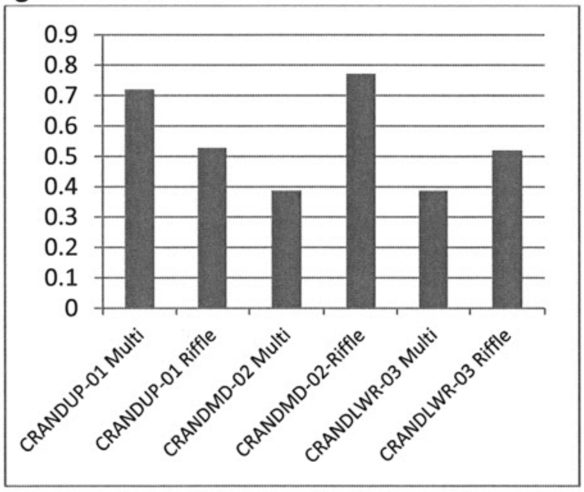


Figure 5b. Abundance

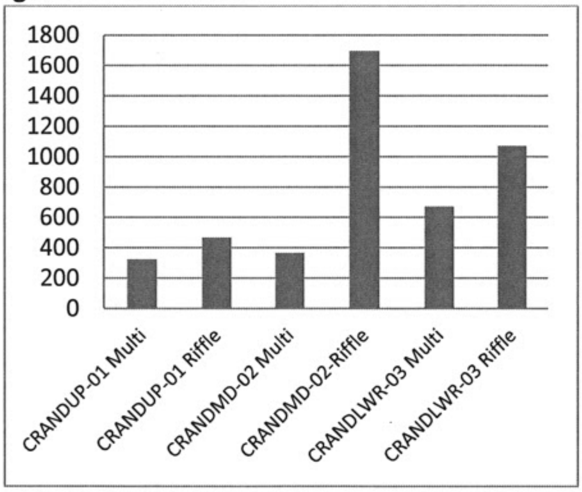


Figure 6b. HBI

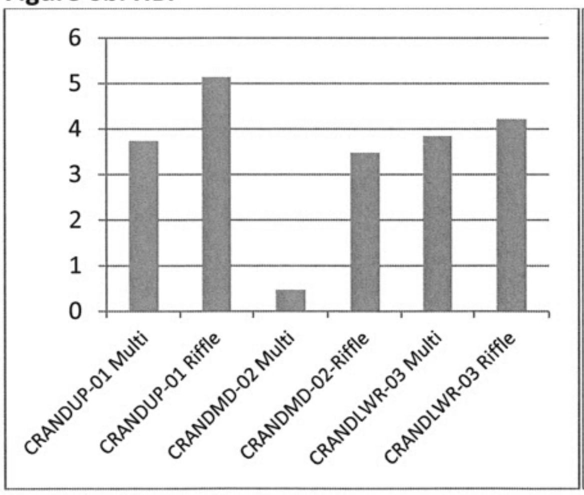
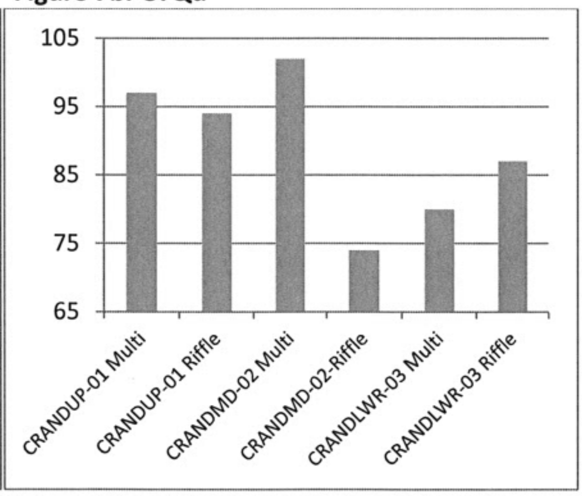


Figure 7b. CTQd



Green colored graphs indicate that lower values, or a decline, specify more desirable conditions.

Figure 8b. EPT Taxa Abundance

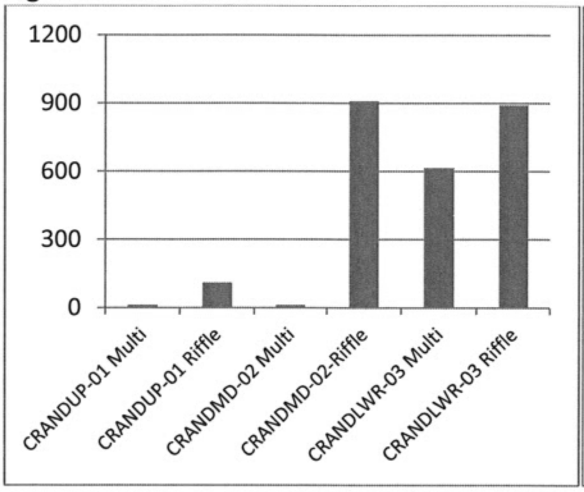


Figure 9b. Percent EPT

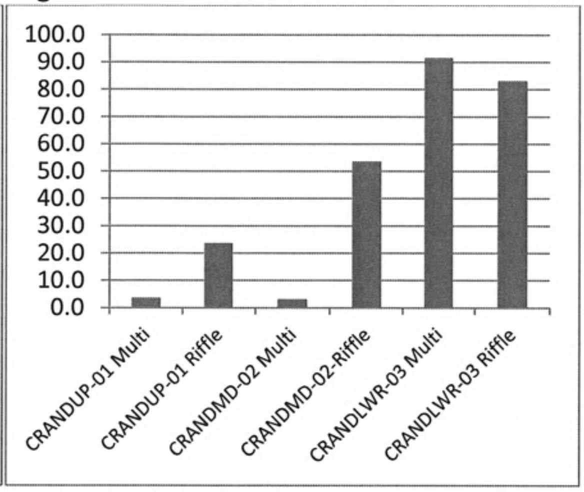


Figure 10b. Percent Chironomids

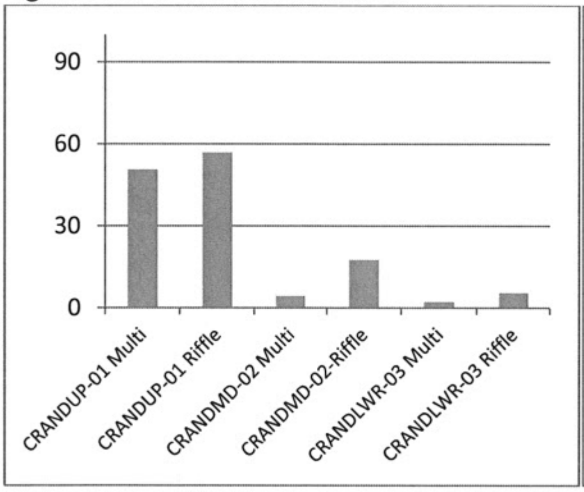


Figure 11b. Ratio of EPT to Chironmonids

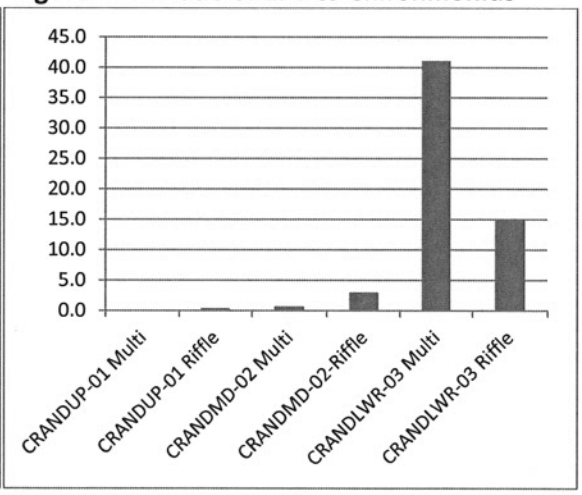


Figure 12b. Number of Tolerant Taxa

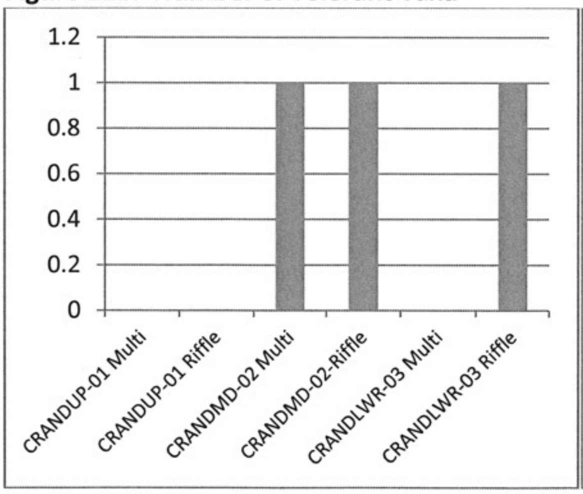


Figure 13b. Percent Tolerant Organisms

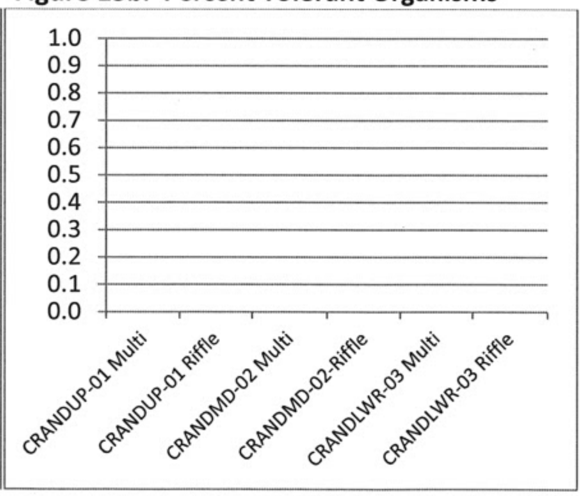


Figure 14b. Number of Intolerant Taxa

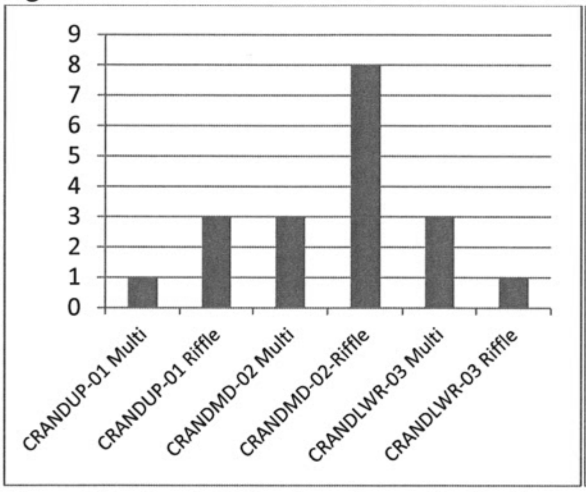


Figure 15b. Percent Intolerant Organisms

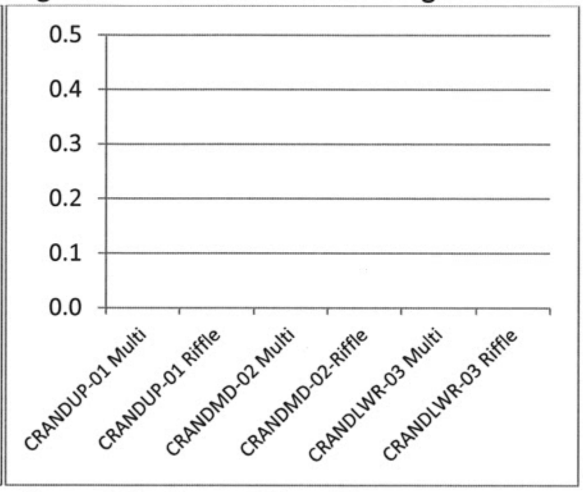


Figure 16b. Specialist Feeders: Generalist Feeders

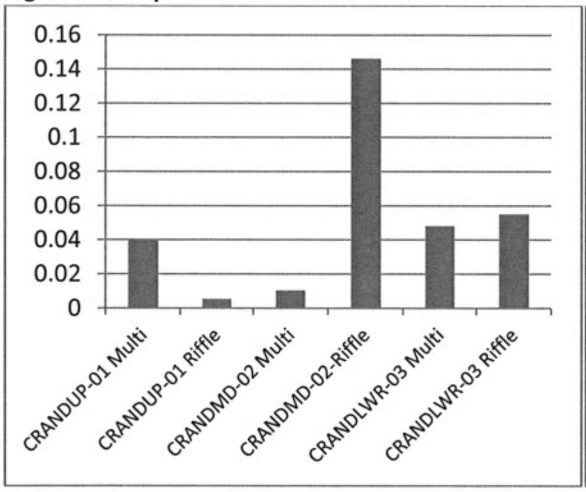


Figure 17b. Percent Shredders

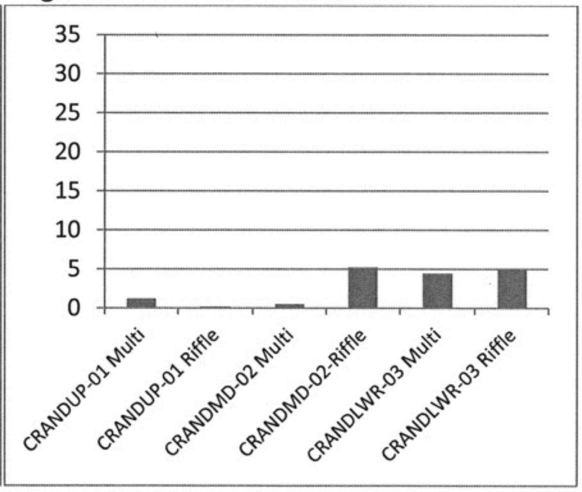


Figure 18b. Percent Scrapers

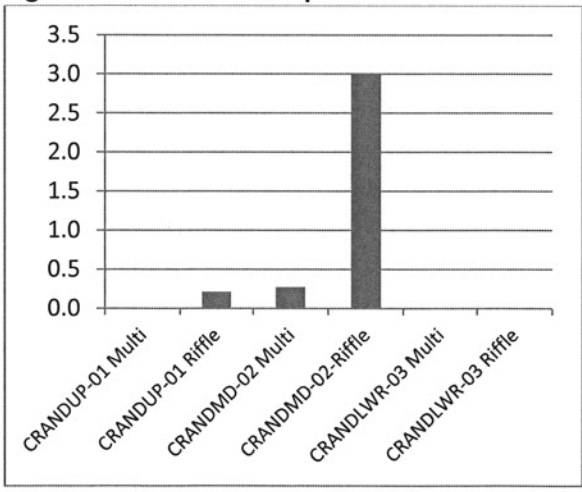


Figure 19b. Number of Long-Lived Taxa

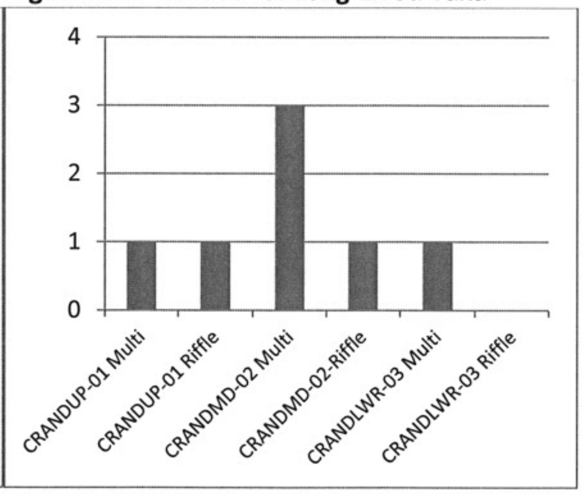


Figure 20b. Number of Clinger Taxa

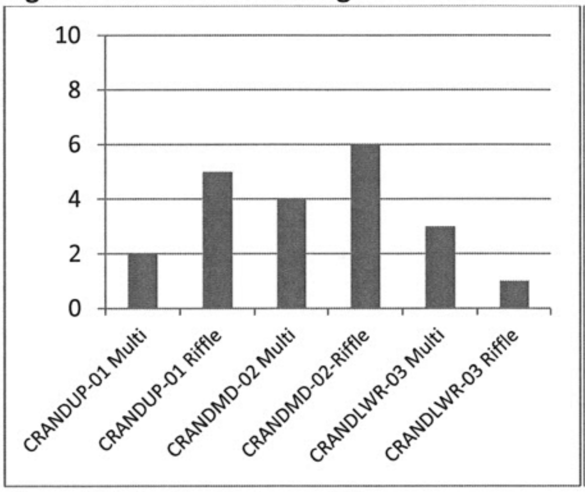


Figure 21b. Baetis:All Ephemetroptera (Percent)

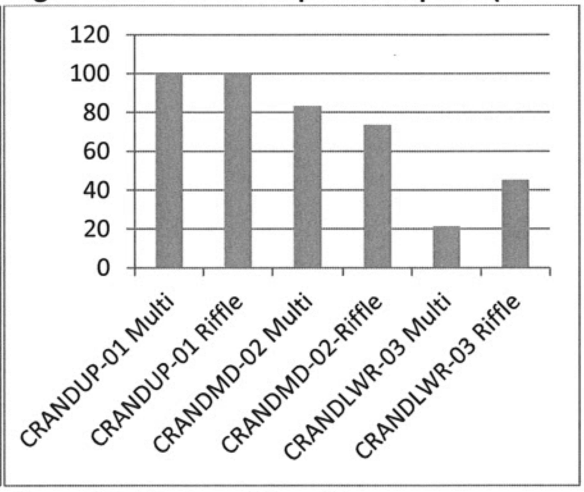


Figure 22b. Baetis, Hydropsychidae & Orthocladiinae (Percent)

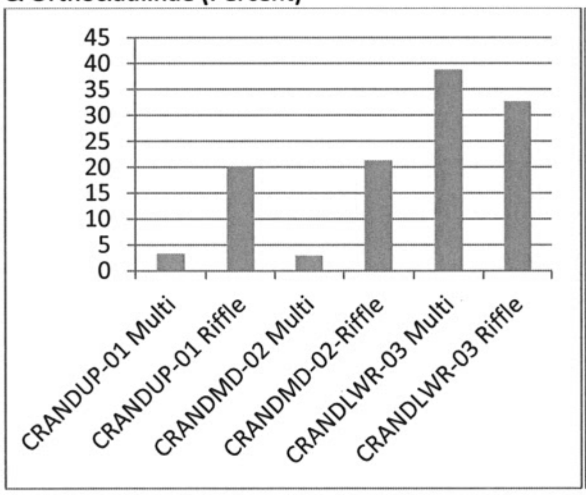


Figure 23b. Heptageniidae: All Ephemeroptera (Percent)

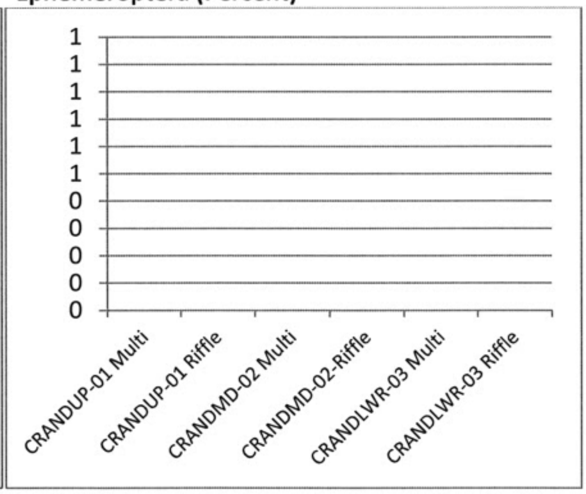
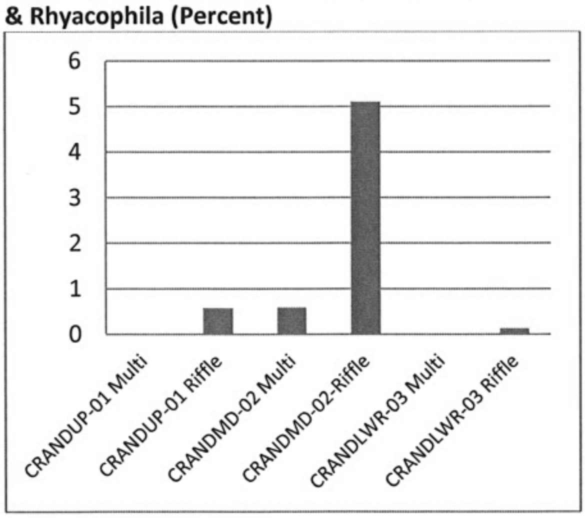


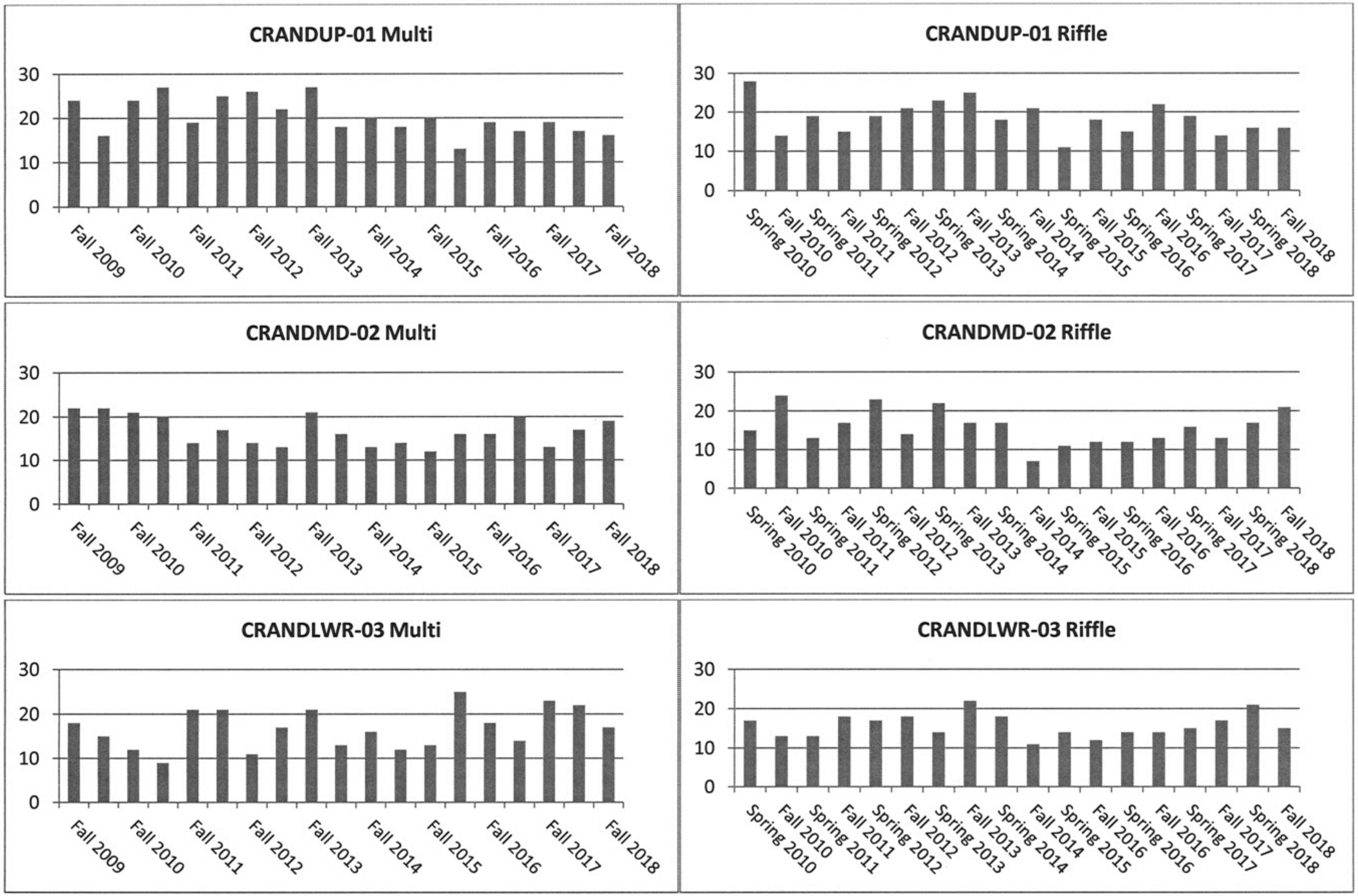
Figure 24b. Heptageniidae, Chloroperlidae & Rhyacophila (Percent)



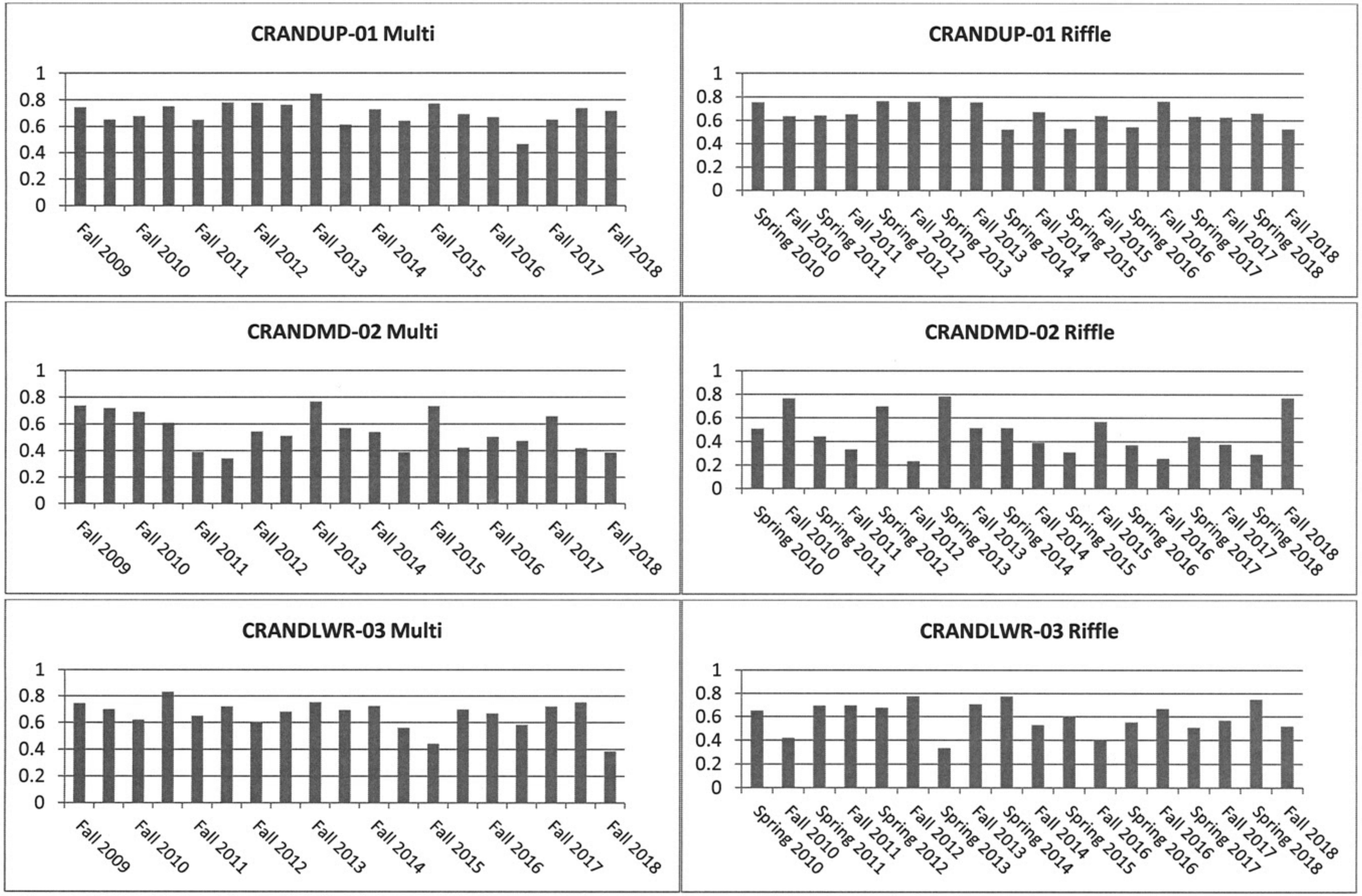
APPENDIX C

MACROINVERTEBRATE FIGURES FALL 2009- FALL 2018

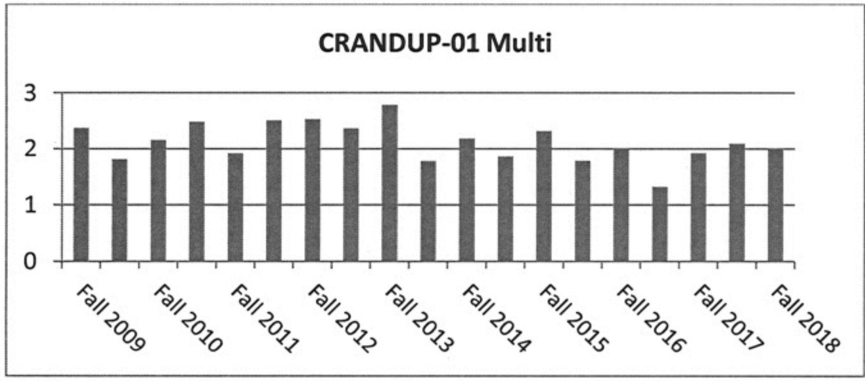
Figures 1c. Richness values for each reach and habitat type from 2009-2018

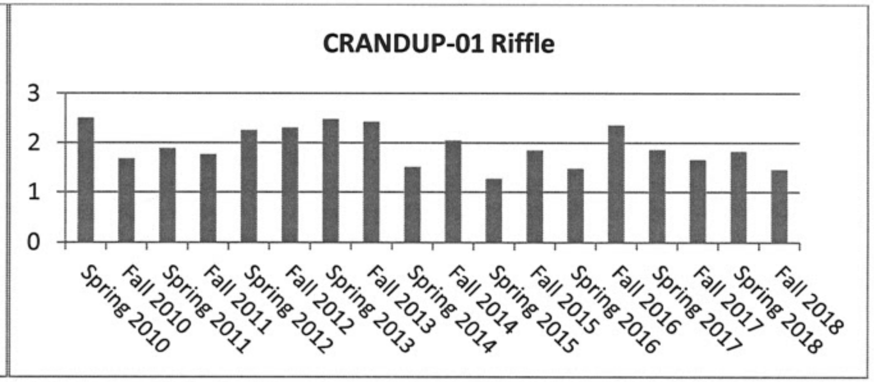


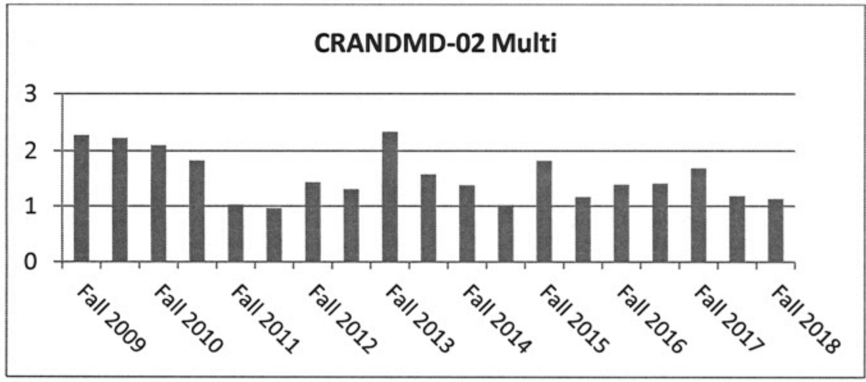
Figures 2c. Evenness values for each reach and habitat type from 2009-2018

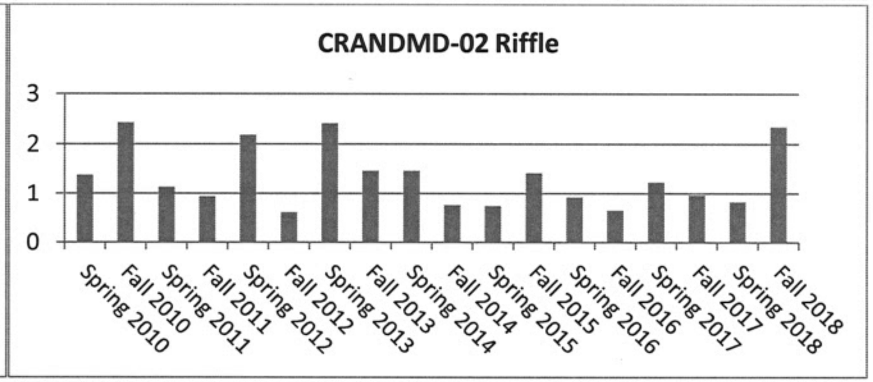


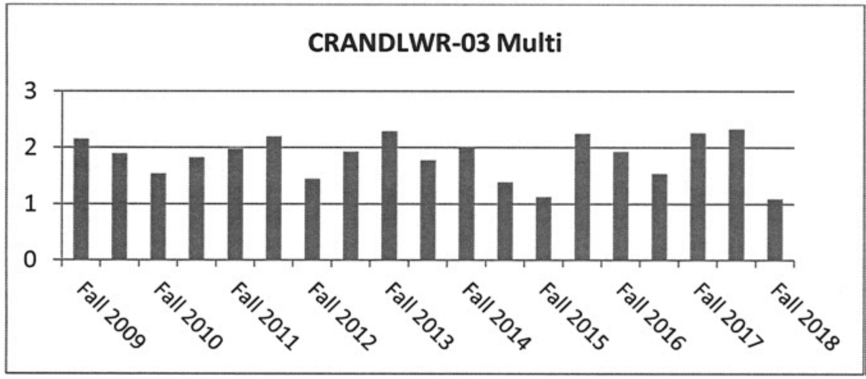
Figures 3c. Shannon's Diversity values for each reach and habitat type from 2009-2018

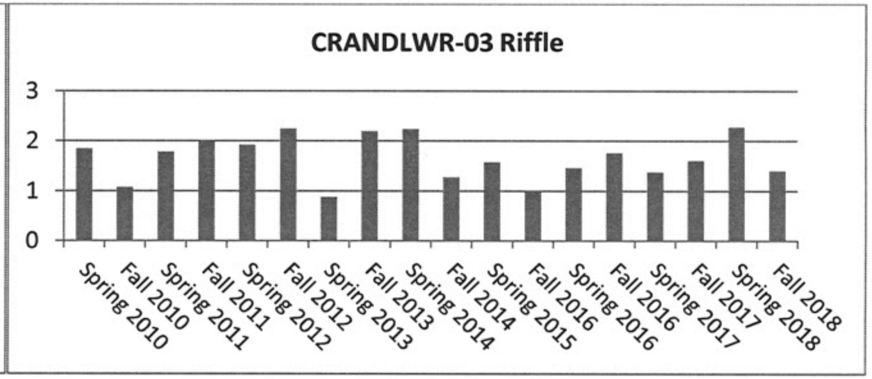




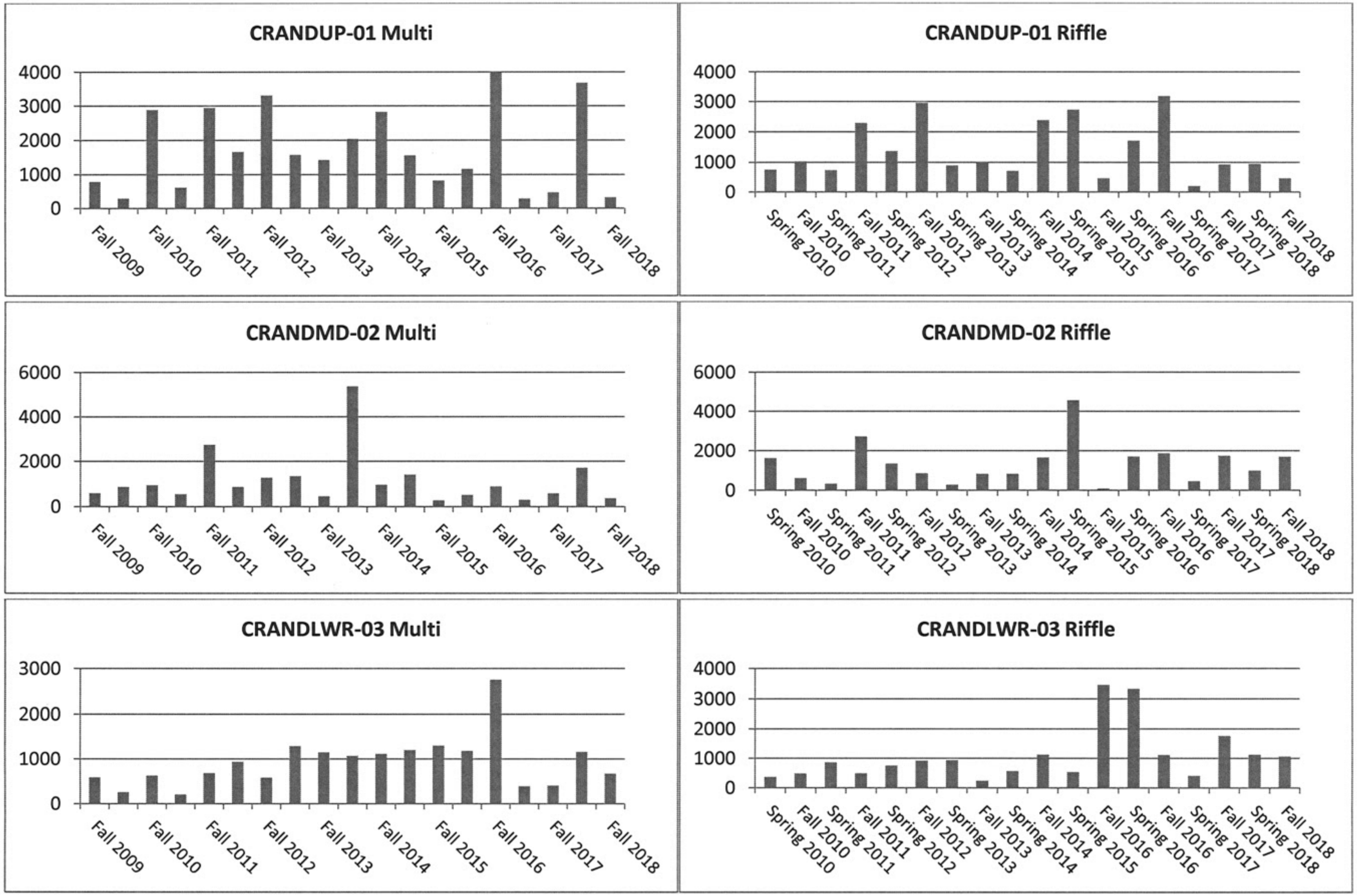




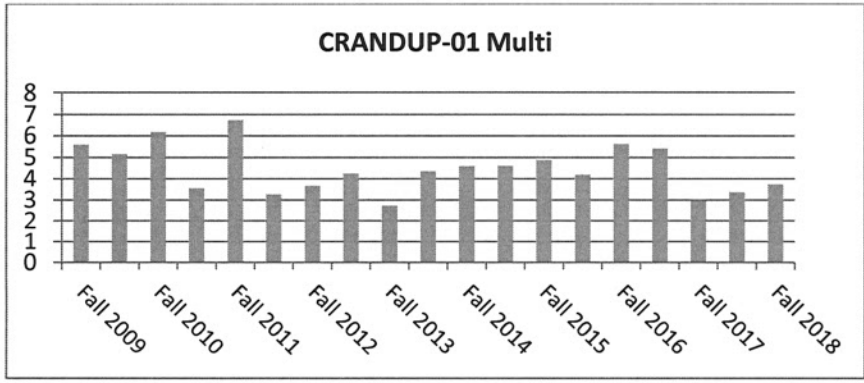


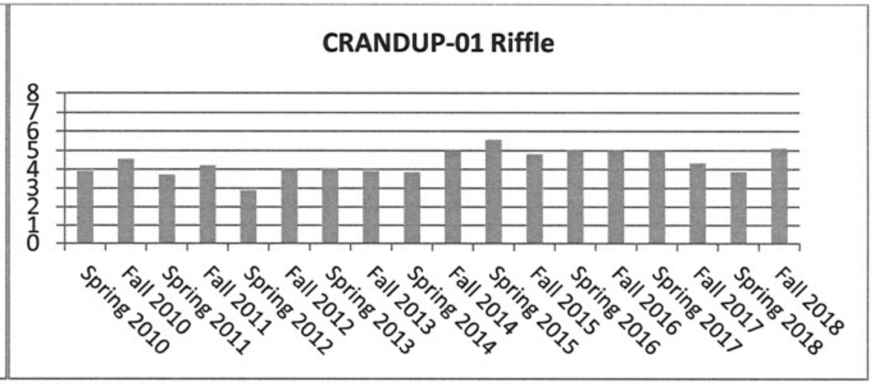


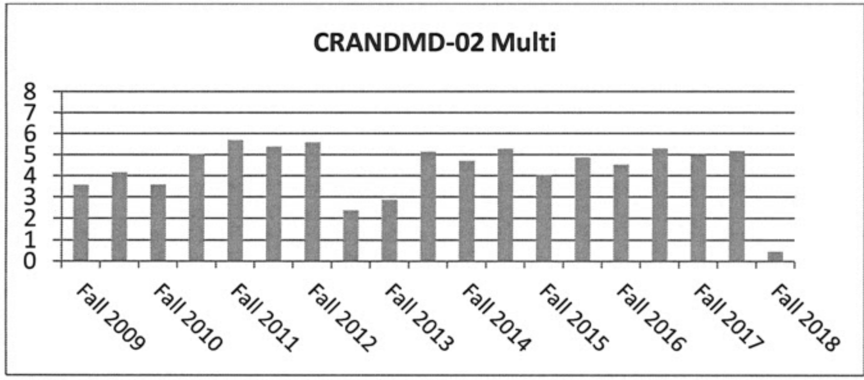
Figures 4c. Abundance values for each reach and habitat type from 2009-2018

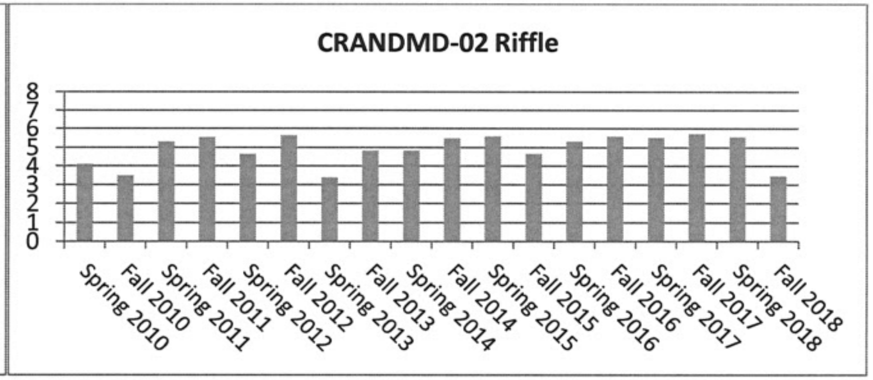


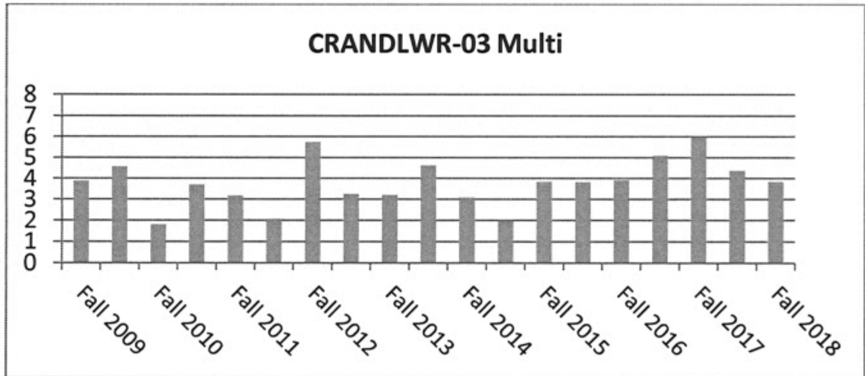
Figures 5c. Hilsenhoff Biotic Index values for each reach and habitat type from 2009-2018

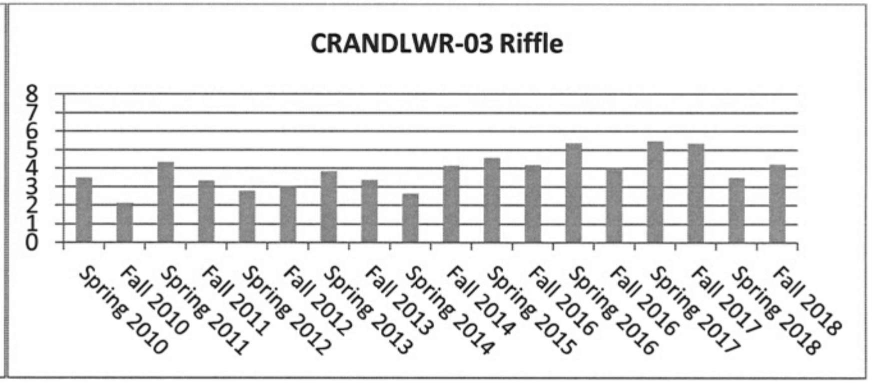




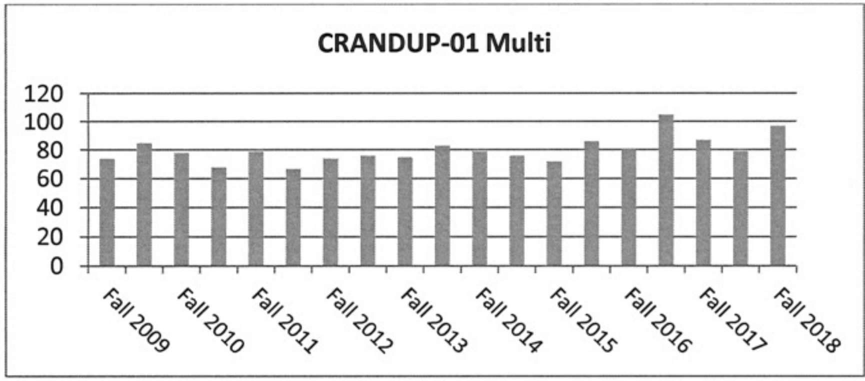


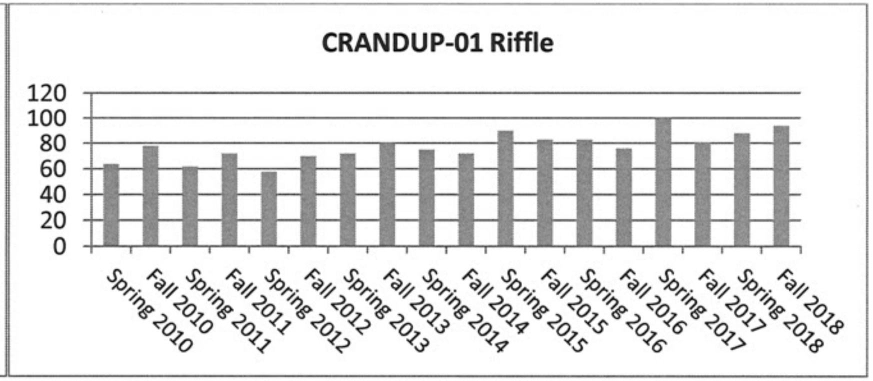


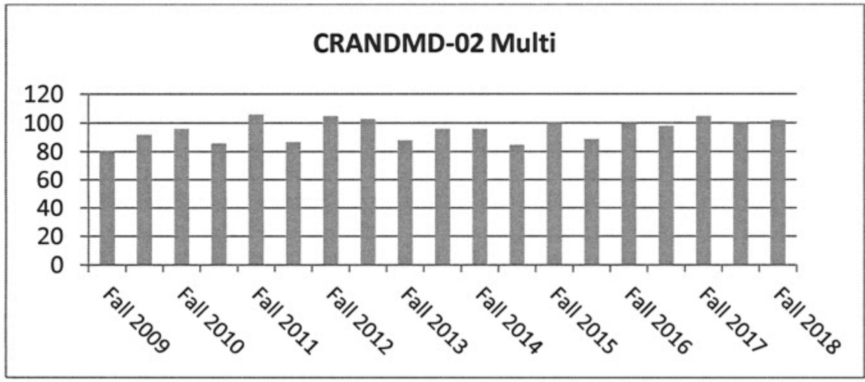


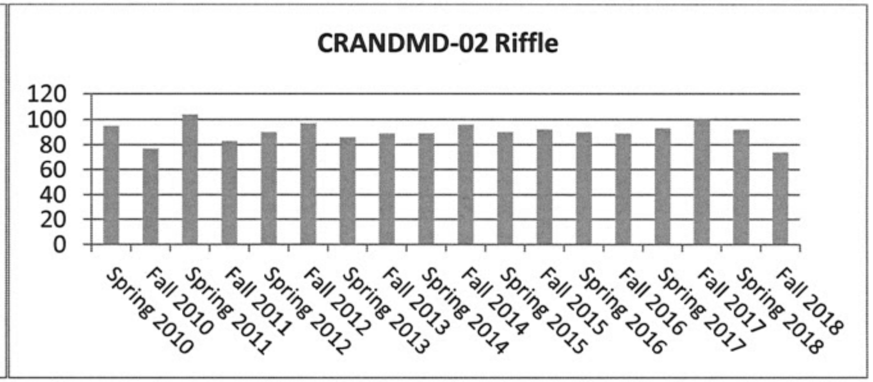


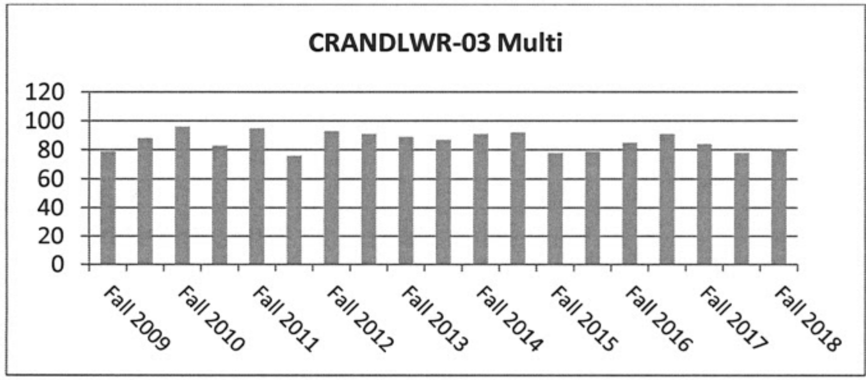
Figures 6c. USFS Community Tolerance Quotient (CTQd) values for each reach and habitat type from 2009-2018

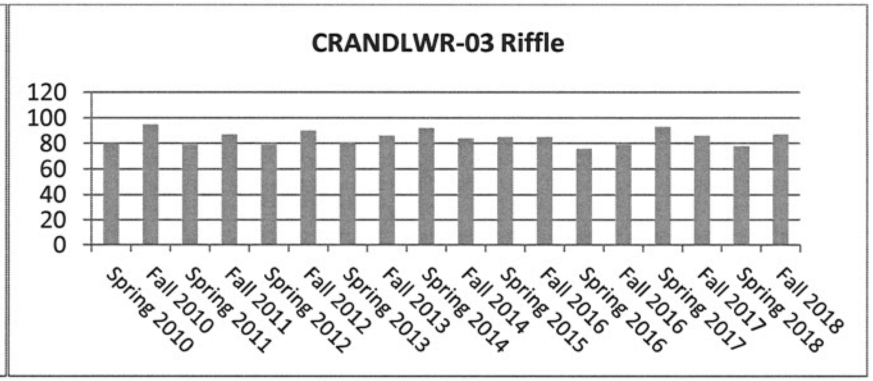




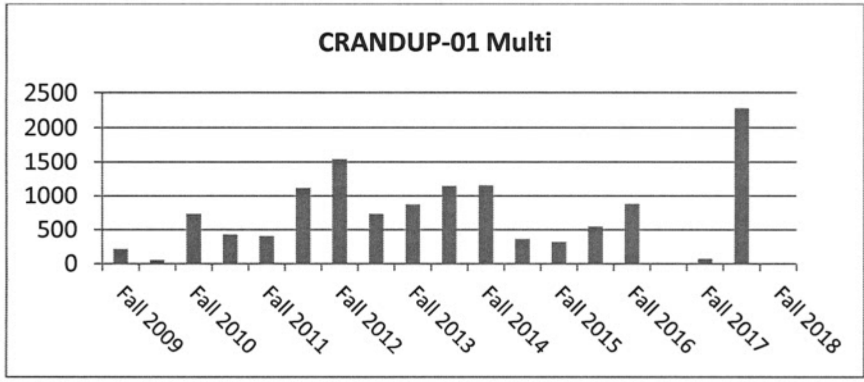


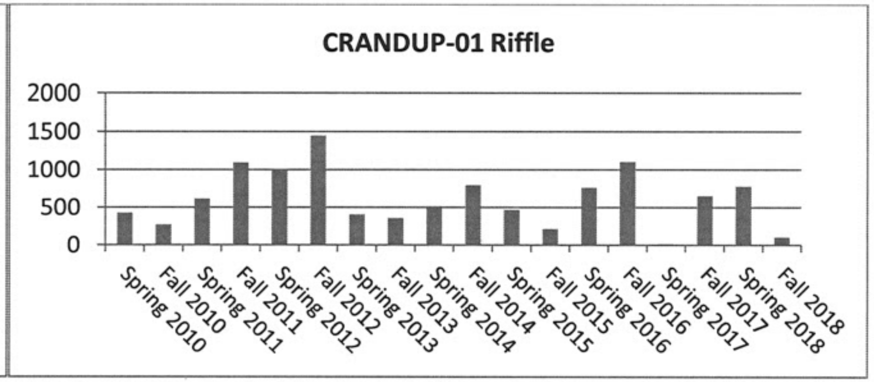


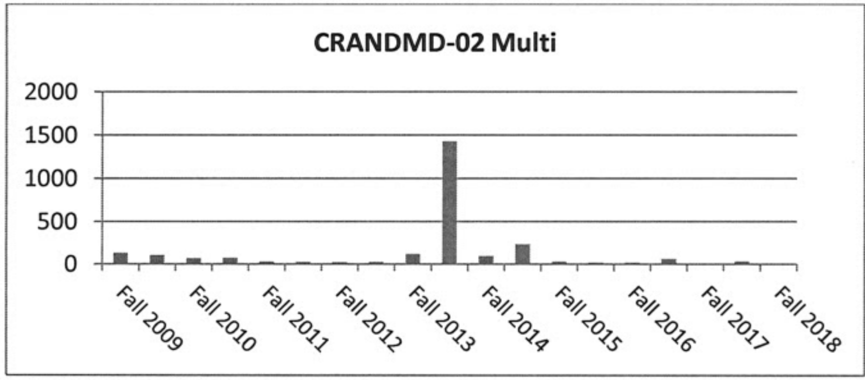


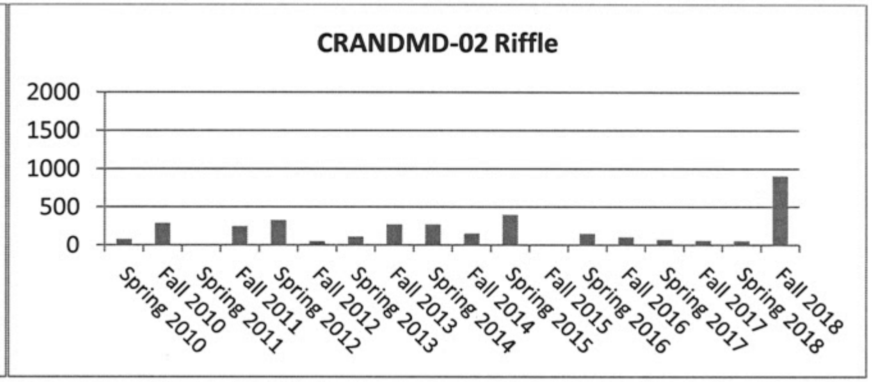


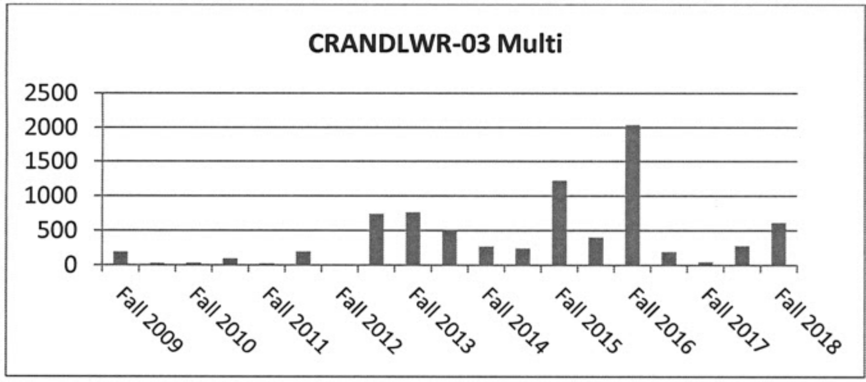
Figures 7c. EPT taxa abundance values for each reach and habitat type from 2009-2018

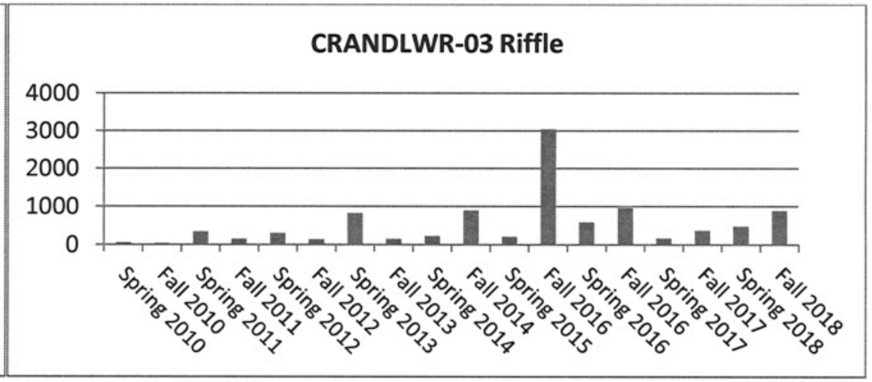




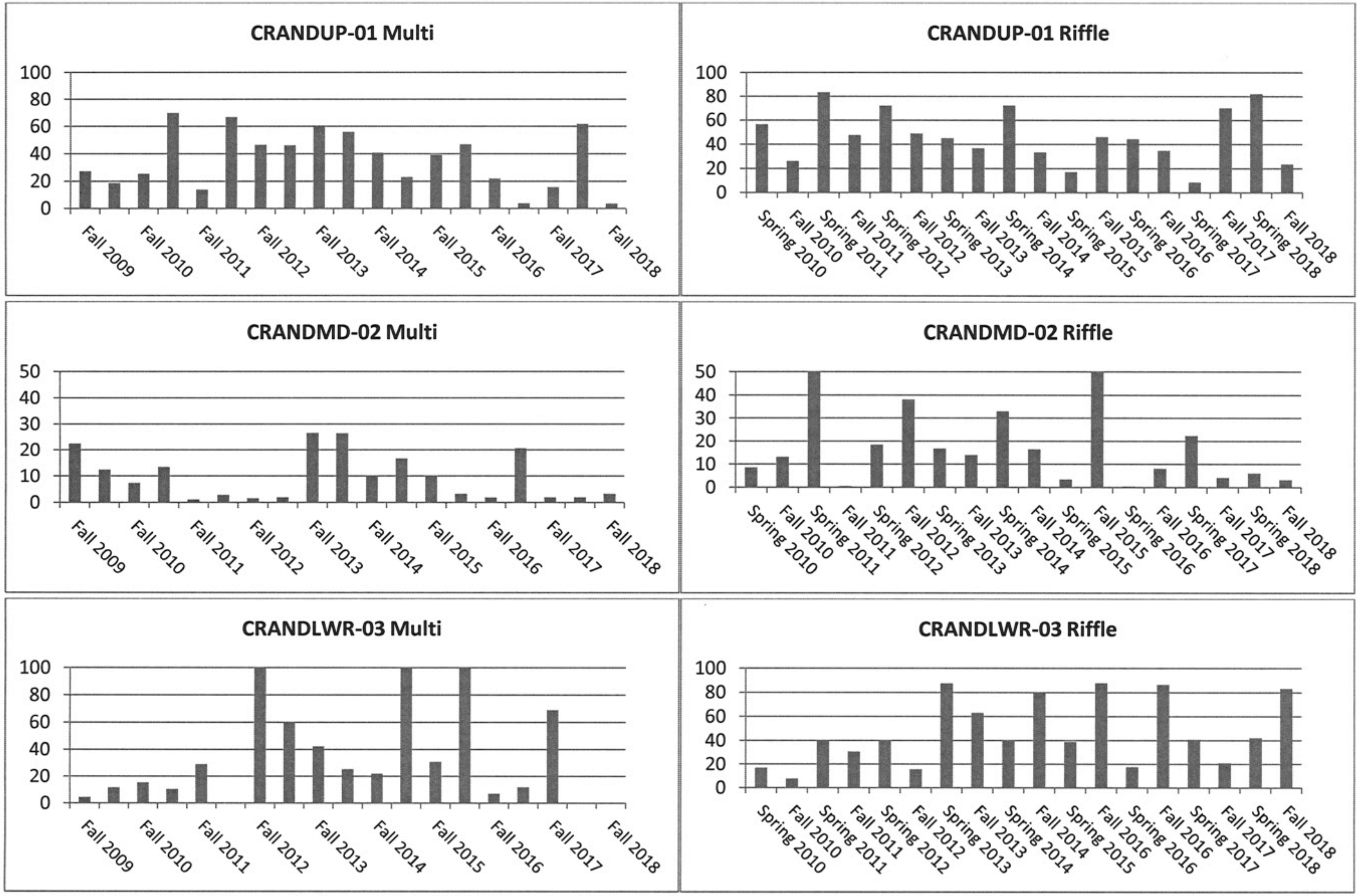




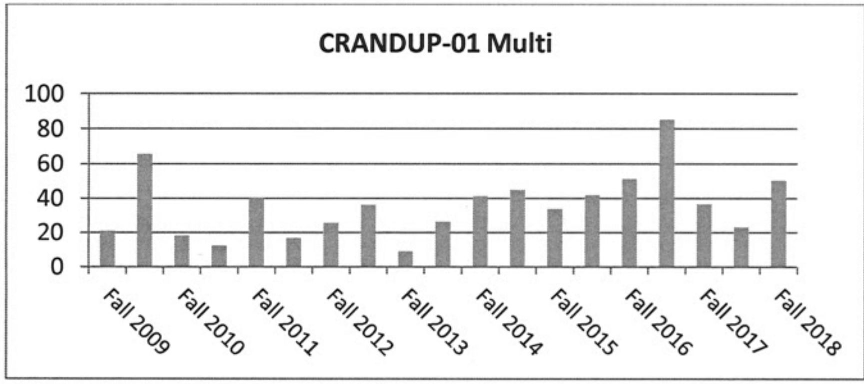


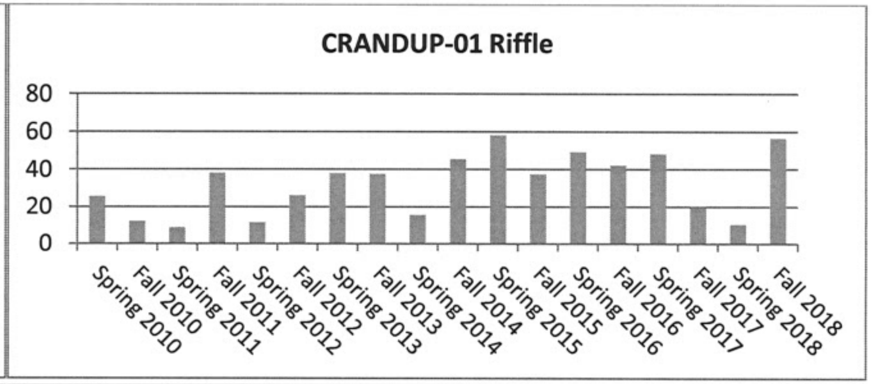


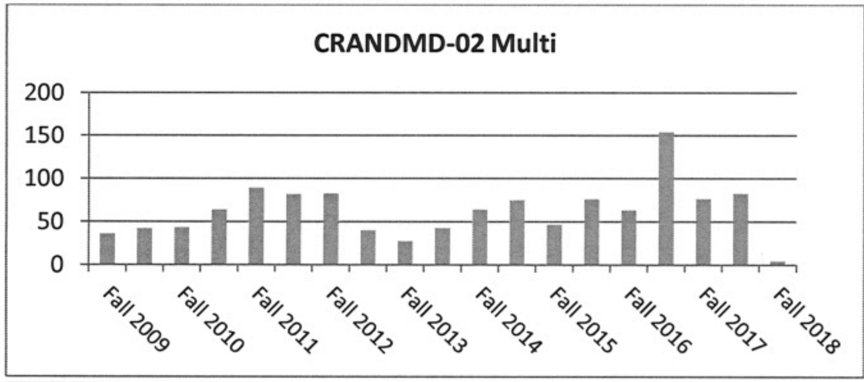
Figures 8c. Percent EPT for each reach and habitat type from 2009-2018

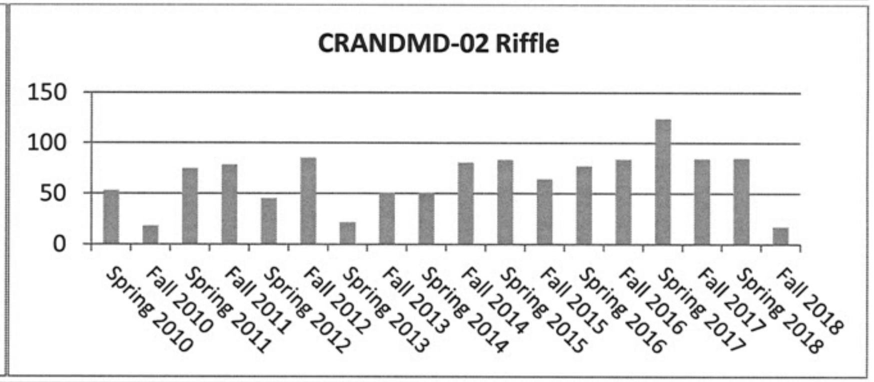


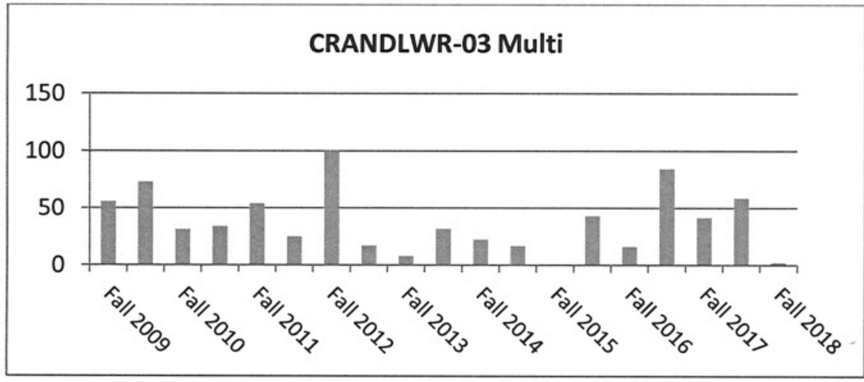
Figures 9c. Percent Chironomids for each reach and habitat type from 2009-2018

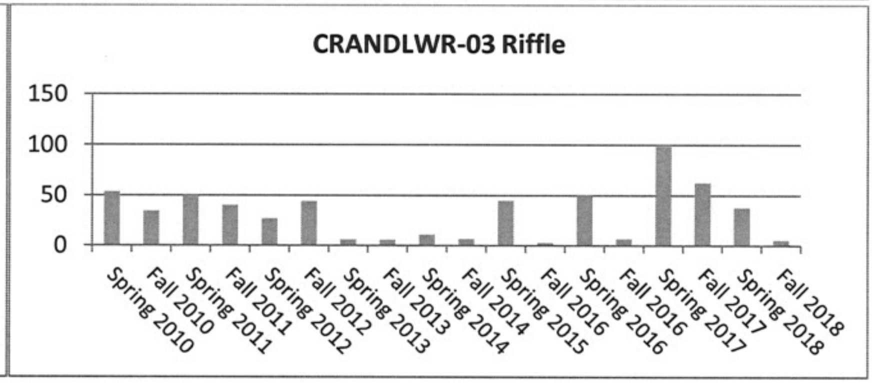




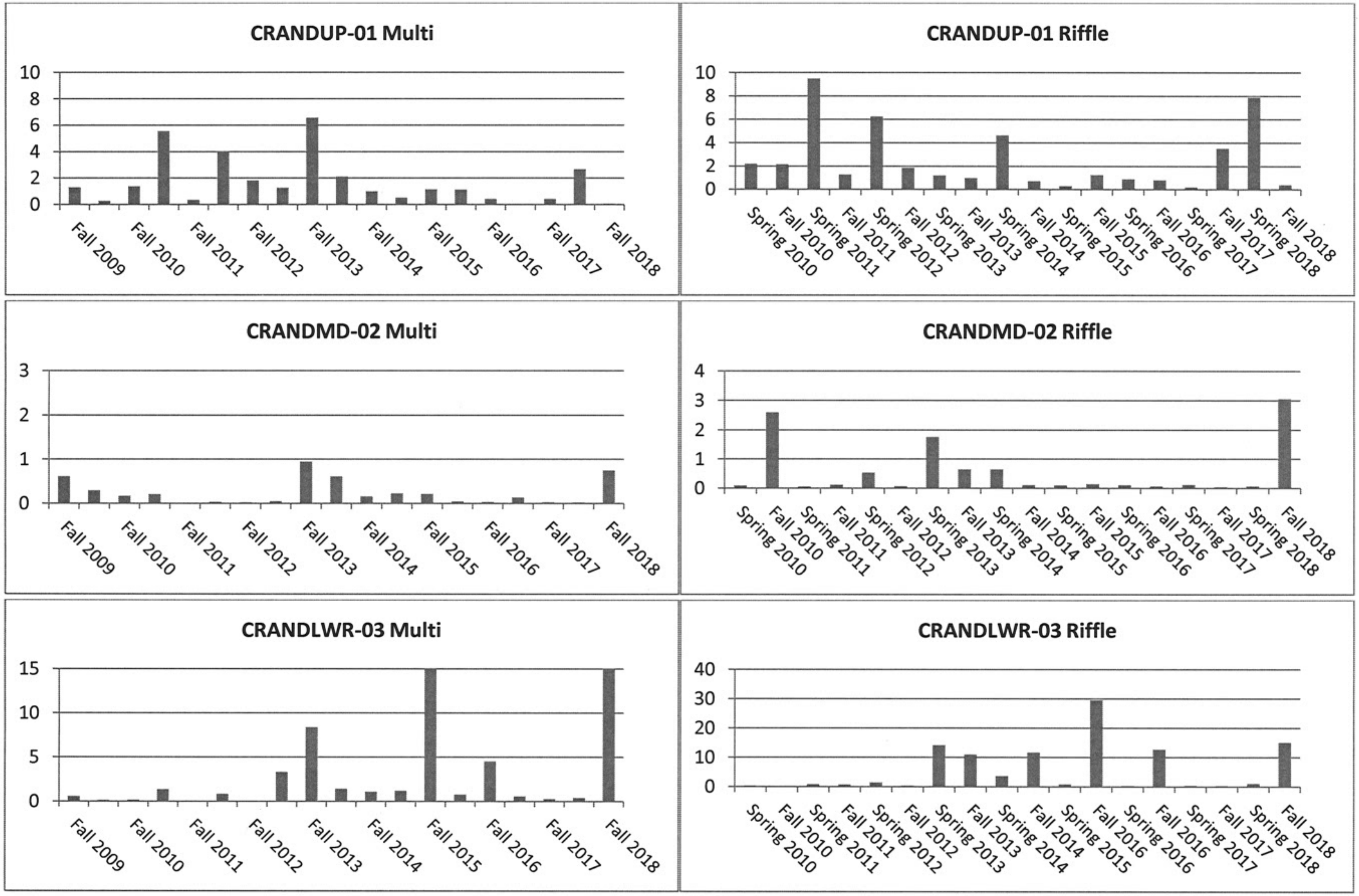




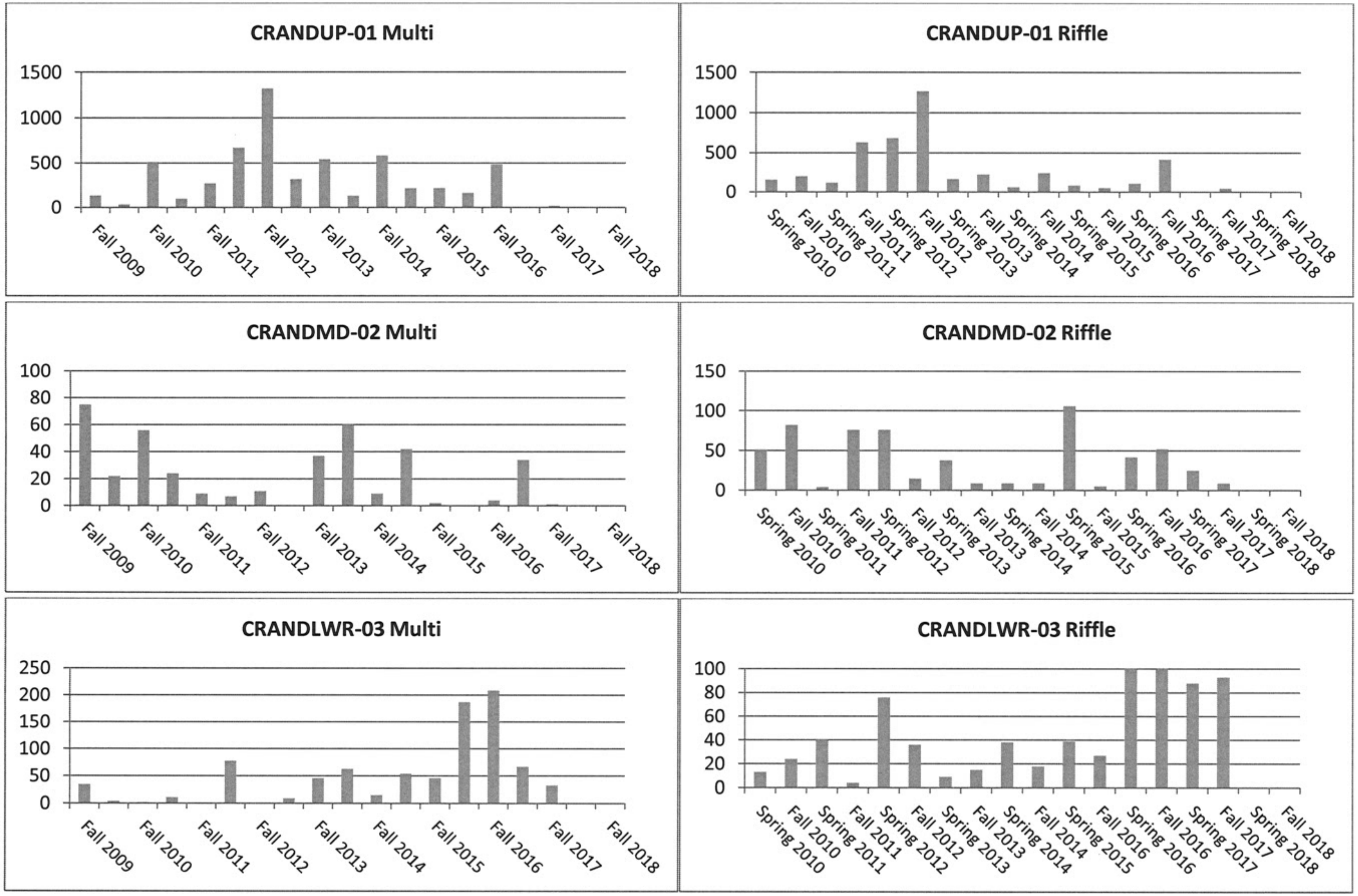




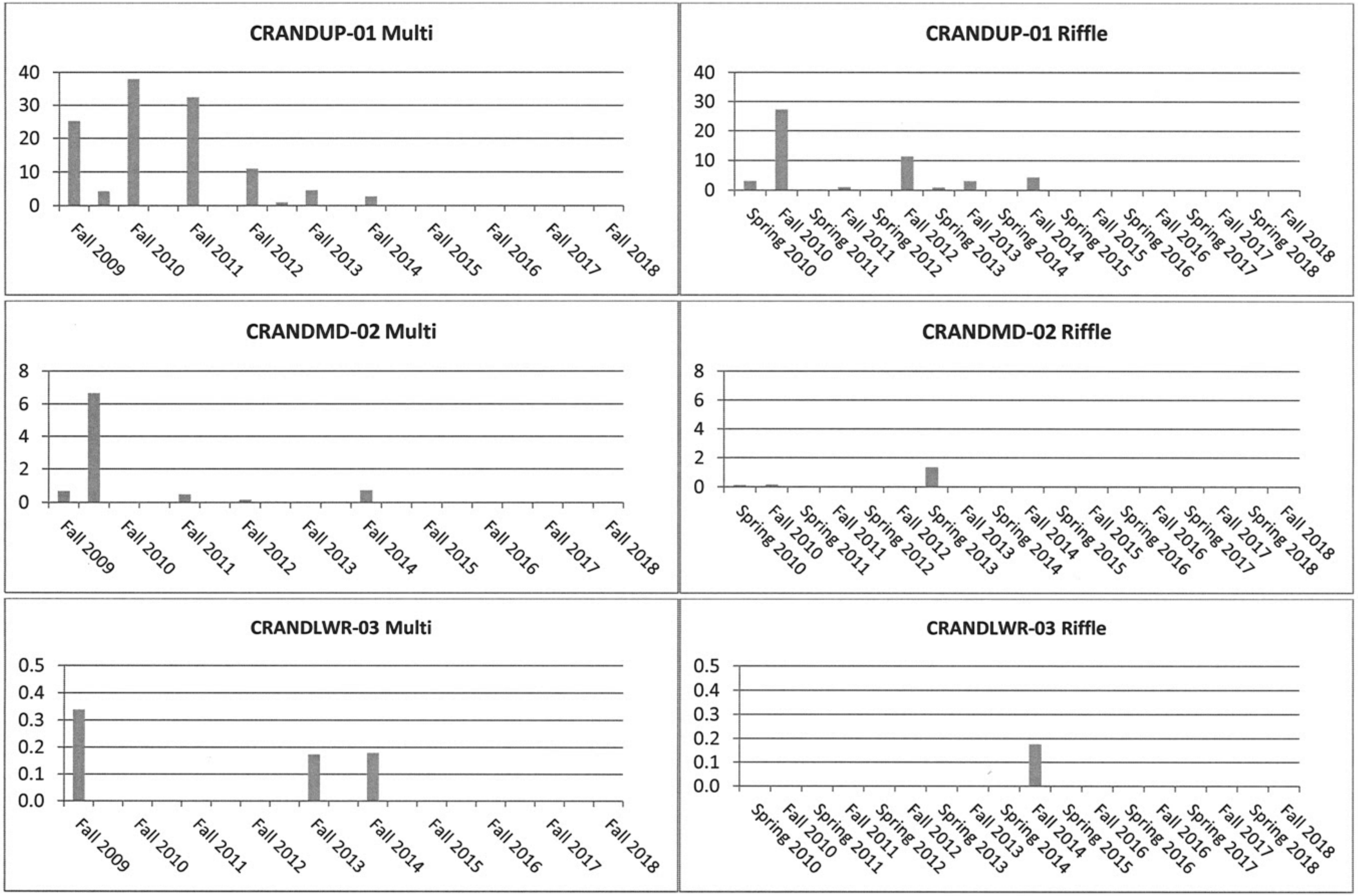
Figures 10c. Ratio of EPT to Chironomids values for each reach and habitat type from 2009-2018



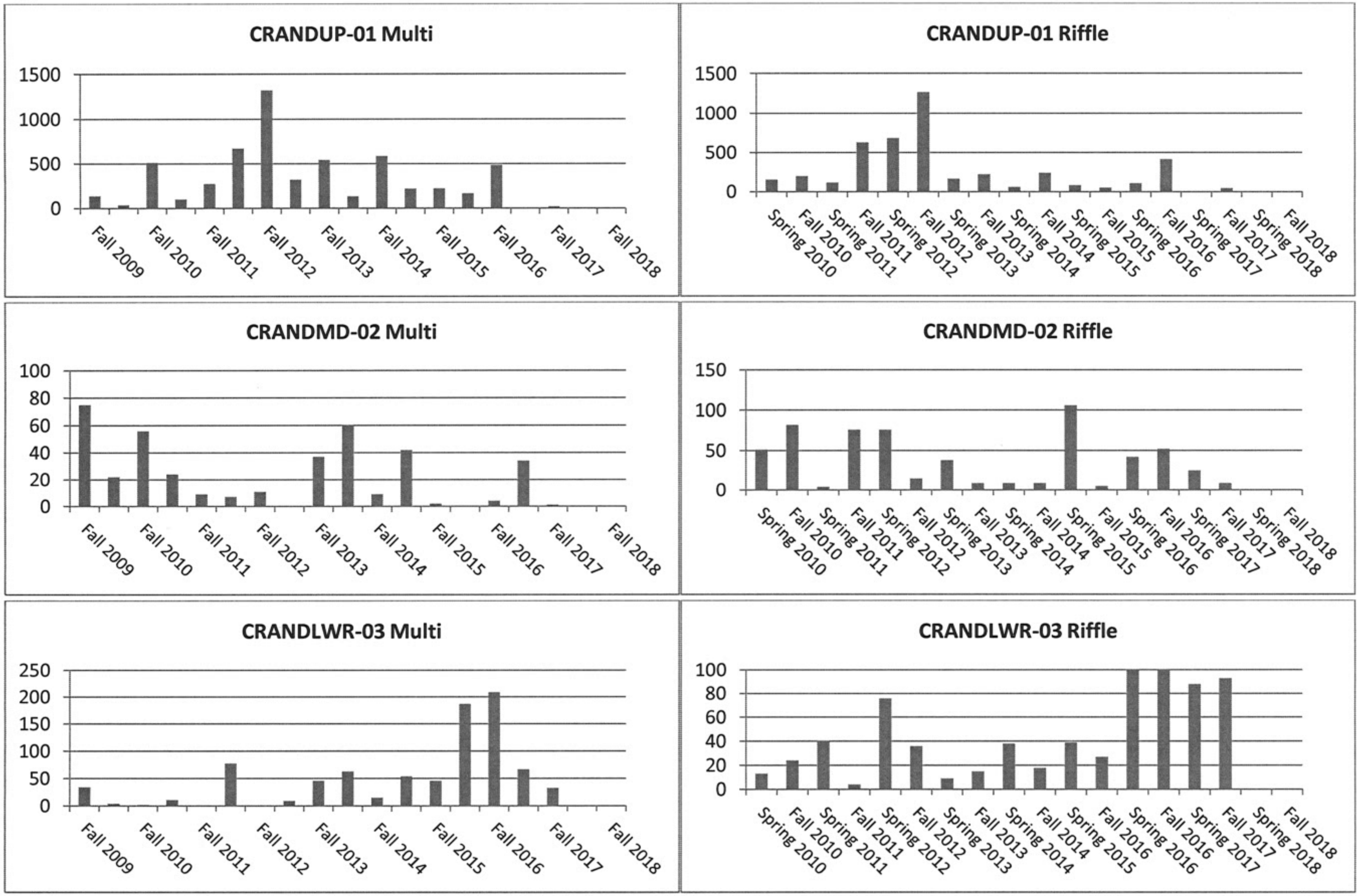
Figures 11c. Number of tolerant taxa for each reach and habitat type from 2009-2018



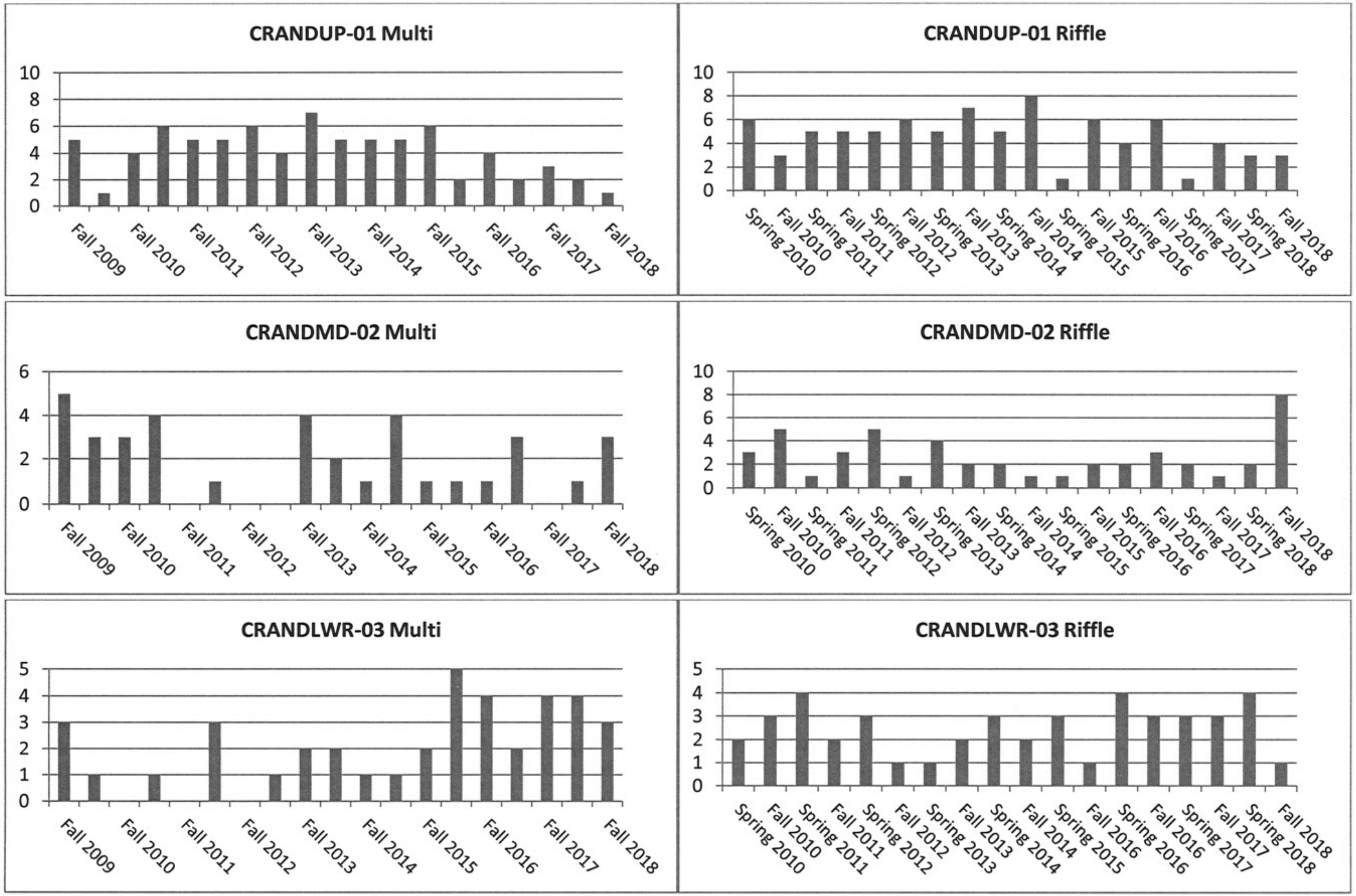
Figures 12c. Percent tolerant organisms for each reach and habitat type from 2009-2018



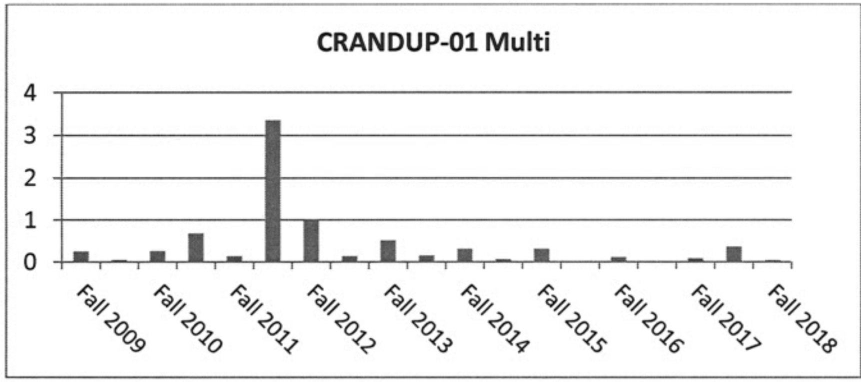
Figures 13c. Number of intolerant taxa for each reach and habitat type from 2009-2018

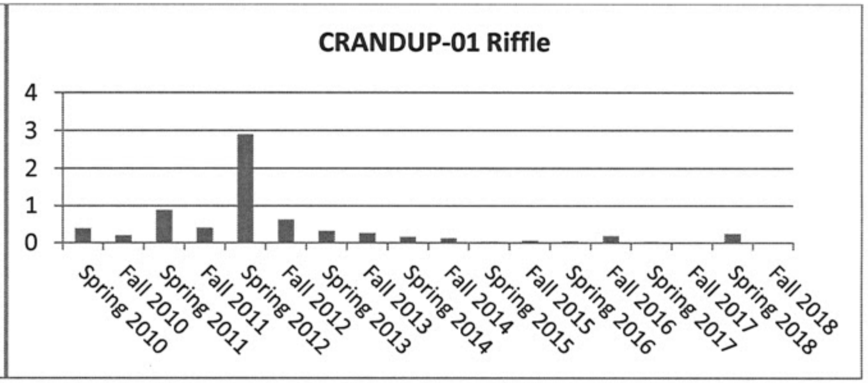


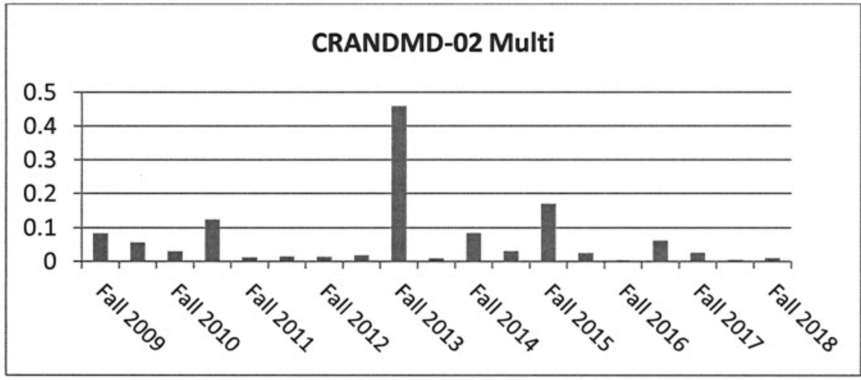
Figures 14c. Percent intolerant organisms for each reach and habitat type from 2009-2018

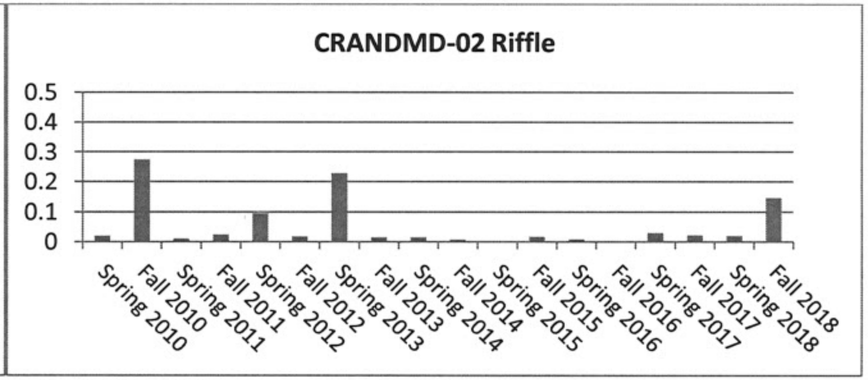


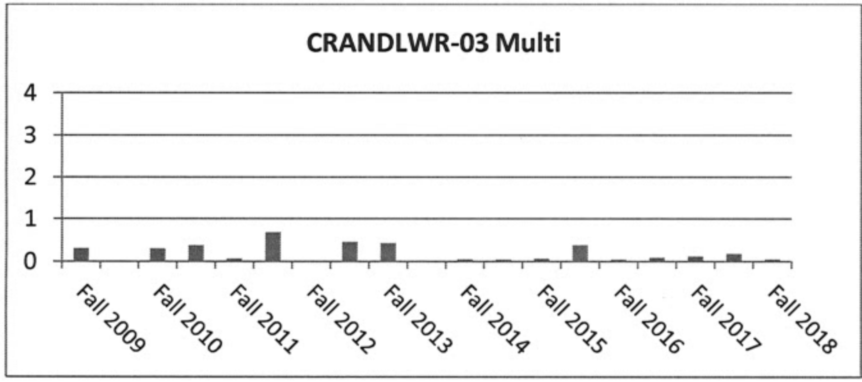
Figures 15c. Ratio of specialist feeders to generalist feeders for each reach and habitat type from 2009-2018

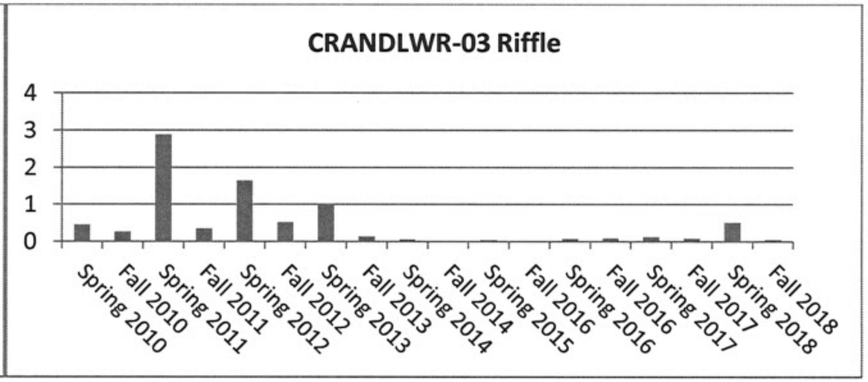




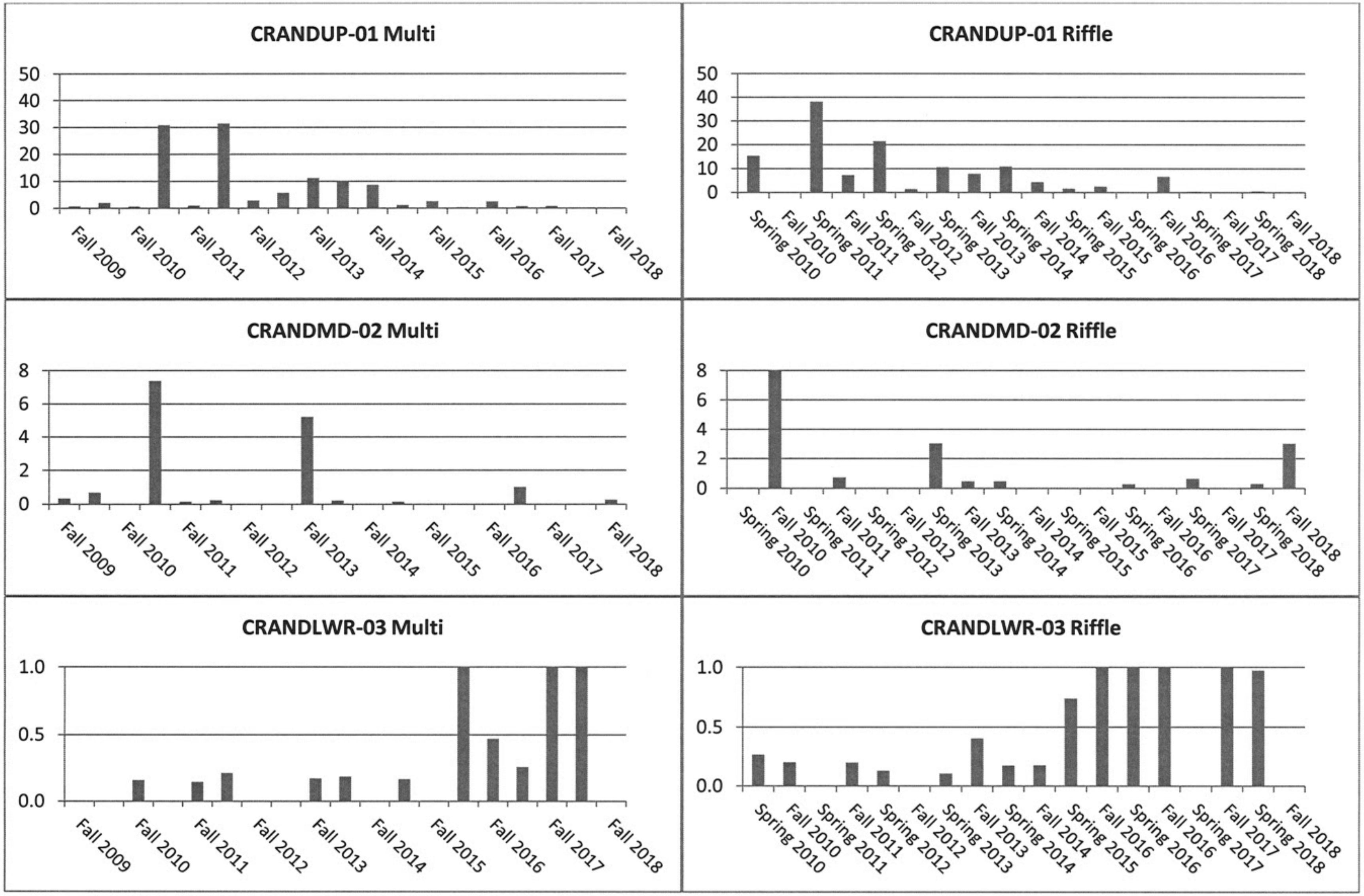




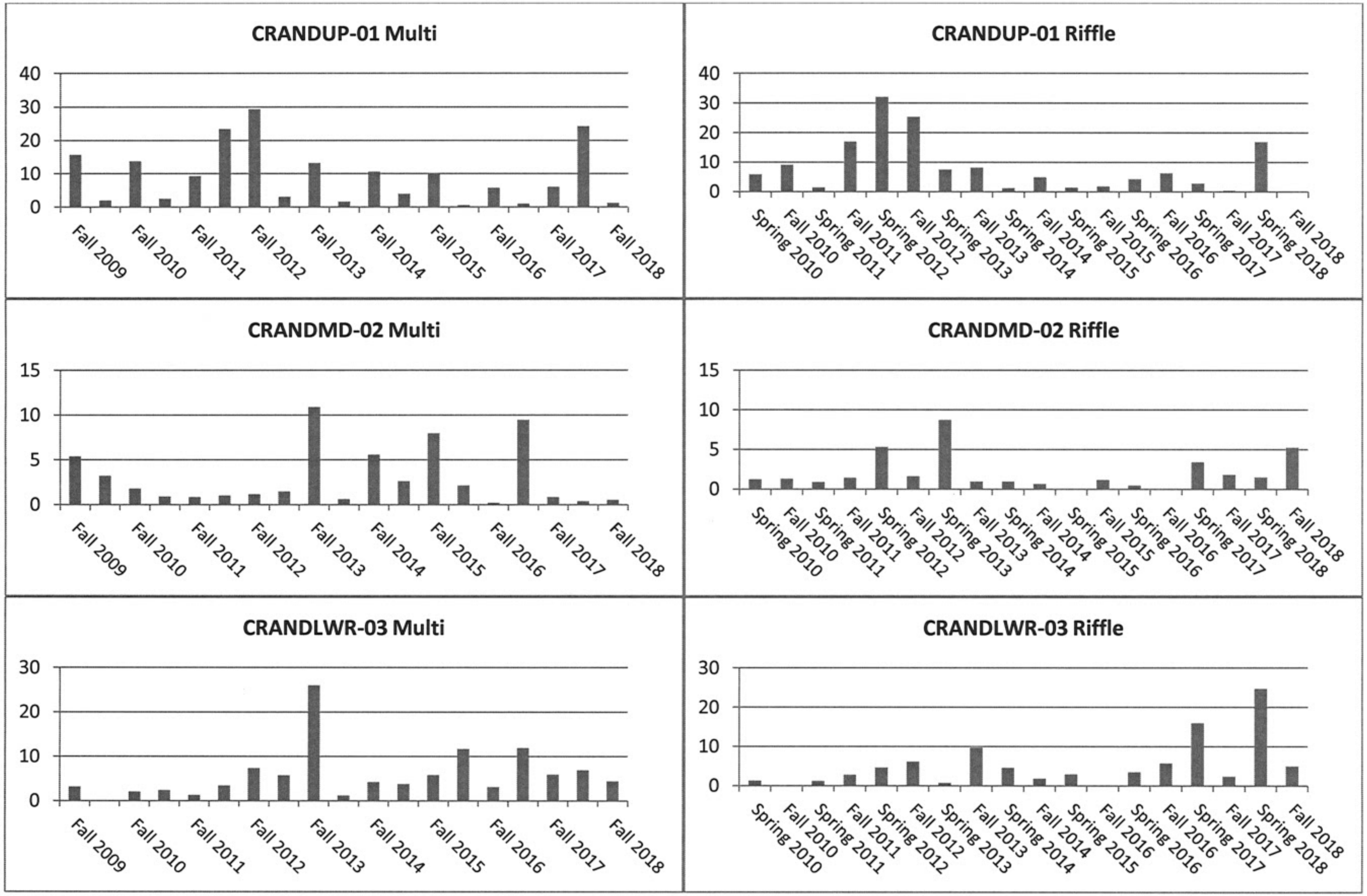




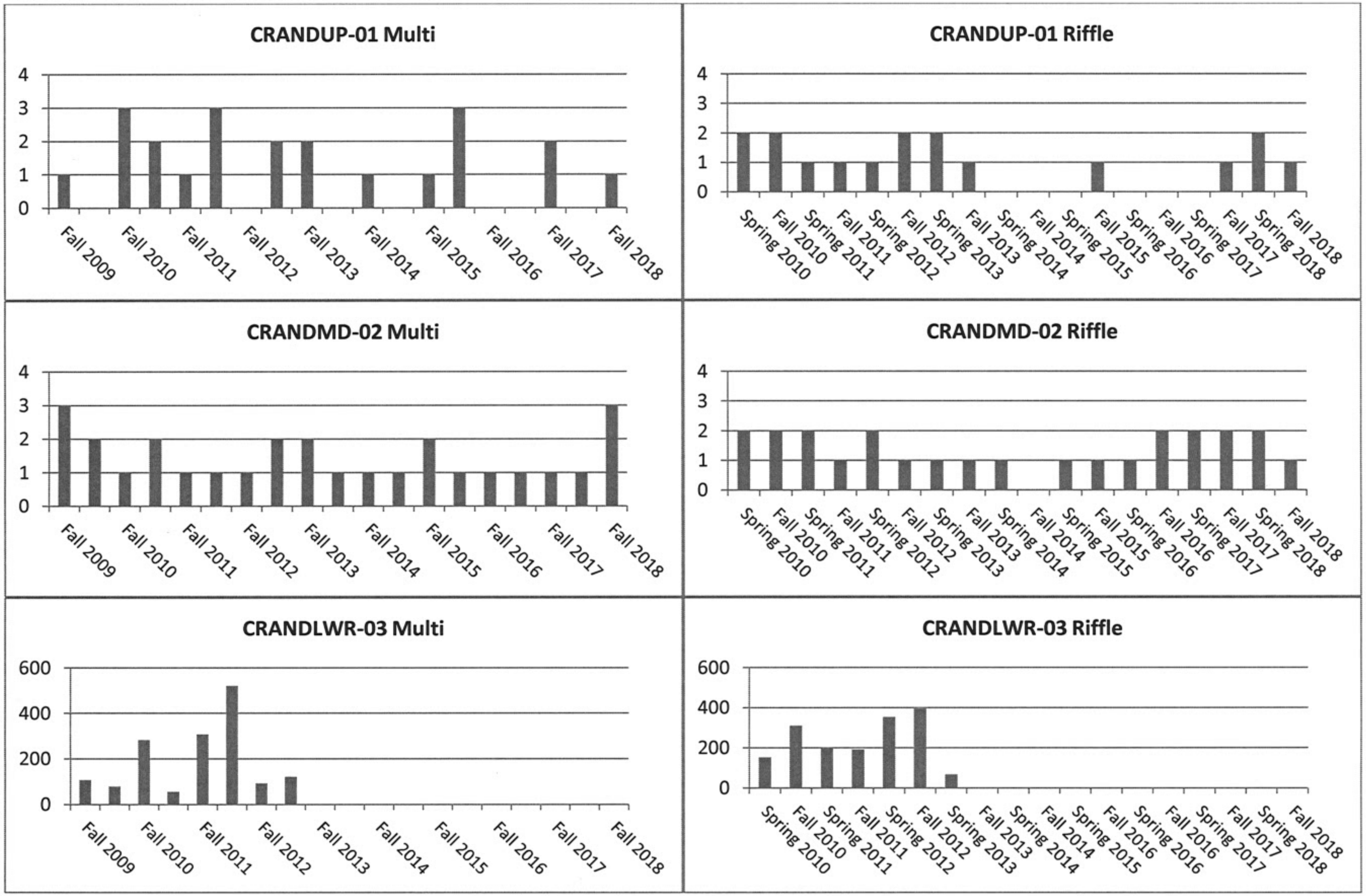
Figures 16c. Percent scrapers for each reach and habitat type from 2009-2018



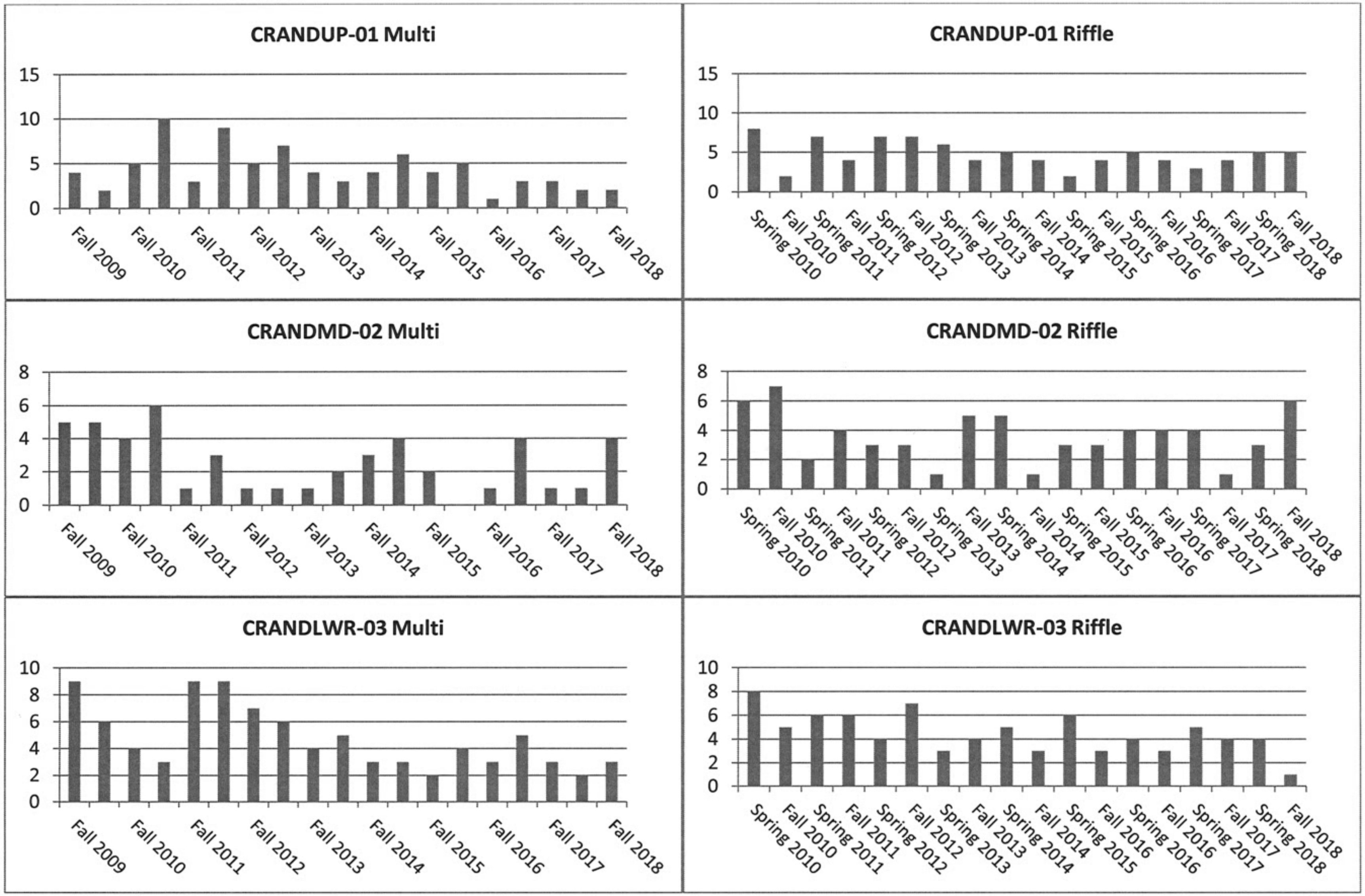
Figures 17c. Percent shredders for each reach and habitat type from 2009-2018



Figures 18c. Number of long-lived taxa for each reach and habitat type from 2009-2018

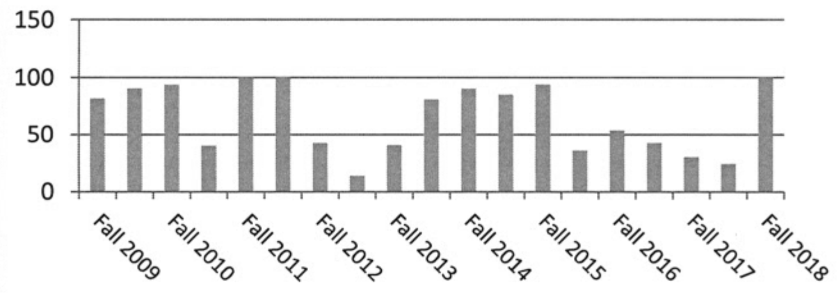


Figures 19c. Number of clinger taxa for each reach and habitat type from 2009-2018

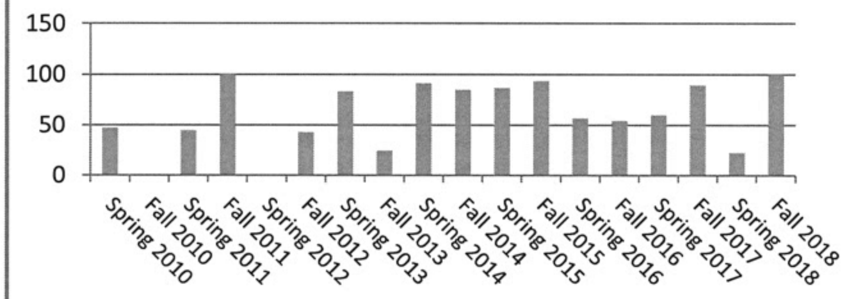


Figures 20c. Percent ratio of *Baetis* to all Ephemeroptera for each reach and habitat type from 2009-2018

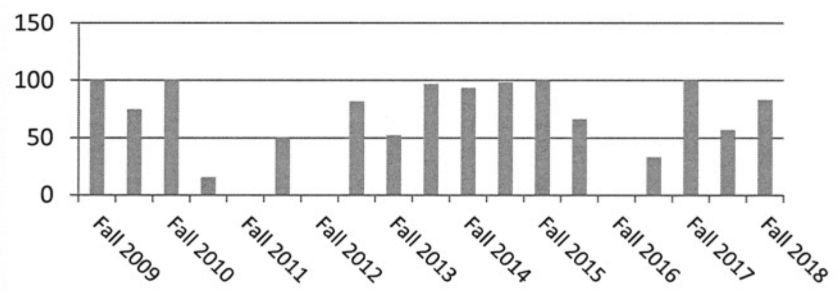
CRANDUP-01 Multi



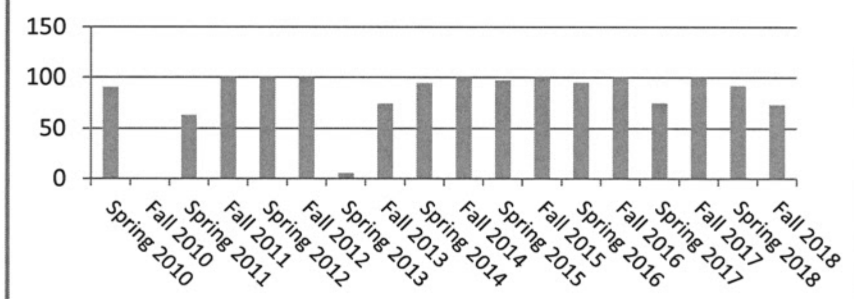
CRANDUP-01 Riffle



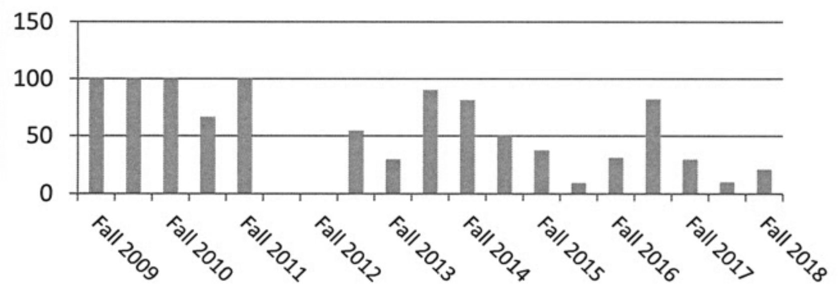
CRANDMD-02 Multi



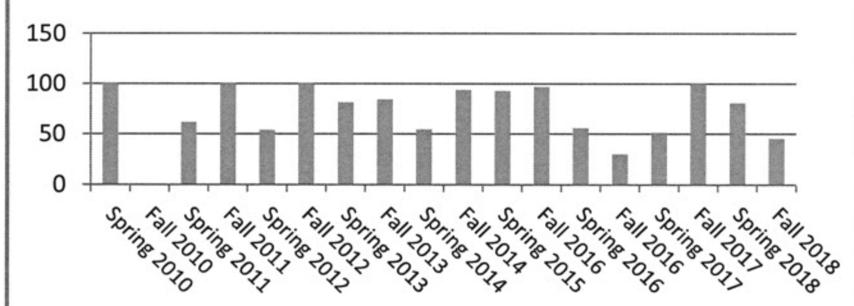
CRANDMD-02 Riffle



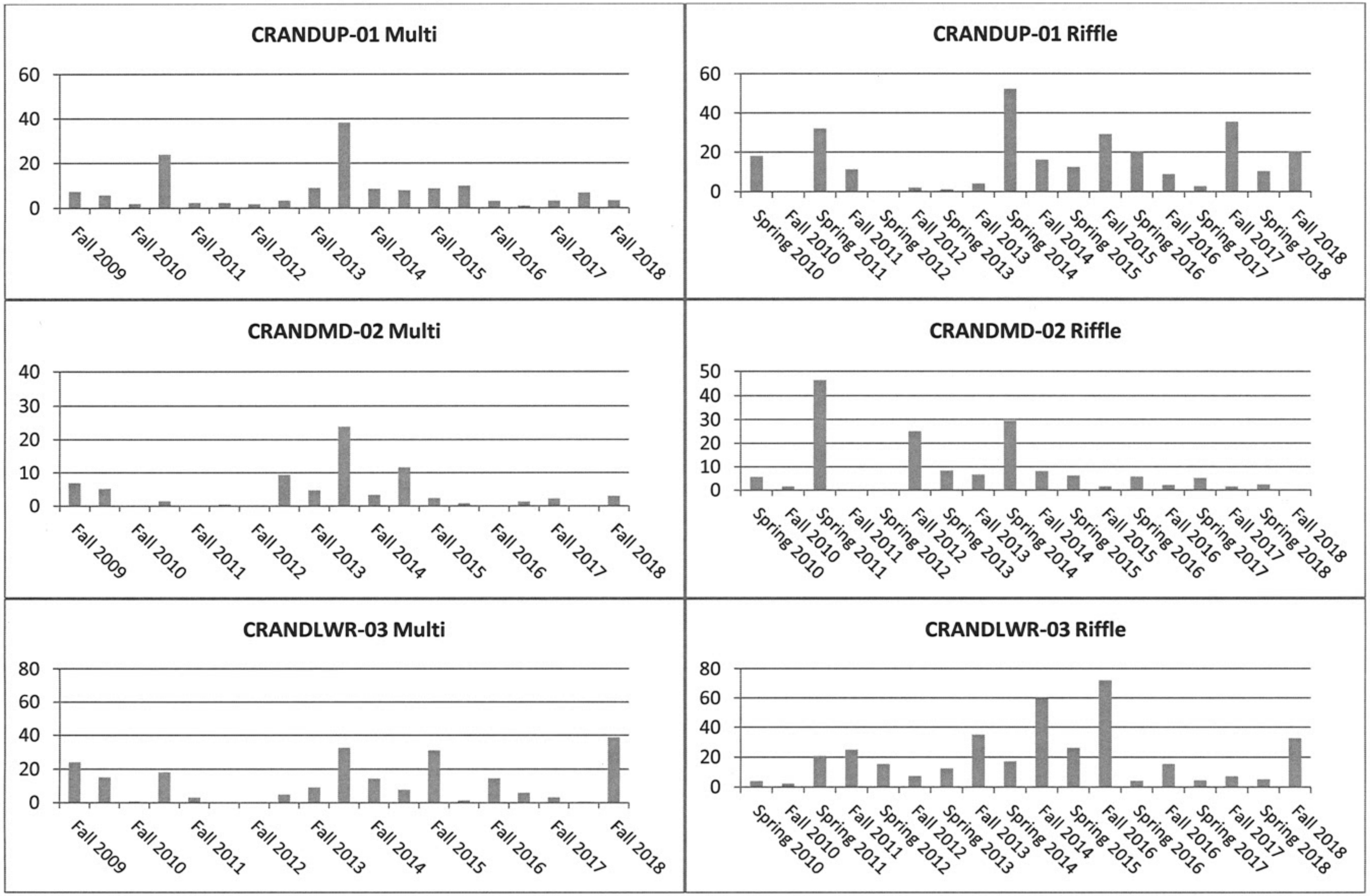
CRANDLWR-03 Multi



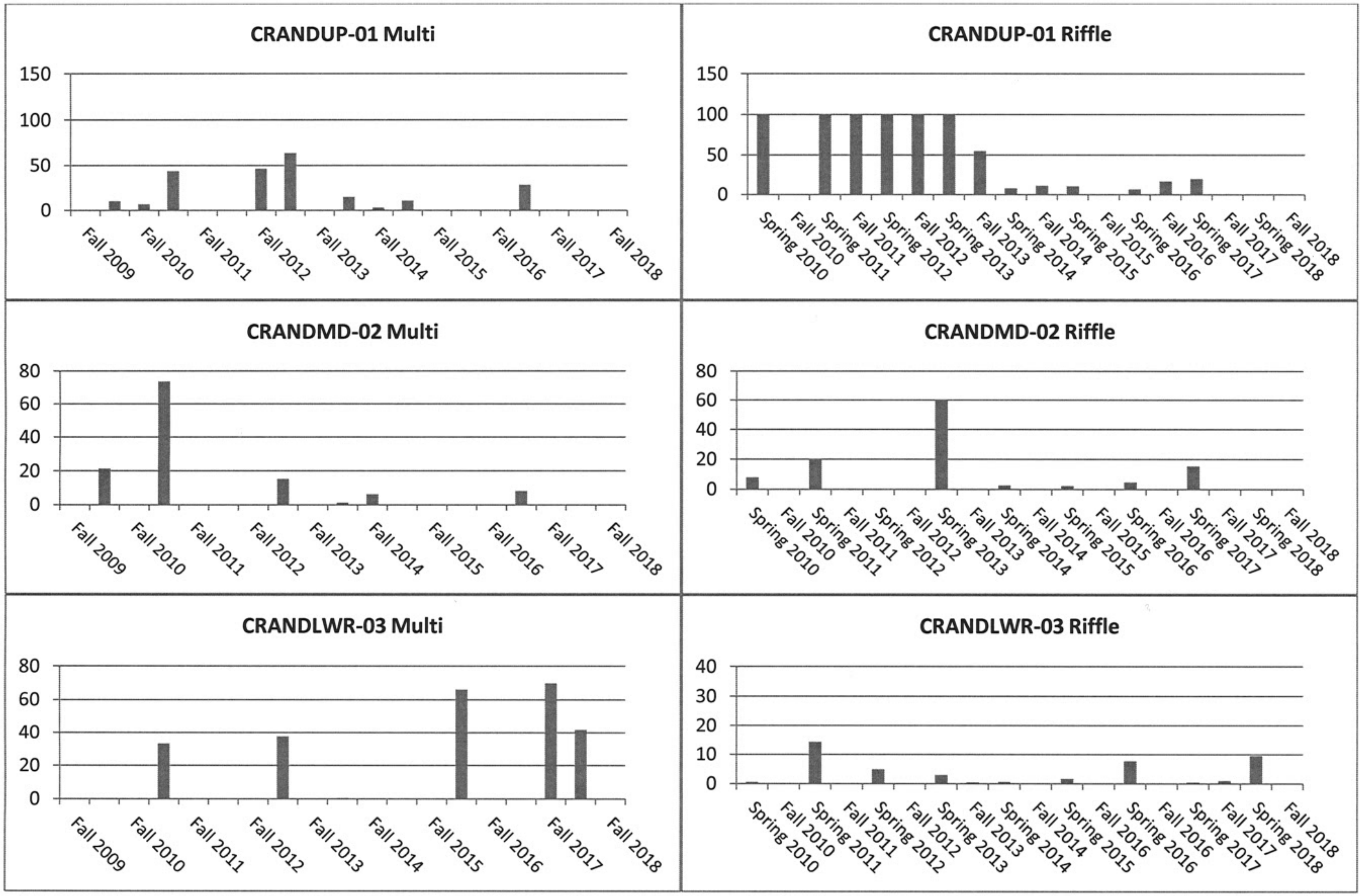
CRANDLWR-03 Riffle



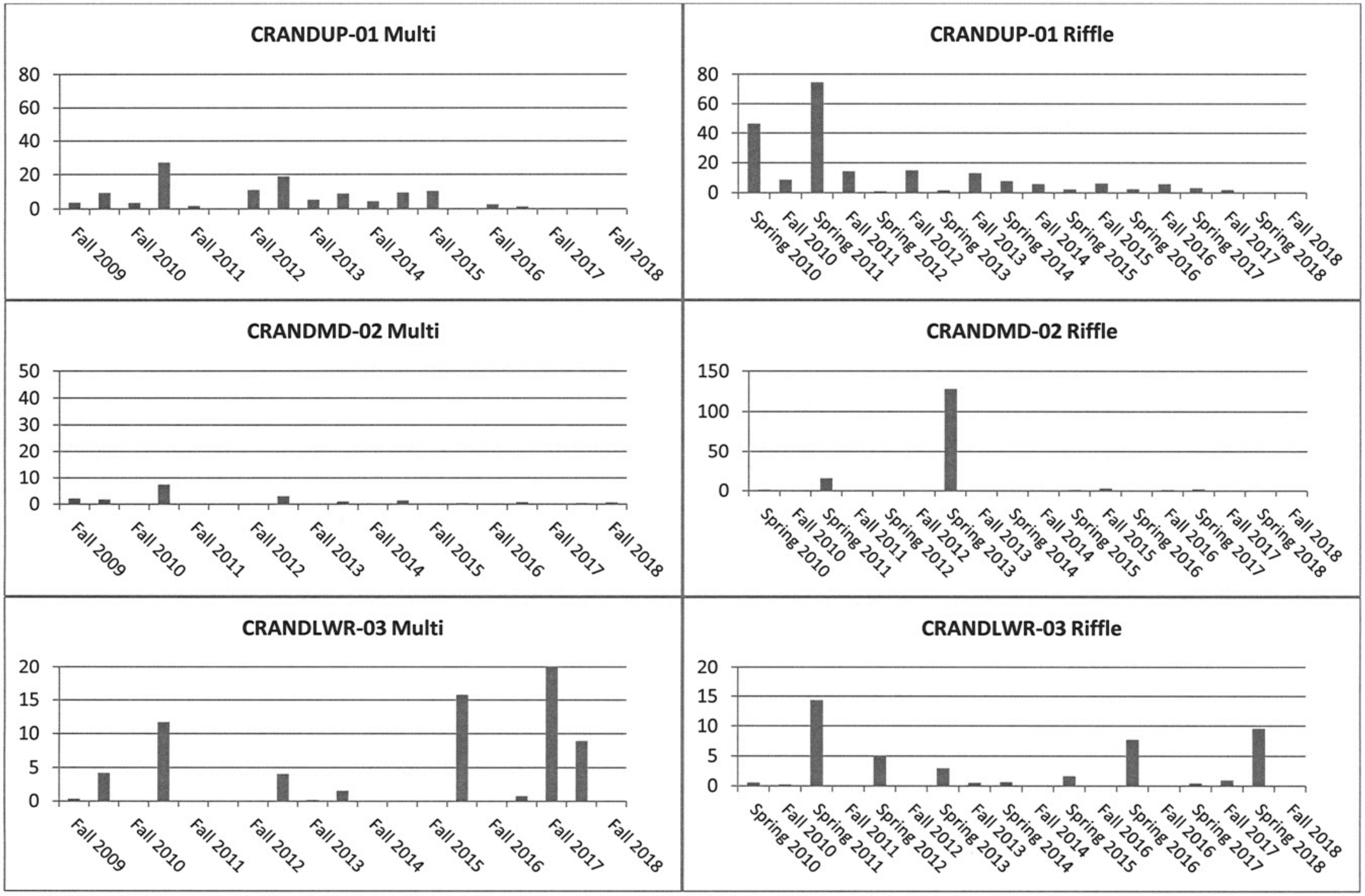
Figures 21c. Percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2018



Figures 22c. Percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2018



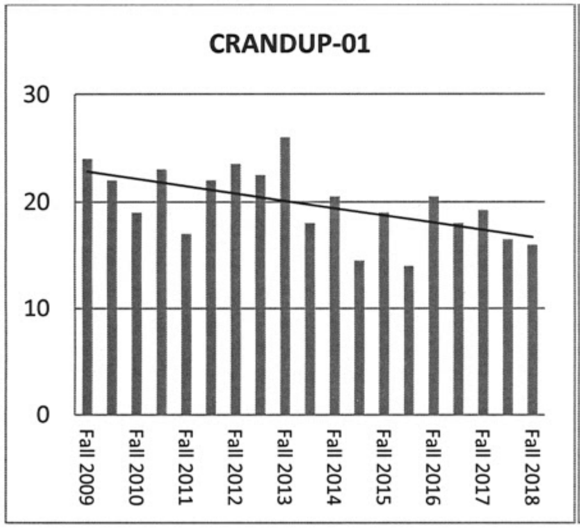
Figures 23c. Percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2018

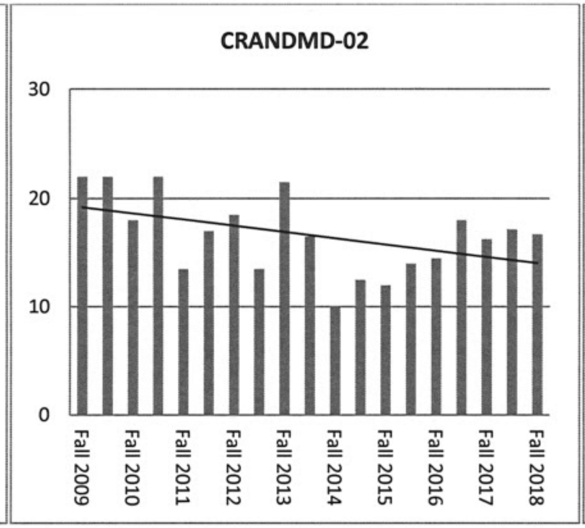


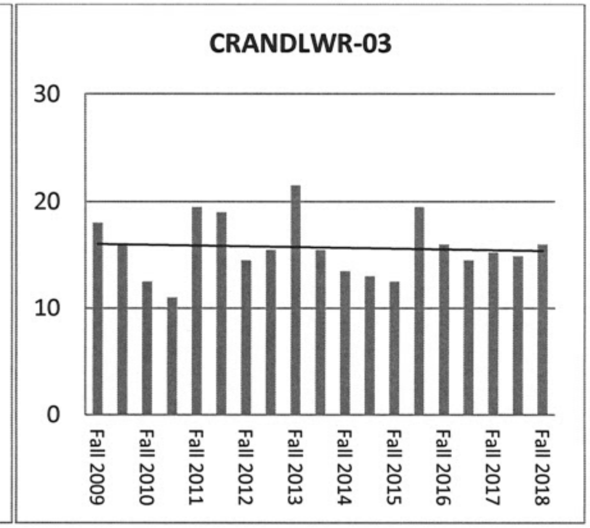
APPENDIX D

MACROINVERTEBRATE FIGURES FALL 2009- FALL 2018 AVERAGED

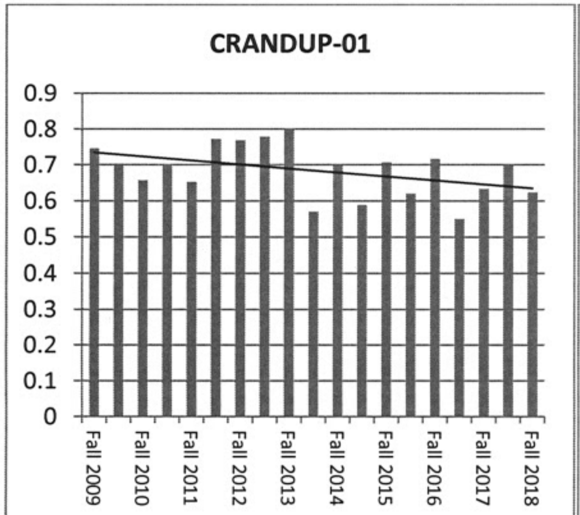
Figures 1d. Average richness in each reach from Fall 2009-Fall 2018

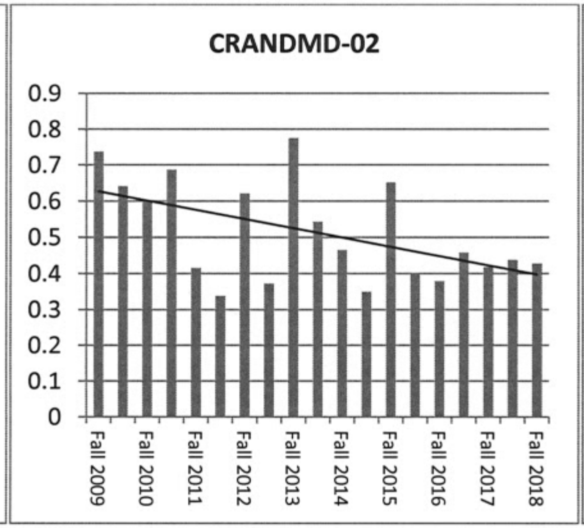


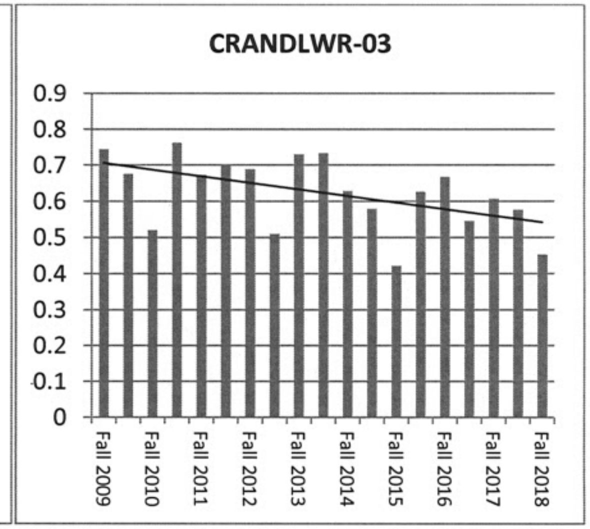




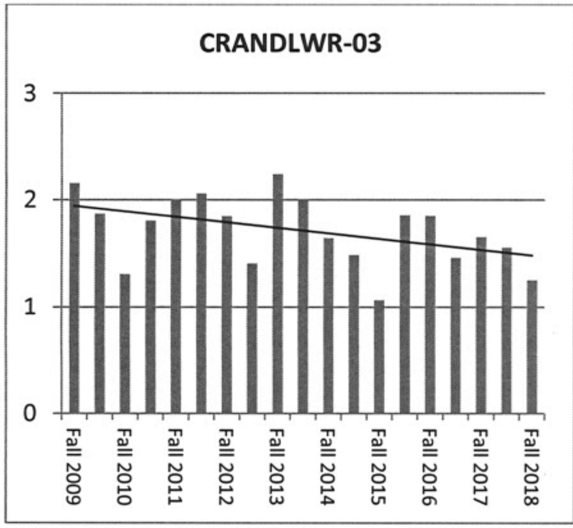
Figures 2d. Average evenness in each reach from Fall 2009-Fall 2018

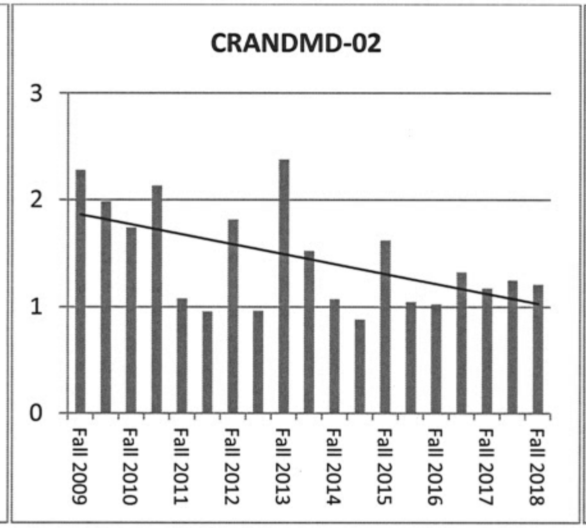


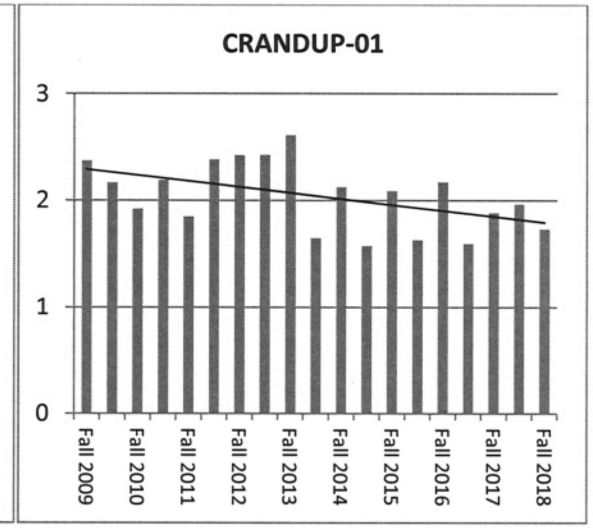




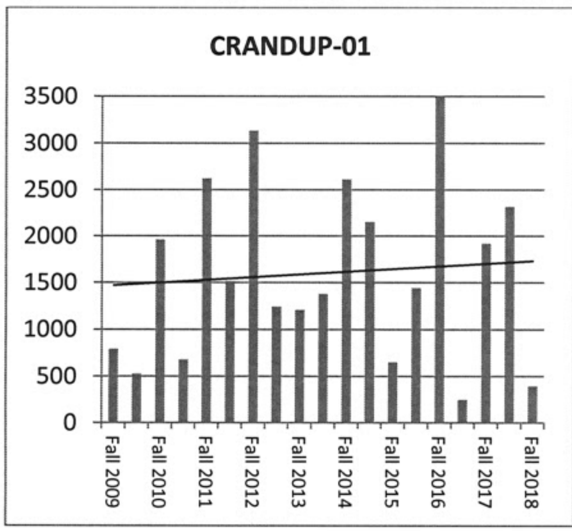
Figures 3d. Average Shannon's Diversity in each reach from Fall 2009-Fall 2018

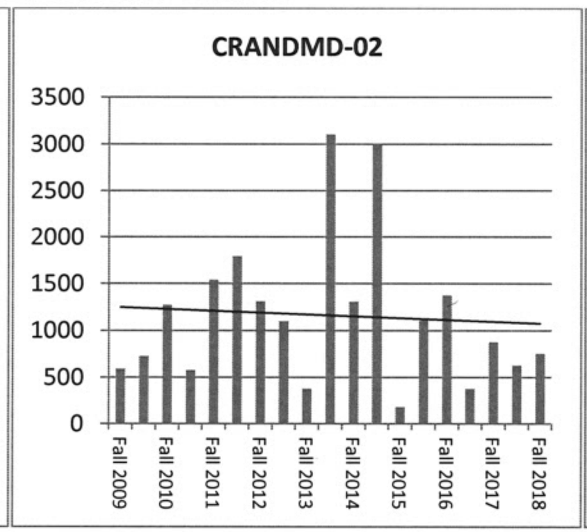


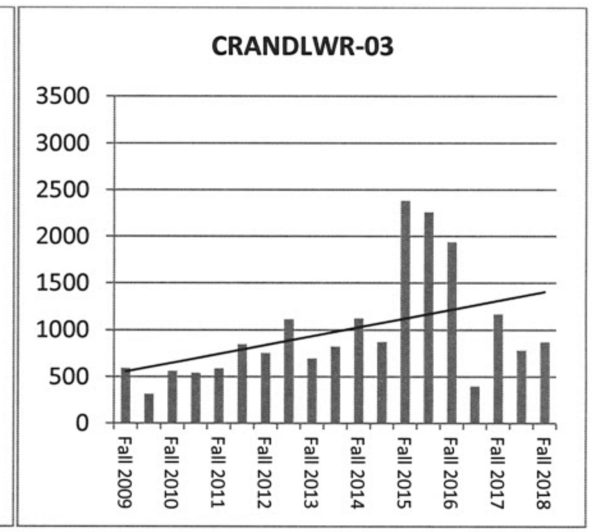




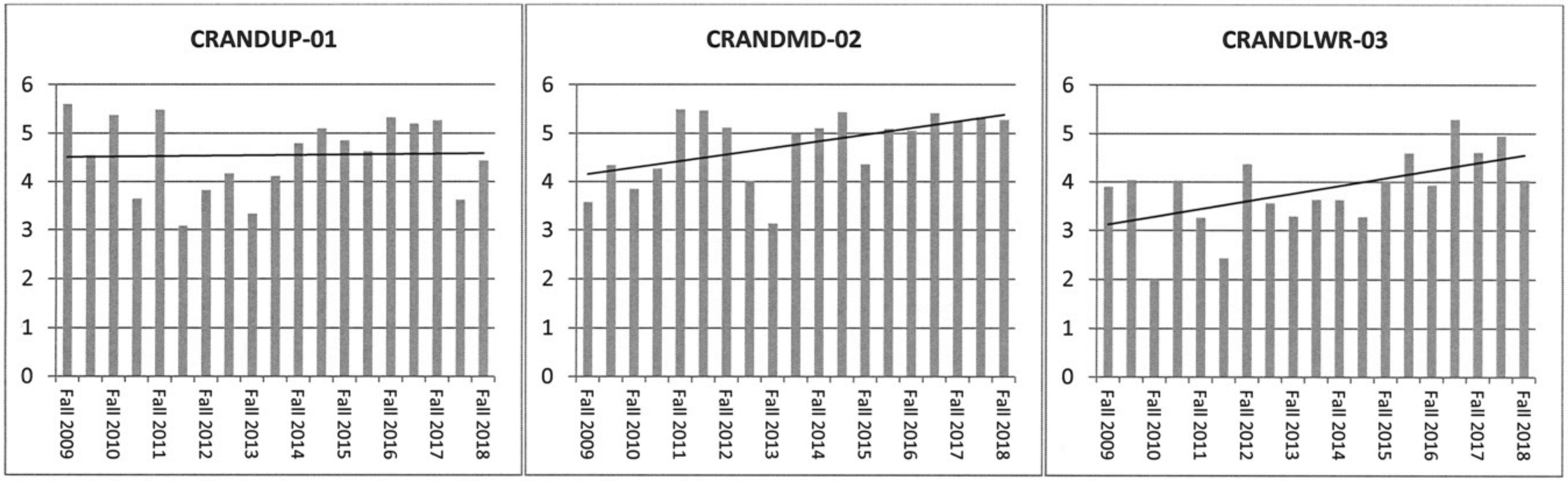
Figures 4d. Average abundance in each reach from Fall 2009-Fall 2018





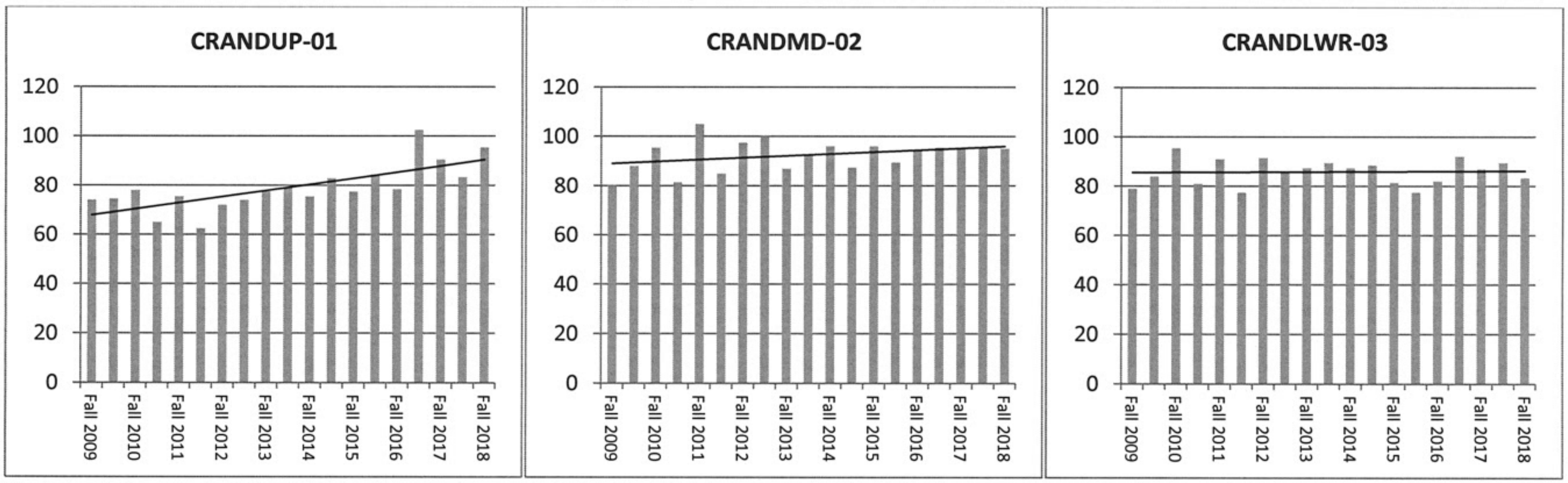


Figures 5d. Average Hilsenhoff Biotic Index in each reach from Fall 2009-Fall 2018*



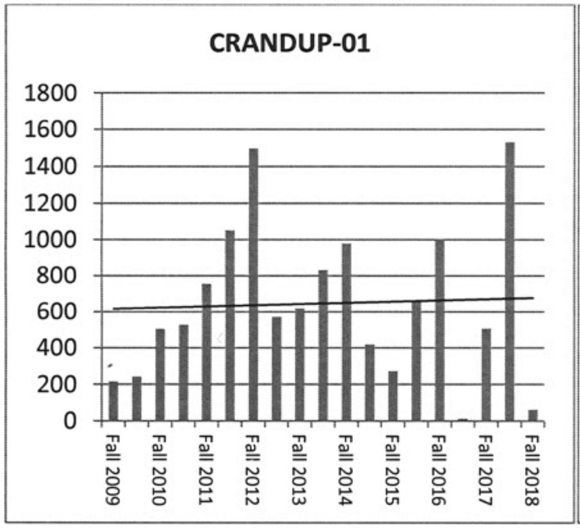
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

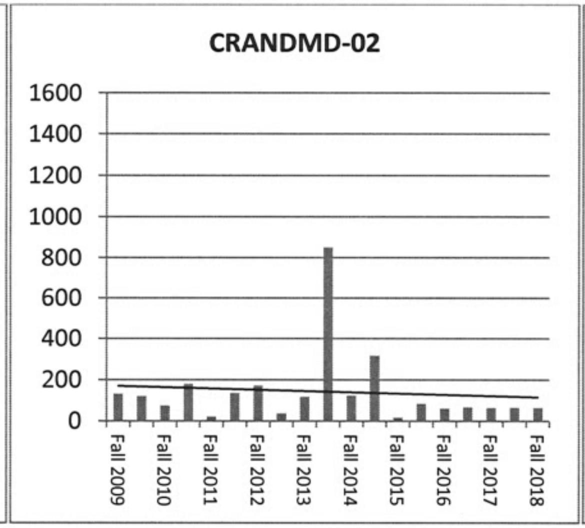
Figures 6d. Average USFS community tolerant quotient (CTQd) in each reach from Fall 2009-Fall 2018*

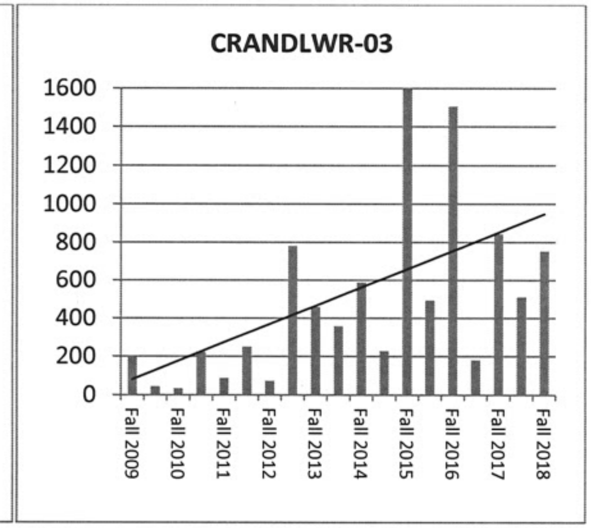


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

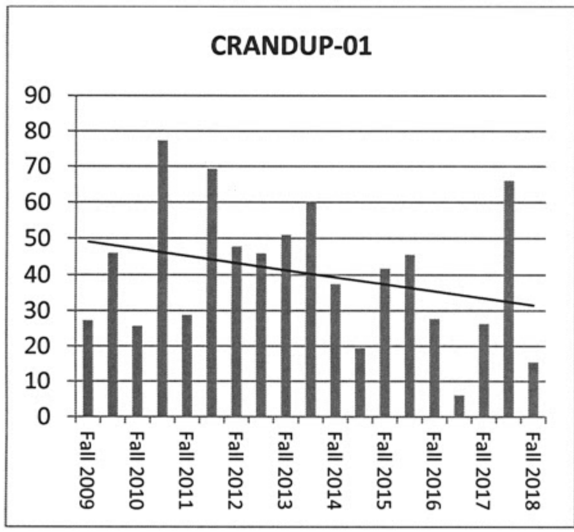
Figures 7d. Average EPT taxa abundance in each reach from Fall 2009-Fall 2018

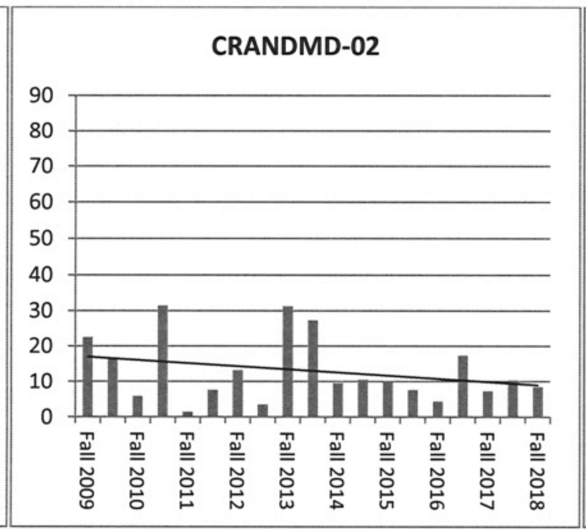


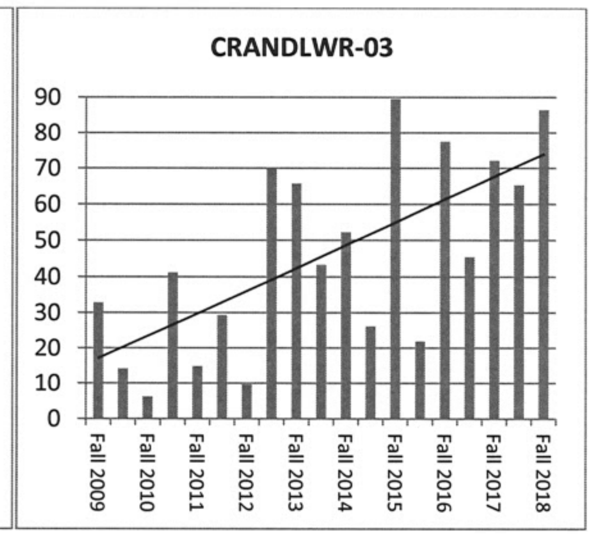




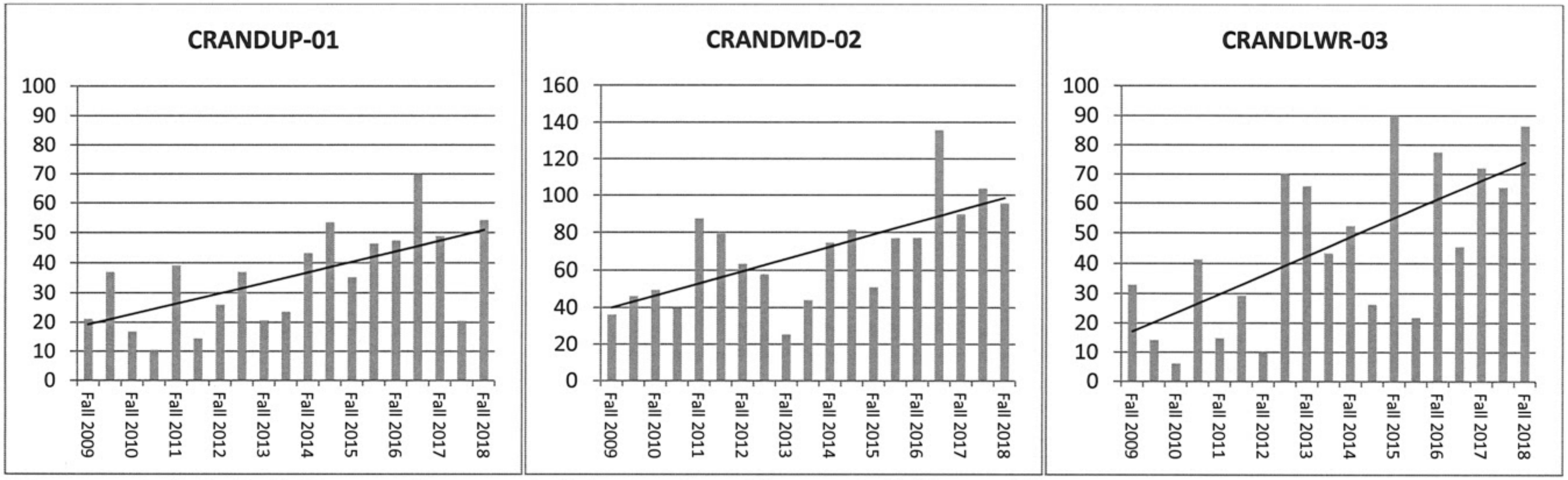
Figures 8d. Average percent EPT in each reach from Fall 2009-Fall 2018





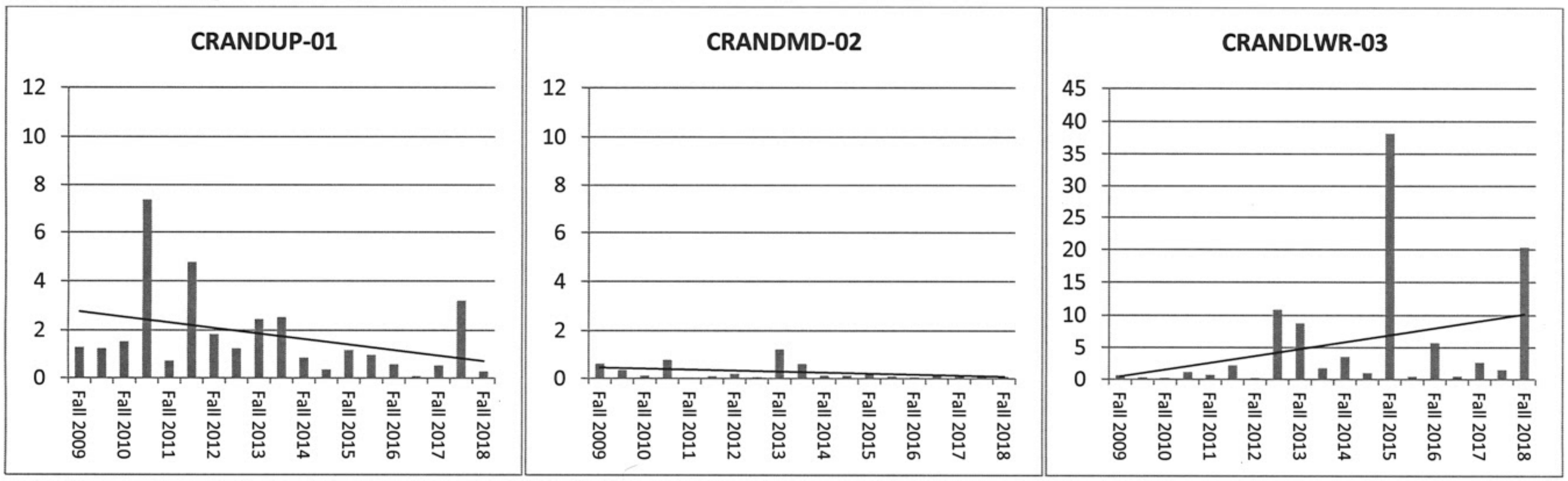


Figures 9d. Average percent Chironomids in each reach from Fall 2009-Fall 2018*

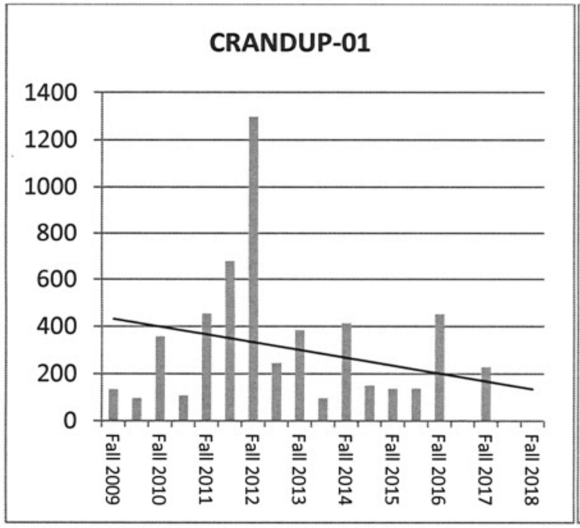


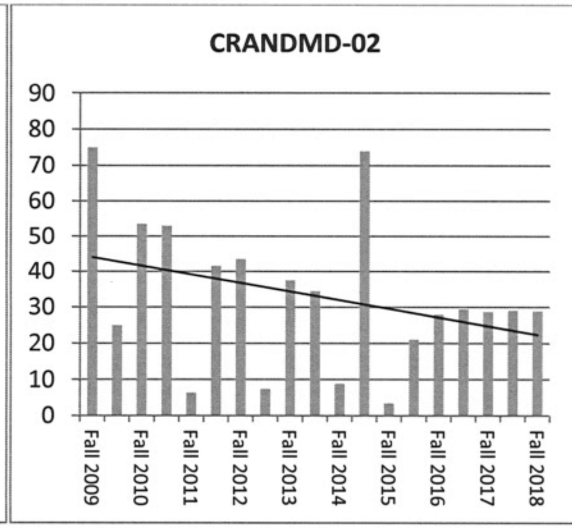
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

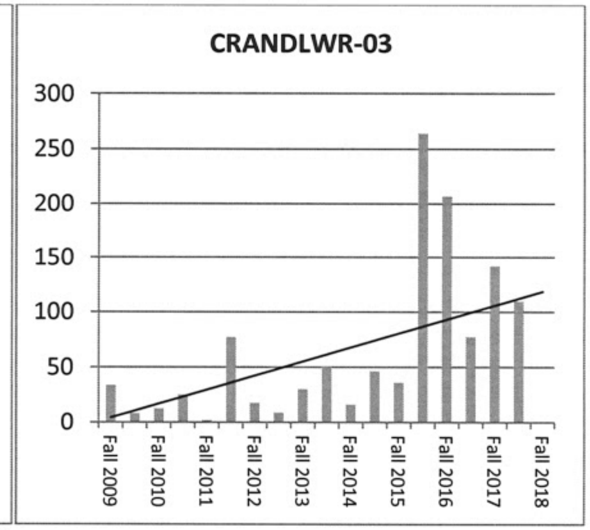
Figures 10d. Average ratio of EPT to Chironomids in each reach from Fall 2009-Fall 2018



Figures 11d. Average number of tolerant taxa in each reach from Fall 2009-Fall 2018*

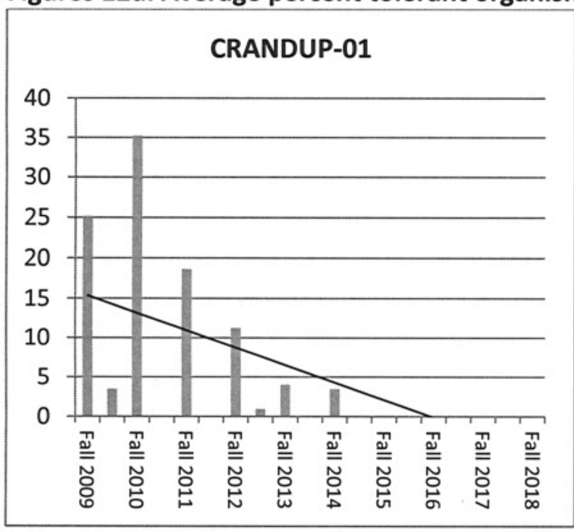


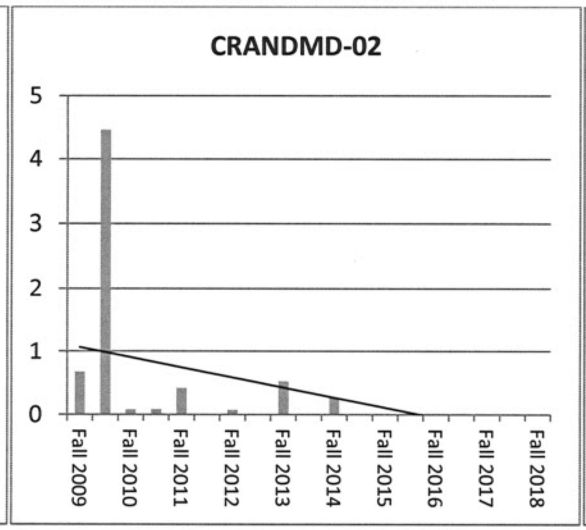


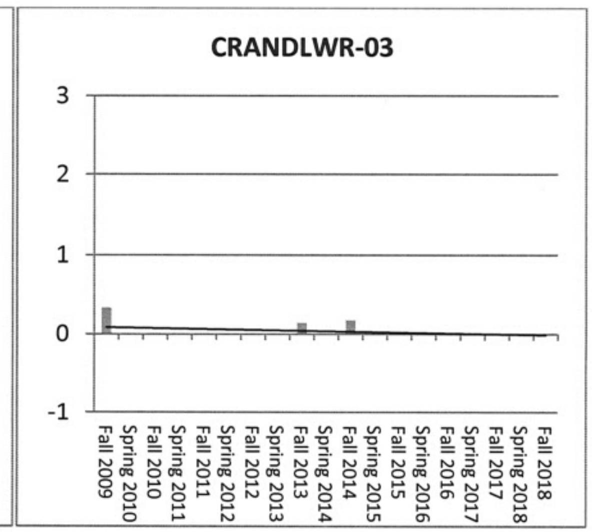


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 12d. Average percent tolerant organisms in each reach from Fall 2009-Fall 2018*

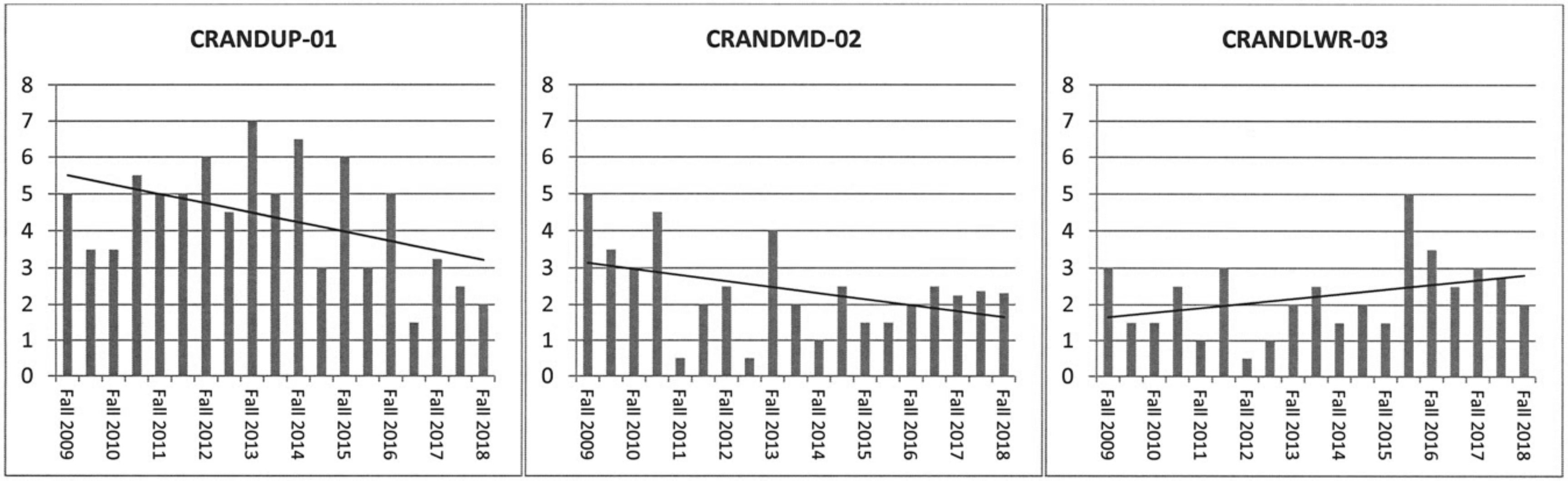




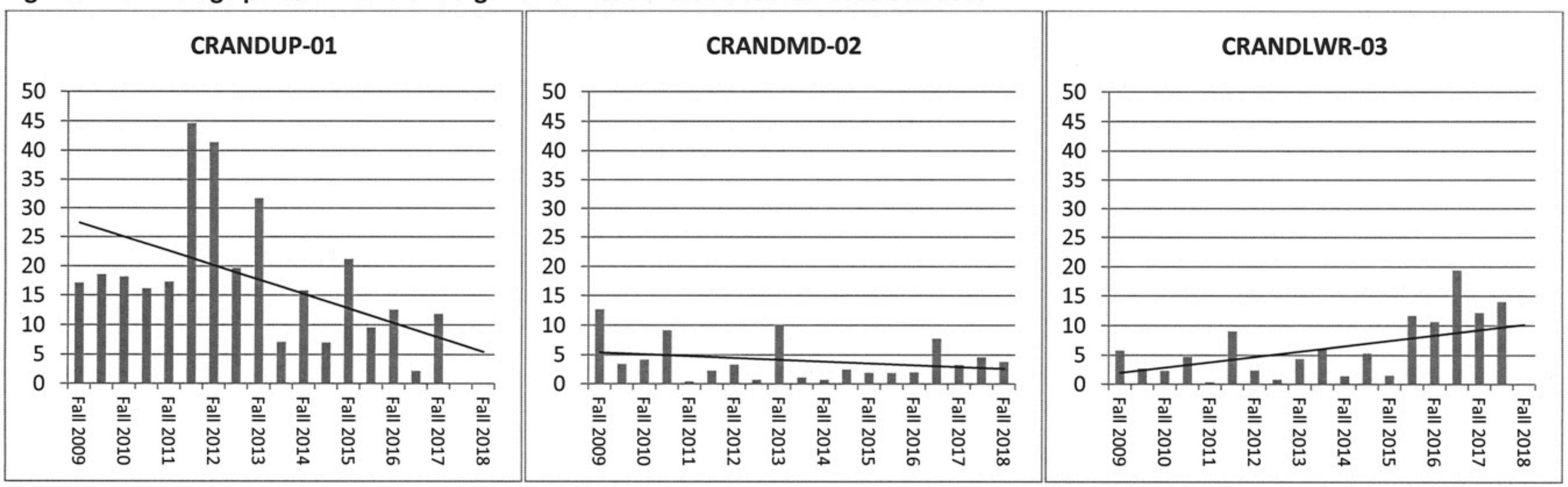


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

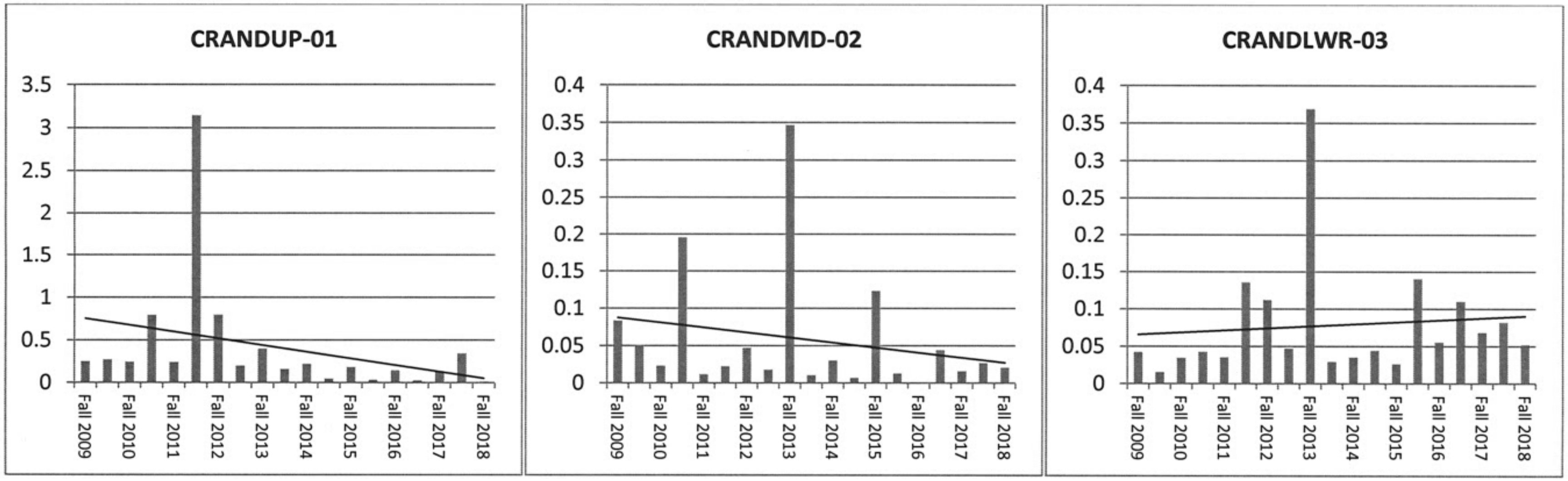
Figures 13d. Average number of intolerant taxa in each reach from Fall 2009-Fall 2018



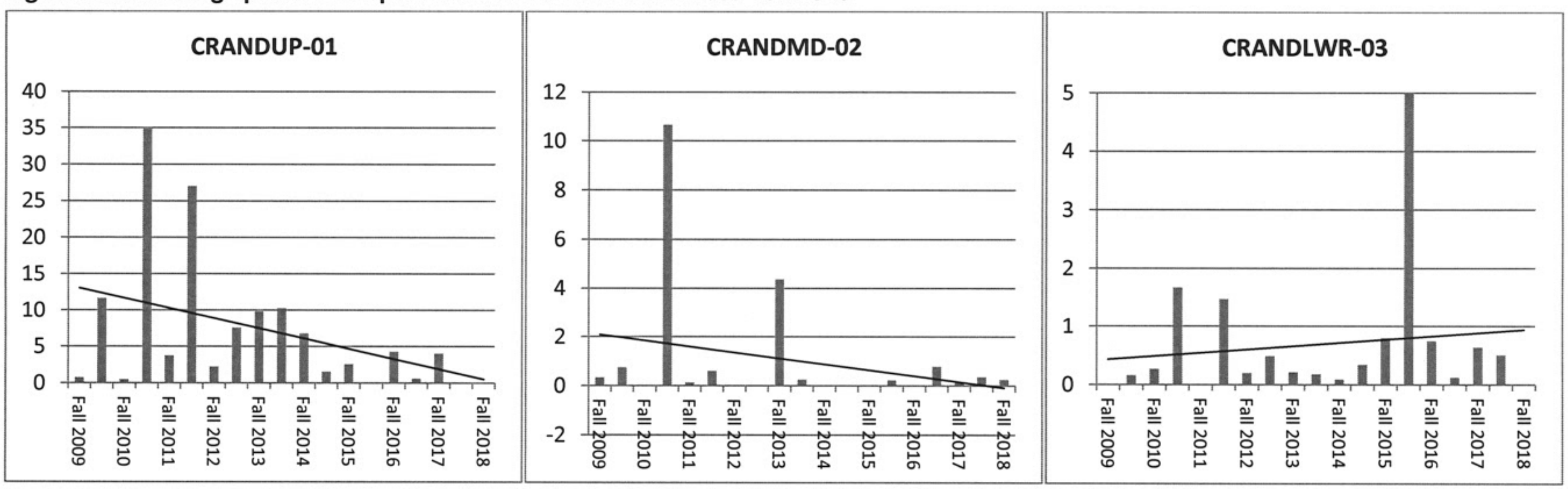
Figures 14d. Average percent intolerant organisms in each reach from Fall 2009-Fall 2018



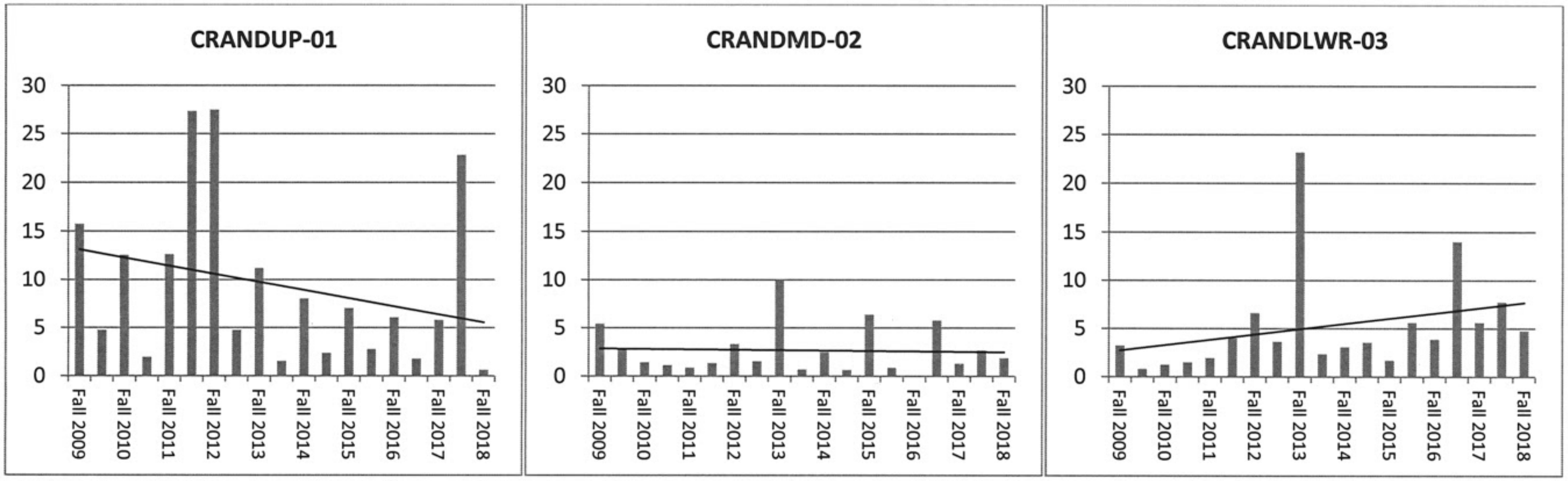
Figures 15d. Average ratio of specialist feeders to generalist feeders in each reach from Fall 2009-Fall 2018



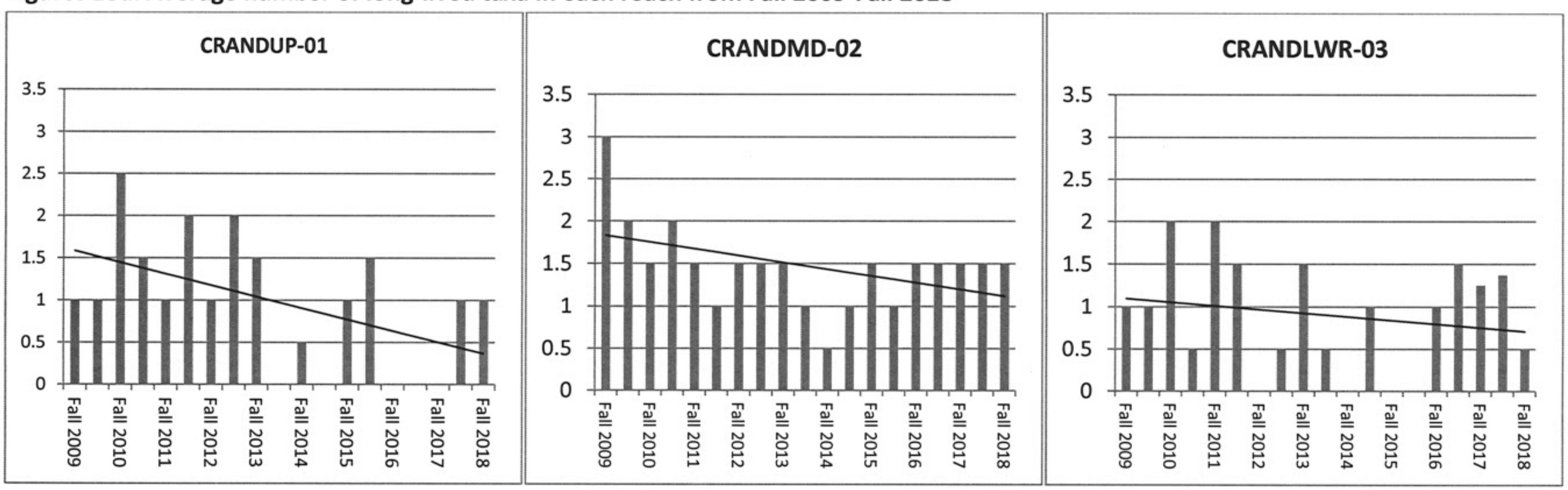
Figures 16d. Average percent scrapers in each reach from Fall 2009-Fall 2018



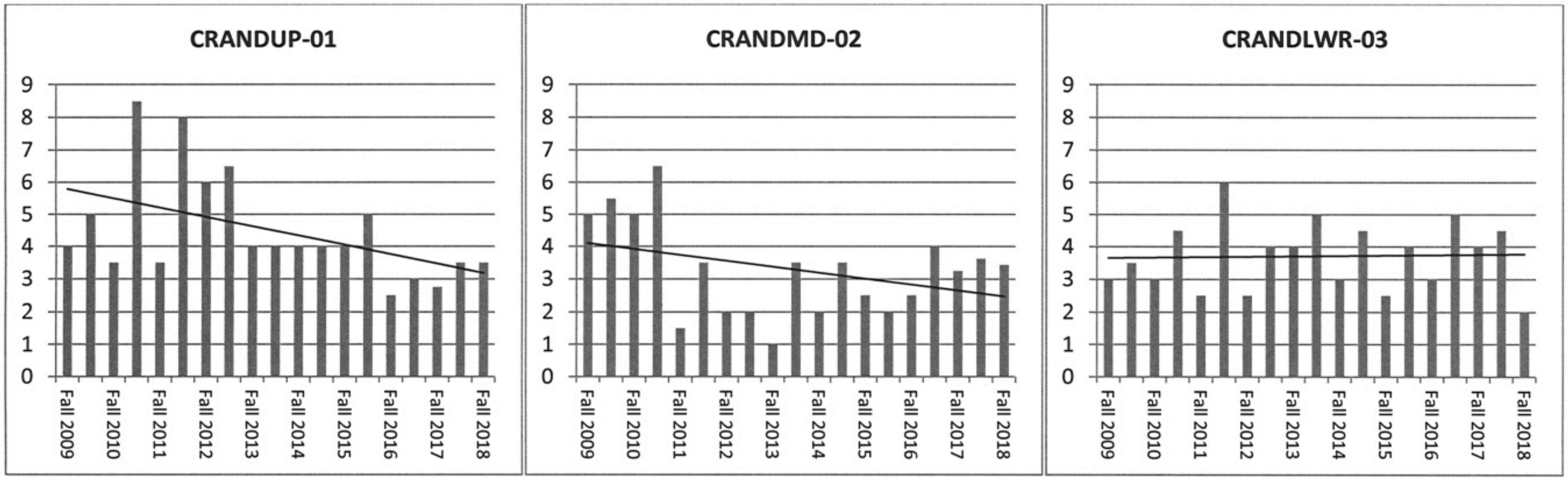
Figures 17d. Average percent shredders in each reach from Fall 2009-Fall 2018



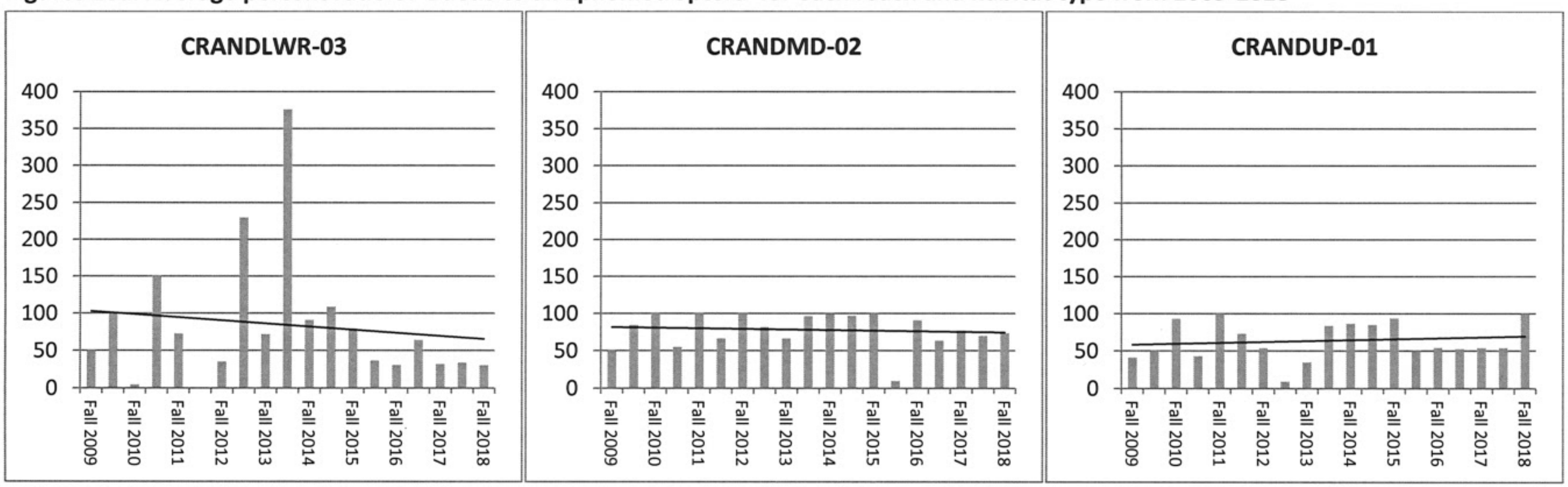
Figures 18d. Average number of long-lived taxa in each reach from Fall 2009-Fall 2018



Figures 19d. Average number of clinger taxa reach from Fall 2009-Fall 2018

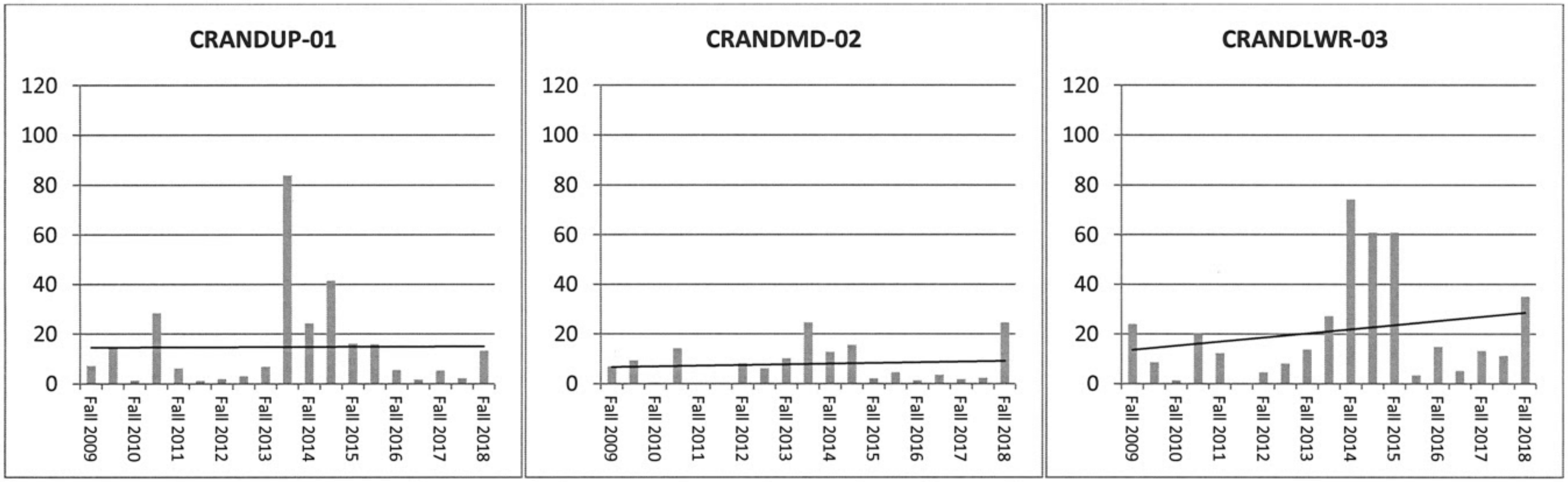


Figures 20d. Average percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2009-2018*



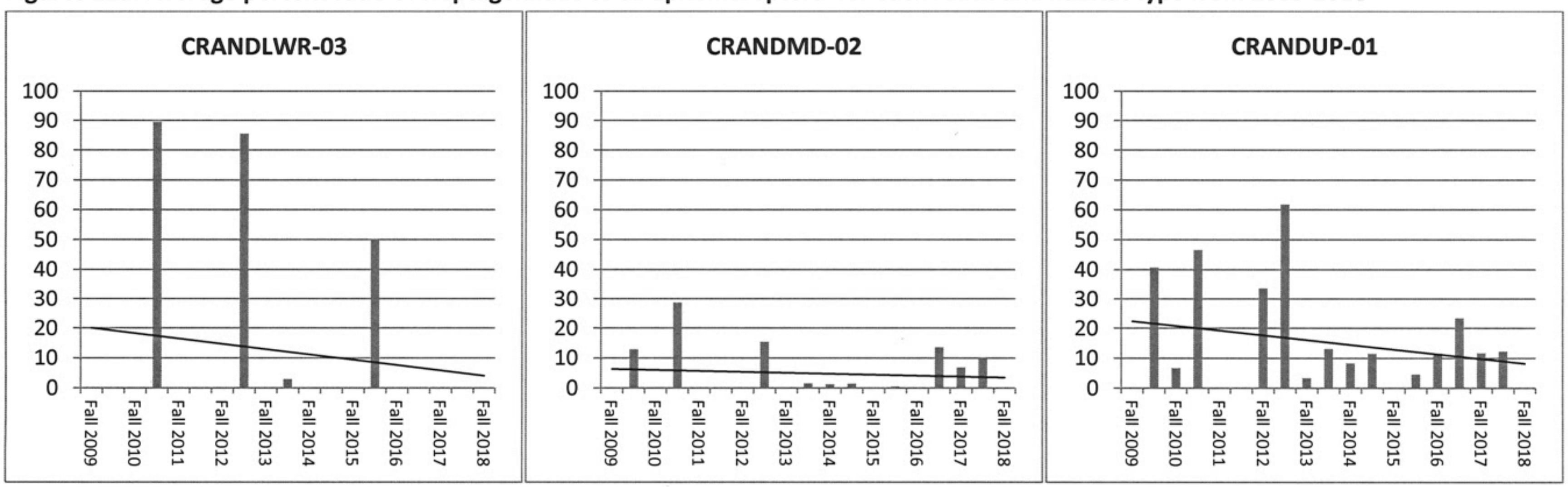
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 21d. Average percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2018*

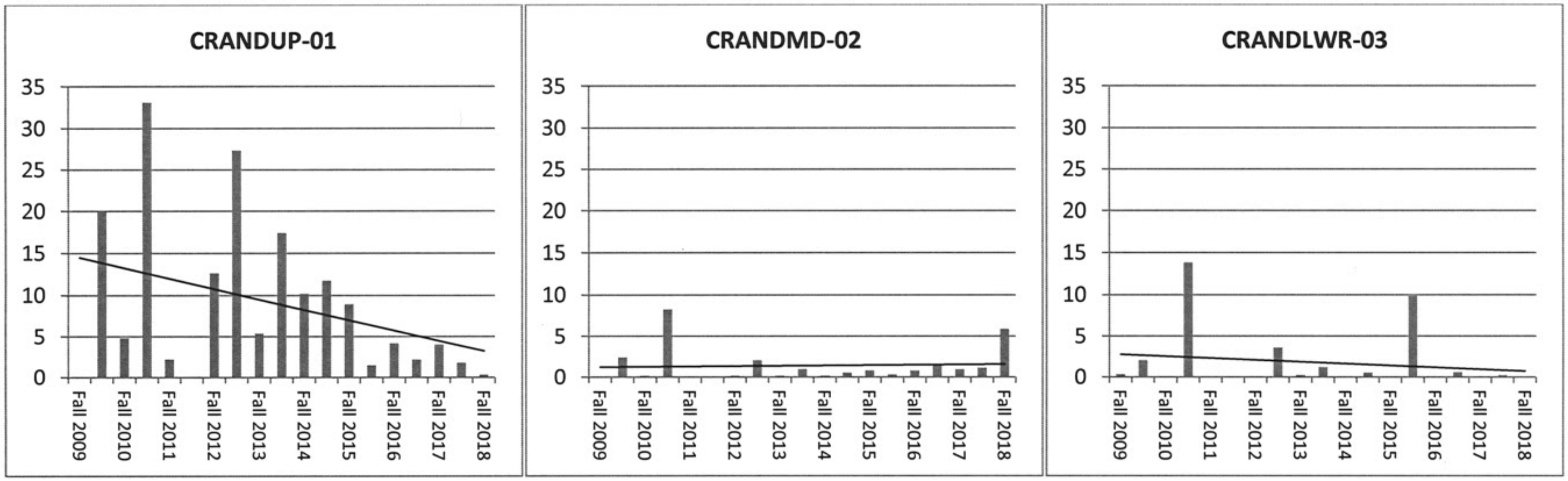


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 22d. Average percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2018



Figures 23d. Average percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2018



Appendix E

Macro Report USU Bug Lab

BLM/USU National Aquatic Monitoring Center (NAMC) Department of Watershed Sciences (WATS) - Utah State University 5210 Old Main Hill Logan, UT 84322-5210 http://www.usu.edu/buglab/

Report prepared by:
Trip Armstrong: 760.709.1210 / trip.armstrong@usu.edu

Report Table of Contents

Metadata
- Contact
- Worksheet
- Metrics
- References

Metrics
Species Matrix (Raw)
Species Matrix (Standardized)

Excel Worksheet Name	Worksheet Description
Metrics	Common metrics used to assess freshwater biological integrity, as well as operational taxonomic units (OTUs; sensu Cuffney et al. 2007) and a fixed indicated with an asterisk. NAMC OTU standardization uses the method o coarser levels. We are able to standardize your data to custom OTUs and, well as references, can be obtained by contacting NAMC and will soon be **This report was generated with the following settings - OTUs: OTUCODE**
Species Matrix (Raw)	Raw taxonomic and abundance data for sampled sites. Abundance data is individuals per sample for qualitative samples. Note that the taxonomic d redundancy likely exists in the taxonomic hierarchy.
Species Matrix (Standardized)	Taxonomic and abundance data (Species matrix) for sampled sites that ha data has not been standardized to a fixed count as in the 'Standardized M the estimated number per sample for qualitative samples.

Description of the fields contained in the 'Metrics' worksheet. A more detailed explanation of each metric is a

Category	Column Name	Explanation
Collection information	SampleID	NAMC unique tracking number

	Station (NAMC)	NAMC station tracking id
	Station (Customer)	Station abbreviation provided by the customer
	Waterbody	Specific location name
	County	Administrative boundary
	State	Administrative boundary
	Latitude	Y coordinate in decimal degree units
	Longitude	X coordinate in decimal degree units
	Collection Date	Date of sampling event
	Habitat Sampled	Microhabitat or channel unit(s) where sample(s) was taken. Values are restricted to predetermined values as specified in the PDF metadata.
	Collection Method	Method used to collect sample. Values are restricted to predetermined values as specified in the PDF metadata.
	Field Notes	Field notes provided by customer
	Lab Notes	Laboratory processing notes, particularly regarding condition of received samples and QAQC
	Area Sampled	Total area sampled in square meters
Laboratory Processing	Field Split	% sample submitted for processing
	Lab Split	% of sample processed to obtain 600 random individuals (if present)
	Split Count	# of organisms randomly subsampled from [Lab Split] for identification
	Fixed count	# of computationally resampled organisms
	Big Rare Count	# of "big and rare" organisms selected NON-RANDOMLY for identification from the entire submitted sample
Richness (metrics summarizing all unique	Richness	# of unique taxa, standardized to OTU

taxa in a sample)	Abundance	Estimated # number of individuals per unit area (m^2) for quantitative samples OR the estimated number per sample for qualitative samples.
	Shannon's Diversity	Measure of richness and evenness (based on relative abundance of each species); weighted toward rare species
	Simpson's Diversity	Measure of richness and evenness (based on relative abundance of each species); weighted toward common species
	Evenness	Measure of relative abundance indicative of taxa dominance
	# of EPT Taxa	Richness of Ephemeroptera, Plecoptera, and Trichoptera taxa
	EPT Taxa Abundance	Abundance of Ephemeroptera, Plecoptera, and Trichoptera taxa
Dominance Metrics (metrics summarizing all most abundant taxa in a sample)	Dominant Family	Taxonomic family with the highest abundance
	Abundance of Dominant Family	Abundance of dominant family
	Dominant Taxa	Individual taxa with the highest abundance
	Abundance of Dominant Taxa	Abundance of dominant taxa
Tolerance Indices (indices based on the indicator species concept in which taxa are assigned tolerance values)	Hilsenhoff Biotic Index	Abundance-weighted average of family-level pollution tolerances
	# of Intolerant Taxa	# of taxa with an HBI score <= 2
	Intolerant Taxa abundance	Abundance of taxa with an HBI score <= 2
	# of Tolerant Taxa	# of taxa with an HBI score>=8
	Tolerant Taxa abundance	Abundance of taxa with an HBI score >=8
	USFS Community Tolerance Quotient (d)	Dominance weighted community tolerance quotient

Functional Feeding Groups (classification of organisms based on morphological or behavioral adaptations for where and how food is acquired)	# of shredder taxa	# of taxa utilizing living or decomposing vascular plant tissue and CPOM
	Shredder Abundance	Abundance of taxa utilizing vascular plant tissue and CPOM
	# of scraper taxa	# of taxa utilizing periphyton, particularly algae and diatoms
	Scraper abundance	Abundance of taxa utilizing periphyton, particularly algae and diatoms
	# of collector-filterer taxa	# of taxa utilizing FPOM in the water column
	Collector-filterer abundance	Abundance of taxa utilizing FPOM in the water column
	# of collector-gatherer taxa	# of taxa utilizing FPOM from benthic deposits
	Collector-gatherer abundance	Abundance of taxa utilizing FPOM from benthic deposits
	# of predator taxa	# of taxa utilizing living animal tissue
	Predator abundance	Abundance of taxa utilizing living animal tissue
Functional Traits (metrics based on morphological and life history traits)	# of clinger taxa	# of taxa with fixed retreats or other strategies for clinging to rocks
	"# of" Long-lived Taxa	# of taxa with 2 to 3 year life cycles
Compositional Metrics (richness and abundance of various taxonomic groups)	# of Ephemeroptera taxa	
	Ephemeroptera abundance	
	# of Plecoptera taxa	
	Plecoptera abundance	
	# of Trichoptera taxa	
	Trichoptera abundance	
	# of Coleoptera taxa	
	Coleoptera abundance	
	# of Elmidae taxa	
	Elmidae abundance	
	# of Megaloptera taxa	
	Megaloptera abundance	
	# of Diptera taxa	
	Diptera abundance	
	# of Chironomidae taxa	
	Chironomidae abundance	
	# of Crustacea taxa	
	Crustacea abundance	
	# of Oligochaete taxa	

	Oligochaete abundance	
	# of Mollusca taxa	
	Mollusca abundance	
	# of Insect taxa	
	Insect abundance	
	# of non-insect taxa	
	Non-insect abundance	

References

Barbour, M.T. et al., 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphytor
Cuffney, T. F., Bilger, M.D. & Haigler, A.M., 2007. Ambiguous taxa: effects on the characterization and interpr
Cuffney, T. F et al., 1993. Methods for collecting benthic invertebrate samples as part of the National Water-(
Hilsenhoff, W.L., 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist, 20(1)
Hilsenhoff, W.L., 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of
Karr, J.R. & Chu, E.W., 1999. Restoring life in running waters: better biological monitoring, Island Press.
Krebs, C.J., 1999. Ecological methodology, Benjamin/Cummings.
Ludwig, J.A. & Reynolds, J.F., 1988. Statistical ecology: a primer on methods and computing, Wiley-Interscien
Merritt, R.W., Cummins, K.W. & Berg, M.B., 2008. An Introduction to the Aquatic Insects of North America 4t
Moulton, S. et al., 2000. Methods of analysis by the US Geological Survey National Water Quality Laboratory-
Vinson, M.R. & Hawkins, C.P., 1996. Effects of sampling area and subsampling procedure on comparisons of t
Winget, R.N. & Mangum, F.A., 1979. Biotic condition index: integrated biological, physical, and chemical strea

Report prepared for:

Customer contact:	Mel Coonrod
Customer:	EIS Environmental and Engin
Customer Address :	31 N Main Street
Customer City, State, Zip:	Helper
Customer Phone:	435-472-3814
Customer Email:	eisec@preciscom.net

basic field and lab processing information. Note that values for richness based metrics
count (i.e., rarefaction) of 300, but density metrics are based on the raw taxa list. Stan
f removing individuals identified to the coarser taxonomic resolution or merging finer l
/or fixed counts if provided, although additional charges may apply. A more detailed ex
available on our website.

_UTDEQ15; Fixed Count: 400.

the estimated number of individuals per square meter for quantitative samples OR the
ata in this worksheet **has not been standardized to operational taxonomic units (OTU**

ıs been standardized to Operational Taxonomic Units (OTUs) but not standardized to fix
etrics worksheet'. Also, abundance data is the estimated number per square meter for

available on our website (http://usu.edu/buglab/SampleProcessing/ResultsAndReports/

Predicted response to increasing perturbation (Barbour et al. 1999)	**Calculation**	**Standardized (OTU and Rarefication)**
NA	NA	NA

NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	
NA	NA	NA
Decrease	$[\text{Richness}]_{\text{UniqueTaxa}}$	Y

Increase or decrease	(([Split Count]* (100/[Lab Split])) + [Big_Rare Count]) *(100/[Field Split]) *(1/[Area Sampled])	N
Decrease	$-\sum([\text{Relative Abundance}]_{taxa} * \ln([\text{Relative Abundance}]_{taxa}))$	Y
Decrease	$1 - [\text{Simpson's Diversity}] = 1 - \sum([\text{Relative Abundance}]_{taxa})^2$	Y
Decrease	[Shannon's Diversity]/ln([Richness])	Y
Decrease	$[\text{Richness}]_E + [\text{Richness}]_P + [\text{Richness}]_T$	Y
Decrease	$[\text{Abundance}]_E + [\text{Abundance}]_P + [\text{Abundance}]_T$	N
NA	NA	N
Increase	$[\text{Abundance}]_{\text{dominant family}}$	N
NA	NA	N
Increase	$[\text{Abundance}]_{\text{dominant taxa}}$	N
Increase	$\sum([\text{Abundance}]_{taxa} * [\text{Tolerance}]_{taxa}) / [\text{Abundance}]_{Total}$	Y
Decrease	$[\text{Richness}]_{intolerant}$	Y
Decrease	$[\text{Abundance}]_{intolerant}$	N
Increase	$[\text{Richness}]_{tolerant}$	Y
Increase	$[\text{Abundance}]_{tolerant}$	N
Increase	$\sum([\text{Tolerance Quotient}] * \log([\text{Abundance}]_{taxa})) / \sum \log([\text{Abundance}]_{taxa})$	Y

Decrease	$[Richness]_{shredder}$	Y
Decrease	$[Abundance]_{shredder}$	N
Decrease	$[Richness]_{scraper}$	Y
Decrease	$[Abundance]_{scraper}$	N
Variable	$[Richness]_{collector\text{-}filterer}$	Y
Variable	$[Abundance]_{collector\text{-}filterer}$	N
Variable	$[Richness]_{collector\text{-}gatherer}$	Y
Variable	$[Abundance]_{collector\text{-}gatherer}$	N
Decrease	$[Richness]_{predator}$	Y
Decrease	$[Abundance]_{predator}$	N
Decrease	$[Richness]_{clinger}$	Y
Decrease	$[Richness]_{long\text{-}lived}$	Y
Decrease	$[Richness]_{Ephemeroptera}$	Y
Decrease	$[Abundance]_{Ephemeroptera}$	N
Decrease	$[Richness]_{Plecoptera}$	Y
Decrease	$[Abundance]_{Plecoptera}$	N
Decrease	$[Richness]_{Trichoptera}$	Y
Decrease	$[Abundance]_{Trichoptera}$	N
Variable	$[Richness]_{Coleoptera}$	Y
Variable	$[Abundance]_{Coleoptera}$	N
Decrease	$[Richness]_{Elmidae}$	Y
Decrease	$[Abundance]_{Elmidae}$	N
Variable	$[Richness]_{Megaloptera}$	Y
Variable	$[Abundance]_{Megaloptera}$	N
Variable	$[Richness]_{Diptera}$	Y
Variable	$[Abundance]_{Diptera}$	N
Increase	$[Richness]_{Chironomidae}$	Y
Increase	$[Abundance]_{Chironomidae}$	N
Variable	$[Richness]_{Crustacea}$	Y
Variable	$[Abundance]_{Crustacea}$	N
Increase	$[Richness]_{Oligochaeta}$	Y

Increase	$[\text{Abundance}]_{\text{Oligochaeta}}$	N
Variable	$[\text{Richness}]_{\text{Mollusca}}$	Y
Variable	$[\text{Abundance}]_{\text{Mollusca}}$	N
Decrease	$[\text{Richness}]_{\text{Insect}}$	Y
Decrease	$[\text{Abundance}]_{\text{Insect}}$	N
Increase	$[\text{Richness}]_{\text{Non-insect}}$	Y
Increase	$[\text{Abundance}]_{\text{Non-insect}}$	N

ı, benthic macroinvertebrates, and fish. EPA 841-B-99-002, US Environmental Protectioı
etation of invertebrate assemblages. Journal of the North American Benthological Socie
Quality Assessment Program, US Geological Survey, http://water.usgs.gov/nawqa/protc
), p.31–40.
the North American Benthological Society, 7(1), p.65–68.

ce, http://books.google.com/books?hl=en&lr=&id=sNsRYBixkpcC&oi=fnd&pg=PA3&dq=
h ed., Kendall Hunt Publishing.
processing, taxonomy, and quality control of benthic macroinvertebrate samples, US G
axa richness among streams. Journal of the North American Benthological Society, 15(3
ım parameters for management, US Department of Agriculture, Forest Service, Intermo

ɛering Consulting

UT 84526

are standardized to
dardized metrics are
ɛvel identifications to
planation of each metric, as

: estimated number of
;), thus considerable

:ed count. Please note that
quantitative samples OR is

/#item=85).

Reference
NA

NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
Cuffney et al. (1993), Moulton et al. (2000), Vinson and Hawkins (1996)
"
"
"
NA

NA
Ludwig and Reynolds (1988, equation 8.9, page 92)
Ludwig and Reynolds (1988, equation 8.6, page 91), Krebs (1999, equation 12.27-12.30)
Ludwig and Reynolds (1988, equation 8.11, page 93)
Barbour et al. (1999), Karr and Chu (1998)
"
NA
NA
NA
NA
Hilsenhoff (1987, 1988)
"
"
"
"
Winget and Mangum (1979)

Merritt et. al (2008)
"
"
"
"
"
"
"
"
"
Karr and Chu (1998), Merritt et al. (2008)
"
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA

NA
NA
NA
NA
NA
NA
NA

ı Agency, Office of Water, Washington, DC, http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfı
:ty, 26(2), p.286–307.
ıcols/OFR-93-406/.

=ludwig+and+reynolds+1988.

eological Survey, http://nwql.usgs.gov/OFR-00-212.shtml.
), p.392–399.
ıuntain Region, Ogden, UT.

Crandall Canyon Mine Macroinvertebrate Study Spring 2019

March 2020

Prepared By:
EIS Environmental & Engineering Consulting
31 North Main Street * Helper, Utah 84526
Office – (435) 472-3814 * Toll free – (800) 641-2927 * Fax – (435) 472-8780
eisec@preciscom.net * www.EISenviro.com

Table of Contents

1.0 Introduction **1**

1.1 Background 1

2.0 Site locations and Description **2**

3.0 Methods **4**

3.1 Multi-Habitat Samples 4

3.2 Riffle Habitat Samples 5

3.3 Composite Sample Preparation 6

3.4 Sample Analysis 6

4.0 Results and Discussion **11**

4.1 Comparison of Targeted Riffle and Multi-habitat Samples 13

4.2 Spatial Variation in Macroinvertebrate Community 14

4.3 Temporal Variation in Macroinvertebrate Community 14

Conclusion **15**

References **16**

Authors **17**

Appendix A BugLab Report

Appendix B Macroinvertebrate Metrics Spring 2018 Data

Appendix C Macroinvertebrate Metrics Fall 2009-Spring 2018 Data

Appendix D Macroinvertebrate Metrics Fall 2009-Spring 2018 Averaged Data

Taxa Lists for Individual Samples

Appendix E Raw Data USU bug Lab

1.0 INTRODUCTION

EIS Environmental & Engineering Consulting (EIS) collected benthic macroinvertebrate samples from Crandall Creek on June 28th, 2019. The creek is located near Huntington, Utah. From 2009 to 2012, the creek was sampled by JBR Environmental Consultants, Inc. (JBR). Samples were collected from three different reaches of Crandall Creak. These three reaches were located directly upstream of the Crandall Canyon mine (CRANDUP-01), in the middle reach (CRANDMD-02) which is immediately downstream of the mine's discharge location, and a lower reach (CRANDLWR-03) located at the end of the creek before the confluence of Crandall Creek and Huntington Creek. Each reach was 150 meters long.

UtahAmerican Energy, Inc. (UEI) hired EIS to sample Crandall Creek's benthic macroinvertebrates and evaluate the subsequent data to determine whether the mine's discharge is affecting the creeks aquatic community and to what degree. EIS was provided with the data collected by JBR since September 2009 for use in discussing the trends and comparisons by The National Aquatic Monitoring Center (BugLab). Starting with the September 2011 dataset, the BugLab began reporting the richness-based metrics off of standardized results. This generally results in a lesser value for these metrics when compared to data prior to this change in calculation methodology. Therefore there were some discrepancies within the data provided by the BugLab and what JBR had reported prior to 2011 due to the lab switching to a standardized fixed count which allows for better comparison between samples. The attached tables, charts, and graphs (Appendices A-C) were all computed with the revised historical data (personal communication with BugLab July 26th, 2013).

As stated in previous JBR reports, there were some changes to the sampling methodology and these changes were implemented in 2010. EIS also followed the new methodology that was addressed in JBR's June 2010 report (JBR 2010). This report is intended to continue to meet the Utah Division of Oil, Gas, and Mining (DOGM) for the biannual sampling and reporting.

1.1 Background

The Crandall Canyon Mine began discharging ground water in 1995 and continued until the mine was closed in 2007. The discharged water flowed into Crandall Creek with little or no treatment. The discharge was monitored for pollutants and limits were established by the Utah Division of Water Quality (UDWQ) and permitted through the Utah Pollution Discharge Elimination System. Without actively pumping out water from the mine after the closure, water began flowing from beneath the portal seals. The water contained higher concentrations of iron than permitted and flowed into the creek. The mine began iron treatments in 2010 and has reduced the concentration of iron in the discharged water to the limit set by UDWQ.

In 2009, DOGM required the mine to contract a qualified biologist to sample macroinvertebrates in Crandall Creek twice yearly (Spring and Fall) to monitor water quality and provide reports documenting the survey results. The first seven surveys were completed by JBR (JBR 2012). They included surveys from the Fall of 2009 until the Fall of 2012. EIS has since completed two surveys a year (Spring and Fall) starting in the Spring of 2013. This report provides the results of the Spring survey of 2019. The samples were collected June 28th, 2019. The samples were then shipped to the BugLab in Logan, Utah for processing, as per UDWQ requirements.

2.0 SITE LOCATIONS AND DESCRIPTION

The 3 reaches sampled are the same as previous surveys (JBR 2012). The downstream transect for the CRANDUP-01 reach is approximately 6 feet (2 meters) upstream from the flow measurement flume west of the mine site and extends approximately 500 feet (150 meters) upstream. Crandall Creek in this reach is narrow with dense riparian vegetation at the stream banks. The width of the creek in this reach is generally less than 3 feet (1 meter), except for various riffle-pools and beaver ponds. Substrate within this reach ranges from gravel to cobble. This reach has more riffle habitat than the other reaches and appeared to have a faster flow velocity. There were areas above the beaver dams with finer sediment substrate.

The upstream transect in the reach CRANDMD-02 is located approximately 16 feet (5 meters) downstream from the mine's discharge culvert and extends approximately 500 feet (150 meters) downstream. This reach has more open area between vegetation than the other reaches and the creek is wider than the CRANDUP-01 reach. There are several beaver dams and areas above the dams with fine sediment deposits. Substrate was generally fine to gravel sized rock.

The downstream transect in the CRANDLWR-03 reach is approximately 6 feet (2 meters) upstream from where the mine access road crosses the creek and extends approximately 500 feet (150 meters) upstream. Substrate was generally bedrock or fine sediment and gravel. The vegetation is denser along the stream banks than CRANDMD-02 and less dense than the stream bank in CRANDUP-01. The creek in the CRANDLWR-03 reach has a lower gradient and stream velocity than the other reaches.

CRANDUP-01 June 28th, 2019 – Upstream

CRANDMD-02 June 28th, 2019 – Upstream

CRANDLWR-03 June 28th, 2019 - Upstream

3.0 METHODS

The methods used for the survey are described by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program Field Operations Manual (EMAP 2006) and were modified as in previous sampling (JBR 2010). Representative samples were collected from multiple kick net samples throughout each reach to create a composite sample of each survey type, multi-habitat and riffle, for each reach.

One person would collect samples using a kick net, and another person would time the collection. A 1-foot wide D-frame kick net with 500-micron mesh was used to collect one sample from each location (transect or riffle). The net was placed securely on the stream bottom to close gaps along the bottom of the net and to prevent macroinvertebrates from passing under the net. While the net was held firmly with the opening facing upstream, a quadrat was visually estimated to be 1 net width wide and 1 net width long, approximately 1 foot squared, upstream of the positioned net. The quadrat was checked for larger organisms, such as snails. Loose rocks that were golf ball-sized or larger within the quadrat or at least half way within the quadrat were picked up and scrubbed to dislodge organisms so they were washed into the net. After scrubbing, the rocks were placed outside of the quadrat. Starting with the upstream end of the quadrat, the upper 1.5 to 2 inches (4 to 5 centimeters) of the substrate within the quadrat was kicked using feet and toes to dislodge organisms for 30 seconds. After the 30 seconds of kicking, the net was pulled out of the water and partially immersed in the stream to remove fine sediments and collect organisms at the bottom of the net. The net was then inverted and emptied into the appropriate composite sample bucket, i.e., multi-habitat or riffle. The net was then inspected to find clinging organisms. The organisms were removed by using a squirt bottle and forceps and deposited in the bucket. Large objects in the bucket were inspected and organisms were removed from the object before discarding the object. The bucket was then sealed with a lid. The net was rinsed before collecting the next sample.

Riffle samples were collected in conjunction with the multi-habitat samples to minimize the number of passes within the stream. The samples from each type were carefully placed in the correct sample container, multi-habitat or riffle, to avoid contaminating the samples.

3.1 Multi-Habitat Samples

Each reach was divided by 11 transects located approximately 50 feet (15 meters) apart to distribute samples throughout habitat types. If the flagging marking the transect line from previous studies remained, that transect was used for sampling. When flagging was not present, the transect was located by using a measuring tape to measure 50 feet from the adjacent transect. The EMAP methods describe collecting samples at each of the 11 cross-section transects, A through K, at assigned locations left, center, and right across the creek. In order to provide comparative data to previous macroinvertebrate studies conducted by the Manti-La Sal National Forest and by previous surveys (JBR 2012), only 5 samples were collected and each sample location was not chosen randomly or systematically. Instead, the samples were collected at every other transect starting with transect B at the site that most suitable for the placement of the kick net as done in previous surveys. Sample locations were located as close to each transect as possible. Samples from the 5 locations were combined into a single composite sample bucket labeled "multi-habitat." At each sampling transect the dominant substrate and habitat type was recorded on the sample collection form. Samples were collected from downstream transects to upstream transects.

3.2 Riffle Habitat Samples

Eight riffle samples were collected from each of the 3 reaches using the methods form the EMAP manual. Before sampling, the total number and area of riffle microhabitat was estimated for each reach. If the reach contained more than 1 riffle microhabitat but less than 8, the 8 sample locations were spread throughout the reach as much as possible with more than 1 sample collected from a single riffle unit. If the reach contained more than 8 riffle units, 1 or more units were skipped at random to spread the sampling locations throughout the reach. Samples were collected from downstream to upstream units in the order they were encountered. Since Crandall Creek is narrow, the riffle sampling locations within a unit were not chosen randomly, but were chosen by the most suitable location for kick net placement as done in previous surveys (JBR

2012). The 8 samples were combined into a single composite sample bucket labeled "riffle."

3.3 Composite Sample Preparation

The contents from each composite bucket for each reach (multi-habitat or riffle) were poured through a 300-micron sieve into a bucket. The composite bucket was inspected for organisms and rinsed using a squirt bottle filled with stream water. The composite bucket contents were again poured through the sieve. Large objects such as sticks, rocks, or plant material were inspected and any clinging organisms were dislodged using the squirt bottle over the sieve. The squirt bottle was used to rinse the material in the sieve to one side and then into a sample jar using as little water as possible. Remaining organisms on the sieve were then transferred to the jar using a squirt bottle filled with 95% ethanol to rinse the sieve into the jar or by using forceps. Additional jars were used if the contents filled over two-thirds of the sample jar, as instructed by the BugLab. If multiple jars were used, the jar number and total number of jars in the sample were recorded on the jar and the sample collection form. The sample jar was filled with 95% ethanol so that the final ethanol concentration was between 75 and 90%. A waterproof label with stream ID, date, sample type, reach ID, and number of kick net samples collected was placed in the jar. The lid was placed on the jar and the jar was slowly tipped to a horizontal position and gently rotated to mix the contents with the ethanol solution. The jar was then sealed with tape and labeled with sample information taped to the outside of the jar. This procedure was repeated for each Multi-habitat and Riffle composite sample for each of the 3 reaches for a total of 6 samples from the creek.

3.4 Sample Analysis

The samples were shipped to the BugLab for identification of taxa within the samples. The BugLab generally uses subsampling to collect approximately 600 individual organisms and sort them by major taxonomic orders. Collection and sorting is completed using a 7x or greater dissecting scope. Once the subsample has been sorted by major taxonomic orders, a "big/rare" search is completed using the entire sample to identify taxa that may have been missed in the subsample. Qualified taxonomists then identify the collected organisms to the lowest taxa possible (family, genus, and species if possible) without fixed slides. The laboratory results were prepared by the BugLab (Armstrong, Miller and Courtwright 2017) and are used in Appendices A-C and in the Taxa Lists. This data includes standardized and raw data used for the tables and graphs. In 2011, the began using a newly revised output format, which includes richness-based metrics standardized to Operational Taxonomic Units (OTU) and a fixed count of 300 for more accurate comparison between samples. The fixed count or standard rarefaction count was changed to 400 in 2017, and back to 300 for this year's samples. The data from previous surveys has been obtained from the BugLab in a standardized format in order to compare metrics between surveys since previous studies did not include standardized data. The BugLab provided summaries and calculated many different indices and metrics. The findings are discussed further in the results; more detail and reference for how the calculations were made are also in Appendix A along with the corresponding tables.

Additional comparisons from the BugLab's data have been calculated for comparison with previous studies (JBR 2012). These different comparisons may be used to relate the species composition to the water quality of the creek. Graphs of these comparisons are included in Appendices B, C, and D. Some of these graphs include a breakdown of predominant taxonomic groups, graphs of the different diversity and biotic indices, abundances, total taxa richness, EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa richness, individual taxa richness, Tolerant and Intolerant taxa richness, percent richness, Hilsenhoff Biotic Index, different functional feeding group richnesses, and abundances. As mentioned in previous reports, no one metrics can be used to explain the potential influences the mine may have on the creek. Multiple metrics were used as in previous years to compare data from site to site and year to year. Descriptions of why these values are beneficial are below and have been taken directly out of the Bug Labs report (Judson and Miller 2013)

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. It is important to note that USU's BugLab discovered that the Tolerant Taxa abundance calculations they use produce all zeros, and as a result in 2017 reported this figure as 0. 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 according to Standard Taxonomic Effort (see NAMC website), 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 Judson and Miller 2010).

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 single taxa becomes more dominant.

Clinger taxa- The number of clinger taxa have been found by Karr and Chu (1998, as referenced in Judson and Miller 2010) 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 Judson and Miller 2010).

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 Judson and Miller 2010). 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 Judson and Miller 2010) 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 2-8 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, EIS used the BugLab's data set to calculate several other metrics that JBR also indicated being potentially useful for macroinvertebrate analysis. 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.

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 *Rhyacophia* 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).

The Ratio of Specialist Feeders to Generalist Feeders shows the ratio of stress tolerant species, generalists, to less tolerant specialized feeders. The Ratio of Ephemeroptera, Plecoptera, and

Trichoptera orders (EPT) to Chironomidae shows the more tolerant Chironomidae species abundance to the less tolerant EPT species. The Percent *Baetis*, Hydropsychidae, and Orthocladinae and the Ratio of *Baetis* to all Ephemeroptera are used to show the relative abundance of the stress tolerant *Baetis* mayflies. The Percent Heptageniidae, Chloroperlidae, and *Rhacophila* show these taxa percentages to other species as they are more sensitive to trace minerals.

4.0 RESULTS & DISCUSSION

The results prepared by the BugLab (Armstrong, Miller 2018) are incorporated into the tables of the following appendices. As with assessment, multiple metrics and datasets should be relied upon to make a finding of whether any impact or nonimpact has occurred between the mine's groundwater discharge and Crandall Creek. Numerous metrics should be used in evaluating what may be happening in the creek. In this study, the natural variability of any of these metrics is not known due to limited number of samples sites, absence of replicates, and partial historical baseline information. Therefore, it is difficult to determine whether there is an impact between sites from analyzing only one metric. This section and its associated appendices will review these metrics within this season's individual sample, spatially among each reach and habitat type, and any temporal changes since 2009. In the appendices, a blue colored graph is used when an increase in values indicate a more desirable habitat. A green colored graph is used when the lower the number, or a decline, specifies a healthier steam. Data is compared from the reference reach (CRANDUP-01) to the other two reaches. Additionally, a comparison between the middle reach directly below the mine (CRANDMD-02) and the lowest reach (CRANDLWR-03) can be made to assess the spatial limit and overall condition. The metrics evaluated include the various measurement types recommended by EPA (Barbour et al 1999). They include tolerance indices (HBI, CTQd), diversity (Shannon's), community composition (% EPT), and functional feeding groups (Percent Scraper/Shredders).

Appendix A of the report includes a summarization of the raw and standardized data for the samples collected in June 2018. The following Appendices (B-D) graph the previously mentioned matrices to show a visual comparison. Appendix B begins with a graph showing the distribution of the dominate orders within each reach and sample type (Figure 1b) as well as the numerical values (Table 1b). It is followed by numerous graphs that represent the Spring 2018 sample set and show a visual comparison of potential differences between the habitat types as well as spatial variation (Figures 2b-24b). The graphs of Appendix C include all the data gathered since Fall 2009 for temporal comparison among all the samples. They are differentiated by the multi-habitat and target riffle samples for further comparison (Figures 1c-23c). The graphs in Appendix D also contain data since the Fall of 2009; however the values from both the multi-habitats and riffle habitats sample were combined to obtain an average value assess any potential overall trends throughout the years (Figures 24c-42c).

A total of 69 operational taxonomic units (OTU) were identified in the Spring 2018 sample set. There were 30 families and 41 genera present. Most of the insect orders most commonly found in macroinvertebrate communities were found in each reach, orders Diptera, Ephemeroptera, and Trichoptera. The common order Plecoptera was not found in the middle reach riffle habitat sample. Non-insect invertebrates were also identified in all samples.

The dominate order in all samples, except the upper reach, was found to be Diptera. In the middle reach the dominate order in both the multi-habitat and riffle habitat made up 85 and 89 percent of the sample, respectively. In the upper reach, Diptera was also found but was outnumbered by the order Ephemeroptera. In the lower reach the dominate macroinvertebrate order in the multi-habitat was 66 percent and 46 percent in the riffle habitat (Figure 1b and Table 1b). A dominance of any single order or taxon greater than 50 percent suggests environmental stress, which the middle reach appears to exhibit.

The orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) are commonly considered sensitive to pollution and fluctuation in their abundance can be an indicator of stream health (Karr & Chu 1999). In the upper reach, the orders EPT made up over 60 percent of the taxa found in the multi habitat, and over 80 percent of the riffle habitat (Figure 9b). In the middle reach directly below the mine, EPT percentages were at less than 10 percent of abundance in multi-habitat and riffle samples. In the lower reach, EPT was between 20 and 45 percent in the two habitat types (Figure 9b).

Although Crandall Creek as a whole continues to provide less than ideal habitat for a macroinvertebrate community, all of the samples contained at least one distinct taxon that is considered to be intolerant to pollution. The middle reach had the lowest number of intolerant taxa in both habitat types with 1 distinct taxa in the multi-habitat and 2 in the riffle habitat. The upper reach had 2 distinct intolerant taxa in the multi-habitat and 3 in the riffle habitat. The lower reach had 4 distinct intolerant taxa in each habitat (Figure 14b). The upper multi-habitat had 17 unique taxa and there were 16 distinct taxa in the riffle, based off the standardized data. The middle reach multi-habitat had 17 distinct taxa and the riffle sample had 17. The richness in the lower reach multi-habitat was 22 and was 21 in the riffle habitat (Figure 2b). The number of distinct taxa appears to be fluctuating within all reaches and both habitat types year to year; more data is likely required to find a real discernible trend. These same results were found when evaluating many of the other metrics.

As with previous years, the differences in overall habitat among the three reaches likely influence the result of this study. The upper most reach and the lowest reach have similar substrate size compositions, which was largely bedrock overlaid with larger rocks. The lowest reach had a much more cemented substrate. The lack of interstitial spaces results in poorer habitat conditions for macroinvertebrates (Mize and Deacon 2002). These two reaches were narrower than the middle reach as well as more of a vegetative overstory. It is also important to note the changes in the stream morphology of Crandall Creek when comparing data from previous years. The colonization of beaver and subsequent dams are continuing to change the creek, mainly in the middle reach. The catastrophic impacts to Huntington Creek from major flooding resulting from a major wildfire in 2012 in the upper drainage areas should also be considered. The high flows have directly impacted macroinvertebrate populations in Huntington Creek, which are sources for movement into Crandall Creek. In 2018, conditions could have been impacted by severe drought conditions and a controlled burn that led to a wildfire on the South side of Crandall Canyon. Therefore, the spatial comparisons discussed further should consider that there may be an indication of degradation that may be due to these physical attributes, to some extent

4.1 Comparison of Targeted Riffle and Multi-Habitat Samples

As with the prior years' analyses (JBR 2010; 2011a; 2011b) and the data provided by the BugLab for 2012 (no report of their findings was provided to EIS), all the indices and metrics have been calculated and graphed in the appendices. In 2010, JBR recommended that the targeted riffle samples be collected based upon the observation that habitat types varied. It is also in Utah's DWQ monitoring program that all samples be collected using only a targeted riffle method (DWQ 2006). EIS continued to collect both riffle and multi-habitat sample to allow for a more comprehensive data interpretation for the future.

The graphs in Appendix B display the differences between the two habitats within this dataset (June 2018). Appendix C graphs each habitat type since Fall of 2009. The richness in the riffle-habitat upper reach had a slightly lower value than the multi, at 16 compared to 17, respectively. In the middle reach the multi-habitat and riffle-habitat were the same at 17. The lowest reach multi-habitat had a richness value of 22 whereas the riffle had a lower value of 21 (Figure 2b). The same pattern was found in the Shannon's Diversity values with the lower reach exhibiting higher numbers. In the upper multi-reach habitat the value was 2.09 and 1.83 in the riffle habitat. In the middle reach the multi-habitat was 1.18 and the riffle habitat it was .83. In the lower reach the multi-habitat was 2.32 and the riffle habitat was 2.27 (Figure 3b). The evenness in the upper multi and riffle habitats were 0.739 and 0.662, respectively. In the middle reach the multi-habitat was 0.419 and the riffle was 0.293, and in the lower reach the evenness was 0.753 and 0.747, respectively (Figure 4b).

The abundance in the upper reach was 3688 in the multi-habitat and 950 in the riffle. In the middle reach multi-habitat it was 1707 and 993 in the riffle and in the lower reach it was 1161 and 1127, respectively (Figure 5b). The HBI, which a lower value indicates less pollution, was 3.363 in the upper reach multi-habitat and 3.876 in the riffle. It was 5.176 and 5.553 in the middle reach, respectively. In the lowest reach, the HBI was 4.383 in the multi-habitat and 3.506

in the riffle (Figure 6b). The CTQd, which a lower the value indicates higher quality unpolluted water as well, was 79 in the upper reach multi-habitat and 88 in the riffle. In the middle reach these values were 100 in the multi-habitat and 92 in the riffle habitat. In the lower reach the multi-habitat and riffle were both at 78 (Figure 7b). Appendices A and B have more specific detail on all the values found and metrics graphed for visual comparison. While addressing any trends or spatial differences, both the riffle and multi-habitat results were averaged and this value was then used (Appendix D).

4.2 Spatial Variation in Macroinvertebrate Community

As mentioned in earlier parts of this report, there were 3 different reaches sampled in Crandall Creek. CRANDUP-01 (upper) is upstream of any potential impact from the mine's discharge, CRANDMD-02 (middle) is immediately below the discharge, and CRNDLWR-03 (lower) is further downstream. Averages between the two habitat types (multi and riffle) were used in the following results to gauge whether any spatial variation is present.

The average richness, or number of distinct taxa, in the upper reach was found to be 16.5, in the middle reach the average was 17.125 and in the lower reach it was 14.875 (Figure 1d). The average evenness value was 0.701 in the upper reach, 0.438 in the middle reach and 0.576 in the lower reach (Figure 2d). The average Shannon's Diversity in the upper reach was 1.96, in the middle reach it was 1.24, and in the lower reach it was 1.55 (Figure 3d). The average abundance of individuals was 2319 in the upper reach, 630.5 in the middle reach and 784.25 in the lower reach (Figure 4d). The HBI, which the lower the value indicates less pollution in the stream ranging from 0-10, was found to be 3.62 in the upper reach, 5.32 in the middle reach and 4.95 in the lower reach (Figure 5d). The CTQd, which a lower value also indicates higher quality unpolluted water, ranges from 2 to 108. The CTQd was found as 83.5 in the upper reach, 95.25 in the middle reach and 89.5 in the lower reach (Figure 6d). Overall, it appears that the quality of water in the middle reach may be in decline when compared to the upper and lower reach. The lowest reach and upper reach appear to be very similar in quality.

4.3 Temporal Variation in Macroinvertebrate Community

EIS was able to obtain the standardized data from the BugLab dating back to 2009 to assess any temporal variations. The graphs in Appendices C and D provide a visual means to examine the temporal variation within the creek. In all reaches, the data fluctuates from year to year. A trendline was added to the averaged overall data in Appendix D to assist in observing any overall trends.

The upper reach, which should not be impacted by the mine's discharge, has great variability within each metric. For example the average richness in Fall 2009 was found to be 24, and since it has gone up and down year to year with no real pattern. This sample set produced a richness value of 16.5. The evenness values were around 0.74 in 2009, dropped down to .65 in Fall 2010, increased to around 0.77 from 2012-2013, and dropped slightly to 0.70 this sample. Similar variability is present within all the metrics.

The middle reach also has this variation occurring throughout the years. The averaged richness value in the Fall 2009 and Spring 2010 sample set was found to be 22. It fluctuated to a low of 13.5 in the Spring of 2013, then back up to 21.5 in the Fall of 2013. In 2017 it was found to be at 16.25 distinct taxa. This sample it went up to 17.125. The evenness has also fluctuated throughout the years. In the earlier samples, it was found to be around .60 to .73. It has dropped down to a 0.34 in Spring of 2012, went back up to 0.78 in the Fall of 2013. It has dropped to 0.438 this sample set. Throughout the years, the reach directly below the mine has shown signs of decline. The Spring 2018 samples, however, show an increase in both richness and evenness since Fall 2017.

The lowest reach has shown signs of variable conditions. As with the other two reaches, the numbers have also fluctuated throughout years. In Fall of 2009 the richness was found to be 18, it dropped to 11 in Spring of 2011, went up to 21.5 in the Fall of 2013. There were 14.875 distinct taxa found this sample. The evenness in 2009 was 0.74, has gone up and down and is currently at 0.576. Refer to Appendix D for further results.

5.0 CONCLUSION

The samples for the 2018 Spring Macroinvertebrate Study were collected on June15th, and 27th, 2018 from each of the three reaches of Crandall Creek. The upper reach is located upstream from the mine and is should not be influenced from ground water discharge from the mine, therefore it is considered as a reference of how conditions should be. The middle and lower reaches are below the mine water discharge. The objective of the survey was to collect macroinvertebrate samples as indicators of water quality in Crandall Creek. The samples collected were sorted and identified to the lowest taxa possible by the BugLab. Abundances of taxa and community composition relationships from the samples are provided to assess the water quality of Crandall Creek.

The survey results show variability among all the sampled reaches and generally show reduced habitat quality and less than optimal conditions in all sampled locations. It does appear that the upper reach has decreased in quality standards over the past year, and that the lower reach has improved since 2009. In the middle reach, the overall quality seems to be lower than the other two reaches, based on most indicators. The data for all three reaches fluctuate from year to year and season to season. It is important to note that the substrate and habitat differs greatly between reaches and should be taken into consideration in the results. The changes in stream morphology due to increased beaver dams in the middle reach and upper reach should also be considered, along with heavy precipitation in 2017, and drought conditions in 2018.

In 2019 snow pack in the Crandall Creek drainage area was 200% of the previous year (2018). This resulted in extremely high runoff and a scouring of the creek channel. It was felt that the data resulting from this a-typical event was not indicative of the typical range and number of both families and general represent the typical orders normally found. Diptera, Ephemeroptera, Trichoptera, and Plecoptera were notably absent in all areas they had been represented in previously.

Based on the data or lack of data it was felt that the raw data from the spring 2019 samples included in its entirety. Rather than try to speculate on the net effect of the mine discharge and is attached as appendix E

REFERENCES

Barbour, M.T. et al., 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish. EPA 841-B-99-002*, US Environmental Protection Agency, Office of Water, Washington, DC, http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm.

Division of Water Quality (DWQ). 2006. Utah Division of Water Quality Monitoring Manual.

Environmental Protection Agency. 2006. Environmental Monitoring and Assessment Program-Surface Waters Western Pilot Study: Field Operation Manual for Wadeable Streams. EPA/620/R-06/003. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

Karr, J.R. & E. W. Chu. 1999. *Restoring life in running waters: better biological monitoring*, Island Press.

Kiffney, P. M. & W. H. Clements. 1994. Effects of heavy metals on a macroinvertebrate assemblage from a Rocky Mountain stream in experimental microcosms. Journal of the North American Benthological Society. *13*(4) pp. 511-523

JBR Environmental Consultants, Inc. (JBR). 2010. Crandall Canyon Mine Macroinvertebrate Study September 2009. Prepared for Genwal Resources, Inc. January 27, 2010.

JBR Environmental Consultants, Inc. (JBR). 2011a. Crandall Canyon Mine Macroinvertebrate Study June 2010. Prepared for Genwal Resources, Inc. January 17, 2011.

JBR Environmental Consultants, Inc. (JBR). 2011b. Crandall Canyon Mine Macroinvertebrate Study September 2011. Prepared for Genwal Resources, Inc. August 22, 2011.

JBR Environmental Consultants, Inc. (JBR). 2012. Crandall Canyon Mine Macroinvertebrate Study September 2011. Prepared for Genwal Resources, Inc. Oct 2012.

Miller, S. and S. Judson. 2011. Macroinvertebrate Sample Processing and Reporting Methodologies of the National Aquatic Monitoring Center. National Aquatic Monitoring Center <www.usu.edu/buglab/> Accessed 31 Jul 2013.

Miller, S. and T. Armstrong. 2018. Aquatic Invertebrate Report for Samples Collected by EIS. Report prepared October 2018. U.S. Bureau of Land Management, National Aquatic Monitoring Center, Department of Watershed Sciences, Utah State University.

Mize, S.V., and Deacon, J.R. 2002. Relations of benthic macroinvertebrates to concentration of trace elements in water, streambed sediment, and transplanted bryophytes and stream habitat conditions in nonmining and mining areas of the Upper Colorado River Basin, Colorado, 1995-98. U.S. Geological Survey Water-Resources Investigation.

Report prepared and reviewed by:

Melvin Coonrod, CEO/Owner EIS

Mel has post graduate work in Ecology, an M.S. in Silviculture, and a B.S. in Zoology from Utah State University. He is the owner/CEO of EIS Environmental & Engineering Consulting.

Molly Hocanson, Biological and Natural Resource Specialist

Molly has a B.S. in Natural Resource Management from Utah State University. She has a number of years working for EIS Environmental & Engineering Consulting as a Biological Technician and the U.S. Forest Service.

Davie Stokes

Davie has a BS degree from Utah State University and worked with EIS for several years prior to taking a position with the NRCS.

APPENDIX A

BUGLAB REPORT

Report prepared for:

Customer contact:	Mel Coonrod
Customer:	EIS Environmental and Engineering Consulting
Customer Address :	31 N Main Street
Customer City, State, Zip:	Helper UT 84526
Customer Phone:	435-472-3814
Customer Email:	eisec@preciscom.net

Report prepared by:
Trip Armstrong: 760.709.1210 / trip.armstrong@usu.edu
Scott Miller: 435.797.2612 / scott.miller@usu.edu

BLM/USU National Aquatic Monitoring Center (NAMC)
Department of Watershed Sciences (WATS) - Utah State University 5210
Old Main Hill Logan, UT 84322-5210
http://www.usu.edu/buglab/

October 2018

Table 1a. Sampling site locations

Station	Location	Latitude	Longitude	Elevation (meters)
CRANDUP-01	Crandall Creek, Lower, Emery County, UT	39.459722	-111.16778	2363
CRANDMD-02	Crandall Creek, Middle, Emery County, UT	39.460278	-111.16528	2384
CRANDLWR-03	Crandall Creek, Upstream, Emery County, UT	39.463611	-111.14639	2389

Table 2a. Field comments and laboratory processing information

Sample ID	Station	Collection Date	Habitat Sampled	Collection Method	Area sampled (m^2)	% of Sample Processed	Number of individuals identified
167887	CRANDUP-01	6/15/2018	Reachwide	Kick net	0.46	43.75	736
167886	CRANDUP-01	6/15/2018	Targeted Riffle	Kick net	0.74	100	703
167885	CRANDMD-02	6/15/2018	Reachwide	Kick net	0.46	100	785
167884	CRANDMD-02	6/15/2018	Targeted Riffle	Kick net	0.74	81.25	596
167883	CRANDLWR-03	6/27/2018	Reachwide	Kick net	0.46	100	534
167882	CRANDLWR-03	6/27/2018	Targeted Riffle	Kick net	0.74	75	622

Results

The following data is based off of the estimated number of individuals per square meter for quantitative samples and the estimated number per sample for qualitative samples.

Table 3a. Total Abundance, EPT Abundance, Dominant Family, Percent Contribution

Sample ID	Collection Date	Station	Total Abundance	EPT Abundance	Dominant Family	% Contribution dominant family
167887	6/15/2018	CRANDUP-01 Multi	3688	2283	Baetidae	27.09
167886	6/15/2018	CRANDUP-01 Riffle	950	782	Baetidae	46.63
167885	6/15/2018	CRANDMD-02 Multi	1707	33	Chironomidae	82.66
167884	6/15/2018	CRANDMD-02 Riffle	993	55	Chironomidae	85.10
167883	6/27/2018	CRANDLWR-03 Multi	1161	280	Chironomidae	58.83
167882	6/27/2018	CRANDLWR-03 Riffle	1127	477	Chironomidae	37.62
Mean			1604.3	651.7		56.32

Diversity Indices

Table 4a. Richness totals for taxa, genera, families, and EPT based off of raw qualitative data

Sample ID	Collection Date	Station	Total taxa richness	Total genera richness	Total family richness	EPT taxa richness
167887	6/15/2018	CRANDUP-01 Multi	26	16	13	9
167886	6/15/2018	CRANDUP-01 Riffle	32	23	19	11
167885	6/15/2018	CRANDMD-02 Multi	28	17	16	8
167884	6/15/2018	CRANDMD-02 Riffle	24	15	15	8
167883	6/27/2018	CRANDLWR-03 Multi	38	22	20	16
167882	6/27/2018	CRANDLWR-03 Riffle	35	23	18	11
Mean			30.5	19.3	16.8	10.5

Table 5a. Diversity indicies based on standardized OTU

Sample ID	Collection Date	Station	Total taxa richness	EPT taxa richness	Shannon diversity index	Evenness
167887	6/15/2018	CRANDUP-01 Multi	17	6	2.096347	0.739919
167886	6/15/2018	CRANDUP-01 Riffle	16	7	1.837379	0.662694
167885	6/15/2018	CRANDMD-02 Multi	17	3	1.188119	0.419354
167884	6/15/2018	CRANDMD-02 Riffle	17	5	0.830929	0.293282
167883	6/27/2018	CRANDLWR-03 Multi	22	9	2.329061	0.753487
167882	6/27/2018	CRANDLWR-03 Riffle	21	8	2.276843	0.747849
Mean			18.33333	6	1.75978	0.602764

Table 6a. Genera richness by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemeroptera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
167887	6/15/2018	CRANDUP-01 Multi	0	11	2	0	0	0	3	4	1	0	1
167886	6/15/2018	CRANDUP-01 Riffle	5	11	3	0	0	0	3	5	1	0	1
167885	6/15/2018	CRANDMD-02 Multi	2	12	2	0	0	0	1	5	1	0	1
167884	6/15/2018	CRANDMD-02 Riffle	2	11	3	0	0	0	0	5	0	0	0
167883	6/27/2018	CRANDLWR-03 Multi	2	13	5	0	0	0	5	6	0	0	1
167882	6/27/2018	CRANDLWR-03 Riffle	3	14	3	0	0	0	3	5	1	0	1
Mean			2.3	12.0	3.0	0.0	0.0	0.0	2.5	5.0	0.7	0.0	0.8

Table 7a. Total Abundance by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemeroptera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
167887	6/15/2018	CRANDUP-01 Multi	0	948	999	0	0	0	1072	212	70	0	318
167886	6/15/2018	CRANDUP-01 Riffle	11	124	445	0	0	0	214	124	15	0	7
167885	6/15/2018	CRANDMD-02 Multi	13	1452	7	0	0	0	2	24	59	0	17
167884	6/15/2018	CRANDMD-02 Riffle	5	883	27	0	0	0	0	28	0	0	0
167883	6/27/2018	CRANDLWR-03 Multi	11	767	70	0	0	0	48	163	0	0	13
167882	6/27/2018	CRANDLWR-03 Riffle	5	516	73	0	0	0	272	131	14	0	41
Mean			8	782	270	0	0	0	267.9	113.7	26.3	0.0	66.1

Biotic Indices

Table 8a. Hilsenhoff Biotic Index and CTQd

Sample ID	Collection Date	Station	Hilsenhoff Biotic Index		USFS Community CTQd
			Index	Indication	
167887	6/15/2018	CRANDUP-01 Multi	3.363333	Some organic pollution	79
167886	6/15/2018	CRANDUP-01 Riffle	3.876667	Some organic pollution	88
167885	6/15/2018	CRANDMD-02 Multi	5.176667	Some organic pollution	100
167884	6/15/2018	CRANDMD-02 Riffle	5.553333	Some organic pollution	92
167883	6/27/2018	CRANDLWR-03 Multi	4.383333	Some organic pollution	78
167882	6/27/2018	CRANDLWR-03 Riffle	3.506667	Some organic pollution	78
Mean			4.31		85.83

Table 9a. Intolerant taxa richness and abundance values and percentages.

Sample ID	Collection Date	Station	Intolerant Taxa				Tolerant Taxa			
			Richness	Percent	Abundance	Percent	Richness	Percent	Abundance	Percent
167887	6/15/2018	CRANDUP-01 Multi	2	12	0	0	0	0	0	0
167886	6/15/2018	CRANDUP-01 Riffle	3	19	0	0	0	0	0	0
167885	6/15/2018	CRANDMD-02 Multi	1	6	0	0	0	0	0	0
167884	6/15/2018	CRANDMD-02 Riffle	2	12	0	0	0	0	0	0
167883	6/27/2018	CRANDLWR-03 Multi	4	18	0	0	0	0	0	0
167882	6/27/2018	CRANDLWR-03 Riffle	4	19	0	0	0	0	0	0
Mean			2.7	14	0.0	0	0.0	0	0.0	0

Functional Feeding Groups

Table 10a. Taxa richness by functional feeding groups

Sample ID	Collection Date	Station	Shredders Richness	Shredders Percent	Scrapers Richness	Scrapers Percent	Collector-filterers Richness	Collector-filterers Percent	Collector-gatherers Richness	Collector-gatherers Percent	Predators Richness	Predators Percent	Unknown Richness	Unknown Percent
167887	6/15/2018	CRANDUP-01 Multi	2	12	0	0	2	12	2	12	7	41	4	24
167886	6/15/2018	CRANDUP-01 Riffle	1	6	1	6	2	13	2	13	5	31	5	31
167885	6/15/2018	CRANDMD-02 Multi	1	6	0	0	1	6	1	6	6	35	8	47
167884	6/15/2018	CRANDMD-02 Riffle	2	12	1	6	1	6	1	6	4	24	8	47
167883	6/27/2018	CRANDLWR-03 Multi	4	18	1	5	2	9	2	9	6	27	7	32
167882	6/27/2018	CRANDLWR-03 Riffle	4	19	1	5	2	10	2	10	8	38	4	19
Mean			2.3	12.1	0.7	3.6	1.7	9.1	1.7	9.1	6.0	32.8	6.0	33.3

Table 11a. Taxa abundance by functional feeding group

Sample ID	Collection Date	Station	Shredders Abundance	Shredders Percent	Scrapers Abundance	Scrapers Percent	Collector-filterers Abundance	Collector-filterers Percent	Collector-gatherers Abundance	Collector-gatherers Percent	Predators Abundance	Predators Percent	Unknown Abundance	Unknown Percent
167887	6/15/2018	CRANDUP-01 Multi	897	24	0	0	479	13	1943	53	349	9	20	1
167886	6/15/2018	CRANDUP-01 Riffle	161	17	5	1	104	11	558	59	118	12	4	0
167885	6/15/2018	CRANDMD-02 Multi	7	0	0	0	20	1	1457	85	211	12	12	1
167884	6/15/2018	CRANDMD-02 Riffle	15	2	3	0	2	0	886	89	83	8	4	0
167883	6/27/2018	CRANDLWR-03 Multi	80	7	28	2	15	1	596	51	439	38	3	0
167882	6/27/2018	CRANDLWR-03 Riffle	279	25	11	1	99	9	468	42	269	24	1	0
Mean			239.8	12.5	7.8	0.7	119.8	5.9	984.7	63.1	244.8	17.4	7.3	0.4

Data summarization

Compositional changes in macroinvertebrate assemblages are most frequently used to quantify freshwater ecosystem responses to anthropogenic disturbances (Bonada et al. 2006). Common approaches range from the computation and evaluation of individual metrics characterizing the composition, richness, function or tolerance of invertebrate assemblages to complex multivariate analyses and statistical modelling that aims to predict assemblage composition in the absence of impairment (e.g., RIVPAVS or O/E) (V. H. Resh et al. 1993; Wright et al. 2000; Merritt et al. 2008). Regardless of the analytical approach, determinations of biological condition are generally achieved by comparing the deviation of macroinvertebrate metrics or assemblages composition at test sites (i.e., sampled sites) to that of reference or minimally impacted conditions. The NAMC's output for macroinvertebrate samples aims to support both (multi-) metric and multivariate approaches.

Related fields in Excel Output:

[Fixed Count]

The number of resampled organisms to a fixed count of 300 (unless otherwise requested). If the number of sub-sampled organisms ([Split Count]) was less than the fixed count, the fixed count will be less than the target of 300 and should approximate the [Split Count] but may be slightly lower due to taxa omitted during OTU standardization.

Richness metrics

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 according to Standard Taxonomic Effort (see Appendix 1 or NAMC website), 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.

Related fields in Excel Output:

[Richness]

The number of unique taxa at the lowest possible taxonomic resolution (typically genus or species).

[# of EPT Taxa]

The taxonomic richness for the insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT). These orders are commonly considered sensitive to pollution (Karr & Chu 1999). This is reported along with the accompanying density metric, [Abundance of EPT Taxa].

[Shannon's Diversity]

The Shannon-Wiener diversity function is a measure of community structure and heterogeneity defined by the relationship between the number of distinct taxa and their relative abundances. The Shannon's diversity index is noted to weight rare species slightly more heavily than the Simpson's diversity index (Krebs 1999). The calculation is made as follows:

-Σ([Relative Abundance]taxa*ln([Relative Abundance]taxa)) after Ludwig and Reynolds (1988, equation 8.9, page 92):

[Simpson's Diversity]

The Simpson's diversity index is a measure of community structure and heterogeneity defined by the relationship between the number of distinct taxa and their relative abundances. The Simpson's diversity index is noted to weight common species slightly more heavily than the Shannon's diversity index (Krebs 1999). The calculation is provided in the common form as follows:

1 - [Simpson's Diversity] = 1 - Σ([Relative Abundance]taxa)2

after Ludwig and Reynolds (1988, equation 8.6, page 91):

Modified to the complement of the Simpson's probability measure as shown in Krebs (1999, equation12.28, page 443).

[Evenness]

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. The evenness index used in this report was calculated as: [Shannon's Diversity]/ln([Richness]) following Ludwig and Reynolds (1988, equation 8.11, page 93).

Dominance metrics

Metrics used to characterize the absolute or proportional abundance of individual taxa within a sampled assemblage. An assemblage largely dominated (>50%) by a single taxon or several taxa from the same family suggests environmental stress.

Related fields in Excel Output:

[Dominant Family]

The taxonomic family with the highest abundance per sample. The name of this family is given to provide information about the life history and pollution tolerance of the dominant taxa.

[Abundance of Dominant Family]

The density of the most abundant family. This number should be compared to the total abundance for the sample to determine what percent of the total abundance is comprised by the dominant family. An assemblage dominated (e.g., >50%) by a single family suggests environmental stress; although the specific dominant family needs to be considered. For example, dominance by Chironomidae, Hydropsychidae, Baetidae, or Leptohyphidae frequently suggest impaired conditions, while other families within the orders Coleoptera, Ephemeroptera, Plecoptera or Trichoptera may suggest otherwise. Dominance of the macroinvertebrate assemblage by a few taxa can also be evaluated with the Evenness metric.

[Dominant Taxa]

The taxa (usually identified to genus) with the highest abundance in a sample. The name of this taxa is given to provide information about the life history and pollution tolerance of the dominant taxa.

[Abundance of Dominant Taxa]

The density of the numerically dominant taxon. This number should be compared to the total abundance for the sample to determine what percent of the total abundance is comprised by the dominant taxa. An assemblage largely dominated (e.g., >50%) by a single taxon suggests environmental stress. This can also be evaluated in conjunction with the Eveness metric.

Tolerance (Biotic) Indices

Taxa are assigned values based on their tolerance to a single or multiple pollutants (e.g., nutrients, temperature, fine sediment). Pollution tolerance scores are typically weighted by taxa relative abundance and summed among all observed taxa. In the United States the most commonly used biotic index is the Hilsenhoff Biotic Index developed for organic matter enrichment (Hilsenhoff 1987; 1988). The USFS and BLM throughout the western United States have also historically used the USFS Community Tolerance Quotient (Winget & Mangum 1979).

Related fields in Excel Output:

[Hilsenhoff Biotic Index]

The Hilsenhoff Biotic Index (HBI) was originally developed to quantify the tolerance of macroinvertebrate assemblages to organic pollution, but this index has been used to detect nutrient enrichment, fine sediment loading, low dissolved oxygen, and thermal impacts. Families are assigned an index value from 0 (taxa normally found only in unpolluted water) to 10 (taxa found only in severely polluted waters). following Hilsenhoff (1987; 1988) and a family level HBI is calculated using the below equation.Sampling locations with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 polluted. The HBI is calculated as:

Σ([Abundance]taxa*[Tolerance]taxa)/[Abundance]Total

following the equation presented in Hilsenhoff (1988)

[# of Intolerant Taxa]

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 our report, taxa with HBI values < 2 were considered 'intolerant', clean water taxa (Vinson unpublished). The provided value is the richness (count) of taxa with HBI values < 2.

[Abundance of Intolerant Taxa]

The abundance of taxa with HBI values < 2, which were considered to be 'intolerant', clean water taxa in this report (Vinson unpublished).

[# of Tolerant Taxa]

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 our report, taxa with HBI values > 8 were considered pollution 'tolerant' taxa (Vinson unpublished). The provided value is the richness (count) of taxa with HBI values > 8.

[Abundance of Tolerant Taxa]

This figure, for 2018, is 0. USU BugLab has found an error in this calculation and this field in the report was omitted because of this. Normally, the abundance of taxa with HBI values > 8, which were considered to be pollution 'tolerant' taxa in this report (Vinson unpublished).

[USFS Community Tolerance Quotient (d)]

Taxa are assigned a tolerant quotient (TQ) from 2 (taxa found only in high quality, unpolluted waters) to 108 (taxa only found in severely polluted waters) following Winget and Mangum (1979). A dominance weighted community tolerance quotient (CTQd) is calculated according to the equation below where values can range from 20 to 100, with lower values indicating better water quality.

Σ([Tolerance Quotient] * log([Abundance]taxa))/Σ log([Abundance]taxa)

Functional Feeding Groups and Traits

Aquatic macroinvertebrates can be categorized by mode of feeding, adaptations to local habitat conditions, time to complete a life cycle, and other life history traits. Such classification schemes attempt to understand how individuals interact with local environmental conditions, with specific emphasis on the functional role of macroinvertebrate assemblages within aquatic ecosystems.

One of the most population classification schemes is functional feeding groups (FFG), which classify individuals based on their morpho-behavioral adaptations for food acquisition (e.g., scraping, piercing, net building); recognizing that all macroinvertebrates exhibit some degree of omnivory. The richness and relative abundance of different FFGs indicate the dependency of observed macroinvertebrate assemblages on different food resources and thus the trophic basis for secondary production. For example, the ratio of scrapers to shredders indicates the degree to which the local macroinvertebrate assemblage depends on instream algal production versus inputs of terrestrial leaf litter.

Functional feeding group designations are derived from Merritt et al (2008). Taxa are not included that are highly variable in their food habits, are parasites, or their primary feeding mode is currently unknown.

Related fields in Excel Output:

Functional feeding group measures

[# of Shredder Taxa] & [Shredder Abundance]

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

[#of Scraper Taxa] & [Scraper Abundance]

Scrapers feed on periphyton (i.e., attached algae) and associated material. Scraper populations increase with increasing abundance of diatoms and can decrease as filamentous algae, mossesor 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.

[# of Collector-filterer Taxa] & [Collector-filterer Abundance]

Collector-filterers feed on suspended fine particulate organic matter and often construct fixed retreats or have morpho-behavioral adaptation for filtering particles. Collector-filterers are sensitive highly mobile substrate condition, the quantity of fine particulate organic matter and pollutants that adhere to organic matter.

[# of Collector-gatherer Taxa] & [Collector-gatherer Abundance]

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

[# of Predator Taxa] & [Predator Abundance]

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.

Life History Trait measures

[# of Clinger Taxa]

Clingers typically have behavioral (e.g., fixed retreat construction including rock ballasts, silk production) or morphological (e.g., modified gill structures, long curved claws, crochet hooks) adaptations for attachment to the tops of rocks or wood surfaces. Clingers have been found to respond negatively to fine sediment loading or abundant algal growth (Karr & Chu 1999). Clinger taxa were determined using information in Merritt et al. (2008).

[# of Long-lived Taxa]

Taxa that take two or more years to complete their life cycle are considered to be long-lived. Macroinvertebrates with such protracted life cycles are considered good bioindicators since their presence indicates the maintenance of certain water quality or habitat conditions; the number of long-lived taxa typically decreases in response to degraded water quality of physical conditions (Karr & Chu 1999). The classification of long-lived taxa was based on life cycles greater than two years following Merritt et al. (2008).

Taxa Richness and Abundance

For taxa groups that are indicators of water quality or that are commonly used in multimetric indices, richness and abundance within that taxa are given.

[# of ** Taxa]

The richness (count of unique taxa) within each specified group.

[Abundance of ** Taxa]

The abundance, density, or number of aquatic macroinvertebrates of the indicated group per unit area. 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. Abundance 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.

Literature Cited

Barbour, M.T. et al., 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish. EPA 841-B-99-002*, US Environmental Protection Agency, Office of Water, Washington, DC, http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm.

Bonada, N. et al., 2006. Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. *Annual review of entomology*.

Cuffney, T. F et al., 1993. *Methods for collecting benthic invertebrate samples as part of the National Water-Quality Assessment Program*, US Geological Survey.

Cuffney, T. F., Bilger, M.D. & A.M. Haigler. 2007. Ambiguous taxa: effects on the characterization and interpretation of invertebrate assemblages. *Journal of the North American Benthological Society*, 26(2), pp.286–307.

Hilsenhoff, W.L., 1987. An improved biotic index of organic stream pollution. *Great Lakes Entomologist*, 20(1), pp.31–40.

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

Karr, J.R. & E. W. Chu. 1999. *Restoring life in running waters: better biological monitoring*, Island Press.

Krebs, C.J., 1999. *Ecological methodology*, Benjamin/Cummings.

Ludwig, J.A. & J. F. Reynolds. 1988. *Statistical ecology: a primer on methods and computing*, Wiley-Interscience,http://books.google.com/books?hl=en&lr=&id=sNsRYBixkpcC&oi=fnd&pg=PA3&dq=ludwig+and+reynolds+1988.

Merritt, R.W., K. W. Cummins, & M. B. Berg. 2008. *An Introduction to the Aquatic Insects of North America* 4th ed., Kendall Hunt Publishing.

Moulton, S. et al., 2000. *Methods of analysis by the US Geological Survey National Water Quality Laboratory-processing, taxonomy, and quality control of benthic macroinvertebrate samples*, US Geological Survey.

Resh, V.H., J.K. Jackson, & D. M. Rosenberg. 1993. *Freshwater biomonitoring and benthic macroinvertebrates*, New York: Chapman and Hall.

Vinson, M.R. & C. P. Hawkins. 1996. Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams. *Journal of the North American Benthological Society*, 15(3), pp.392–399.

Winget, R.N. & F. A. Mangum. 1979. *Biotic condition index: integrated biological, physical, and chemical stream parameters for management*, US Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT.

Wright, J.F., D. W. Sutcliffe, & M. T. Furse. 2000. *Assessing the Biological Quality of Fresh Waters: RIVPACS and Other Techniques*, Freshwater Biological Assn.

APPENDIX B

MACROINVERTEBRATE METRICS SPRING 2018

Figure 1b. Percent Predominant Taxonomic Groups Spring 2018 Samples

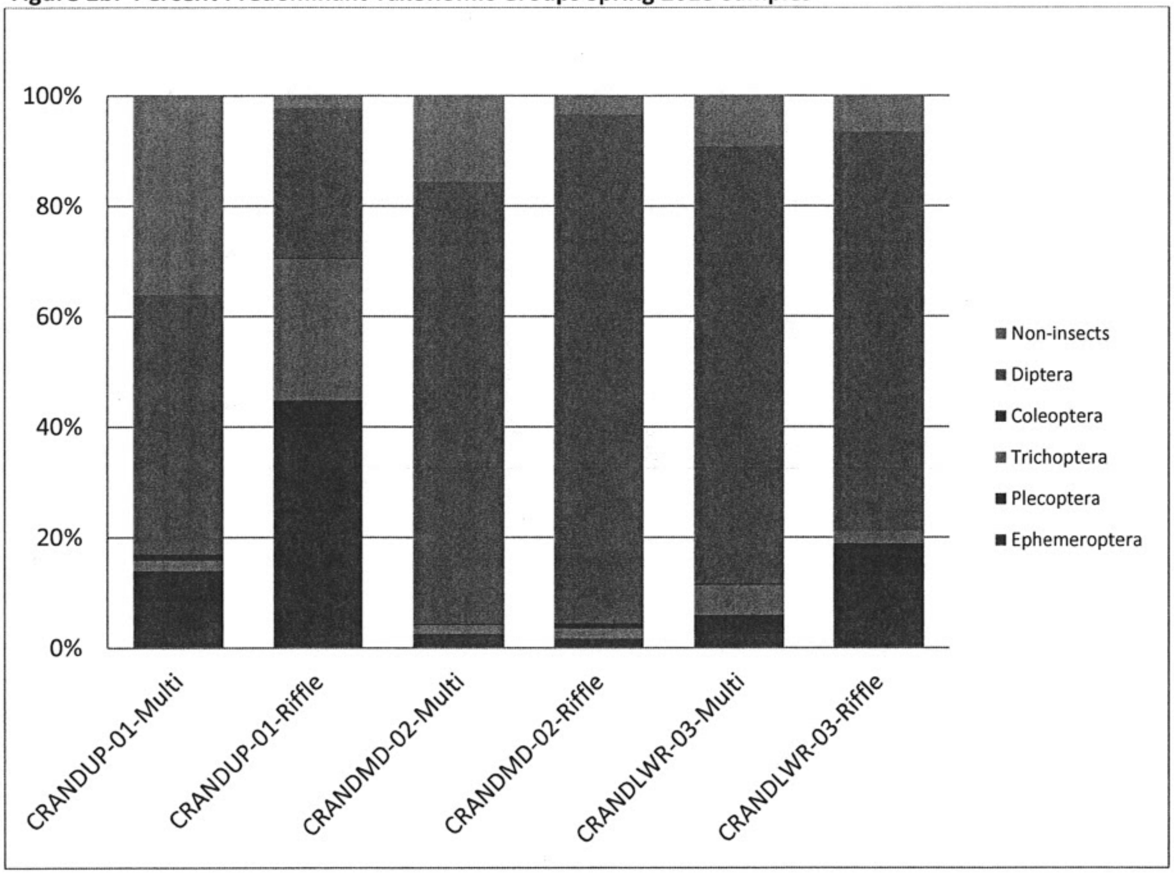


Table 1b. Percent Predominant Taxonomic Groups in the Spring 2018 Samples

	CRANDUP-01-Multi	CRANDUP-01-Riffle	CRANDMD-02-Multi	CRANDMD-02-Riffle	CRANDLWR-03-Multi	CRANDLWR-03-Riffle
Non-insects	36	2	16	3	9	7
Diptera	47	27	80	92	79	72
Coleoptera	1.1	0.1	0.2	0.9	0.2	0.0
Trichoptera	2	26	2	2	5	2
Plecoptera	6	5	0	0	3	6
Ephemeroptera	8	40	3	2	2	13

Figure 2b. Richness

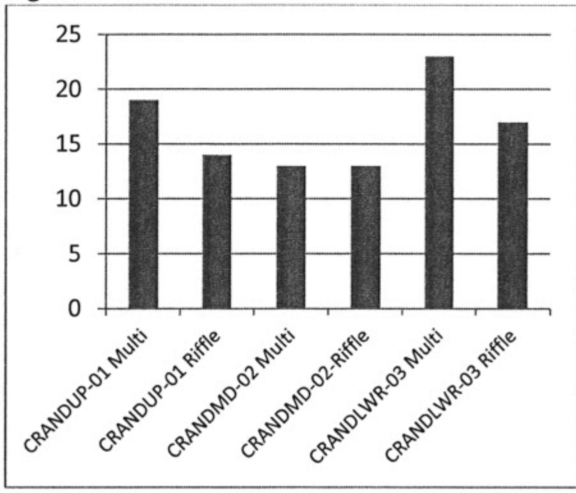


Figure 3b. Shannon's Diversity

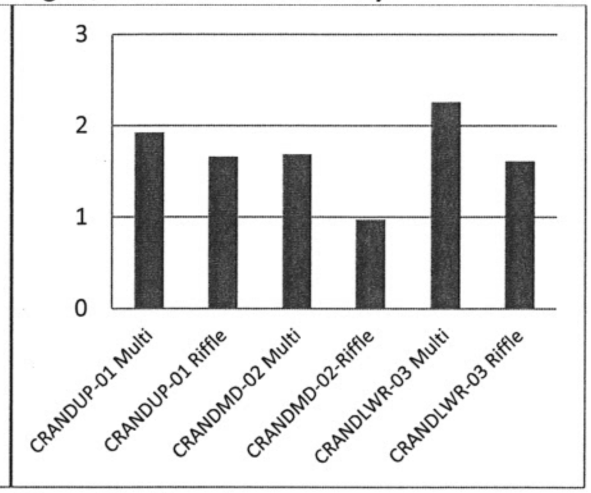


Figure 4b. Evenness

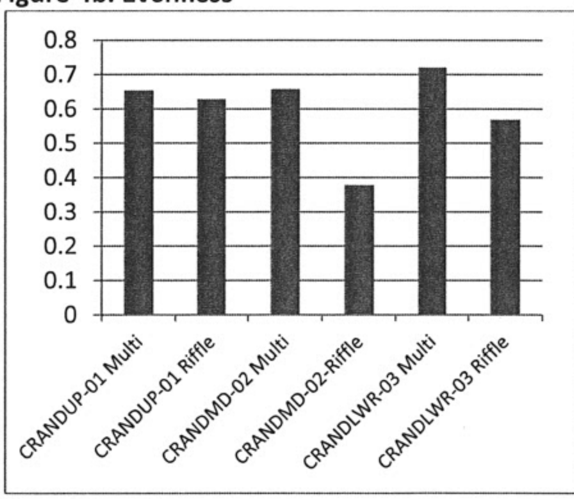


Figure 5b. Abundance

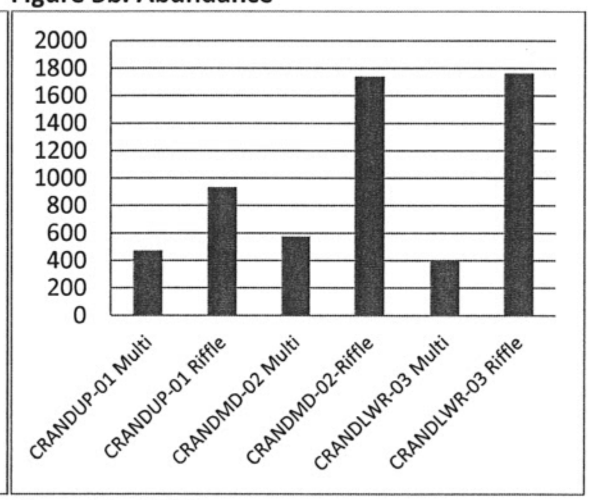


Figure 6b. HBI

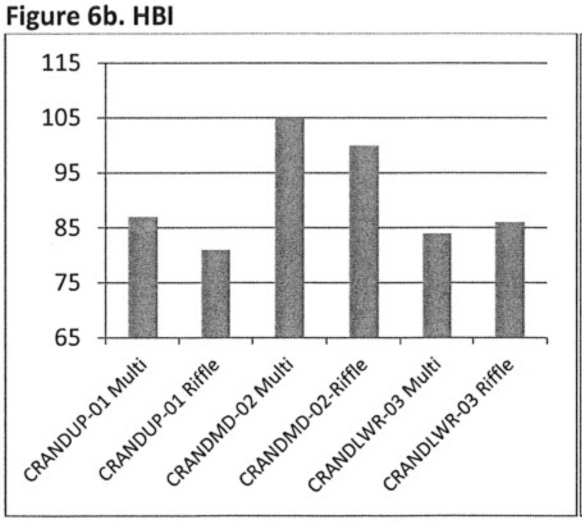
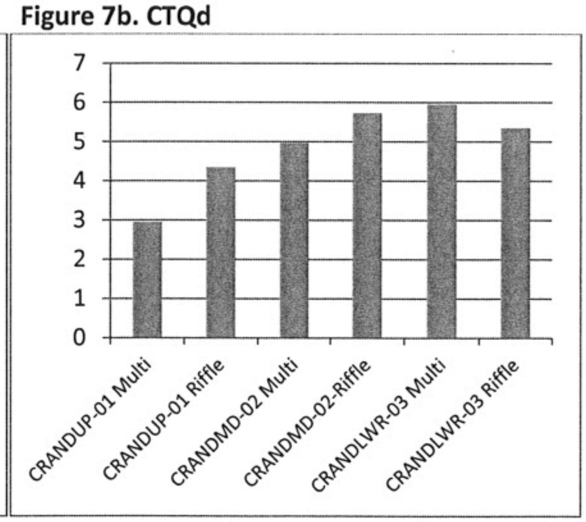


Figure 7b. CTQd



Green colored graphs indicate that lower values, or a decline, specify more desirable conditions.

Figure 8b. EPT Taxa Abundance

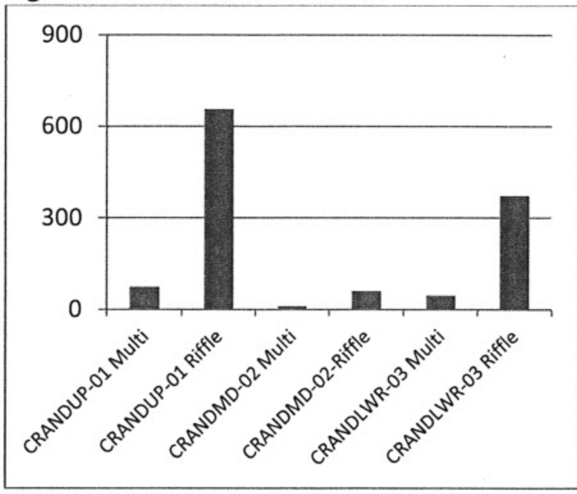


Figure 9b. Percent EPT

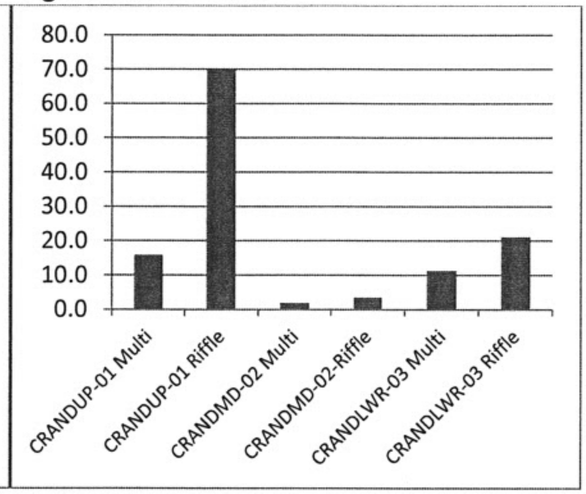


Figure 10b. Percent Chironomids

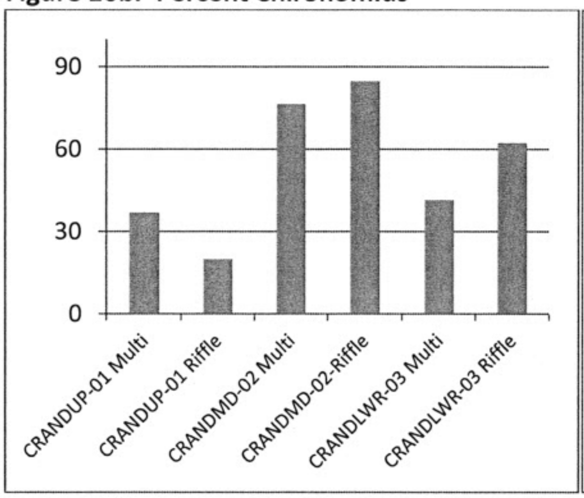


Figure 11b. Ratio of EPT to Chironmonids

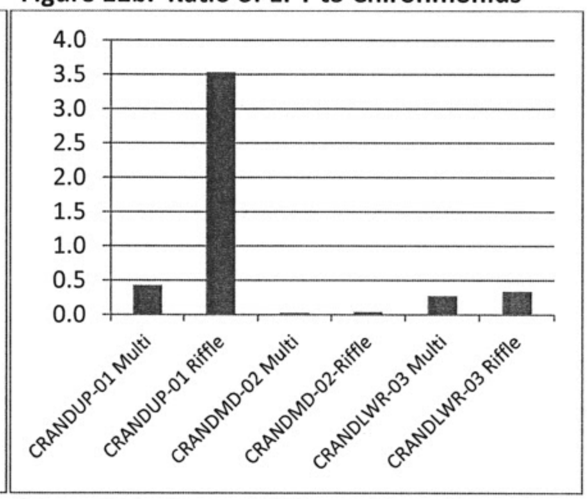


Figure 12b. Number of Tolerant Taxa

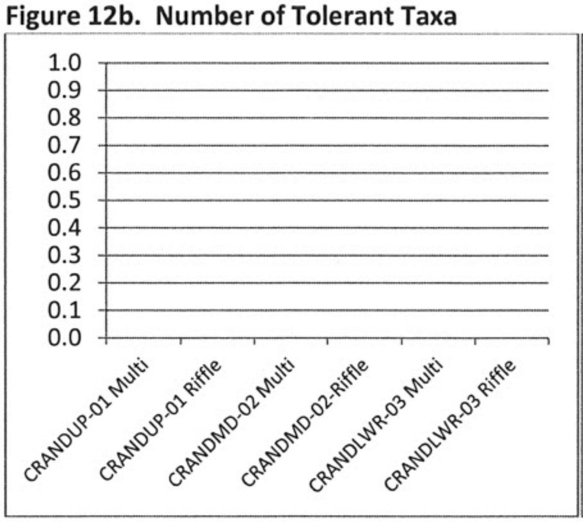


Figure 13b. Percent Tolerant Organisms

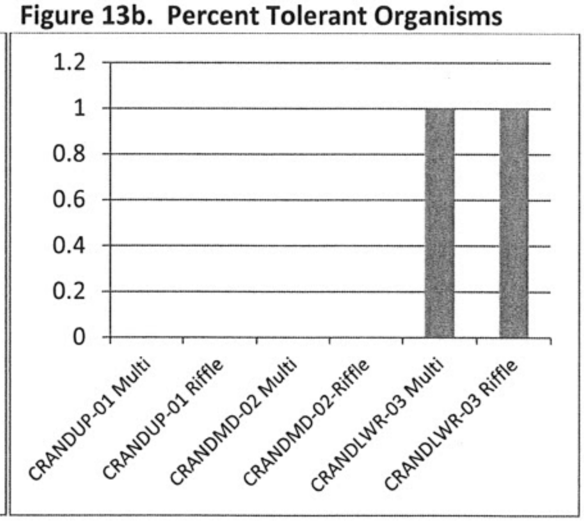


Figure 14b. Number of Intolerant Taxa

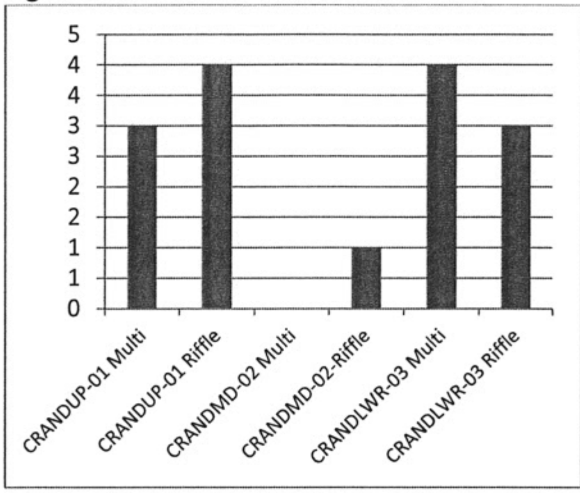


Figure 15b. Percent Intolerant Organisms

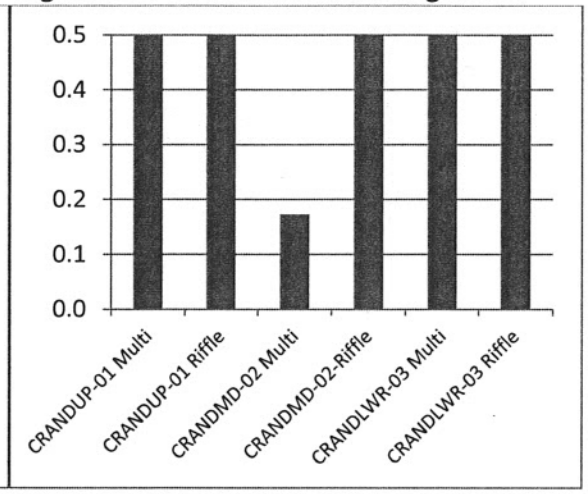


Figure 16b. Specialist Feeders: Generalist Feeders

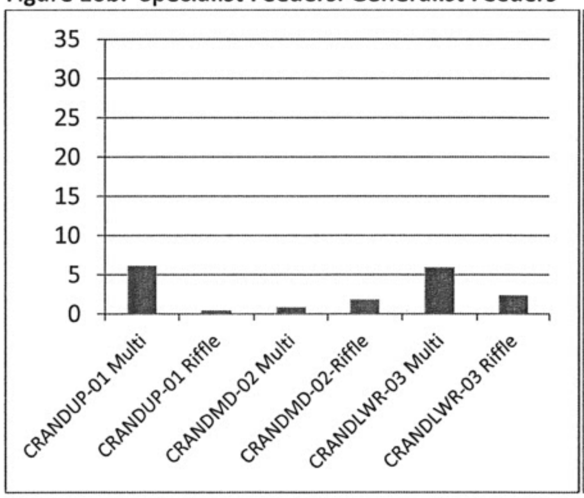


Figure 17b. Percent Shredders

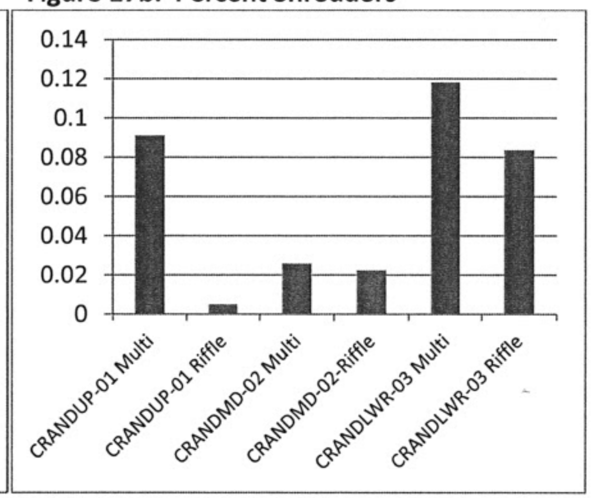


Figure 18b. Percent Scrapers

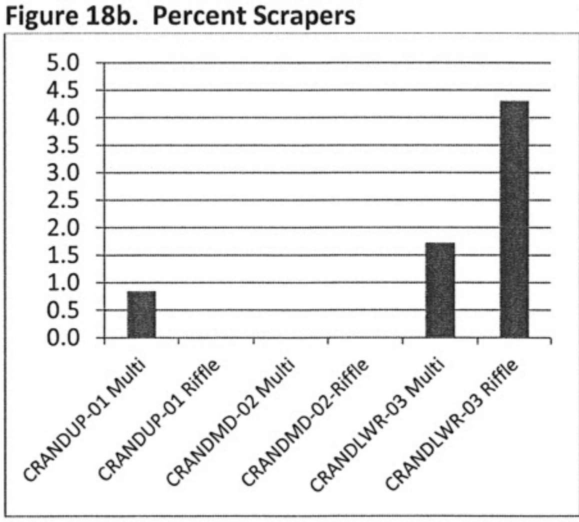


Figure 19b. Number of Long-Lived Taxa

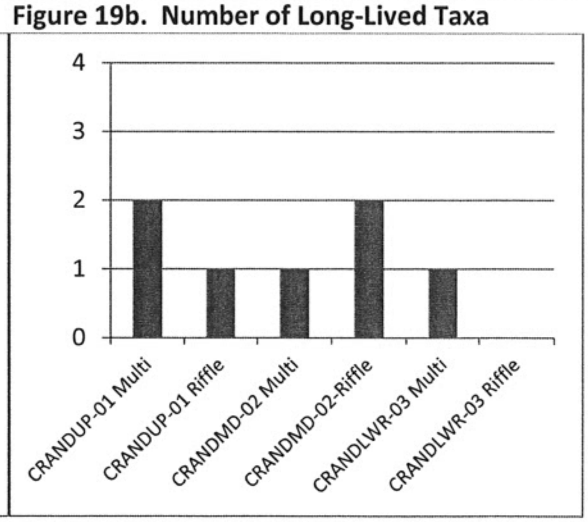


Figure 20b. Number of Clinger Taxa

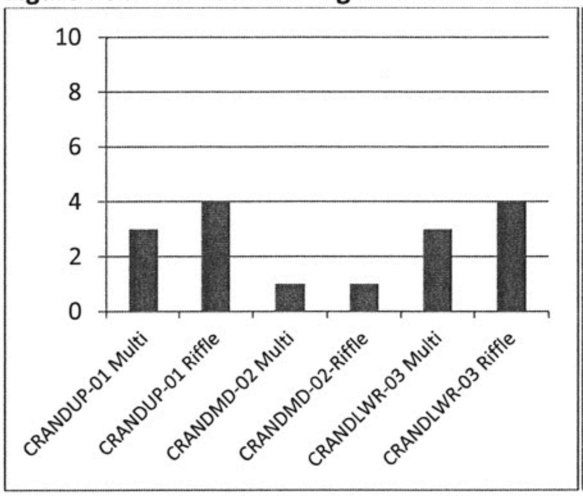


Figure 21b. Baetis:All Ephemetroptera (Percent)

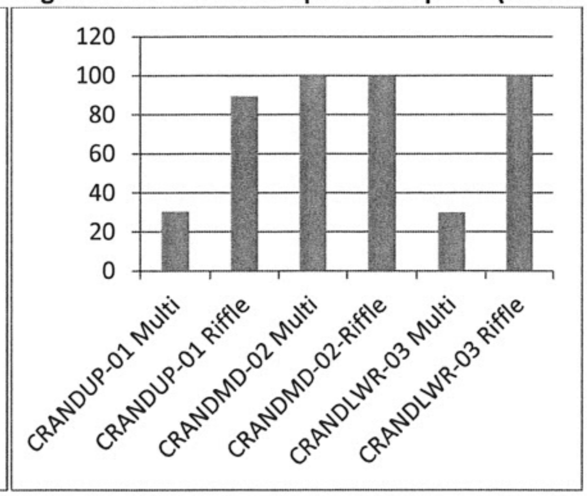


Figure 22b. Baetis, Hydropsychidae & Orthocladiinae (Percent)

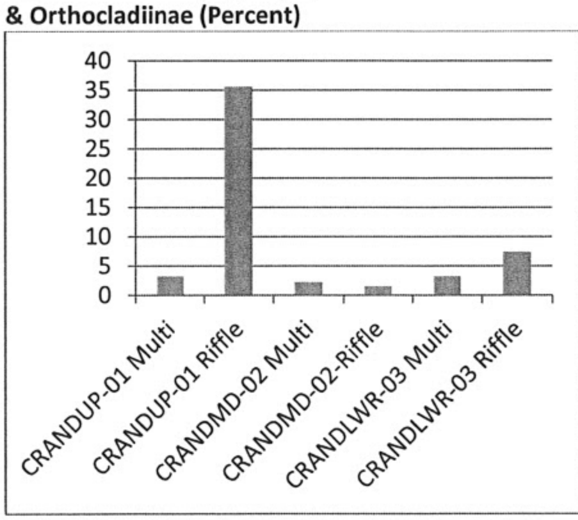


Figure 23b. Heptageniidae: All Ephemeroptera (Percent)

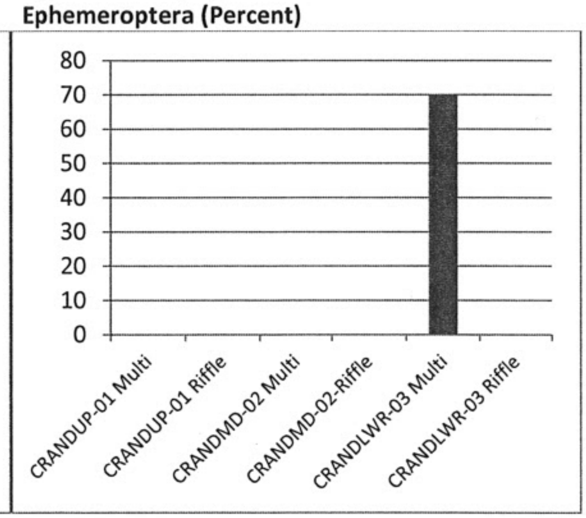
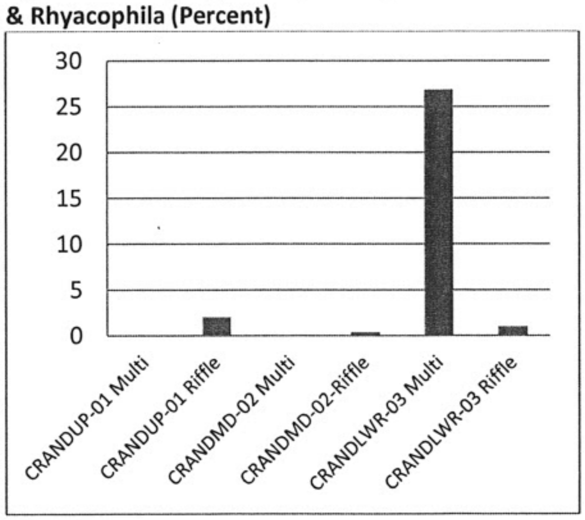


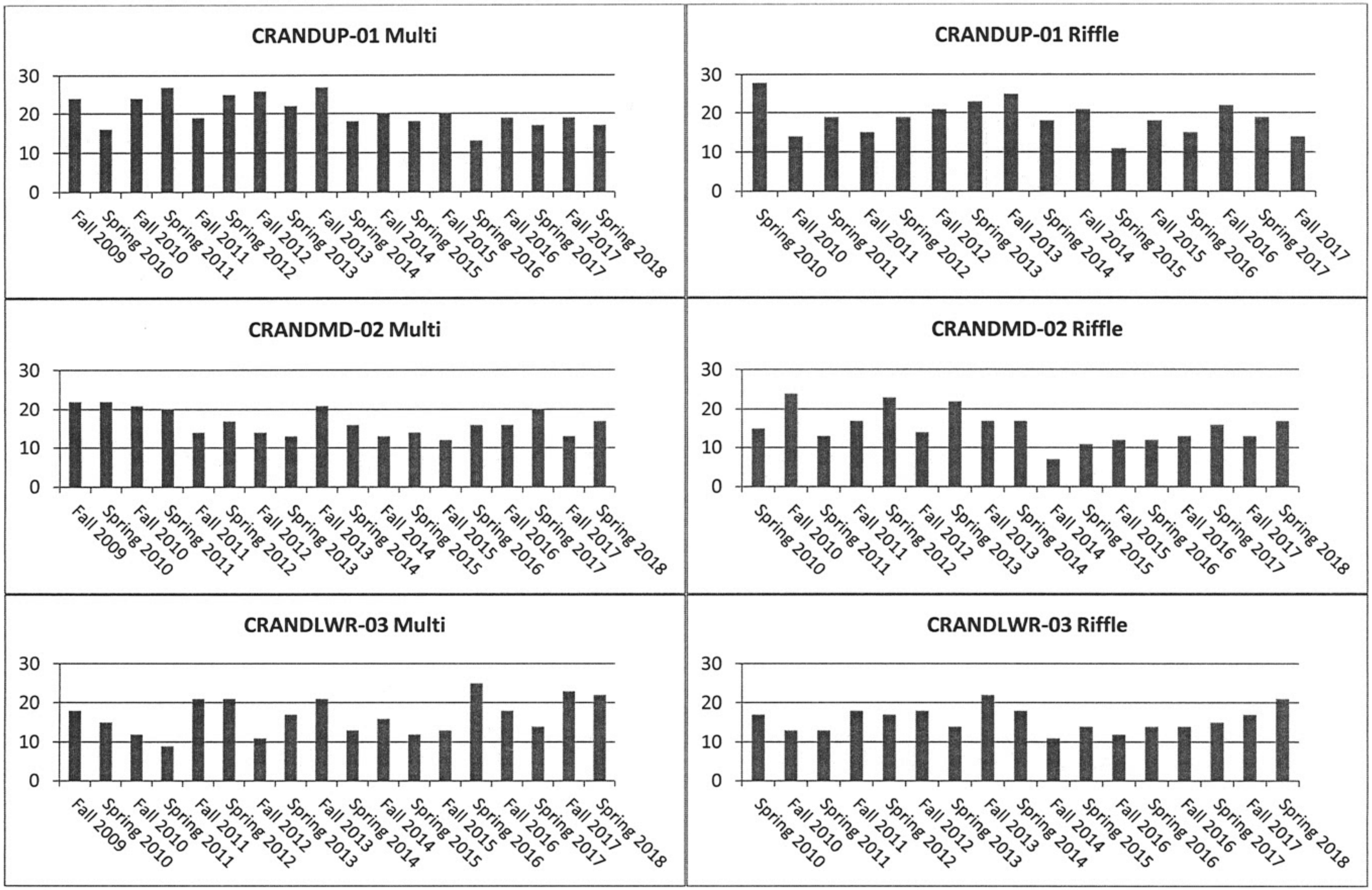
Figure 24b. Heptageniidae, Chloroperlidae & Rhyacophila (Percent)



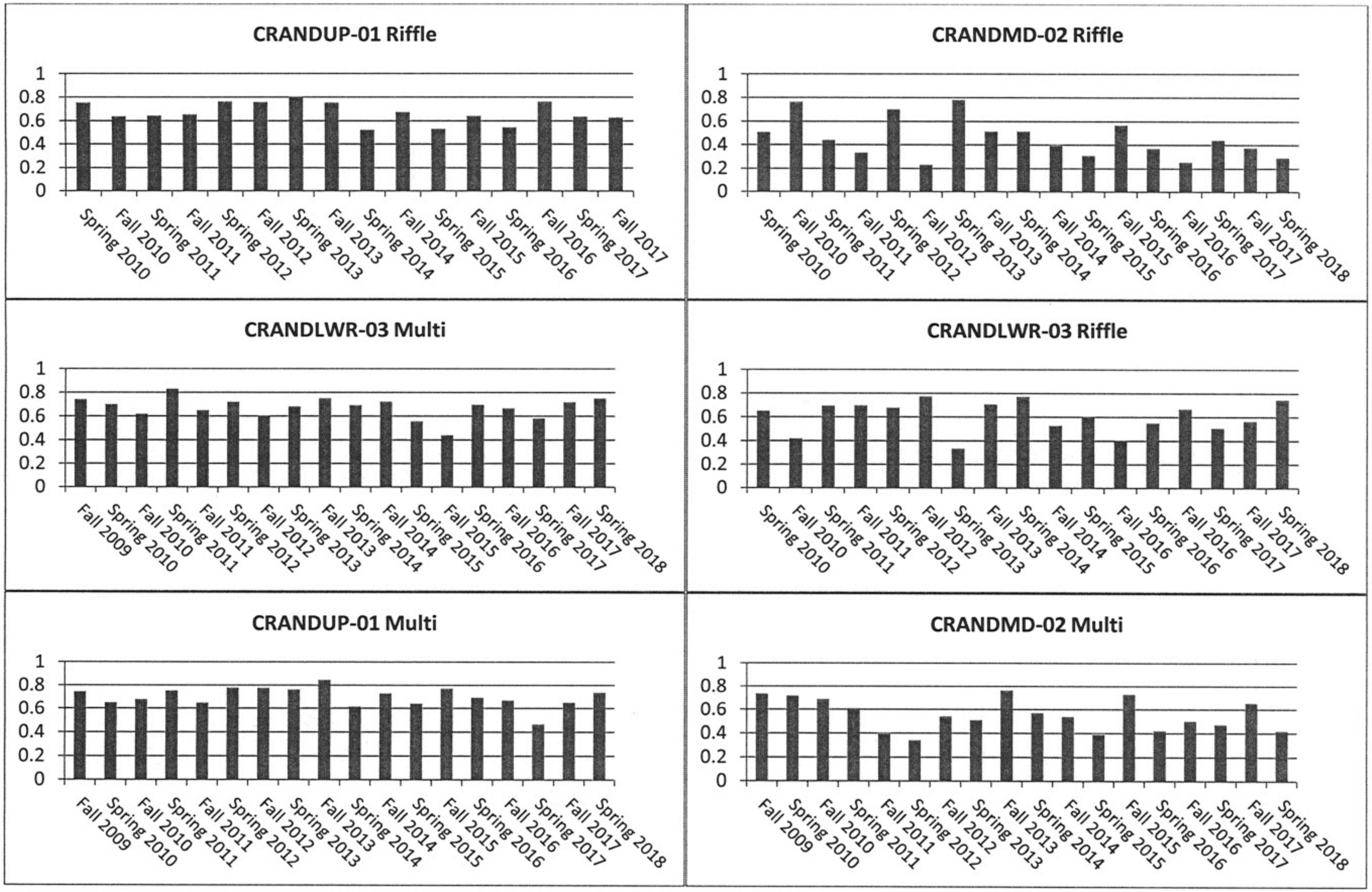
APPENDIX C

MACROINVERTEBRATE FIGURES FALL 2009- SPRING 2018

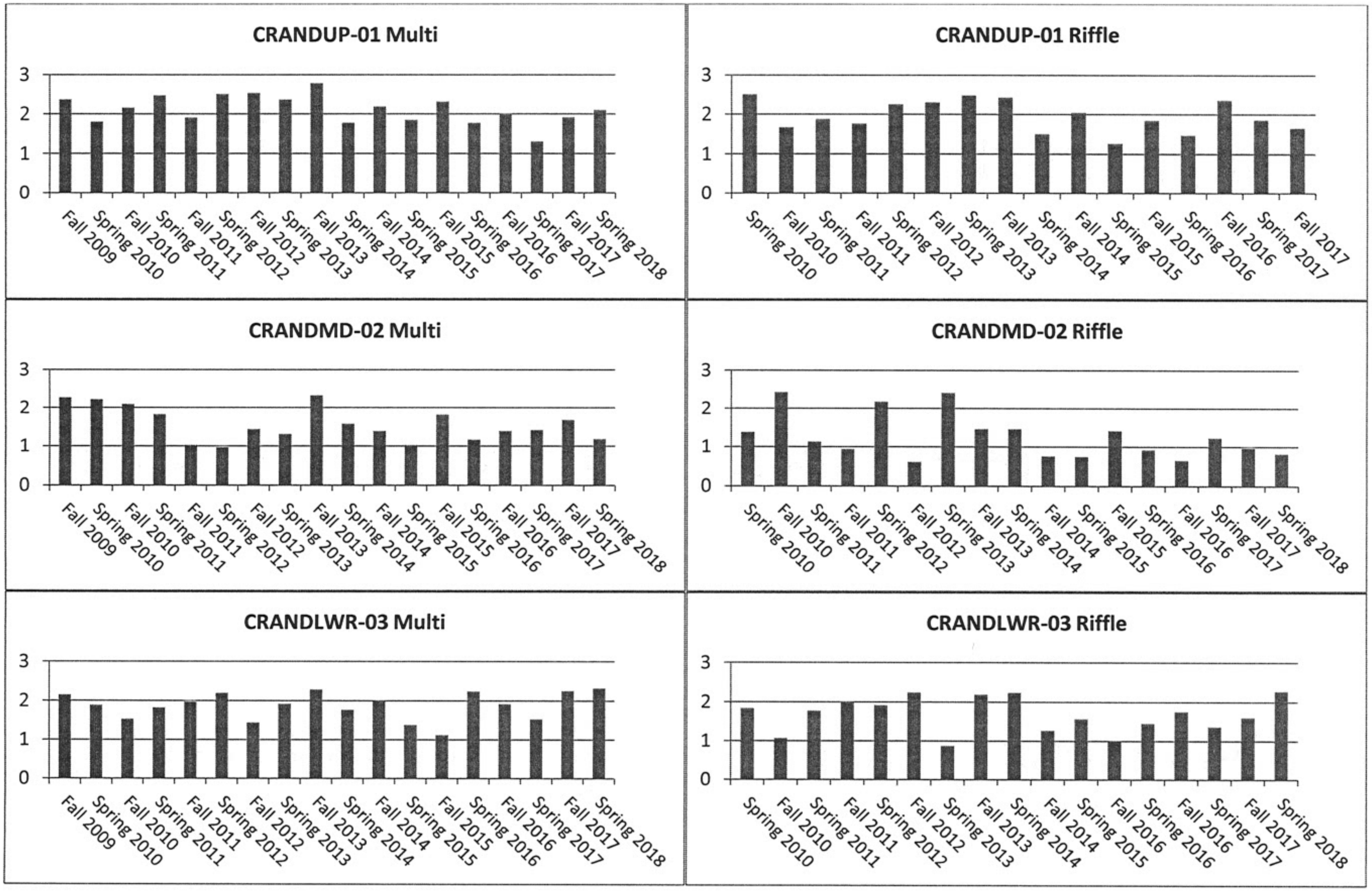
Figures 1c. Richness values for each reach and habitat type from 2009-2018



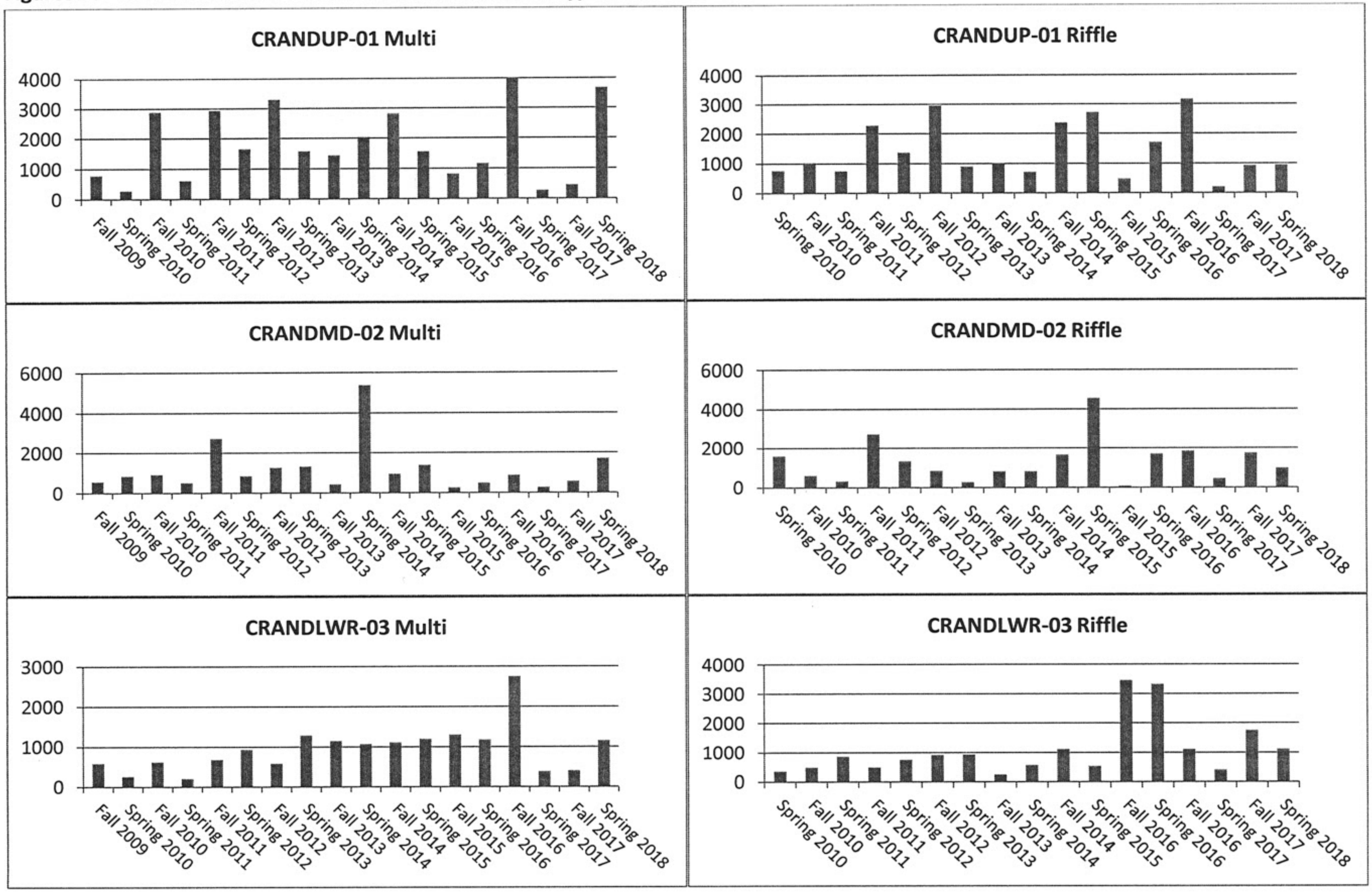
Figures 2c. Evenness values for each reach and habitat type from 2009-2018



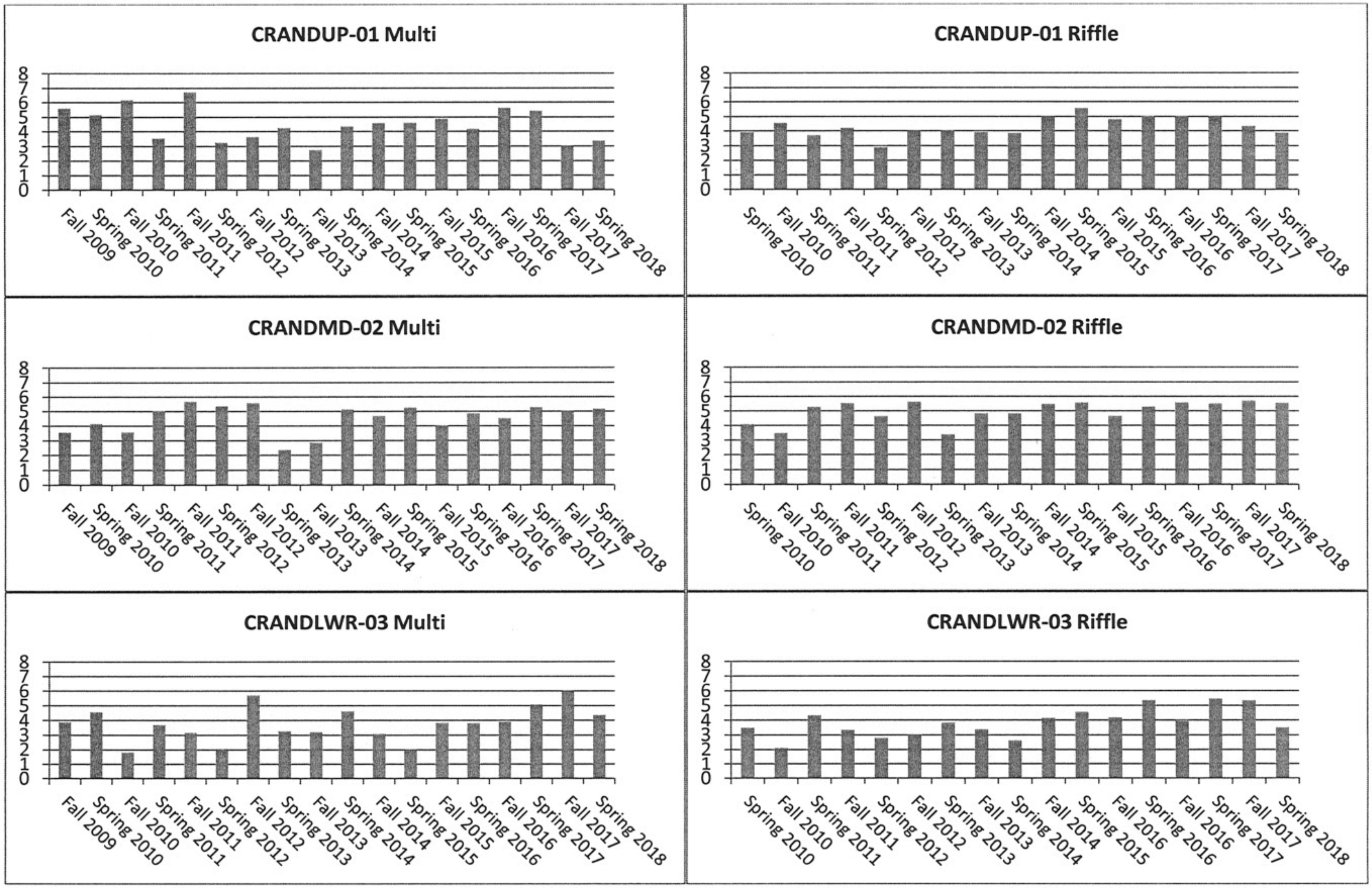
Figures 3c. Shannon's Diversity values for each reach and habitat type from 2009-2018



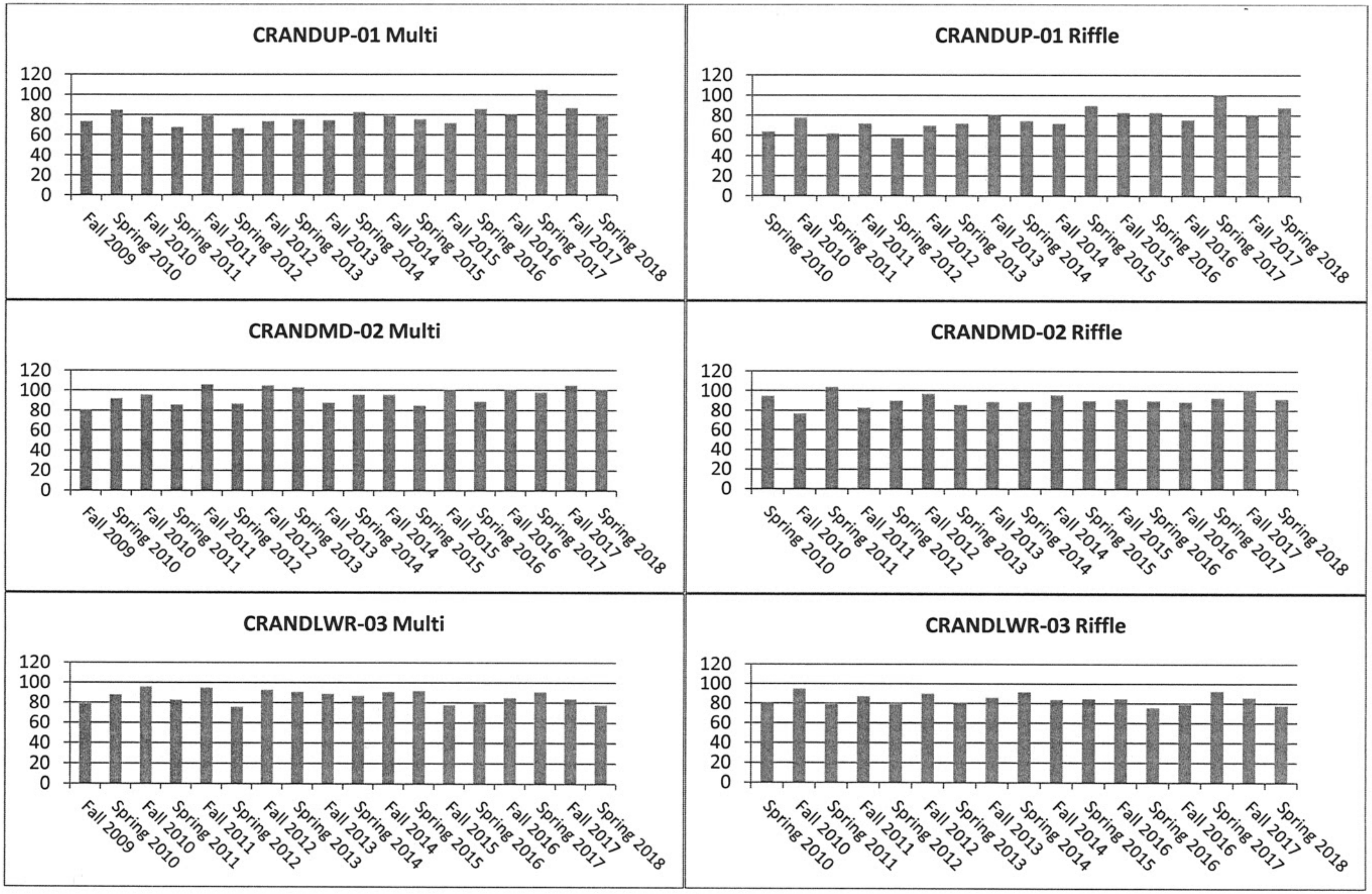
Figures 4c. Abundance values for each reach and habitat type from 2009-2018



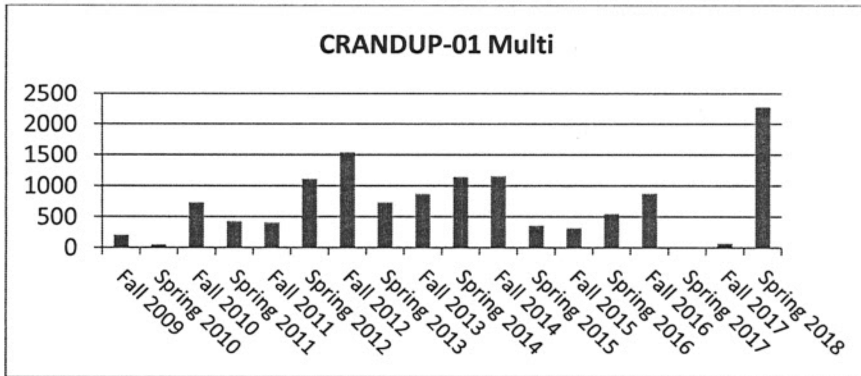
Figures 5c. Hilsenhoff Biotic Index values for each reach and habitat type from 2009-2018

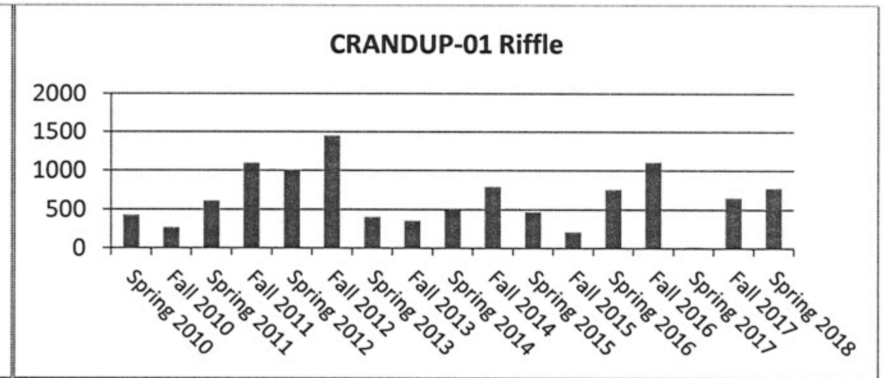


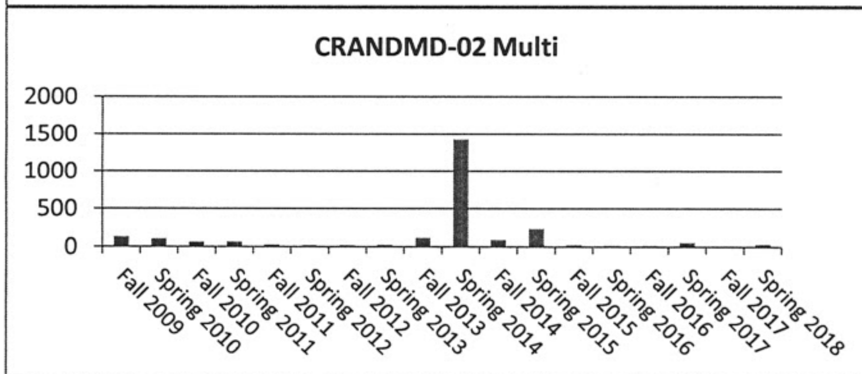
Figures 6c. USFS Community Tolerance Quotient (CTQd) values for each reach and habitat type from 2009-2018

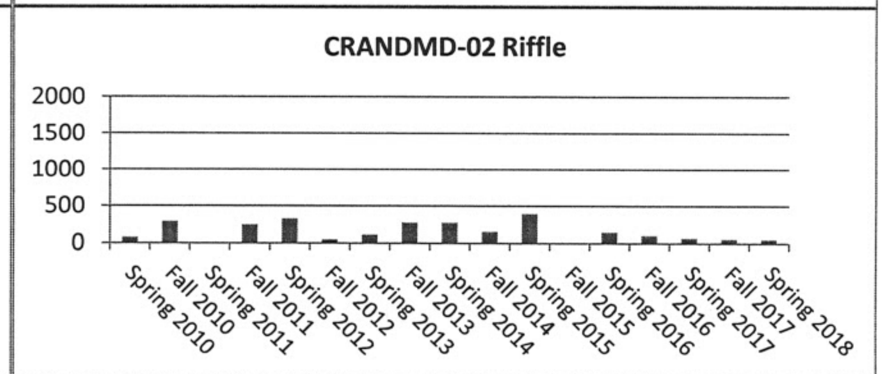


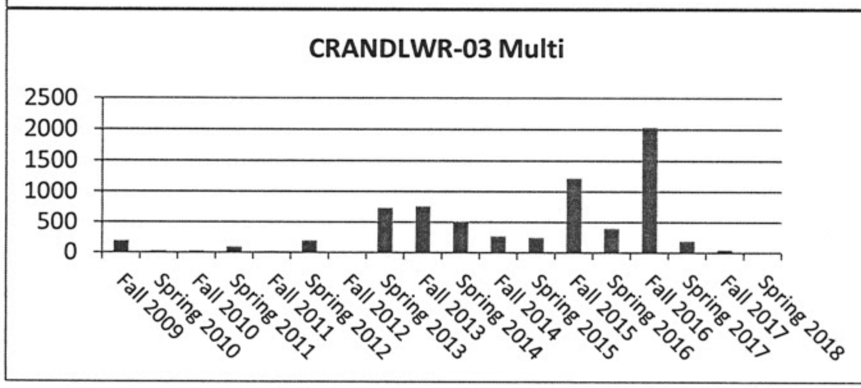
Figures 7c. EPT taxa abundance values for each reach and habitat type from 2009-2018

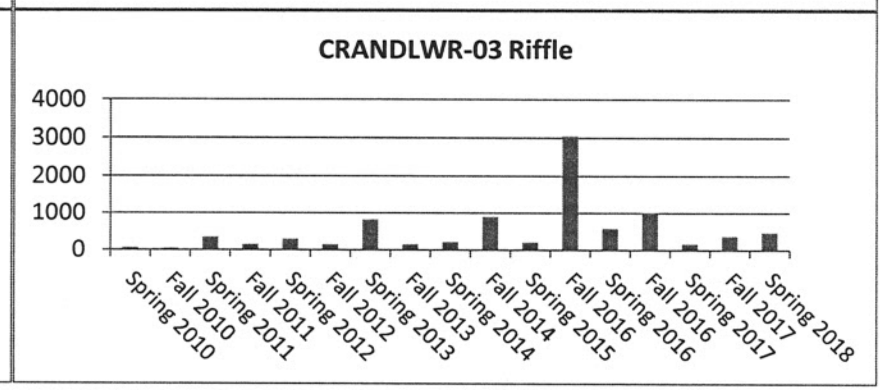








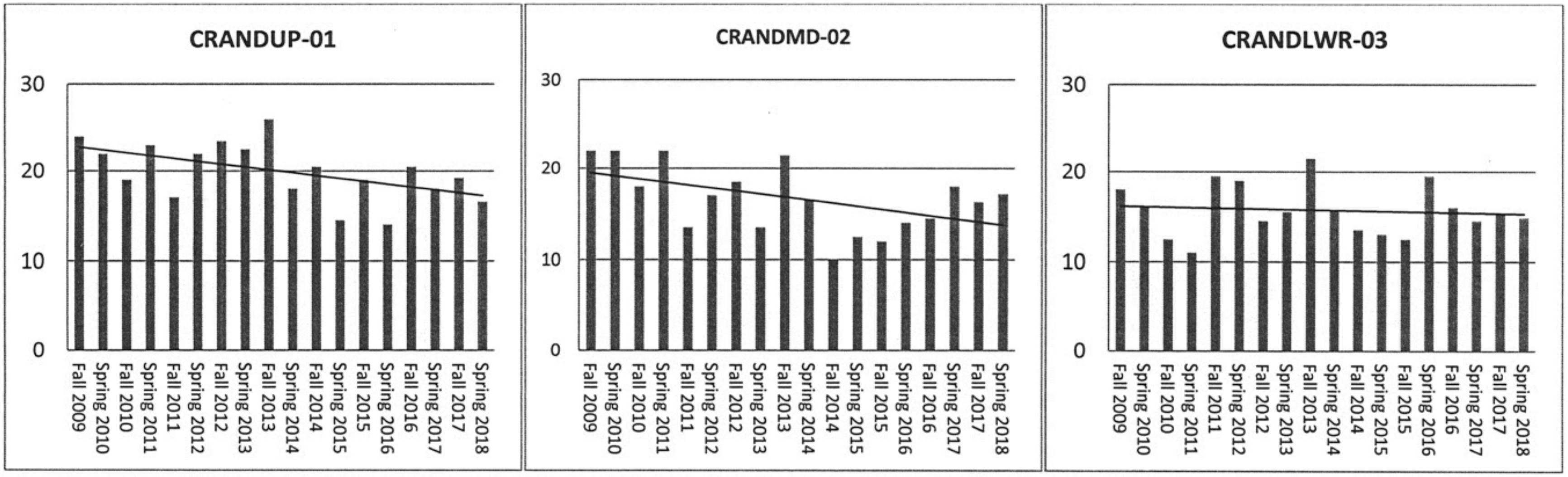




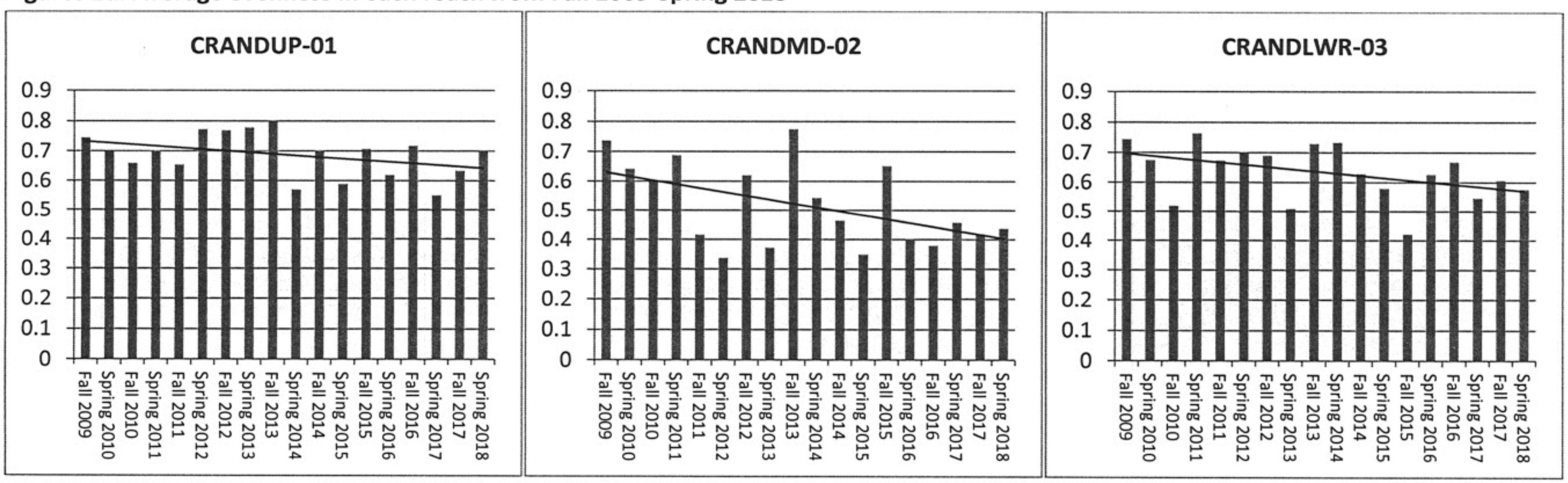
APPENDIX D

MACROINVERTEBRATE FIGURES FALL 2009- SPRING 2018 AVERAGED

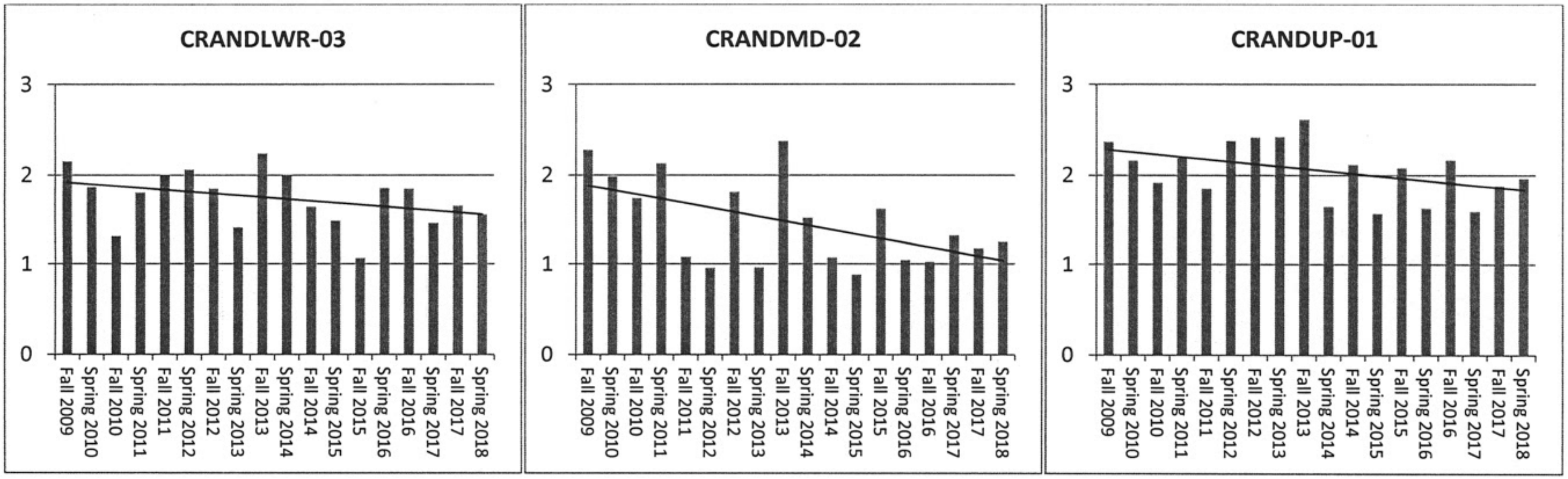
Figures 1d. Average richness in each reach from Fall 2009-Spring 2018



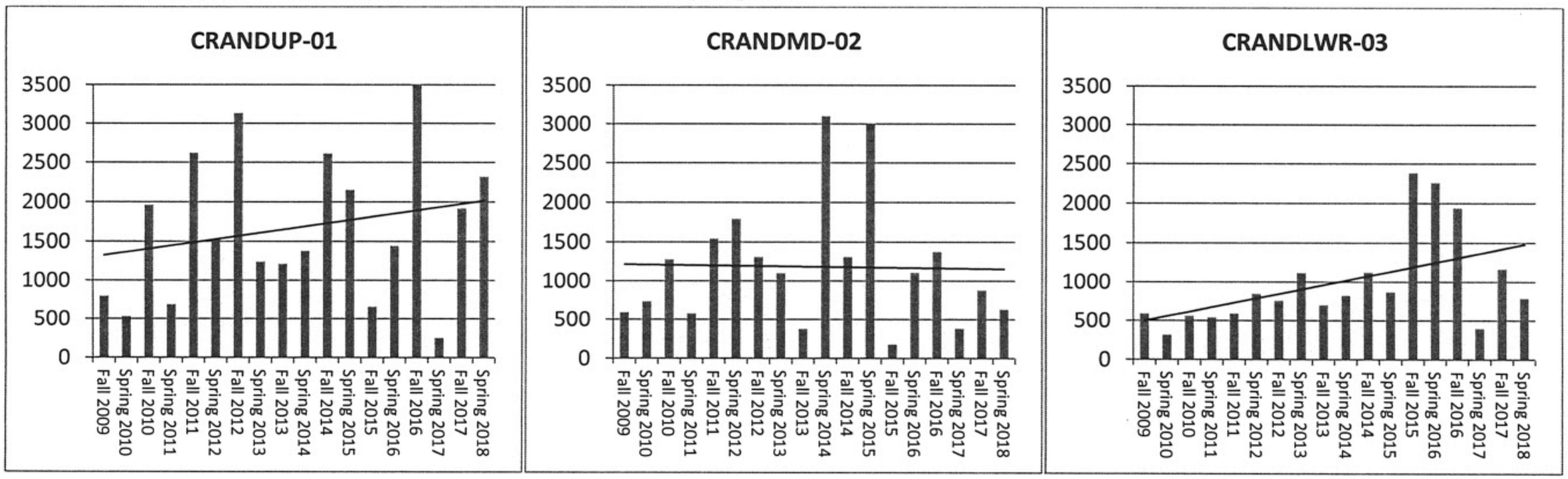
Figures 2d. Average evenness in each reach from Fall 2009-Spring 2018



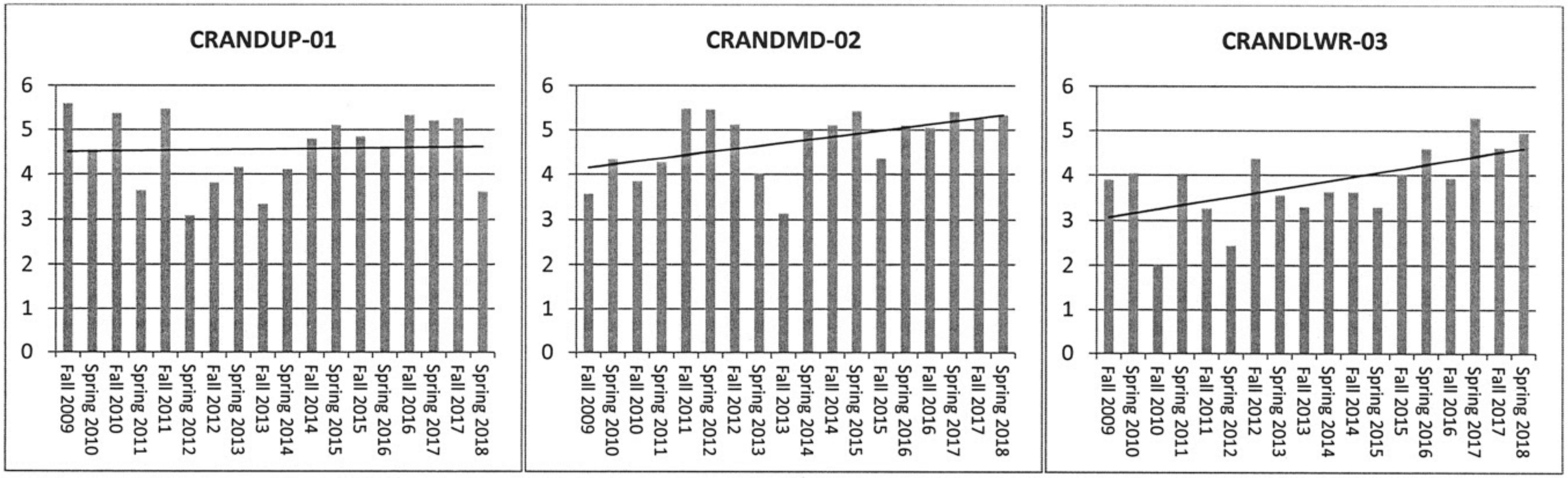
Figures 3d. Average Shannon's Diversity in each reach from Fall 2009-Spring 2018



Figures 4d. Average abundance in each reach from Fall 2009-Spring 2018

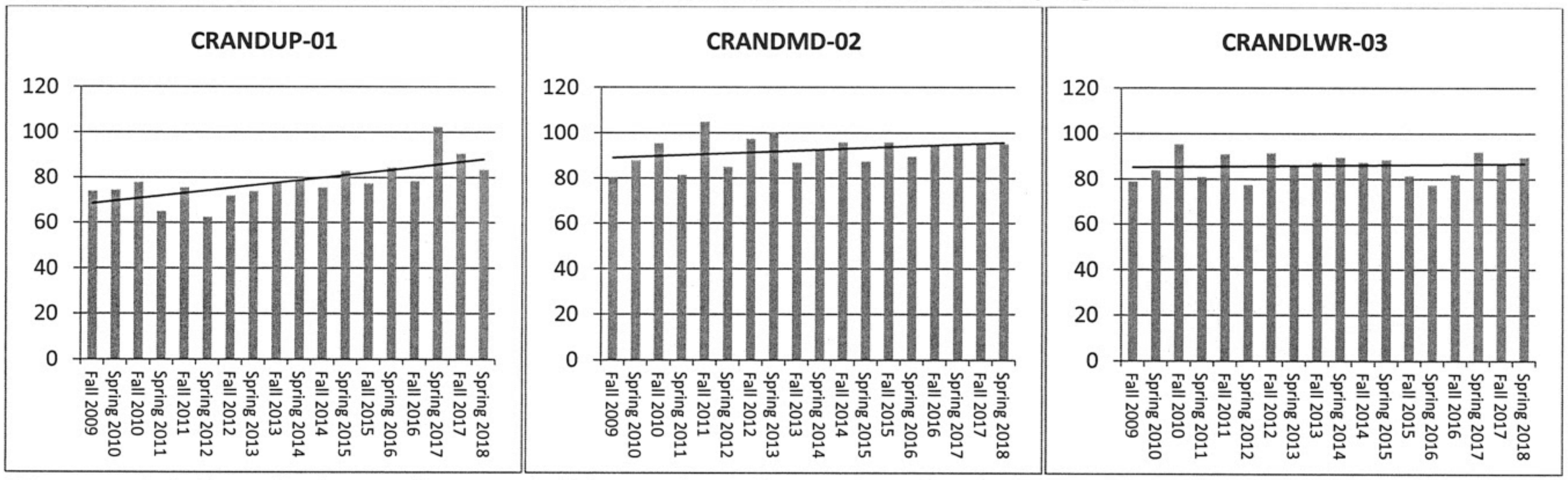


Figures 5d. Average Hilsenhoff Biotic Index in each reach from Fall 2009-Spring 2018*



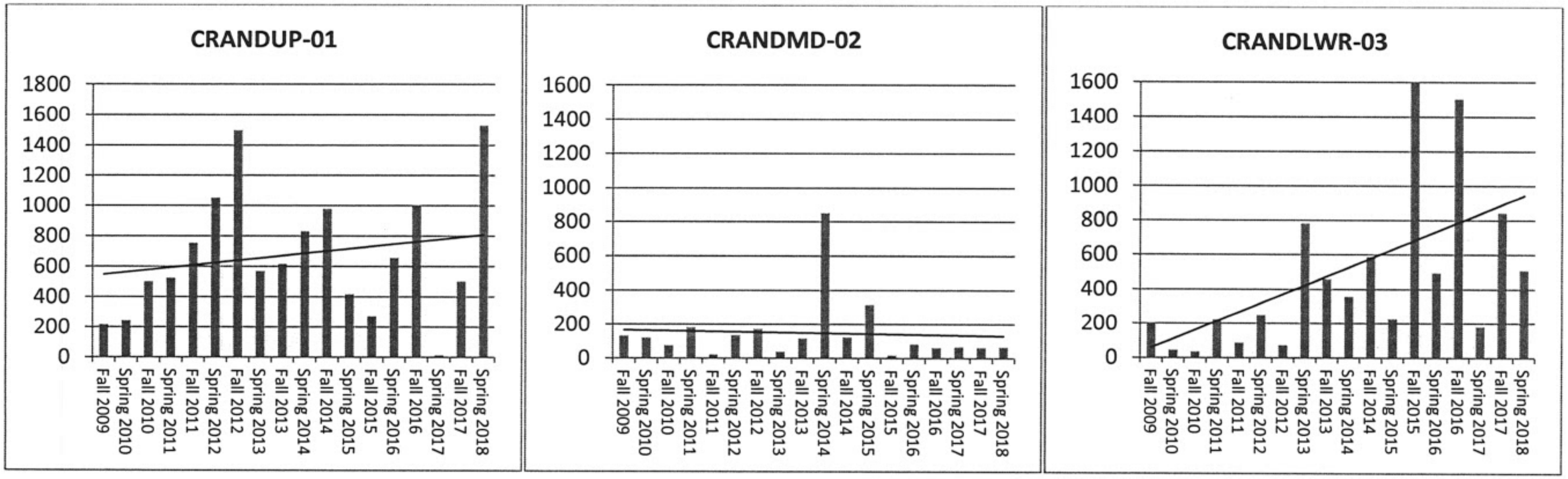
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 6d. Average USFS community tolerant quotient (CTQd) in each reach from Fall 2009-Spring 2018*

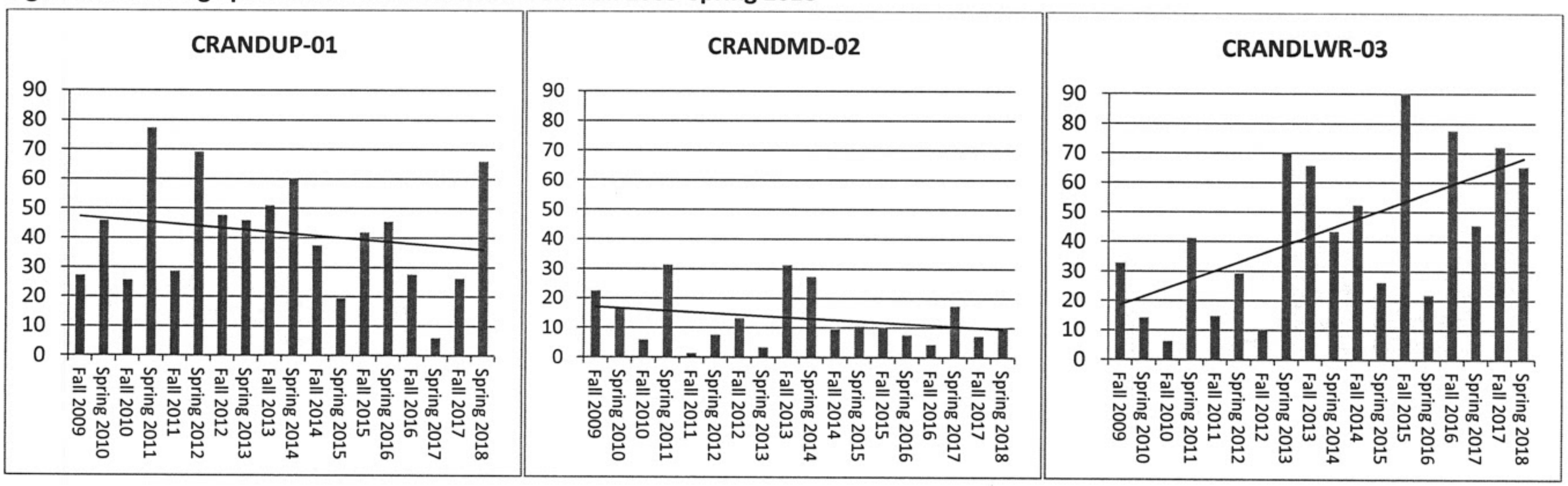


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

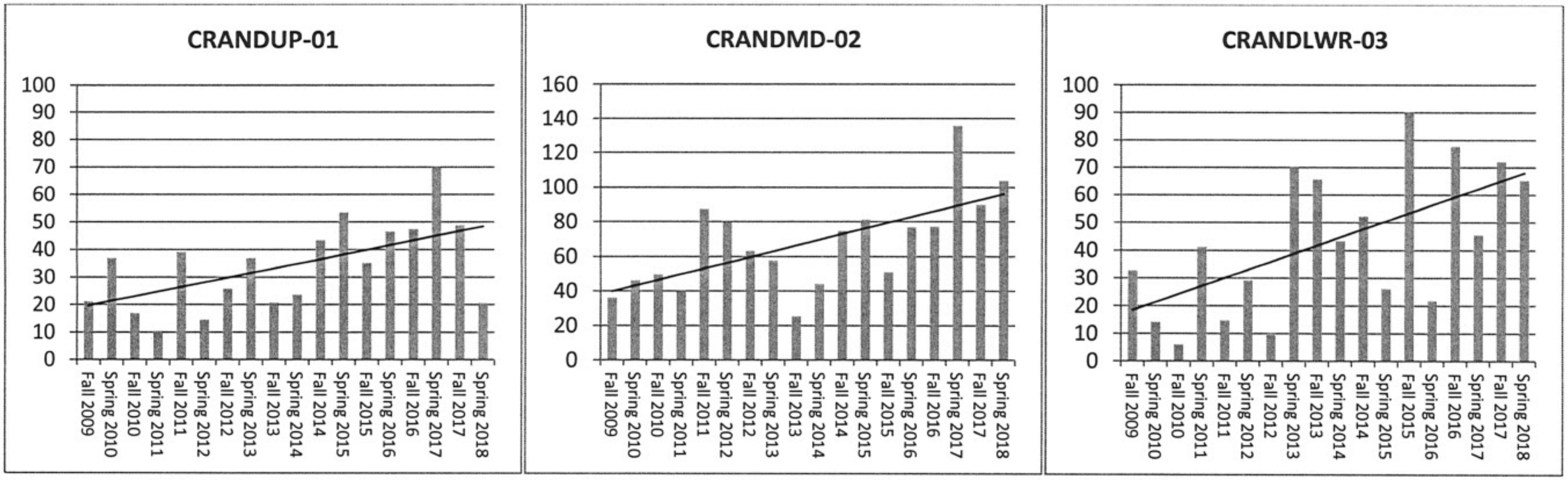
Figures 7d. Average EPT taxa abundance in each reach from Fall 2009-Spring 2018



Figures 8d. Average percent EPT in each reach from Fall 2009-Spring 2018

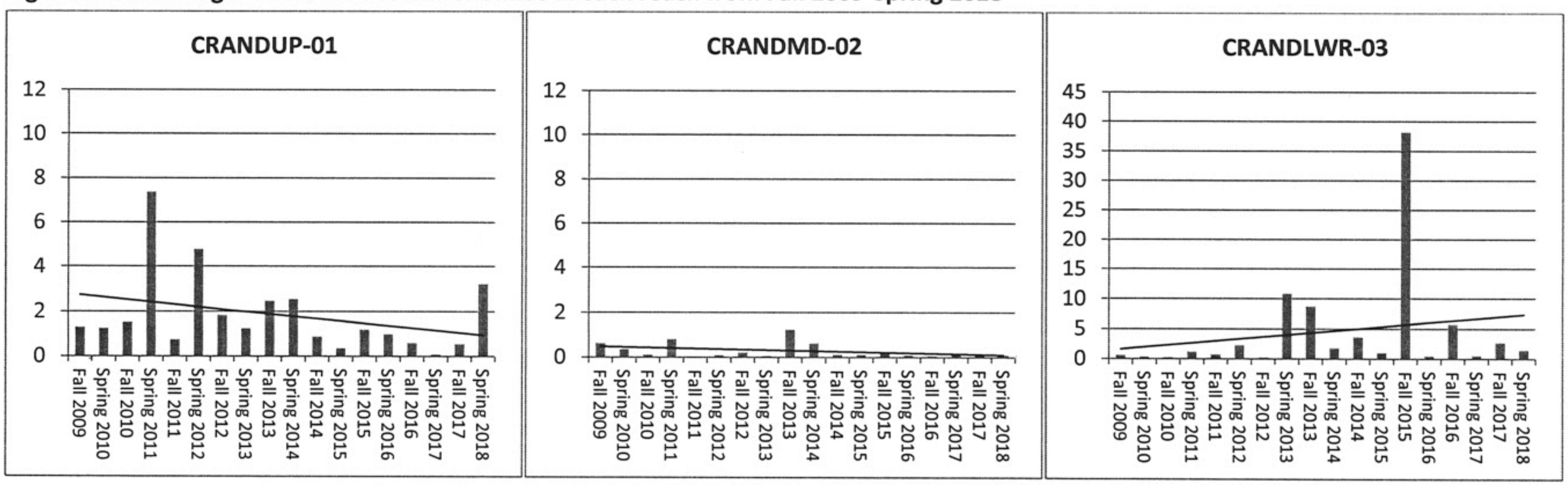


Figures 9d. Average percent Chironomids in each reach from Fall 2009-Spring 2018*

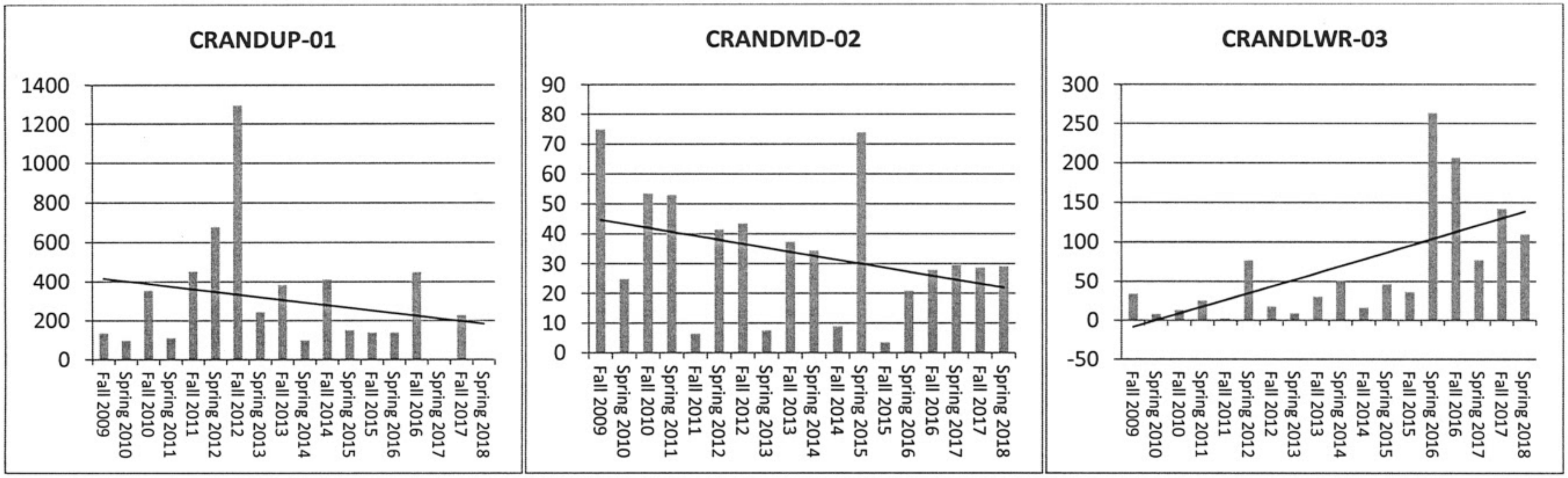


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 10d. Average ratio of EPT to Chironomids in each reach from Fall 2009-Spring 2018

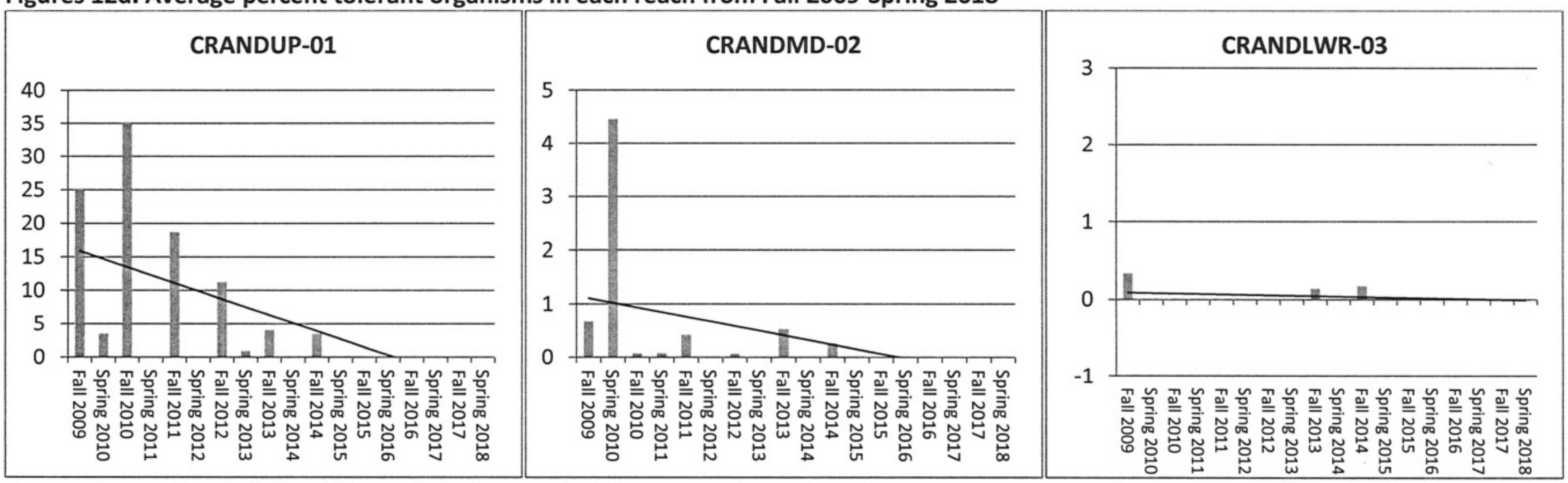


Figures 11d. Average number of tolerant taxa in each reach from Fall 2009-Spring 2018*



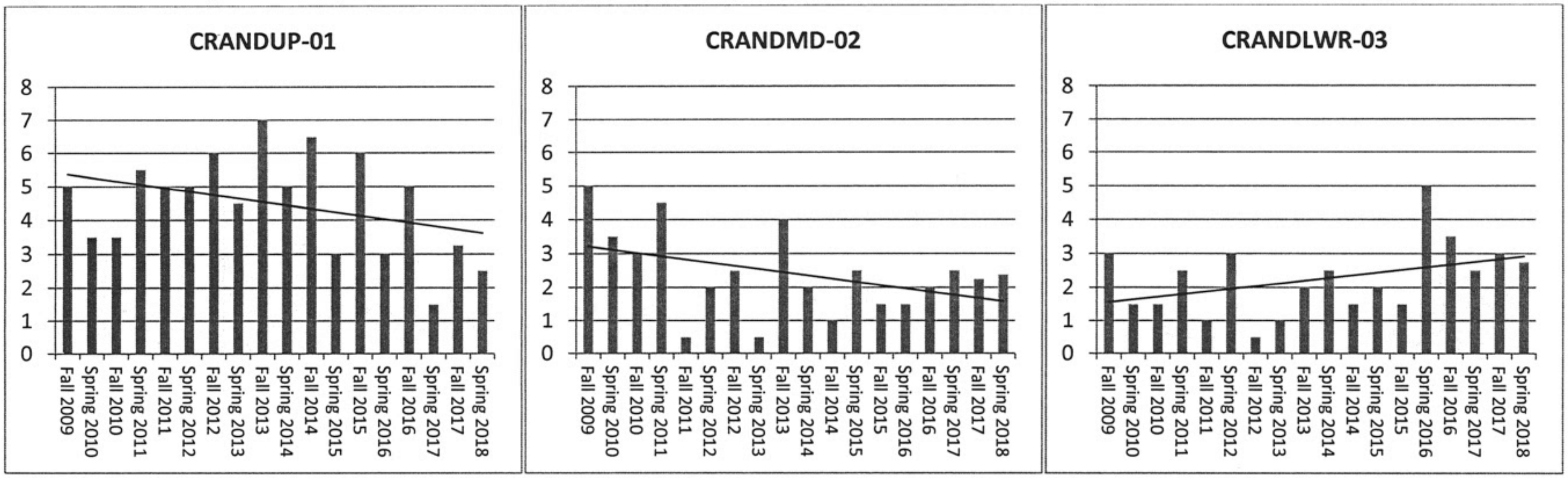
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 12d. Average percent tolerant organisms in each reach from Fall 2009-Spring 2018*

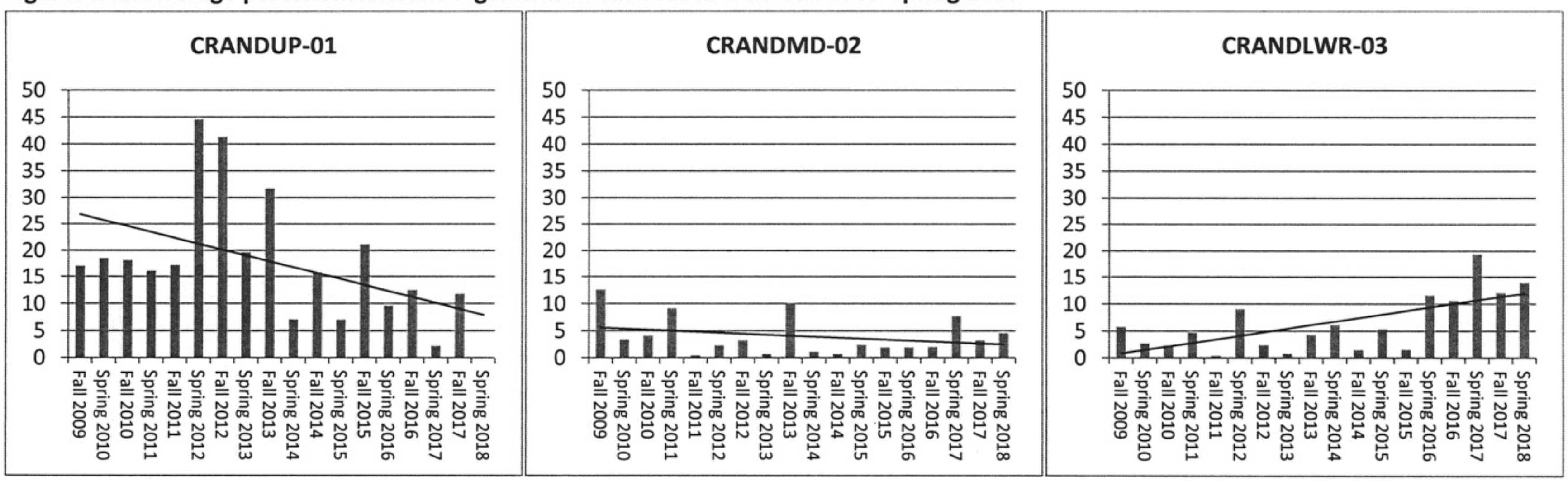


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

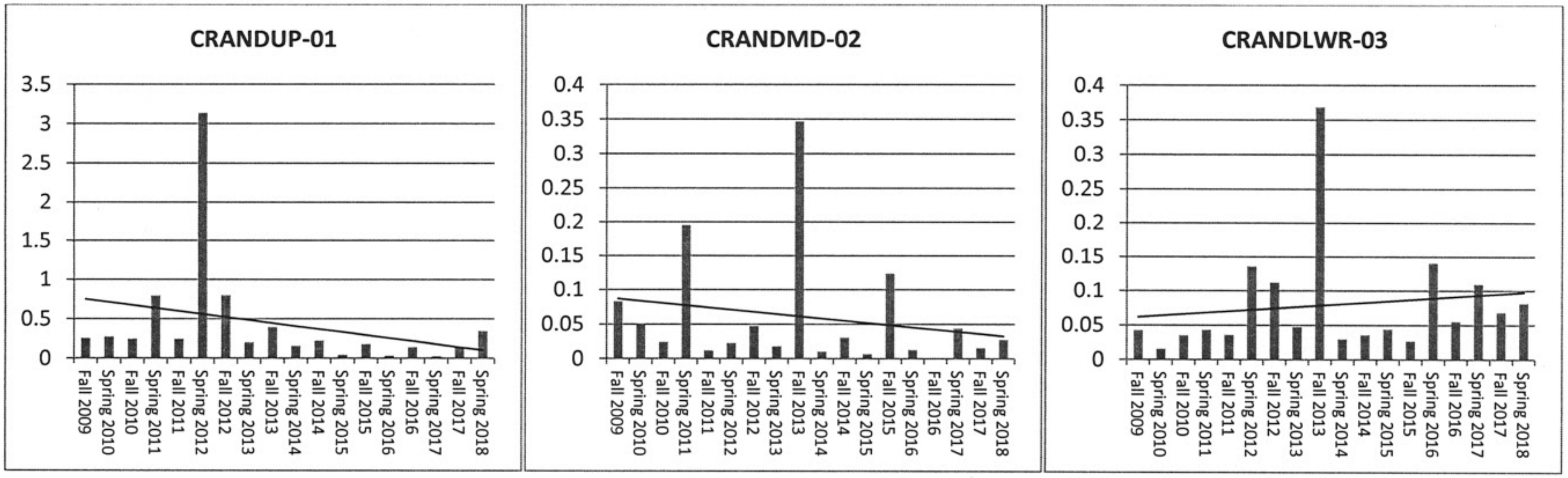
Figures 13d. Average number of intolerant taxa in each reach from Fall 2009-Spring 2018



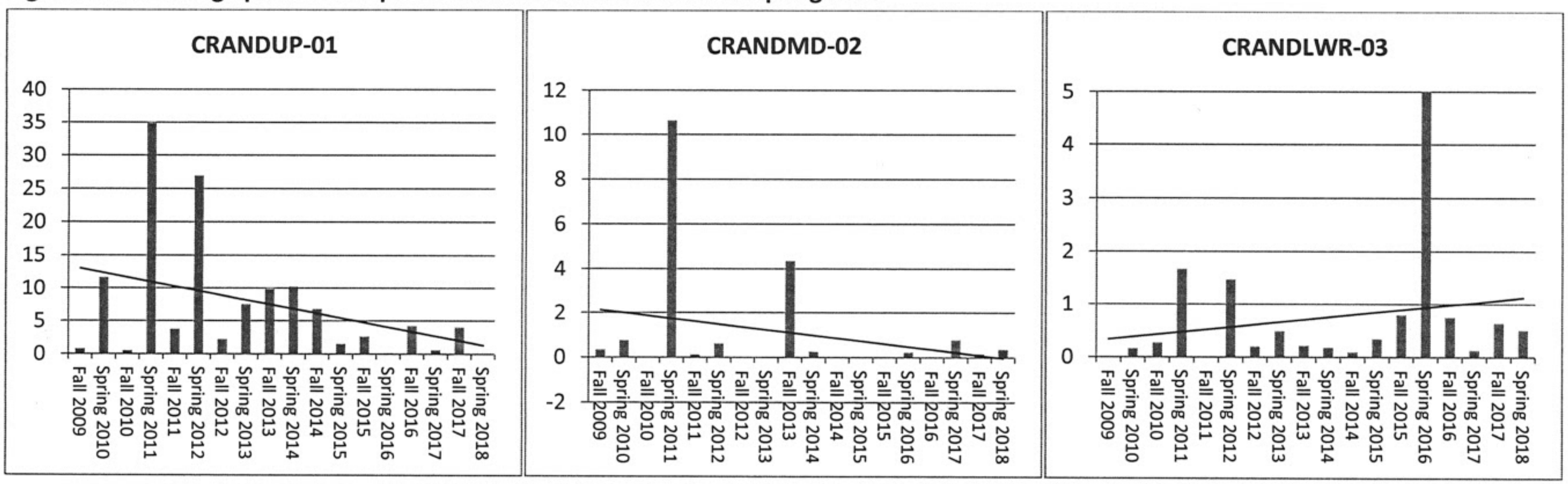
Figures 14d. Average percent intolerant organisms in each reach from Fall 2009-Spring 2018



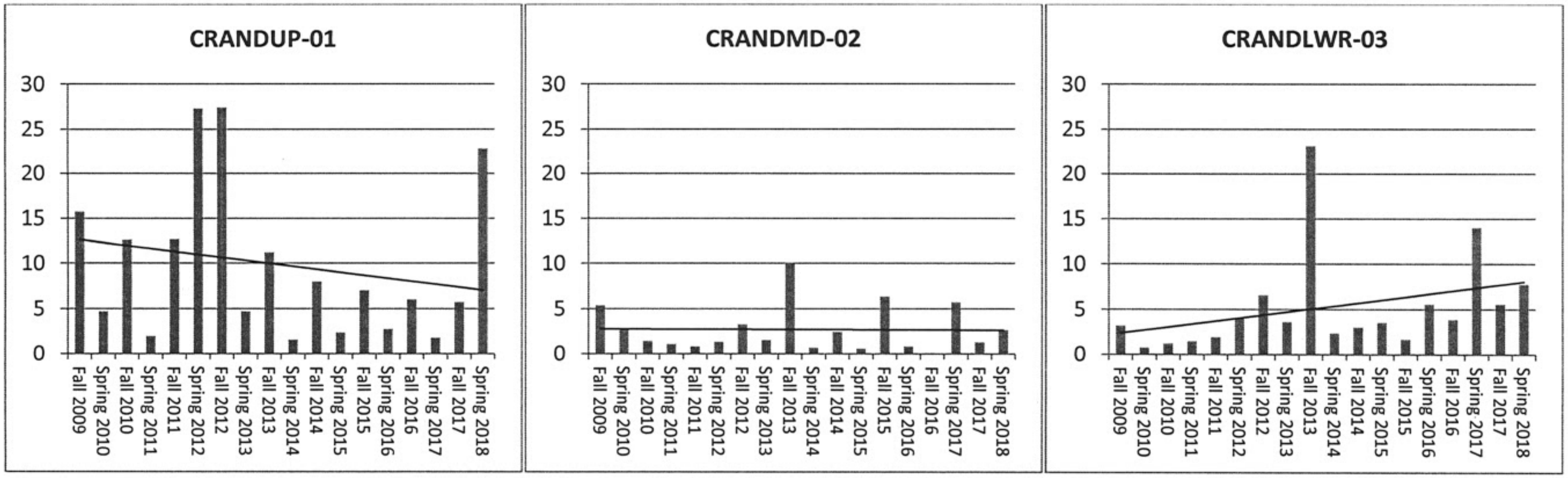
Figures 15d. Average ratio of specialist feeders to generalist feeders in each reach from Fall 2009-Spring 2018



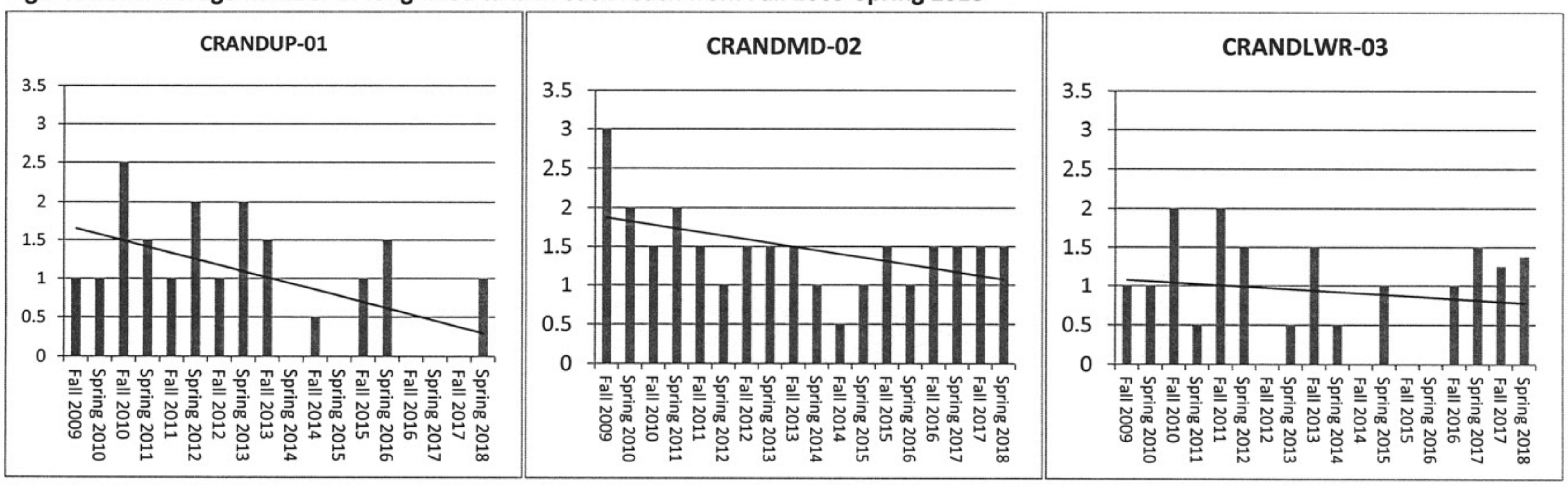
Figures 16d. Average percent scrapers in each reach from Fall 2009-Spring 2018



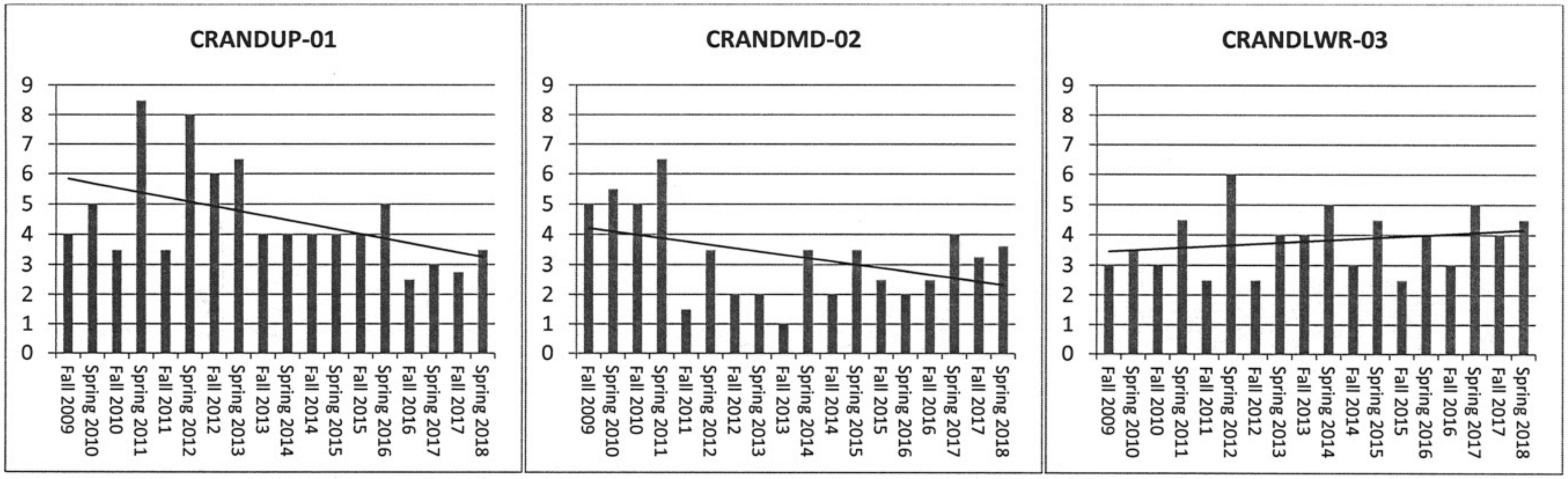
Figures 17d. Average percent shredders in each reach from Fall 2009-Spring 2018



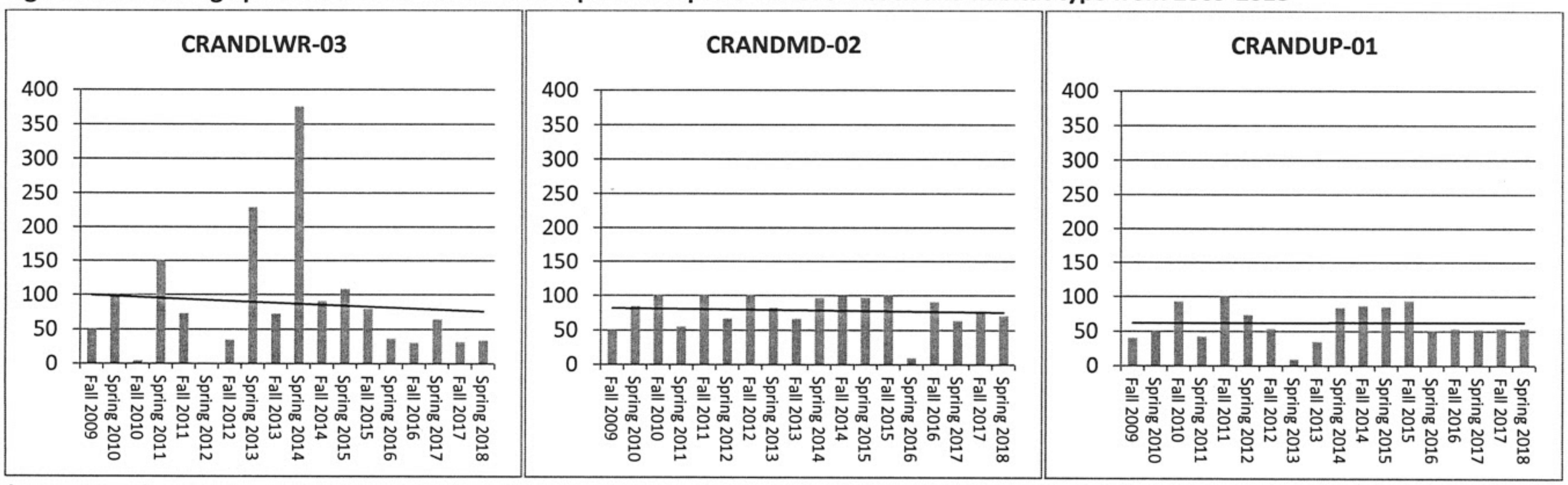
Figures 18d. Average number of long-lived taxa in each reach from Fall 2009-Spring 2018



Figures 19d. Average number of clinger taxa reach from Fall 2009-Spring 2018

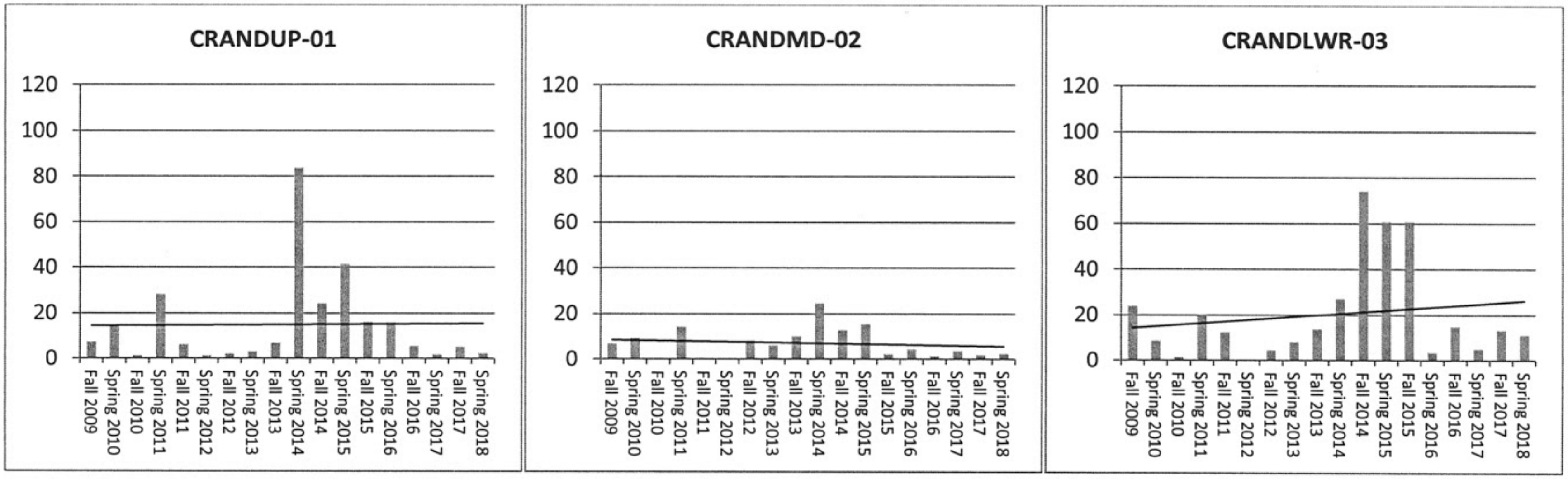


Figures 20d. Average percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2009-2018*



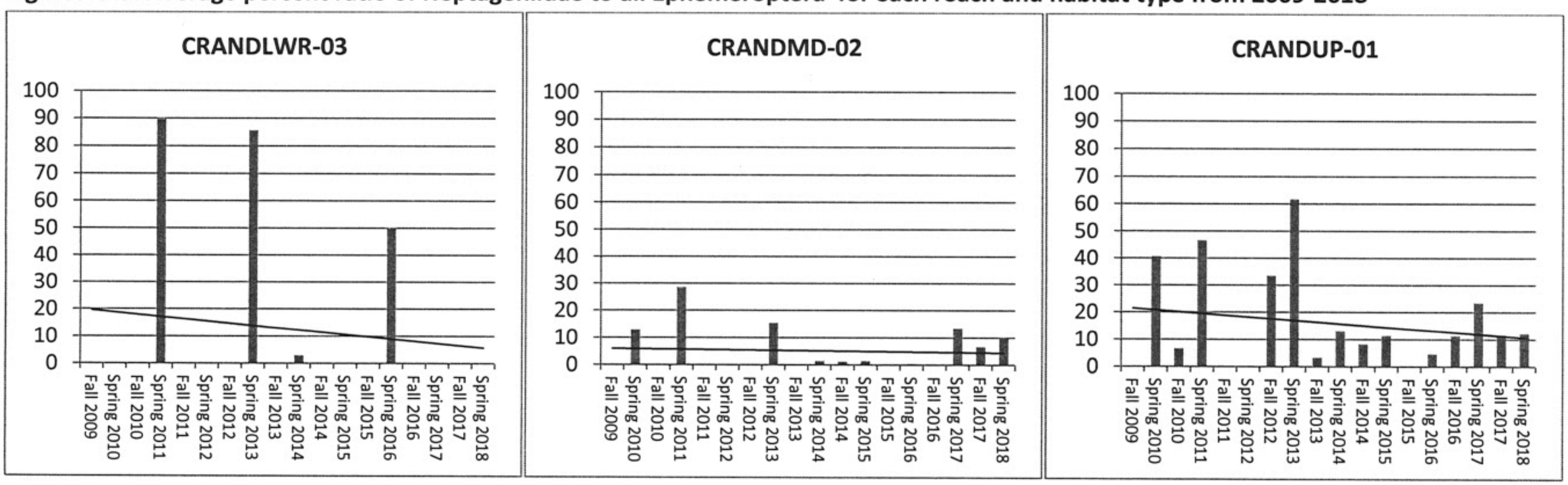
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 21d. Average percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2018*

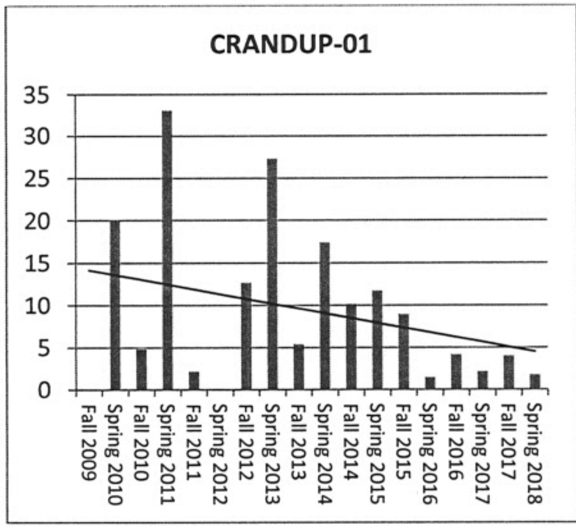


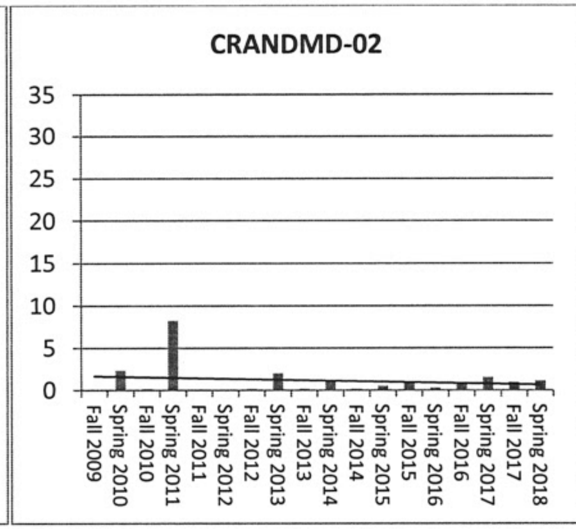
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

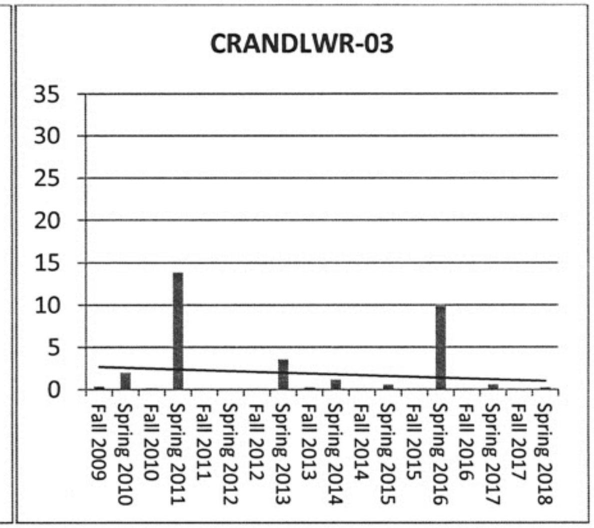
Figures 22d. Average percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2018



Figures 23d. Average percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2018







Appendix E

Macro Report USU Bug Lab

BLM/USU National Aquatic Monitoring Center (NAMC) Department of Watershed Sciences (WATS) - Utah State University 5210 Old Main Hill Logan, UT 84322-5210 http://www.usu.edu/buglab/

Report prepared by:
Trip Armstrong: 760.709.1210 / trip.armstrong@usu.edu

Report Table of Contents

Metadata
- Contact
- Worksheet
- Metrics
- References

Metrics
Species Matrix (Raw)
Species Matrix (Standardized)

Excel Worksheet Name	Worksheet Description
Metrics	Common metrics used to assess freshwater biological integrity, as well as operational taxonomic units (OTUs; sensu Cuffney et al. 2007) and a fixed indicated with an asterisk. NAMC OTU standardization uses the method o coarser levels. We are able to standardize your data to custom OTUs and, well as references, can be obtained by contacting NAMC and will soon be **This report was generated with the following settings - OTUs: OTUCODE**
Species Matrix (Raw)	Raw taxonomic and abundance data for sampled sites. Abundance data is individuals per sample for qualitative samples. Note that the taxonomic d redundancy likely exists in the taxonomic hierarchy.
Species Matrix (Standardized)	Taxonomic and abundance data (Species matrix) for sampled sites that ha data has not been standardized to a fixed count as in the 'Standardized M the estimated number per sample for qualitative samples.

Description of the fields contained in the 'Metrics' worksheet. A more detailed explanation of each metric is a

Category	Column Name	Explanation
Collection information	SampleID	NAMC unique tracking number

	Station (NAMC)	NAMC station tracking id
	Station (Customer)	Station abbreviation provided by the customer
	Waterbody	Specific location name
	County	Administrative boundary
	State	Administrative boundary
	Latitude	Y coordinate in decimal degree units
	Longitude	X coordinate in decimal degree units
	Collection Date	Date of sampling event
	Habitat Sampled	Microhabitat or channel unit(s) where sample(s) was taken. Values are restricted to predetermined values as specified in the PDF metadata.
	Collection Method	Method used to collect sample. Values are restricted to predetermined values as specified in the PDF metadata.
	Field Notes	Field notes provided by customer
	Lab Notes	Laboratory processing notes, particularly regarding condition of received samples and QAQC
	Area Sampled	Total area sampled in square meters
Laboratory Processing	Field Split	% sample submitted for processing
	Lab Split	% of sample processed to obtain 600 random individuals (if present)
	Split Count	# of organisms randomly subsampled from [Lab Split] for identification
	Fixed count	# of computationally resampled organisms
	Big Rare Count	# of "big and rare" organisms selected NON-RANDOMLY for identification from the entire submitted sample
Richness (metrics summarizing all unique	Richness	# of unique taxa, standardized to OTU

taxa in a sample)	Abundance	Estimated # number of individuals per unit area (m^2) for quantitative samples OR the estimated number per sample for qualitative samples.
	Shannon's Diversity	Measure of richness and evenness (based on relative abundance of each species); weighted toward rare species
	Simpson's Diversity	Measure of richness and evenness (based on relative abundance of each species); weighted toward common species
	Evenness	Measure of relative abundance indicative of taxa dominance
	# of EPT Taxa	Richness of Ephemeroptera, Plecoptera, and Trichoptera taxa
	EPT Taxa Abundance	Abundance of Ephemeroptera, Plecoptera, and Trichoptera taxa
Dominance Metrics (metrics summarizing all most abundant taxa in a sample)	Dominant Family	Taxonomic family with the highest abundance
	Abundance of Dominant Family	Abundance of dominant family
	Dominant Taxa	Individual taxa with the highest abundance
	Abundance of Dominant Taxa	Abundance of dominant taxa
Tolerance Indices (indices based on the indicator species concept in which taxa are assigned tolerance values)	Hilsenhoff Biotic Index	Abundance-weighted average of family-level pollution tolerances
	# of Intolerant Taxa	# of taxa with an HBI score <= 2
	Intolerant Taxa abundance	Abundance of taxa with an HBI score <= 2
	# of Tolerant Taxa	# of taxa with an HBI score>=8
	Tolerant Taxa abundance	Abundance of taxa with an HBI score >=8
	USFS Community Tolerance Quotient (d)	Dominance weighted community tolerance quotient

Functional Feeding Groups (classification of organisms based on morphological or behavioral adaptations for where and how food is acquired)	# of shredder taxa	# of taxa utilizing living or decomposing vascular plant tissue and CPOM
	Shredder Abundance	Abundance of taxa utilizing vascular plant tissue and CPOM
	# of scraper taxa	# of taxa utilizing periphyton, particularly algae and diatoms
	Scraper abundance	Abundance of taxa utilizing periphyton, particularly algae and diatoms
	# of collector-filterer taxa	# of taxa utilizing FPOM in the water column
	Collector-filterer abundance	Abundance of taxa utilizing FPOM in the water column
	# of collector-gatherer taxa	# of taxa utilizing FPOM from benthic deposits
	Collector-gatherer abundance	Abundance of taxa utilizing FPOM from benthic deposits
	# of predator taxa	# of taxa utilizing living animal tissue
	Predator abundance	Abundance of taxa utilizing living animal tissue
Functional Traits (metrics based on morphological and life history traits)	# of clinger taxa	# of taxa with fixed retreats or other strategies for clinging to rocks
	"# of" Long-lived Taxa	# of taxa with 2 to 3 year life cycles
Compositional Metrics (richness and abundance of various taxonomic groups)	# of Ephemeroptera taxa	
	Ephemeroptera abundance	
	# of Plecoptera taxa	
	Plecoptera abundance	
	# of Trichoptera taxa	
	Trichoptera abundance	
	# of Coleoptera taxa	
	Coleoptera abundance	
	# of Elmidae taxa	
	Elmidae abundance	
	# of Megaloptera taxa	
	Megaloptera abundance	
	# of Diptera taxa	
	Diptera abundance	
	# of Chironomidae taxa	
	Chironomidae abundance	
	# of Crustacea taxa	
	Crustacea abundance	
	# of Oligochaete taxa	

	Oligochaete abundance	
	# of Mollusca taxa	
	Mollusca abundance	
	# of Insect taxa	
	Insect abundance	
	# of non-insect taxa	
	Non-insect abundance	

References

Barbour, M.T. et al., 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphytor
Cuffney, T. F., Bilger, M.D. & Haigler, A.M., 2007. Ambiguous taxa: effects on the characterization and interpr
Cuffney, T. F et al., 1993. Methods for collecting benthic invertebrate samples as part of the National Water-(
Hilsenhoff, W.L., 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist, 20(1)
Hilsenhoff, W.L., 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of
Karr, J.R. & Chu, E.W., 1999. Restoring life in running waters: better biological monitoring, Island Press.
Krebs, C.J., 1999. Ecological methodology, Benjamin/Cummings.
Ludwig, J.A. & Reynolds, J.F., 1988. Statistical ecology: a primer on methods and computing, Wiley-Interscien
Merritt, R.W., Cummins, K.W. & Berg, M.B., 2008. An Introduction to the Aquatic Insects of North America 4t
Moulton, S. et al., 2000. Methods of analysis by the US Geological Survey National Water Quality Laboratory-
Vinson, M.R. & Hawkins, C.P., 1996. Effects of sampling area and subsampling procedure on comparisons of t
Winget, R.N. & Mangum, F.A., 1979. Biotic condition index: integrated biological, physical, and chemical strea

Report prepared for:

Customer contact:	Mel Coonrod
Customer:	EIS Environmental and Engine
Customer Address :	31 N Main Street
Customer City, State, Zip:	Helper
Customer Phone:	435-472-3814
Customer Email:	eisec@preciscom.net

basic field and lab processing information. Note that values for richness based metrics
l count (i.e., rarefaction) of 300, but density metrics are based on the raw taxa list. Stan
f removing individuals identified to the coarser taxonomic resolution or merging finer le
/or fixed counts if provided, although additional charges may apply. A more detailed ex
available on our website.

_UTDEQ15; Fixed Count: 400.

; the estimated number of individuals per square meter for quantitative samples OR the
ata in this worksheet **has not been standardized to operational taxonomic units (OTUs**

is been standardized to Operational Taxonomic Units (OTUs) but not standardized to fix
letrics worksheet'. Also, abundance data is the estimated number per square meter for

available on our website (http://usu.edu/buglab/SampleProcessing/ResultsAndReports/

Predicted response to increasing perturbation (Barbour et al. 1999)	**Calculation**	**Standardized (OTU and Rarefication)**
NA	NA	NA

NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	
NA	NA	NA
Decrease	$[\text{Richness}]_{\text{UniqueTaxa}}$	Y

ɜering Consulting

UT 84526

are standardized to
dardized metrics are
ɜvel identifications to
planation of each metric, as

: estimated number of
;), thus considerable

:ed count. Please note that
quantitative samples OR is

/#item=85).

Reference
NA

BLM/USU National Aquatic Monitoring Center (NAMC) Department of Watershed Sciences (WATS) - Utah State University 5210 Old Main Hill Logan, UT 84322-5210 http://www.usu.edu/buglab/

Report prepared by:
Trip Armstrong: 760.709.1210 / trip.armstrong@usu.edu

Report Table of Contents

Metadata
- Contact
- Worksheet
- Metrics
- References

Metrics
Species Matrix (Raw)
Species Matrix (Standardized)

Excel Worksheet Name	**Worksheet Description**
Metrics	Common metrics used to assess freshwater biological integrity, as well as operational taxonomic units (OTUs; sensu Cuffney et al. 2007) and a fixed indicated with an asterisk. NAMC OTU standardization uses the method o coarser levels. We are able to standardize your data to custom OTUs and/ well as references, can be obtained by contacting NAMC and will soon be **This report was generated with the following settings - OTUs: OTUCODE**
Species Matrix (Raw)	Raw taxonomic and abundance data for sampled sites. Abundance data is individuals per sample for qualitative samples. Note that the taxonomic d redundancy likely exists in the taxonomic hierarchy.
Species Matrix (Standardized)	Taxonomic and abundance data (Species matrix) for sampled sites that ha data has not been standardized to a fixed count as in the 'Standardized M the estimated number per sample for qualitative samples.

Description of the fields contained in the 'Metrics' worksheet. A more detailed explanation of each metric is a

Category	Column Name	Explanation
Collection information	SampleID	NAMC unique tracking number

	Station (NAMC)	NAMC station tracking id
	Station (Customer)	Station abbreviation provided by the customer
	Waterbody	Specific location name
	County	Administrative boundary
	State	Administrative boundary
	Latitude	Y coordinate in decimal degree units
	Longitude	X coordinate in decimal degree units
	Collection Date	Date of sampling event
	Habitat Sampled	Microhabitat or channel unit(s) where sample(s) was taken. Values are restricted to predetermined values as specified in the PDF metadata.
	Collection Method	Method used to collect sample. Values are restricted to predetermined values as specified in the PDF metadata.
	Field Notes	Field notes provided by customer
	Lab Notes	Laboratory processing notes, particularly regarding condition of received samples and QAQC
	Area Sampled	Total area sampled in square meters
Laboratory Processing	Field Split	% sample submitted for processing
	Lab Split	% of sample processed to obtain 600 random individuals (if present)
	Split Count	# of organisms randomly subsampled from [Lab Split] for identification
	Fixed count	# of computationally resampled organisms
	Big Rare Count	# of "big and rare" organisms selected NON-RANDOMLY for identification from the entire submitted sample
Richness (metrics summarizing all unique	Richness	# of unique taxa, standardized to OTU

taxa in a sample)	Abundance	Estimated # number of individuals per unit area (m^2) for quantitative samples OR the estimated number per sample for qualitative samples.
	Shannon's Diversity	Measure of richness and evenness (based on relative abundance of each species); weighted toward rare species
	Simpson's Diversity	Measure of richness and evenness (based on relative abundance of each species); weighted toward common species
	Evenness	Measure of relative abundance indicative of taxa dominance
	# of EPT Taxa	Richness of Ephemeroptera, Plecoptera, and Trichoptera taxa
	EPT Taxa Abundance	Abundance of Ephemeroptera, Plecoptera, and Trichoptera taxa
Dominance Metrics (metrics summarizing all most abundant taxa in a sample)	Dominant Family	Taxonomic family with the highest abundance
	Abundance of Dominant Family	Abundance of dominant family
	Dominant Taxa	Individual taxa with the highest abundance
	Abundance of Dominant Taxa	Abundance of dominant taxa
Tolerance Indices (indices based on the indicator species concept in which taxa are assigned tolerance values)	Hilsenhoff Biotic Index	Abundance-weighted average of family-level pollution tolerances
	# of Intolerant Taxa	# of taxa with an HBI score <= 2
	Intolerant Taxa abundance	Abundance of taxa with an HBI score <= 2
	# of Tolerant Taxa	# of taxa with an HBI score>=8
	Tolerant Taxa abundance	Abundance of taxa with an HBI score >=8
	USFS Community Tolerance Quotient (d)	Dominance weighted community tolerance quotient

Functional Feeding Groups (classification of organisms based on morphological or behavioral adaptations for where and how food is acquired)	# of shredder taxa	# of taxa utilizing living or decomposing vascular plant tissue and CPOM
	Shredder Abundance	Abundance of taxa utilizing vascular plant tissue and CPOM
	# of scraper taxa	# of taxa utilizing periphyton, particularly algae and diatoms
	Scraper abundance	Abundance of taxa utilizing periphyton, particularly algae and diatoms
	# of collector-filterer taxa	# of taxa utilizing FPOM in the water column
	Collector-filterer abundance	Abundance of taxa utilizing FPOM in the water column
	# of collector-gatherer taxa	# of taxa utilizing FPOM from benthic deposits
	Collector-gatherer abundance	Abundance of taxa utilizing FPOM from benthic deposits
	# of predator taxa	# of taxa utilizing living animal tissue
	Predator abundance	Abundance of taxa utilizing living animal tissue
Functional Traits (metrics based on morphological and life history traits)	# of clinger taxa	# of taxa with fixed retreats or other strategies for clinging to rocks
	"# of" Long-lived Taxa	# of taxa with 2 to 3 year life cycles
Compositional Metrics (richness and abundance of various taxonomic groups)	# of Ephemeroptera taxa	
	Ephemeroptera abundance	
	# of Plecoptera taxa	
	Plecoptera abundance	
	# of Trichoptera taxa	
	Trichoptera abundance	
	# of Coleoptera taxa	
	Coleoptera abundance	
	# of Elmidae taxa	
	Elmidae abundance	
	# of Megaloptera taxa	
	Megaloptera abundance	
	# of Diptera taxa	
	Diptera abundance	
	# of Chironomidae taxa	
	Chironomidae abundance	
	# of Crustacea taxa	
	Crustacea abundance	
	# of Oligochaete taxa	

	Oligochaete abundance	
	# of Mollusca taxa	
	Mollusca abundance	
	# of Insect taxa	
	Insect abundance	
	# of non-insect taxa	
	Non-insect abundance	

References

Barbour, M.T. et al., 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphytor
Cuffney, T. F., Bilger, M.D. & Haigler, A.M., 2007. Ambiguous taxa: effects on the characterization and interpr
Cuffney, T. F et al., 1993. Methods for collecting benthic invertebrate samples as part of the National Water-(
Hilsenhoff, W.L., 1987. An improved biotic index of organic stream pollution. Great Lakes Entomologist, 20(1)
Hilsenhoff, W.L., 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of
Karr, J.R. & Chu, E.W., 1999. Restoring life in running waters: better biological monitoring, Island Press.
Krebs, C.J., 1999. Ecological methodology, Benjamin/Cummings.
Ludwig, J.A. & Reynolds, J.F., 1988. Statistical ecology: a primer on methods and computing, Wiley-Interscien
Merritt, R.W., Cummins, K.W. & Berg, M.B., 2008. An Introduction to the Aquatic Insects of North America 4t
Moulton, S. et al., 2000. Methods of analysis by the US Geological Survey National Water Quality Laboratory-
Vinson, M.R. & Hawkins, C.P., 1996. Effects of sampling area and subsampling procedure on comparisons of t
Winget, R.N. & Mangum, F.A., 1979. Biotic condition index: integrated biological, physical, and chemical strea

Report prepared for:

Customer contact:	Mel Coonrod
Customer:	EIS Environmental and Engin
Customer Address :	31 N Main Street
Customer City, State, Zip:	Helper
Customer Phone:	435-472-3814
Customer Email:	eisec@preciscom.net

basic field and lab processing information. Note that values for richness based metrics
count (i.e., rarefaction) of 300, but density metrics are based on the raw taxa list. Stan
f removing individuals identified to the coarser taxonomic resolution or merging finer l
/or fixed counts if provided, although additional charges may apply. A more detailed ex
available on our website.

_UTDEQ15; Fixed Count: 400.

the estimated number of individuals per square meter for quantitative samples OR the
ata in this worksheet **has not been standardized to operational taxonomic units (OTUs**

is been standardized to Operational Taxonomic Units (OTUs) but not standardized to fix
letrics worksheet'. Also, abundance data is the estimated number per square meter for

available on our website (http://usu.edu/buglab/SampleProcessing/ResultsAndReports/

Predicted response to increasing perturbation (Barbour et al. 1999)	**Calculation**	**Standardized (OTU and Rarefication)**
NA	NA	NA

NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	NA
NA	NA	
NA	NA	NA
Decrease	$[\text{Richness}]_{\text{UniqueTaxa}}$	Y

Increase or decrease	(([Split Count]*(100/[Lab Split])) + [Big_Rare Count]) *(100/[Field Split]) *(1/[Area Sampled])	N
Decrease	$-\sum([\text{Relative Abundance}]_{taxa} * \ln([\text{Relative Abundance}]_{taxa}))$	Y
Decrease	$1 - [\text{Simpson's Diversity}] = 1 - \sum([\text{Relative Abundance}]_{taxa})^2$	Y
Decrease	[Shannon's Diversity]/ln([Richness])	Y
Decrease	$[\text{Richness}]_E + [\text{Richness}]_P + [\text{Richness}]_T$	Y
Decrease	$[\text{Abundance}]_E + [\text{Abundance}]_P + [\text{Abundance}]_T$	N
NA	NA	N
Increase	$[\text{Abundance}]_{dominant\ family}$	N
NA	NA	N
Increase	$[\text{Abundance}]_{dominant\ taxa}$	N
Increase	$\sum([\text{Abundance}]_{taxa} * [\text{Tolerance}]_{taxa}) / [\text{Abundance}]_{Total}$	Y
Decrease	$[\text{Richness}]_{intolerant}$	Y
Decrease	$[\text{Abundance}]_{intolerant}$	N
Increase	$[\text{Richness}]_{tolerant}$	Y
Increase	$[\text{Abundance}]_{tolerant}$	N
Increase	$\sum([\text{Tolerance Quotient}] * \log([\text{Abundance}]_{taxa})) / \sum \log([\text{Abundance}]_{taxa})$	Y

Decrease	$[Richness]_{shredder}$	Y
Decrease	$[Abundance]_{shredder}$	N
Decrease	$[Richness]_{scraper}$	Y
Decrease	$[Abundance]_{scraper}$	N
Variable	$[Richness]_{collector\text{-}filterer}$	Y
Variable	$[Abundance]_{collector\text{-}filterer}$	N
Variable	$[Richness]_{collector\text{-}gatherer}$	Y
Variable	$[Abundance]_{collector\text{-}gatherer}$	N
Decrease	$[Richness]_{predator}$	Y
Decrease	$[Abundance]_{predator}$	N
Decrease	$[Richness]_{clinger}$	Y
Decrease	$[Richness]_{long\text{-}lived}$	Y
Decrease	$[Richness]_{Ephemeroptera}$	Y
Decrease	$[Abundance]_{Ephemeroptera}$	N
Decrease	$[Richness]_{Plecoptera}$	Y
Decrease	$[Abundance]_{Plecoptera}$	N
Decrease	$[Richness]_{Trichoptera}$	Y
Decrease	$[Abundance]_{Trichoptera}$	N
Variable	$[Richness]_{Coleoptera}$	Y
Variable	$[Abundance]_{Coleoptera}$	N
Decrease	$[Richness]_{Elmidae}$	Y
Decrease	$[Abundance]_{Elmidae}$	N
Variable	$[Richness]_{Megaloptera}$	Y
Variable	$[Abundance]_{Megaloptera}$	N
Variable	$[Richness]_{Diptera}$	Y
Variable	$[Abundance]_{Diptera}$	N
Increase	$[Richness]_{Chironomidae}$	Y
Increase	$[Abundance]_{Chironomidae}$	N
Variable	$[Richness]_{Crustacea}$	Y
Variable	$[Abundance]_{Crustacea}$	N
Increase	$[Richness]_{Oligochaeta}$	Y

Increase	$[\text{Abundance}]_{\text{Oligochaeta}}$	N
Variable	$[\text{Richness}]_{\text{Mollusca}}$	Y
Variable	$[\text{Abundance}]_{\text{Mollusca}}$	N
Decrease	$[\text{Richness}]_{\text{Insect}}$	Y
Decrease	$[\text{Abundance}]_{\text{Insect}}$	N
Increase	$[\text{Richness}]_{\text{Non-insect}}$	Y
Increase	$[\text{Abundance}]_{\text{Non-insect}}$	N

ı, benthic macroinvertebrates, and fish. EPA 841-B-99-002, US Environmental Protectioı
etation of invertebrate assemblages. Journal of the North American Benthological Socie
Quality Assessment Program, US Geological Survey, http://water.usgs.gov/nawqa/protc
), p.31–40.
the North American Benthological Society, 7(1), p.65–68.

ce, http://books.google.com/books?hl=en&lr=&id=sNsRYBixkpcC&oi=fnd&pg=PA3&dq=
h ed., Kendall Hunt Publishing.
processing, taxonomy, and quality control of benthic macroinvertebrate samples, US G
axa richness among streams. Journal of the North American Benthological Society, 15(3
ım parameters for management, US Department of Agriculture, Forest Service, Intermo

:ering Consulting

UT 84526

are standardized to
dardized metrics are
:vel identifications to
planation of each metric, as

: estimated number of
;), thus considerable

:ed count. Please note that
quantitative samples OR is

'#item=85).

Reference
NA

NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
Cuffney et al. (1993), Moulton et al. (2000), Vinson and Hawkins (1996)
"
"
"
NA

NA
Ludwig and Reynolds (1988, equation 8.9, page 92)
Ludwig and Reynolds (1988, equation 8.6, page 91), Krebs (1999, equation 12.27-12.30)
Ludwig and Reynolds (1988, equation 8.11, page 93)
Barbour et al. (1999), Karr and Chu (1998)
"
NA
NA
NA
NA
Hilsenhoff (1987, 1988)
"
"
"
"
Winget and Mangum (1979)

Merritt et. al (2008)
"
"
"
"
"
"
"
"
"
Karr and Chu (1998), Merritt et al. (2008)
"
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA

NA
NA
NA
NA
NA
NA
NA

ı Agency, Office of Water, Washington, DC, http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfı
:ty, 26(2), p.286–307.
ɔcols/OFR-93-406/.

=ludwig+and+reynolds+1988.

eological Survey, http://nwql.usgs.gov/OFR-00-212.shtml.
;), p.392–399.
ıuntain Region, Ogden, UT.

SAMPLE	STATION	NAME	Lat	Long	SAMPDATE	LABSPLIT	HABITAT	METHOD	AREA
169388	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Reachwide	Kick net	0.46
169388	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Reachwide	Kick net	0.46
169388	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Reachwide	Kick net	0.46
169388	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Reachwide	Kick net	0.46
169388	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Reachwide	Kick net	0.46
169389	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Targeted F	Kick net	0.74
169389	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Targeted F	Kick net	0.74
169389	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Targeted F	Kick net	0.74
169389	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Targeted F	Kick net	0.74
169389	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Targeted F	Kick net	0.74
169389	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Targeted F	Kick net	0.74
169389	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Targeted F	Kick net	0.74
169389	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Targeted F	Kick net	0.74
169389	CRANDUP-	Crandall Cı	39.45972	-111.168	6/28/2019	100	Targeted F	Kick net	0.74
169390	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Reachwide	Kick net	0.46
169390	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Reachwide	Kick net	0.46
169390	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Reachwide	Kick net	0.46
169390	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Reachwide	Kick net	0.46
169390	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Reachwide	Kick net	0.46
169390	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Reachwide	Kick net	0.46
169390	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Reachwide	Kick net	0.46
169390	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Reachwide	Kick net	0.46
169390	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Reachwide	Kick net	0.46
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169391	CRANDMD	Crandall Cı	39.46028	-111.165	6/28/2019	100	Targeted F	Kick net	0.74
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46
169392	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Reachwide	Kick net	0.46

169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74
169393	CRANDLW	Crandall Cı	39.46361	-111.146	6/28/2019	100	Targeted F	Kick net	0.74

TSN	CODE	TAXON	Lifestage	SplitCount	BigRareCo	DENSITY (#/m2)
83034	63	Lebertia	A	1	0	2
100800	250	Baetis	L	1	0	2
81400	647	Pisidium	A	1	0	2
NULL	1706	Rhyacophila angelita group	L	1	0	2
NULL	4019	Helodon	L	1	0	2
68422	19	Oligochaeta	A	1	0	1
82769	58	Trombidiformes	A	1	0	1
128457	184	Orthocladiinae	L	4	0	5
126774	223	Simulium	L	1	0	1
100800	250	Baetis	L	28	0	38
102995	462	Isoperla	L	1	0	1
115097	584	Rhyacophila	L	2	0	3
130409	706	Caloparyphus	L	1	0	1
NULL	2103	Amphinemura/Malenka	L	2	0	3
68422	19	Oligochaeta	A	4	0	9
83034	63	Lebertia	A	1	0	2
111963	105	Dytiscidae	L	1	0	2
114144	134	Narpus concolor	L	1	0	2
128457	184	Orthocladiinae	L	2	0	4
100800	250	Baetis	L	7	0	15
115933	528	Limnephilidae	L	2	0	4
81400	647	Pisidium	A	3	0	7
120968	667	Rhabdomastix	L	1	0	2
83034	63	Lebertia	A	1	0	1
83006	67	Sperchon	P	1	0	1
128341	183	Diamesinae	L	1	0	1
128457	184	Orthocladiinae	L	4	0	5
136305	201	Chelifera	L	2	0	3
100800	250	Baetis	L	65	0	88
100557	279	Cinygmula	L	1	0	1
102995	462	Isoperla	L	2	0	3
115453	499	Hydropsyche	L	1	0	1
116001	542	Hesperophylax	L	1	0	1
127729	908	Probezzia	L	1	0	1
NULL	1706	Rhyacophila angelita group	L	4	0	5
136352	2253	Neoplasta	L	1	0	1
119037	247	Tipula	L	1	0	2
100800	250	Baetis	L	9	0	20
100626	280	Epeorus	L	1	0	2
115453	499	Hydropsyche	L	5	0	11
116001	542	Hesperophylax	L	1	0	2
81400	647	Pisidium	A	2	0	4
568598	834	Diphetor hageni	L	2	0	4
NULL	1706	Rhyacophila angelita group	L	1	0	2
82864	2115	Arrenurus	A	1	0	2
NULL	4019	Helodon	L	1	0	2

68422	19	Oligochaeta	A	3	0	4
114144	134	Narpus concolor	L	1	0	1
129228	182	Chironominae	L	2	0	3
128341	183	Diamesinae	L	3	0	4
128457	184	Orthocladiinae	L	4	0	5
127994	187	Tanypodinae	L	1	0	1
119037	247	Tipula	L	2	0	3
100800	250	Baetis	L	59	0	80
100626	280	Epeorus	L	5	0	7
101187	292	Paraleptophlebia	L	1	0	1
103273	419	Sweltsa	L	1	0	1
102995	462	Isoperla	L	6	0	8
115453	499	Hydropsyche	L	5	0	7
116001	542	Hesperophylax	L	1	0	1
81400	647	Pisidium	A	1	0	1
568598	834	Diphetor hageni	L	6	0	8
NULL	2103	Amphinemura/Malenka	L	2	0	3

NA
Ludwig and Reynolds (1988, equation 8.9, page 92)
Ludwig and Reynolds (1988, equation 8.6, page 91), Krebs (1999, equation 12.27-12.30)
Ludwig and Reynolds (1988, equation 8.11, page 93)
Barbour et al. (1999), Karr and Chu (1998)
"
NA
NA
NA
NA
Hilsenhoff (1987, 1988)
"
"
"
"
Winget and Mangum (1979)

Merritt et. al (2008)
"
"
"
"
"
"
"
"
"
Karr and Chu (1998), Merritt et al. (2008)
"
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA

NA
NA
NA
NA
NA
NA
NA

ı Agency, Office of Water, Washington, DC, http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfı
:ty, 26(2), p.286–307.
ɔcols/OFR-93-406/.

=ludwig+and+reynolds+1988.

eological Survey, http://nwql.usgs.gov/OFR-00-212.shtml.
:), p.392–399.
untain Region, Ogden, UT.

NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
NA
Cuffney et al. (1993), Moulton et al. (2000), Vinson and Hawkins (1996)
"
"
"
NA

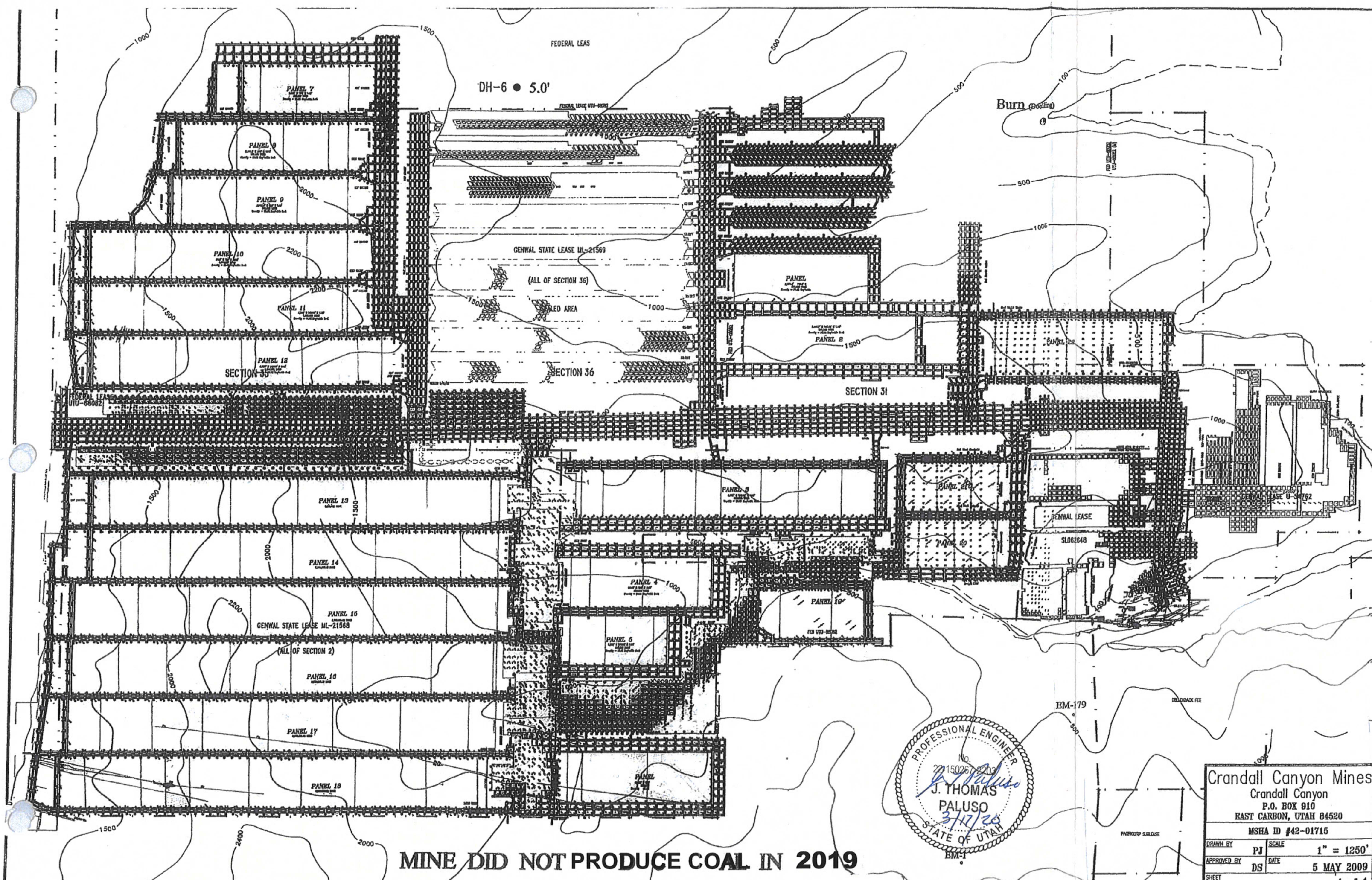
Increase or decrease	(([Split Count]* (100/[Lab Split])) + [Big_Rare Count]) *(100/[Field Split]) *(1/[Area Sampled])	N
Decrease	$-\sum([\text{Relative Abundance}]_{taxa} * \ln([\text{Relative Abundance}]_{taxa}))$	Y
Decrease	$1 - [\text{Simpson's Diversity}] = 1 - \sum([\text{Relative Abundance}]_{taxa})^2$	Y
Decrease	[Shannon's Diversity]/ln([Richness])	Y
Decrease	$[\text{Richness}]_E + [\text{Richness}]_P + [\text{Richness}]_T$	Y
Decrease	$[\text{Abundance}]_E + [\text{Abundance}]_P + [\text{Abundance}]_T$	N
NA	NA	N
Increase	$[\text{Abundance}]_{dominant\ family}$	N
NA	NA	N
Increase	$[\text{Abundance}]_{dominant\ taxa}$	N
Increase	$\sum([\text{Abundance}]_{taxa} * [\text{Tolerance}]_{taxa}) / [\text{Abundance}]_{Total}$	Y
Decrease	$[\text{Richness}]_{intolerant}$	Y
Decrease	$[\text{Abundance}]_{intolerant}$	N
Increase	$[\text{Richness}]_{tolerant}$	Y
Increase	$[\text{Abundance}]_{tolerant}$	N
Increase	$\sum([\text{Tolerance Quotient}] * \log([\text{Abundance}]_{taxa})) / \sum \log([\text{Abundance}]_{taxa})$	Y

Decrease	$[\text{Richness}]_{\text{shredder}}$	Y
Decrease	$[\text{Abundance}]_{\text{shredder}}$	N
Decrease	$[\text{Richness}]_{\text{scraper}}$	Y
Decrease	$[\text{Abundance}]_{\text{scraper}}$	N
Variable	$[\text{Richness}]_{\text{collector-filterer}}$	Y
Variable	$[\text{Abundance}]_{\text{collector-filterer}}$	N
Variable	$[\text{Richness}]_{\text{collector-gatherer}}$	Y
Variable	$[\text{Abundance}]_{\text{collector-gatherer}}$	N
Decrease	$[\text{Richness}]_{\text{predator}}$	Y
Decrease	$[\text{Abundance}]_{\text{predator}}$	N
Decrease	$[\text{Richness}]_{\text{clinger}}$	Y
Decrease	$[\text{Richness}]_{\text{long-lived}}$	Y
Decrease	$[\text{Richness}]_{\text{Ephemeroptera}}$	Y
Decrease	$[\text{Abundance}]_{\text{Ephemeroptera}}$	N
Decrease	$[\text{Richness}]_{\text{Plecoptera}}$	Y
Decrease	$[\text{Abundance}]_{\text{Plecoptera}}$	N
Decrease	$[\text{Richness}]_{\text{Trichoptera}}$	Y
Decrease	$[\text{Abundance}]_{\text{Trichoptera}}$	N
Variable	$[\text{Richness}]_{\text{Coleoptera}}$	Y
Variable	$[\text{Abundance}]_{\text{Coleoptera}}$	N
Decrease	$[\text{Richness}]_{\text{Elmidae}}$	Y
Decrease	$[\text{Abundance}]_{\text{Elmidae}}$	N
Variable	$[\text{Richness}]_{\text{Megaloptera}}$	Y
Variable	$[\text{Abundance}]_{\text{Megaloptera}}$	N
Variable	$[\text{Richness}]_{\text{Diptera}}$	Y
Variable	$[\text{Abundance}]_{\text{Diptera}}$	N
Increase	$[\text{Richness}]_{\text{Chironomidae}}$	Y
Increase	$[\text{Abundance}]_{\text{Chironomidae}}$	N
Variable	$[\text{Richness}]_{\text{Crustacea}}$	Y
Variable	$[\text{Abundance}]_{\text{Crustacea}}$	N
Increase	$[\text{Richness}]_{\text{Oligochaeta}}$	Y

Increase	$[\text{Abundance}]_{\text{Oligochaeta}}$	N
Variable	$[\text{Richness}]_{\text{Mollusca}}$	Y
Variable	$[\text{Abundance}]_{\text{Mollusca}}$	N
Decrease	$[\text{Richness}]_{\text{Insect}}$	Y
Decrease	$[\text{Abundance}]_{\text{Insect}}$	N
Increase	$[\text{Richness}]_{\text{Non-insect}}$	Y
Increase	$[\text{Abundance}]_{\text{Non-insect}}$	N

ı, benthic macroinvertebrates, and fish. EPA 841-B-99-002, US Environmental Protectioı
etation of invertebrate assemblages. Journal of the North American Benthological Socie
Quality Assessment Program, US Geological Survey, http://water.usgs.gov/nawqa/protc
), p.31–40.
the North American Benthological Society, 7(1), p.65–68.

ce, http://books.google.com/books?hl=en&lr=&id=sNsRYBixkpcC&oi=fnd&pg=PA3&dq=
h ed., Kendall Hunt Publishing.
processing, taxonomy, and quality control of benthic macroinvertebrate samples, US G
axa richness among streams. Journal of the North American Benthological Society, 15(3
ım parameters for management, US Department of Agriculture, Forest Service, Intermo



MINE DID NOT PRODUCE COAL IN 2019

Crandall Canyon Mines Crandall Canyon P.O. BOX 910 EAST CARBON, UTAH 84520			
MSHA ID #42-01715			
DRAWN BY	PJ	SCALE	1" = 1250'
APPROVED BY	DS	DATE	5 MAY 2009
SHEET			1 of 1

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT		Page 1 of

Permit Number	ACT/015/032	**Report Date**	12-26-19
Mine Name	Crandall Canyon Mine		
Company Name	UtahAmerican Energy, Inc.		
Impoundment Identification	**Impoundment Name**	Burma Evaporative Pond	
	Impoundment Number	None	
	UPDES Permit Number	UT0024368	
	MSHA ID Number	42-01715	

IMPOUNDMENT INSPECTION

Inspection Date	12-11-19
Inspected By	Karin Madsen
Reason for Inspection (Annual, Quarterly or Other Periodic Inspection, Critical Installation, or Completion of Construction)	4th Quarter

1. **Describe any appearance of any instability, structural weakness, or any other hazardous condition.**

No instability, structural weaknesses, or visible hazards were observed.

Required for an impoundment which functions as a SEDIMENTATION POND.

2. **Sediment storage capacity, including elevation of 60% and 100% sediment storage volumes, and, estimated average elevation of existing sediment.**

Sediment Elevations:

Clean Out Elevation of Sediment	6518.63
Maximum Water Elevation (10year 24 Hr)	6518.63

Water levels in pond were low and frozen over. No cleaning has taken place in recent months at the Crandall site, so no new sediment has been added to the pond.

3. **Principle and emergency spillway elevations.**

Emergency 6519.6

Burma is an evaporative pond and is designed not to discharge and does not have a principal spillway.

4. **Field Information.** Provide current water elevation, whether pond is discharging, type and number of samples taken, monitoring/instrumentation information, inlet/outlet conditions, or other related activities associated with the pond including but not limited to sediment cleanout, pond decanting, embankment erosion/repairs, monitoring information, vegetation on outslopes of embankments, etc.

Pond has a small amount of snow and ice, and is frozen over. Sediment in the bottom has condensed and cracked. Ware Surveying recently surveyed the ponds, but has not reported his data yet.

Pond is functioning as designed. Pond is not discharging and is designed to be an evaporative pond that will not ever discharge.

5. **Field Evaluation.** Describe any changes in the geometry of the impounding structure, average and maximum depths and elevations of impounded water, estimated sediment or slurry volume and remaining storage capacity, estimated volume of water impounded, and any other aspect of the impounding structure affecting its stability or function which has occurred during the reporting period.

No changes in geometry have occurred.

No observable conditions were apparent that could affect the stability or function Of the structure.

Qualification Statement	I hereby certify that; I am experienced in the construction of impoundments; I am qualified and authorized under the direction of a Registered Professional Engineer to inspect the condition and appearance of impoundments in accordance with the certified and approved designs for this structure; that the impoundment has been maintained in accordance with approved design and meet or exceed the minimum design requirements under all applicable federal, state and local regulations; and, that inspections and inspection reports are made by myself and include any appearances of instability, structural weakness or other hazardous conditions of the structure affecting stability. **Signature:** [signature] **Date:** 12·26·19

CERTIFIED REPORT

IMPOUNDMENT EVALUATION (If NO, explain under Comments)	YES	NO
1. Is impoundment designed and constructed in accordance with the approved plan?	XXXXX	
2. Is impoundment free of instability, structural weakness, or any other hazardous condition?	XXXXX	
3. Has the impoundment met all applicable performance standards and effluent limitations from the previous date of inspection?	XXXXX	

COMMENTS AND OTHER INFORMATION

NONE

REGISTERED PROFESSIONAL ENGINEER
RBWhite
No. 168246
RICHARD B. WHITE
7 Jan 2020
STATE OF UTAH

Certification Statement:

I hereby certify that; I am experienced in the construction of impoundments; I am qualified and authorized in the State of Utah to inspect and certify the condition and appearance of impoundments in accordance with the certified and approved designs for this structure; that the impoundment has been maintained in accordance with approved design and meet or exceed the minimum design requirements under all applicable federal, state and local regulations; and, that inspections and inspection reports are made by myself or under my direction and include any appearances of instability, structural weakness or other hazardous conditions of the structure affecting stability in accordance with the Utah R645 Coal Mining Rules.

[PE Cert. Stamp]

By: Richard B. White, Consulting Civil Engineer
(Full Name and Title)

Signature: Richard B White

Date: 7 Jan 2020

P.E. Number & State: 168246 Utah

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT			Page 1 of
Permit Number	Permit Number: 015/032	**Report Date**	12-26-19
Mine Name	Crandall Canyon Mine		
Company Name	UtahAmerican Energy, Inc.		
Impoundment Identification	**Impoundment Name**	Lower Sediment Pond	
	Impoundment Number	None	
	UPDES Permit Number	UT0024368	
	MSHA ID Number	None for the Pond	

IMPOUNDMENT INSPECTION

Inspection Date	12-11-19
Inspected By	Karin Madsen
Reason for Inspection (Annual, Quarterly or Other Periodic Inspection, Critical Installation, or Completion of Construction)	4th Quarter

1. **Describe any appearance of any instability, structural weakness, or any other hazardous condition.**

No appearance of instability, structural weakness, or any other hazardous condition was observed at the time of inspection. All repairs from the gabian wall fail have been repaired and concrete work above has been completed.

Required for an impoundment which functions as a SEDIMENTATION POND.

2. **Sediment storage capacity, including elevation of 60% and 100% sediment storage volumes, and, estimated average elevation of existing sediment.**

Sediment Elevations:

60%	7769.0'
100%	7770.0'

Sediment levels will be surveyed by Ware Surveying in November.

3. **Principle and emergency spillway elevations.**

Principle	7780.81'
Emergency	7781.81'

4. **Field Information.** Provide current water elevation, whether pond is discharging, type and number of samples taken, monitoring/instrumentation information, inlet/outlet conditions, or other related activities associated with the pond including but not limited to sediment cleanout, pond decanting, embankment erosion/repairs, monitoring information, vegetation on outslopes of embankments, etc.

Pond has approximately 3' of ice in the center. The two sediment markers are visible. Snow is currently covering the site.

No discharge has occurred from the pond and therefore no samples have been taken.

No observable problems exist at the inlets or outlets.

Vegetation surrounding the pond is good.

Ware Surveying recently surveyed the ponds, but has not reported his data yet.

5. **Field Evaluation.** Describe any changes in the geometry of the impounding structure, average and maximum depths and elevations of impounded water, estimated sediment or slurry volume and remaining storage capacity, estimated volume of water impounded, and any other aspect of the impounding structure affecting its stability or function which has occurred during the reporting period.

No change in geometry have occurred. No observable conditions were apparent that could affect the stability or function of the structure.

Qualification Statement	I hereby certify that; I am experienced in the construction of impoundments; I am qualified and authorized under the direction of a Registered Professional Engineer to inspect the condition and appearance of impoundments in accordance with the certified and approved designs for this structure; that the impoundment has been maintained in accordance with approved design and meet or exceed the minimum design requirements under all applicable federal, state and local regulations; and, that inspections and inspection reports are made by myself and include any appearances of instability, structural weakness or other hazardous conditions of the structure affecting stability. Signature: [signature] Date: 12-26-19

IMPOUNDMENT EVALUATION (If NO, explain under Comments)	YES	NO
1. Is impoundment designed and constructed in accordance with the approved plan?	XXXXX	
2. Is impoundment free of instability, structural weakness, or any other hazardous condition?	XXXXX	
3. Has the impoundment met all applicable performance standards and effluent limitations from the previous date of inspection?	XXXXX	

COMMENTS AND OTHER INFORMATION

The pond shows no evidence of instability or structural weakness or any other hazardous condition.

REGISTERED PROFESSIONAL ENGINEER
No. 168246
RICHARD B. WHITE
7 Jan 2020
STATE OF UTAH

Certification Statement:

I hereby certify that; I am experienced in the construction of impoundments; I am qualified and authorized in the State of Utah to inspect and certify the condition and appearance of impoundments in accordance with the certified and approved designs for this structure; that the impoundment has been maintained in accordance with approved design and meet or exceed the minimum design requirements under all applicable federal, state and local regulations; and, that inspections and inspection reports are made by myself or under my direction and include any appearances of instability, structural weakness or other hazardous conditions of the structure affecting stability in accordance with the Utah R645 Coal Mining Rules.

[PE Cert. Stamp]

By: Richard B. White, Consulting Civil Engineer
(Full Name and Title)

Signature: Richard B White Date: 7 Jan 2020

P.E. Number & State: 168246 Utah

UtahAmerican Energy, Inc.

Crandall Canyon Mine - Subsidence Survey

9/19/2019

YEAR			2004	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	2018-2019 (FEET)
A	413190.85	2080628.41	10440.47	10439.53	10439.43	10439.47	10439.48	10439.41	10439.43	10439.45	10439.44	10439.45	10439.48	10439.45	10439.42	10439.27	0.15
B	413095.74	2080610.92	10426.40	10425.43	10425.40	10425.41	10425.38	10425.41	10425.40	10425.37	10425.40	10425.47	10425.51	10425.44	10425.38	10425.28	0.10
C	412995.22	2080594.07	10412.27	10411.20	10411.23	10411.23	10411.16	10411.18	10411.17	10411.20	10411.16	10411.24	10411.31	10411.25	10411.24	10411.16	0.08
D	412897.30	2080578.76	10400.21	10399.21	10399.25	10399.18	10399.23	10399.24	10399.21	10399.27	10399.23	10399.27	10399.32	10399.29	10399.30	10399.25	0.06
E	412795.72	2080563.91	10385.11	10384.15	10384.18	10384.13	10384.16	10384.17	10384.18	10384.15	10384.14	10384.20	10384.25	10384.24	10384.27	10384.25	0.01
J	412296.72	2080487.65	10323.47	10323.29	10323.20	10323.15	10323.26	10323.18	10323.19	10323.22	10323.22	10323.26	10323.29	10323.27	10323.22	10323.23	-0.01
N	411898.88	2080428.44	10313.15	10313.15	10313.13	10313.16	10313.16	10313.16	10313.10	10313.17	10313.15	10313.16	10313.21	10313.20	10313.18	10313.15	0.02
O	411798.12	2080415.52	10316.56	10316.49	10316.50	10316.56	10316.52	10316.56	10316.57	10316.55	10316.53	10316.52	10316.52	10316.56	10316.57	10316.62	-0.05
P	411700.03	2080403.24	10321.64	10321.65	10321.65	10321.69	10321.66	10321.65	10321.64	10321.63	10321.65	10321.64	10321.62	10321.63	10321.57	10321.59	-0.03
Q	411599.74	2080390.76	10326.61	---	---	---	---	10326.53	10326.53	10326.56	10326.55	10326.52	10326.48	10326.50	10326.53	10326.52	0.01
R	411550.40	2080383.83	10330.17	---	---	---	---	10330.15	10330.08	10330.11	10330.09	10330.07	10330.05	10330.10	10330.04	10330.06	-0.02
S	411501.07	2080376.56	10333.65	---	---	---	---	10333.51	10333.57	10333.54	10333.52	10333.59	10333.56	10333.55	10333.47	10333.47	0.00
T	411399.27	2080366.35	10342.83	---	---	---	---	10342.74	10342.75	10342.77	10342.74	10342.78	10342.77	10342.75	10342.70	10342.75	-0.05
U	411299.82	2080354.19	10349.80	---	---	---	---	10349.68	10349.64	10349.69	10349.68	10349.67	10349.66	10349.59	10349.54	10349.57	-0.03
V	411247.57	2080350.11	10353.81	---	---	---	---	10353.84	10353.77	10353.80	10353.81	10353.74	10353.70	10353.72	10353.65	10353.65	0.00
W	411198.08	2080343.54	10358.03	---	---	---	---	10357.94	10357.98	10357.93	10357.96	10357.96	10357.92	10357.98	10357.97	10357.93	0.04
X	411147.67	2080337.97	10360.97	---	---	---	---	10360.78	10360.89	10360.83	10360.81	10360.84	10360.78	10360.82	10360.82	10360.78	0.04
Y	411097.90	2080332.61	10365.90	---	---	---	---	10365.78	10365.84	10365.85	10365.85	10365.77	10365.75	10365.82	10365.85	10365.81	0.04
Z	411044.53	2080331.80	10371.01	---	---	---	---	10370.93	10371.01	10370.98	10370.99	10370.99	10370.95	10371.00	10371.01	10370.98	0.03
AA	410994.37	2080331.13	10376.37	---	---	---	---	10376.27	10376.36	10376.34	10376.30	10376.35	10376.34	10376.33	10376.30	10376.31	-0.01
EE	410741.97	2080325.86	10430.72	---	---	---	---	10430.86	10430.97	10430.91	10430.94	10430.95	10430.96	10430.90	10430.94	10430.94	0.00
GG	410619.62	2080334.65	10435.38	---	---	---	---	10435.09	10435.41	10435.40	10435.43	10435.39	10435.38	10435.42	10435.40	10435.36	0.04
HH	410508.23	2080321.51	10435.17	---	---	---	---	10435.63	10435.11	10435.18	10435.15	10435.16	10435.15	10435.14	10435.20	10435.19	0.01
II	410458.36	2080312.15	10433.84	---	---	---	---	10434.29	10433.84	10433.88	10433.82	10433.61	10433.65	10433.68	10433.66	10433.64	0.02
JJ	410409.35	2080302.79	10433.25	---	---	---	---	10433.73	10433.20	10433.23	10433.20	10433.08	10433.12	10433.16	10433.14	10433.15	-0.01
KK	410359.98	2080292.88	10432.40	---	---	---	---	10432.87	10432.42	10432.40	10432.43	10432.22	10432.29	10432.24	10432.27	10432.22	0.05
LL	410265.30	2080265.04	10428.65	---	---	---	---	10428.57	10428.47	10428.49	10428.46	10428.55	10428.54	10428.53	10428.51	10428.49	0.02
NN	409769.08	2080125.54	10347.00	---	---	---	---	10346.66	10346.71	10346.68	10346.70	10346.75	10346.69	10346.69	10346.69	10346.70	-0.01
OO	409498.68	2080210.27	10284.52	---	---	---	---	10284.27	10284.26	10284.29	10284.25	10284.17	10284.20	10284.22	10284.23	10284.26	-0.03
PP	409291.54	2080286.75	10262.98	---	---	---	---	10263.41	10263.41	10263.38	10263.39	10263.17	10263.22	10263.27	10263.20	10263.23	-0.03

WARE SURVEYING & ENGINEERING

G.P.S. & CONVENTIONAL SURVEYING - AUTOCAD MAPPING - CIVIL ENGINEERING

Phone: 435-820-4335
Email: waresurveying@emerytelcom.net

1344 North 1000 West
Price, Utah 84501

UtahAmerican Energy, Inc.

Crandall Canyon Mine

East Mountain Reclaimed Slide Area

9/19/2019

YEAR			2012	2013	2014	2015	2016	2017	2018	2019	
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION DIFFERENCE
Benchmark	413145.90	2079155.88	9986.04	9986.04	9986.04	9986.04	9986.04	9986.04	9986.04	9986.04	0.00
1	413105.83	2079216.62	9987.03	9987.03	9987.06	9987.05	9987.10	9987.06	9987.10	9987.05	0.05
2	413079.15	2079242.82	9985.59	9985.45	9985.47	9985.51	9985.50	9985.53	9985.59	9985.49	0.10
3	413068.96	2079262.42	9982.58	9982.37	9981.89	9981.81	9981.85	9981.91	9981.80	9981.76	0.04
4	413056.95	2079275.88	9980.12	9979.90	9979.56	9979.57	9979.70	9979.75	9979.84	DESTROYED	
4B	413056.86	2079275.96								9983.12	NEW
5	413035.54	2079293.43	9979.24	9979.32	9979.33	9979.35	9979.42	9979.47	9979.36	DESTROYED	
6	413009.81	2079312.22	9977.00	9976.78	9976.80	9976.83	9976.87	9976.84	9976.80	9976.77	0.03
7	413011.56	2079280.20	9967.21	9966.96	9966.95	9967.37	9967.19	9967.15	9967.20	9967.04	0.16
8	413027.60	2079264.79	9963.57	9963.59	9963.59	9963.84	9963.80	9963.86	9963.86	9963.86	0.00
9	413034.15	2079256.20	9964.10	9964.16	9964.10	9964.33	9964.27	9964.19	9964.27	9964.13	0.14
10	413040.75	2079245.24	9963.48	9963.28	9963.28	9963.66	9963.59	9963.49	9963.38	9963.19	0.19
11	413044.33	2079234.13	9966.05	9965.95	9965.88	9966.29	9966.22	9966.29	9966.31	9966.22	0.09
12	413048.37	2079223.30	9963.67	9963.62	9963.63	9963.66	9963.60	9963.65	9963.57	9963.54	0.03
13	413025.61	2079233.40	9954.87	9954.98	9954.97	9955.11	9955.09	9955.07	9955.01	9955.06	-0.05
14	413020.64	2079240.46	9955.37	9955.31	9955.29	9955.31	9955.33	9955.28	9955.30	9955.33	-0.03
15	413009.89	2079253.75	9955.08	9955.03	9955.00	9955.06	9955.01	9955.05	9955.09	9955.06	0.03
16	412997.97	2079264.46	9957.58	9957.45	9957.46	9957.48	9957.51	9957.51	9957.44	9957.49	-0.05
17	412994.73	2079233.22	9945.34	9945.34	9945.35	9945.33	9945.28	9945.25	9945.24	9945.22	0.02
18	413001.96	2079217.74	9940.01	9939.88	9939.91	9939.86	9939.91	9939.90	9939.85	9939.88	-0.03
19	412986.19	2079204.91	9928.78	9928.58	9928.57	9928.59	9928.63	9928.59	9928.61	9928.56	0.05
20	412960.88	2079205.24	9917.01	9916.98	9916.95	9917.00	9916.97	9916.98	9916.91	9916.87	0.04

WARE SURVEYING & ENGINEERING

G.P.S. & CONVENTIONAL SURVEYING - AUTOCAD MAPPING - CIVIL ENGINEERING

Phone: 435-820-4335

Email: waresurveying@emerytelcom.net

UtahAmerican Energy, Inc.

Crandall Canyon Mine - Subsidence Survey

9/19/2019

YEAR			2004	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	2018-2019 (FEET)
A	413190.85	2080628.41	10440.47	10439.53	10439.43	10439.47	10439.48	10439.41	10439.43	10439.45	10439.44	10439.45	10439.48	10439.45	10439.42	10439.27	0.15
B	413095.74	2080610.92	10426.40	10425.43	10425.40	10425.41	10425.38	10425.41	10425.40	10425.37	10425.40	10425.47	10425.51	10425.44	10425.38	10425.28	0.10
C	412995.22	2080594.07	10412.27	10411.20	10411.23	10411.23	10411.16	10411.18	10411.17	10411.20	10411.16	10411.24	10411.31	10411.25	10411.24	10411.16	0.08
D	412897.30	2080578.76	10400.21	10399.21	10399.25	10399.18	10399.23	10399.24	10399.21	10399.27	10399.23	10399.27	10399.32	10399.29	10399.30	10399.25	0.06
E	412795.72	2080563.91	10385.11	10384.15	10384.18	10384.13	10384.16	10384.17	10384.18	10384.15	10384.14	10384.20	10384.25	10384.24	10384.27	10384.25	0.01
J	412296.72	2080487.65	10323.47	10323.29	10323.20	10323.15	10323.26	10323.18	10323.19	10323.22	10323.22	10323.26	10323.29	10323.27	10323.22	10323.23	-0.01
N	411898.88	2080428.44	10313.15	10313.15	10313.13	10313.16	10313.16	10313.16	10313.10	10313.17	10313.15	10313.16	10313.21	10313.20	10313.18	10313.15	0.02
O	411798.12	2080415.52	10316.56	10316.49	10316.50	10316.56	10316.52	10316.56	10316.57	10316.55	10316.53	10316.52	10316.52	10316.56	10316.57	10316.62	-0.05
P	411700.03	2080403.24	10321.64	10321.65	10321.65	10321.69	10321.66	10321.65	10321.64	10321.63	10321.65	10321.64	10321.62	10321.63	10321.57	10321.59	-0.03
Q	411599.74	2080390.76	10326.61	---	---	---	---	10326.53	10326.53	10326.56	10326.55	10326.52	10326.48	10326.50	10326.53	10326.52	0.01
R	411550.40	2080383.83	10330.17	---	---	---	---	10330.15	10330.08	10330.11	10330.09	10330.07	10330.05	10330.10	10330.04	10330.06	-0.02
S	411501.07	2080376.56	10333.65	---	---	---	---	10333.51	10333.57	10333.54	10333.52	10333.59	10333.56	10333.55	10333.47	10333.47	0.00
T	411399.27	2080366.35	10342.83	---	---	---	---	10342.74	10342.75	10342.77	10342.74	10342.78	10342.77	10342.75	10342.70	10342.75	-0.05
U	411299.82	2080354.19	10349.80	---	---	---	---	10349.68	10349.64	10349.69	10349.68	10349.67	10349.66	10349.59	10349.54	10349.57	-0.03
V	411247.57	2080350.11	10353.81	---	---	---	---	10353.84	10353.77	10353.80	10353.81	10353.74	10353.70	10353.72	10353.65	10353.65	0.00
W	411198.08	2080343.54	10358.03	---	---	---	---	10357.94	10357.98	10357.93	10357.96	10357.96	10357.92	10357.98	10357.97	10357.93	0.04
X	411147.67	2080337.97	10360.97	---	---	---	---	10360.78	10360.89	10360.83	10360.81	10360.84	10360.78	10360.82	10360.82	10360.78	0.04
Y	411097.90	2080332.61	10365.90	---	---	---	---	10365.78	10365.84	10365.85	10365.85	10365.77	10365.75	10365.82	10365.85	10365.81	0.04
Z	411044.53	2080331.80	10371.01	---	---	---	---	10370.93	10371.01	10370.98	10370.99	10370.99	10370.95	10371.00	10371.01	10370.98	0.03
AA	410994.37	2080331.13	10376.37	---	---	---	---	10376.27	10376.36	10376.34	10376.30	10376.35	10376.34	10376.33	10376.30	10376.31	-0.01
EE	410741.97	2080325.86	10430.72	---	---	---	---	10430.86	10430.97	10430.91	10430.94	10430.95	10430.96	10430.90	10430.94	10430.94	0.00
GG	410619.62	2080334.65	10435.38	---	---	---	---	10435.09	10435.41	10435.40	10435.43	10435.39	10435.38	10435.42	10435.40	10435.36	0.04
HH	410508.23	2080321.51	10435.17	---	---	---	---	10435.63	10435.11	10435.18	10435.15	10435.16	10435.15	10435.14	10435.20	10435.19	0.01
II	410458.36	2080312.15	10433.84	---	---	---	---	10434.29	10433.84	10433.88	10433.82	10433.61	10433.65	10433.68	10433.66	10433.64	0.02
JJ	410409.35	2080302.79	10433.25	---	---	---	---	10433.73	10433.20	10433.23	10433.20	10433.08	10433.12	10433.16	10433.14	10433.15	-0.01
KK	410359.98	2080292.88	10432.40	---	---	---	---	10432.87	10432.42	10432.40	10432.43	10432.22	10432.29	10432.24	10432.27	10432.22	0.05
LL	410265.30	2080265.04	10428.65	---	---	---	---	10428.57	10428.47	10428.49	10428.46	10428.55	10428.54	10428.53	10428.51	10428.49	0.02
NN	409769.08	2080125.54	10347.00	---	---	---	---	10346.66	10346.71	10346.68	10346.70	10346.75	10346.69	10346.69	10346.69	10346.70	-0.01
OO	409498.68	2080210.27	10284.52	---	---	---	---	10284.27	10284.26	10284.29	10284.25	10284.17	10284.20	10284.22	10284.23	10284.26	-0.03
PP	409291.54	2080286.75	10262.98	---	---	---	---	10263.41	10263.41	10263.38	10263.39	10263.17	10263.22	10263.27	10263.20	10263.23	-0.03

WARE SURVEYING & ENGINEERING

G.P.S. & CONVENTIONAL SURVEYING - AUTOCAD MAPPING - CIVIL ENGINEERING

Phone: 435-820-4335
Email: waresurveying@emerytelcom.net

1344 North 1000 West
Price, Utah 84501

UtahAmerican Energy, Inc.

Crandall Canyon Mine

East Mountain Reclaimed Slide Area

9/19/2019

YEAR			2012	2013	2014	2015	2016	2017	2018	2019	
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION DIFFERENCE
Benchmark	413145.90	2079155.88	9986.04	9986.04	9986.04	9986.04	9986.04	9986.04	9986.04	9986.04	0.00
1	413105.83	2079216.62	9987.03	9987.03	9987.06	9987.05	9987.10	9987.06	9987.10	9987.05	0.05
2	413079.15	2079242.82	9985.59	9985.45	9985.47	9985.51	9985.50	9985.53	9985.59	9985.49	0.10
3	413068.96	2079262.42	9982.58	9982.37	9981.89	9981.81	9981.85	9981.91	9981.80	9981.76	0.04
4	413056.95	2079275.88	9980.12	9979.90	9979.56	9979.57	9979.70	9979.75	9979.84	DESTROYED	
4B	413056.86	2079275.96								9983.12	NEW
5	413035.54	2079293.43	9979.24	9979.32	9979.33	9979.35	9979.42	9979.47	9979.36	DESTROYED	
6	413009.81	2079312.22	9977.00	9976.78	9976.80	9976.83	9976.87	9976.84	9976.80	9976.77	0.03
7	413011.56	2079280.20	9967.21	9966.96	9966.95	9967.37	9967.19	9967.15	9967.20	9967.04	0.16
8	413027.60	2079264.79	9963.57	9963.59	9963.59	9963.84	9963.80	9963.86	9963.86	9963.86	0.00
9	413034.15	2079256.20	9964.10	9964.16	9964.10	9964.33	9964.27	9964.19	9964.27	9964.13	0.14
10	413040.75	2079245.24	9963.48	9963.28	9963.28	9963.66	9963.59	9963.49	9963.38	9963.19	0.19
11	413044.33	2079234.13	9966.05	9965.95	9965.88	9966.29	9966.22	9966.29	9966.31	9966.22	0.09
12	413048.37	2079223.30	9963.67	9963.62	9963.63	9963.66	9963.60	9963.65	9963.57	9963.54	0.03
13	413025.61	2079233.40	9954.87	9954.98	9954.97	9955.11	9955.09	9955.07	9955.01	9955.06	-0.05
14	413020.64	2079240.46	9955.37	9955.31	9955.29	9955.31	9955.33	9955.28	9955.30	9955.33	-0.03
15	413009.89	2079253.75	9955.08	9955.03	9955.00	9955.06	9955.01	9955.05	9955.09	9955.06	0.03
16	412997.97	2079264.46	9957.58	9957.45	9957.46	9957.48	9957.51	9957.51	9957.44	9957.49	-0.05
17	412994.73	2079233.22	9945.34	9945.34	9945.35	9945.33	9945.28	9945.25	9945.24	9945.22	0.02
18	413001.96	2079217.74	9940.01	9939.88	9939.91	9939.86	9939.91	9939.90	9939.85	9939.88	-0.03
19	412986.19	2079204.91	9928.78	9928.58	9928.57	9928.59	9928.63	9928.59	9928.61	9928.56	0.05
20	412960.88	2079205.24	9917.01	9916.98	9916.95	9917.00	9916.97	9916.98	9916.91	9916.87	0.04

WARE SURVEYING & ENGINEERING

G.P.S. & CONVENTIONAL SURVEYING - AUTOCAD MAPPING - CIVIL ENGINEERING

Phone: 435-820-4335

Email: waresurveying@emerytelcom.net