C0150032 Incoming

#4565

GENWAL™ RESOURCES, INC.

P.O. Box 1077, Price, Utah 84501 794 North "C" Canyon Rd, East Carbon, Utah 84520
Telephone (435) 888-4000 Fax (435) 888-4002

March 20, 2014

Daron Haddock
Permit Supervisor
Utah Division of Oil, Gas and Mining
P.O. Box 145801
1594 West North Temple, Suite 1210
Salt Lake City, Utah 84114-5801

Re: Crandall Canyon Mines, C/015/032
2011 Annual Report

Dear Mr. Haddock:

Enclosed are two copies of the 2013 annual report.

If you have any questions or comments regarding this submittal please contact me at 435 888-4000.

Sincerely,

David Hibbs
Resident Agent

RECEIVED
MAR 31 2014
DIV. OF OIL, GAS & MINING

2013

ANNUAL REPORT

GENERAL INFORMATION

Print Form | Submit by Email | Reset Form

Annual Report

This Annual Report shows information the Division has for your mine. Submit the completed document and any additional information identified in the Appendices to the Division by the date specified in the cover letter. During a complete inspection an inspector will check and verify the information.

GENERAL INFORMATION

Company Name	Genwal Resources Inc.	Mine Name	Crandall Canyon Mine
Permit Number	C/015/0032	Permit expiration Date	05/13/2018
Operator Name	Utah American Energy	Phone Number	+1 (435) 888-4000
Mailing Address	P.O. Box 0910	Email	dhibbs@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	
Other:		

OPERATOR COMMENTS

The Crandall Canyon Mine was inactive during 2012.

REVIEWER COMMENTS

☐ Met Requirements ☐ Did Not meet Requirements

COMMITMENTS AND CONDITIONS

The Permittee is responsible for ensuring annual technical commitments in the Mining and .clamation 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: Annually, during the spring and fall beginning in 2009.
Status: Spring and Fall 2012 reports are due to the Division.
Reports: Submit surveys in annual report.
Citation: MRP, Volume A Text, Chapter 3, page 3-17.

Operator Comments

The 2013 Spring & Fall Macroinvertebrate Report's are included.

viewer 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: MRP, Volume B, Chapter 5, Section 5.25.14, page 5-25.

Operator Comments

bsidence Information is included.

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 culverted 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: Needs to be completed as soon as possible.
Reports: Submitted to the Division upon project completion.
Citation: MRP, Volume A, 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 harrass 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: In annual report.
Citation: MRP, Volume A, Chapter 3, page 3-17.

OPERATOR COMMENTS (OPTIONAL)

Not required in 2013.

REVIEWER COMMENTS

REPORTING OF OTHER TECHNICAL DATA

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

Please list attachments:

Reviewer Comments

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
Mine Map		☒	☐	☐	☒
		☐	☐	☐	☐
		☐	☐	☐	☐
		☐	☐	☐	☐
		☐	☐	☐	☐

Reviewer Comments ☐ Met Requirements ☐ Did Not Meet Requirements

2013

ANNUAL REPORT

SEDIMENT

INFORMATION

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT			Page 1 of
Permit Number	ACT/014/032	**Report Date**	November 15, 2013
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	November 20, 2013
Inspected By	R. Jay Marshall
Reason for Inspection (Annual, Quarterly or Other Periodic Inspection, Critical Installation, or Completion of Construction)	**Annual and 4th QTR**

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

No instability, structural weakness, 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

Current Sediment Level: Approximately 6515.5

3. Principle and emergency spillway elevations.

Emergency 6519.50

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

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT		Page 2 of

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.

Current water elevation is approximately 6518.0. Pond is not discharging and is designed to be an evaporative pond that will not 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:** R. Jay Marshall **Date:** 11/19/13

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

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.

REGISTERED PROFESSIONAL ENGINEER #152606 R. JAY MARSHALL STATE OF UTAH

(PE Stamp)

By: Robert Jay Marshall
(Full Name and Title)

Signature: R. Jay Marshall Date: 11/20/13

P.E. Number & State: #152606 Utah

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT			Page 1 of
Permit Number	ACT/014/032	Report Date	March 22, 2013
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	42-01715	

IMPOUNDMENT INSPECTION

Inspection Date	December 28, 2012
Inspected By	R. Jay Marshall
Reason for Inspection (Annual, Quarterly or Other Periodic Inspection, Critical Installation, or Completion of Construction)	Annual

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:

60% 7769.0'
100% 7770.0'

Sediment Level:

Sediment Level was reported to be 7772.59'. Do to the ice and snow it was impossible to clearly see the cleanout markers and the reported elevation was best estimate of the maximum and not an average or true sediment level.

3. Principle and emergency spillway elevations.

Principle 7780.81'

Emergency 7781.81'

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT		Page 2 of

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 is frozen making the cleanout sediment markers impossible to see. No additional Iron sludge has been put into the pond since Burma came on line on January 5, 2013.

Ice/water is below the maximum water level of 7773.2.

Once the ice has melted, the pond will be decanted and the iron sludge removed and hauled to Burma evaporative pond. When the sludge has been removed the pond will be evaluated to see if it needs to be cleaned.

No discharge has occurred from the pond and therefore no samples have been taken.
No observable problems exist at the inlets or outlets.
No observable conditions were apparent that could affect the stability or function of the structure.

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.

The estimated average sediment elevation is believed to be at the cleanout level but could not be observed due to ice and water.

The water elevation at 77773.2 is approximately 7.61' below the spillway.

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:** ______________________ **Date:** __________

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT		Page 3 of

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

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.

REGISTERED PROFESSIONAL ENGINEER
#152606
R. JAY MARSHALL
3/22/13
STATE OF UTAH
PE Cert. Stamp

By: Robert Jay Marshall Project Engineer
(Full Name and Title)

Signature: R. Jay Marshall Date: 3/22/13

P.E. Number & State: 152606 Utah

2013

ANNUAL REPORT

SUBSIDENCE

INFORMATION

UtahAmerican Energy, Inc.

Crandall Canyon Mine - Subsidence Survey

10/1/2013

YEAR			2004	2007	2008	2009	2010	2011	2012	2013
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)
A	413190.85	2080628.41	10440.47	10439.53	10439.43	10439.47	10439.48	10439.41	10439.43	10439.45
B	413095.74	2080610.92	10426.40	10425.43	10425.40	10425.41	10425.38	10425.41	10425.40	10425.37
C	412995.22	2080594.07	10412.27	10411.20	10411.23	10411.23	10411.16	10411.18	10411.17	10411.20
D	412897.30	2080578.76	10400.21	10399.21	10399.25	10399.18	10399.23	10399.24	10399.21	10399.27
E	412795.72	2080563.91	10385.11	10384.15	10384.18	10384.13	10384.16	10384.17	10384.18	10384.15
J	412296.72	2080487.65	10323.47	10323.29	10323.20	10323.15	10323.26	10323.18	10323.19	10323.22
N	411898.88	2080428.44	10313.15	10313.15	10313.13	10313.16	10313.16	10313.16	10313.10	10313.17
O	411798.12	2080415.52	10316.56	10316.49	10316.50	10316.56	10316.52	10316.56	10316.57	10316.55
P	411700.03	2080403.24	10321.64	10321.65	10321.65	10321.69	10321.66	10321.65	10321.64	10321.63
Q	411599.74	2080390.76	10326.61	---	---	---	---	10326.53	10326.53	10326.56
R	411550.40	2080383.83	10330.17	---	---	---	---	10330.15	10330.08	10330.11
S	411501.07	2080376.56	10333.65	---	---	---	---	10333.51	10333.57	10333.54
T	411399.27	2080366.35	10342.83	---	---	---	---	10342.74	10342.75	10342.77
U	411299.82	2080354.19	10349.80	---	---	---	---	10349.68	10349.64	10349.69
V	411247.57	2080350.11	10353.81	---	---	---	---	10353.84	10353.77	10353.80
W	411198.08	2080343.54	10358.03	---	---	---	---	10357.94	10357.98	10357.93
X	411147.67	2080337.97	10360.97	---	---	---	---	10360.78	10360.89	10360.83
Y	411097.90	2080332.61	10365.90	---	---	---	---	10365.78	10365.84	10365.85
Z	411044.53	2080331.80	10371.01	---	---	---	---	10370.93	10371.01	10370.98
AA	410994.37	2080331.13	10376.37	---	---	---	---	10376.27	10376.36	10376.34
EE	410741.97	2080325.86	10430.72	---	---	---	---	10430.86	10430.97	10430.91
GG	410619.62	2080334.65	10435.38	---	---	---	---	10435.09	10435.41	10435.40
HH	410508.23	2080321.51	10435.17	---	---	---	---	10435.63	10435.11	10435.18
II	410458.36	2080312.15	10433.84	---	---	---	---	10434.29	10433.84	10433.88
JJ	410409.35	2080302.79	10433.25	---	---	---	---	10433.73	10433.20	10433.23
KK	410359.98	2080292.88	10432.40	---	---	---	---	10432.87	10432.42	10432.40
LL	410265.30	2080265.04	10428.65	---	---	---	---	10428.57	10428.47	10428.49
NN	409769.08	2080125.54	10347.00	---	---	---	---	10346.66	10346.71	10346.68
OO	409498.68	2080210.27	10284.52	---	---	---	---	10284.27	10284.26	10284.29
PP	409291.54	2080286.75	10262.98	---	---	---	---	10263.41	10263.41	10263.38

WARE SURVEYING & ENGINEERING

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

Phone: 435-613-1266
Email: waresurveying@emerytelcom.net

1344 North 1000 West
Price, Utah 84501

UtahAmerican Energy, Inc.

Crandall Canyon Mine

East Mountain Reclaimed Slide Area

9/18/2013

YEAR			2012	2013	2013
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION DIFFERENCE
Benchmark	413145.90	2079155.88	9986.04	9986.04	
1	413105.83	2079216.62	9987.03	9987.03	0.00
2	413079.15	2079242.82	9985.59	9985.45	0.14
3	413068.96	2079262.42	9982.58	9982.37	0.21
4	413056.95	2079275.88	9980.12	9979.90	0.22
5	413035.54	2079293.43	9979.24	9979.32	-0.08
6	413009.81	2079312.22	9977.00	9976.78	0.22
7	413011.56	2079280.20	9967.21	9966.96	0.25
8	413027.60	2079264.79	9963.57	9963.59	-0.02
9	413034.15	2079256.20	9964.10	9964.16	-0.05
10	413040.75	2079245.24	9963.48	9963.28	0.20
11	413044.33	2079234.13	9966.05	9965.95	0.10
12	413048.37	2079223.30	9963.67	9963.62	0.05
13	413025.61	2079233.40	9954.87	9954.98	-0.11
14	413020.64	2079240.46	9955.37	9955.31	0.06
15	413009.89	2079253.75	9955.08	9955.03	0.05
16	412997.97	2079264.46	9957.58	9957.45	0.14
17	412994.73	2079233.22	9945.34	9945.34	0.01
18	413001.96	2079217.74	9940.01	9939.88	0.13
19	412986.19	2079204.91	9928.78	9928.58	0.20
20	412960.88	2079205.24	9917.01	9916.98	0.03

WARE SURVEYING & ENGINEERING

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

Phone: 435-820-4335

Email: waresurveying@emerytelcom.net

2013

ANNUAL REPORT

MACROINVERTEBRATE

STUDY

Crandall Canyon Mine Macroinvertebrate Study June 2013

July 2013

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

EIS Environmental & Engineering Consulting (EIS) collected benthic macroinvertebrate samples from Crandall Creek on June 10 and 11, 2013. The creek is located near Huntington, Utah. From 2009 to 2013, 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). Please note that there were some discrepancies within the data provided by the BugLab and what JBR had reported. This was due to the BugLab switching to a standardized fixed count which allows for better comparison between samples. The attached tables, charts, and graphs (Appendix 2) were all computed with the revised historical data. These metrics will typically be lower with this new way of computation (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 to monitor water quality and provide reports documenting the survey results. Seven surveys have been completed since 2009 (JBR 2012). This report provides the results of the spring survey of 2013 completed by EIS. The samples were collected June 10 and 11, 2013. The samples were then shipped to the National Aquatic Monitoring Center (BugLab) in Logan, Utah for processing.

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 Transect B

CRANDMD-02 Transect B

CRANDLWR-03 Transect B

3.0 METHODS

The methods used for the survey are described by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) Field Operations Manual (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 (Miller and Judson 2013) and are used in Appendix 1, Appendix 2, and in the Taxa Lists. This data includes standardized and raw data used for the tables and graphs. In 2011, the BugLab 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 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 1 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 Appendix 2. 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 (Davis et al 2001).

Percent *Baetis*, Hydropsychidae, and Orthocladinae; Ratio of *Baetis* to all Ephemeroptera– These two similar measures express the documented higher tolerances of *Baetis*, Hydropsychidae, and Orthocladinae, than other members of their families. Mize and Deacon (2002) among others have used the presence of these taxa when assessing environmental conditions specific to mining (some studies have found the opposite conclusion with *Baetis;* however, the majority appear to consider it one of the more tolerant of the mayflies).

Percent Heptageniidae, Chloroperlidae, and *Rhyacophila;* Ratio of Heptageniidae to all Ephemeroptera– Similarly to the above-noted tolerant taxa, Heptageniidae, Chloroperlidae, and *Rhyacophila* were considered by Mize and Deacon (2002) when assessing elevated trace metals impacts. Heptageniidae, Chloroperlidae, and *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 BugLab results report that was prepared is provided in Appendix 1. It does not discuss or interpret the study results. They provide raw and standardized data that EIS has put into tables and charts to discuss. The Appendix 2 provides many graphs to show a visual comparison of the community composition between the different reaches and sample types. The following discusses a few of our findings.

The commonly found insect orders Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, and Diptera were present in all sites with the exception of the absence of Plecoptera in the CRANDMD-02 reach just below the mine discharge. Non-insect invertebrates were also found in all reaches sampled. As in previous years, Diptera (true flies) was the dominant order found in the upper and middle reaches. The higher abundance of this order in the upper and middle reaches, indicate that these two reaches continue to show they are not in optimum condition, even the upstream reach where there was no influence of mining operations. In the upper reach above the mine, Diptera was 44 and 46% of the abundance in the multi and riffle samples, respectively. The orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) are commonly considered sensitive to pollution (Karr & Chu 1999) and the fluctuation in their abundance can be an indicator of stream health. In the upper reach, EPT made up a majority of the remaining taxa at 46% in the multi habitat and 45% in the riffle. In the middle reach directly below the mine, the Diptera relative abundance was 42 and 89% of abundance in multi-habitat and riffle samples, and EPT's abundance was 2 and 6%, respectively. In the lower reach, the order Diptera was the lowest at 17 and 60%, and EPT was the highest at 57 and 88%, respectively. In the lowest reach, the order Ephemeroptera was found to be dominant at 56 and 86%. The increase of the sensitive macroinvertebrate species can be an indication of improved conditions in the lower reach.

For both riffle and multi-habitat samples, the richness, evenness, and Shannon's Diversity were overall higher in the upper reach than the middle and lower reach. Although Crandall Creek as a whole is still providing less than ideal habitat for the macroinvertebrate community, all but one sample contained at least some taxa that are considered intolerant to pollution. An exception was the multi-habitat in the middle reach. The richness was higher in the upstream reach in both multi and riffle habitats, with values of 22 and 23 respectively. The middle and lower reaches had 14 distinct taxa in the riffle habitat this year. The multi-habitat differed in the two, showing a higher value in the lower reach of 17, and only 13 in the middle reach. Because the number of distinct taxa appears to be fluctuating within all reaches and both habitat types year to year, there is no real discernible trend. For example, it appears that the multi-habitat in the upper reach seems to be getting less diverse, while the riffle habitat seems to be getting more diverse. Both riffle and multi-habitats are getting less diverse in the middle reach compared to 2012 levels, but are getter more diverse than those found in fall 2011. At the lower reach, the multi-habitat is becoming more diverse, but varies greatly year to year, while the riffle habitat is less diverse than 2012 levels, but more diverse than found in 2011. The similar kinds of results are occurring with the other metrics, more detail can be found in the graphs in Appendix 2.

The stream habitat and substrate appeared to be similar to those noted during previous studies. The lower reach has more cemented and embedded substrate than the middle and upper reaches and has less suitable habitat for invertebrates. As JBR had mentioned, these habitat differences also have impact on the macroinvertebrate community. The discharged mine water may not be the only cause for decreased abundance of macroinvertebrates. 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. The catastrophic impacts to Huntington Creek from major flooding resulting from a major wildfire in the upper drainage areas should also be considered. The high flows have directly impacted macroinvertebrate populations in Huntington Creek that are sources for movement into Crandall Creek.

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 2 display the differences between the two habitats within each year.

The richness, or number of distinct taxa, was found to be similar between the two habitat types within each reach, as was the EPT abundance. However, the evenness, or the distribution of the taxa within a community, seemed was higher in the multi-habitats in the middle and lower reaches and they had higher Shannon Diversity index values.

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 is upstream of any potential impact from the mines discharge, CRANDMD-02 is immediately below the discharge, and CRNDLWR-03 is further downstream. As shown in the graphs provided in Appendix 2, there is considerable amount of variation year to year, reach to reach, as well as between multi and riffle habitats. When comparing the data, it does appear that all reaches are in less than optimal condition. However, it does appear that the lowest reach may be improving based on the change of species composition, notably the change from order Diptera to Ephemeroptera. There is a higher abundance of EPT in the lower reach than the other two, at 57 and 88% in the multi and riffle habitats, respectively. The taxa that are thought to be more sensitive to habitat degradation are more prominent in the upper reach, which indicates that there is a difference in habitat quality between the upper reach and reaches below the mine. However, the taxa considered tolerant by the BugLab were found only in the upper reach and intolerant species were found in all 3 reaches.

4.3 Temporal Variation in Macroinvertebrate Community

EIS was able to obtain the standardized data from the BugLab dating back to 2009 to assess temporal variations. As mentioned in previous reports, the analysis of graphed metrics does not show any formidable overall trends in either improvement or degradation. Some of these metrics and indices indicate improvement, others show continued degradation, while some are similar. There are some noticeable changes from season to season, likely due to stream flow rates and macroinvertebrate life cycles.

5.0 CONCLUSION

The samples for the 2013 spring macroinvertebrate study were collected on June 10 and 11, 2013 from the 3 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. 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 that the relative abundance and types of taxa differ between the sampled reaches and generally show reduced habitat quality and less than optimal conditions in all sampled locations. The substrate and habitat also differs between reaches and should be taken into consideration. The changes in stream morphology due to increased beaver dams in the middle reach should also be considered, as well as the environmental impacts from the fire in 2012 and catastrophic flooding in Huntington Canyon as a result.

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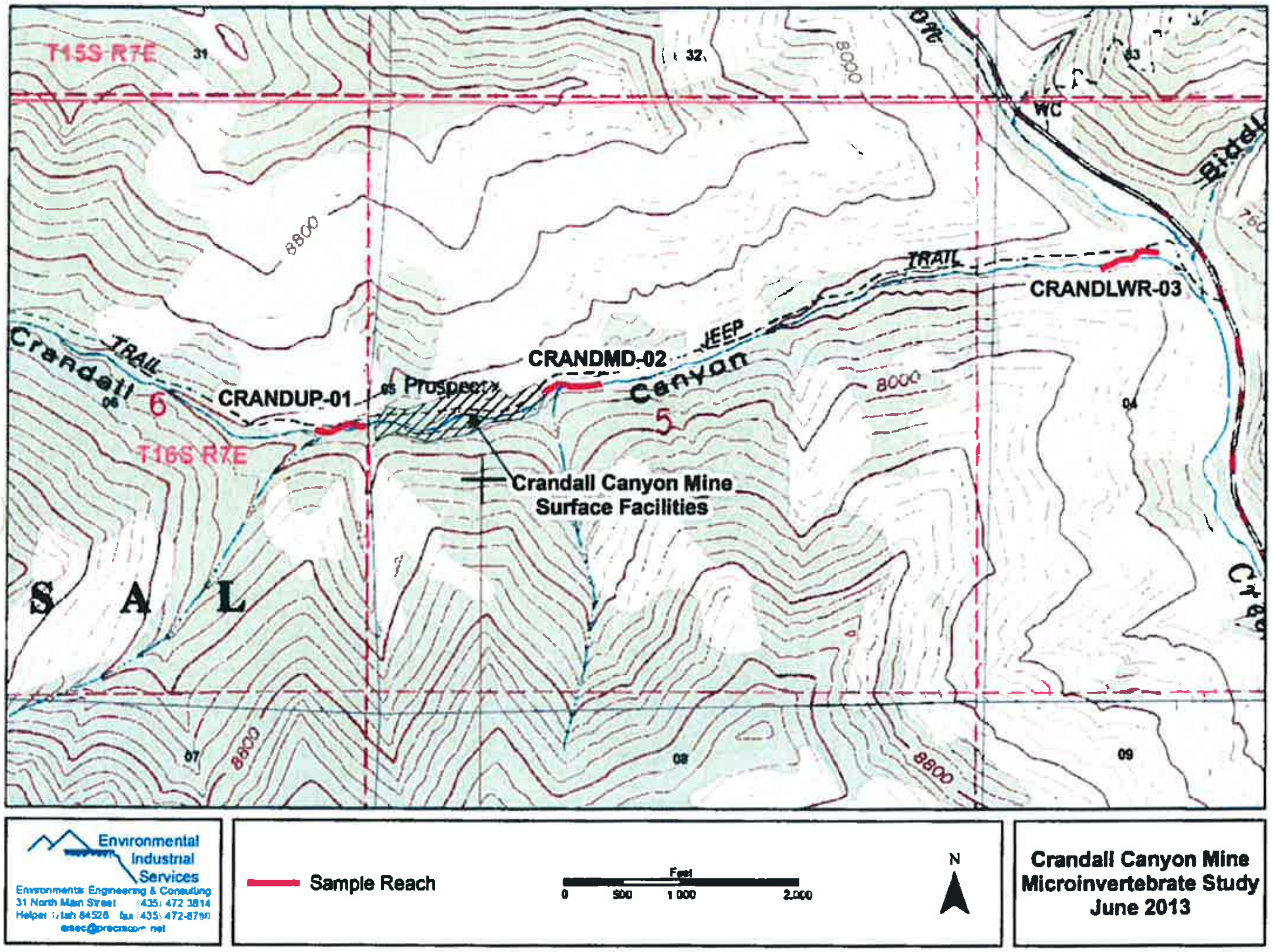
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Microinvertebrate Study
June 2013

APPENDIX 1

BUGLAB REPORT

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July 23, 2013

Table 1. 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 2. Field comments and laboratory processing information

Sample ID	Station	Collection Date	Habitat Sampled	Collection Method	Area sampled (m^2)	% of Sample Processed	of individuals Identified
150025	CRANDUP-01	6/11/2013	Reachwide	Kick net	0.46	87.5	626
150028	CRANDUP-01	6/11/2013	Targeted Riffle	Kick net	0.74	100	668
150027	CRANDMD-02	6/11/2013	Reachwide	Kick net	0.46	100	618
150026	CRANDMD-02	6/11/2013	Targeted Riffle	Kick net	0.74	100	636
150030	CRANDLWR-03	6/10/2013	Reachwide	Kick net	0.46	100	592
150029	CRANDLWR-03	6/10/2013	Targeted Riffle	Kick net	0.74	100	698

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.

Sample ID	Collection Date	Station	Total Abunance	EPT Abundance	Dominant Family	% Contribution dominant family
150025	6/11/2013	CRANDUP-01 Multi	1584	734	Chironomidae	36.55
150028	6/11/2013	CRANDUP-01 Riffle	903	408	Chironomidae	37.98
150027	6/11/2013	CRANDMD-02 Multi	1343	26	Chironomidae	40.43
150026	6/11/2013	CRANDMD-02 Riffle	859	50	Chironomidae	85.45
150030	6/10/2013	CRANDLWR-03 Multi	1287	739	Baetidae	55.71
150029	6/10/2013	CRANDLWR-03 Riffle	943	826	Baetidae	84.09
Mean			1153.2	463.8		56.70

Diversity Indices

Sample ID	Collection Date	Station	Total taxa richness	Total genera richness*	Total family richness*	EPT taxa richness*	Shannon diversity index	Evenness
150025	6/11/2013	CRANDUP-01 Multi	36	22	26	17	2.364986	0.76511
150028	6/11/2013	CRANDUP-01 Riffle	41	28	23	19	2.490664	0.794345
150027	6/11/2013	CRANDMD-02 Multi	24	12	11	16	1.311176	0.51119
150026	6/11/2013	CRANDMD-02 Riffle	24	18	15	7	0.615549	0.233246
150030	6/10/2013	CRANDLWR-03 Multi	25	18	16	7	1.933165	0.682322
150029	6/10/2013	CRANDLWR-03 Riffle	21	16	14	9	0.886552	0.335935
Mean			28.5	19	17.5	12.5	1.600349	0.553691

*Based off raw data, qualitative data versus the standardized quantitative data.

Diversity based on standardized OTU

Sample ID	Collection Date	Station	Total taxa richness	EPT taxa richness	Shannon diversity index	Evenness
150025	6/11/2013	CRANDUP-01 Multi	22	9	2.364986	0.76511
150028	6/11/2013	CRANDUP-01 Riffle	23	10	2.490664	0.794345
150027	6/11/2013	CRANDMD-02 Multi	13	2	1.311176	0.51119
150026	6/11/2013	CRANDMD-02 Riffle	14	3	0.615549	0.233246
150030	6/10/2013	CRANDLWR-03 Multi	17	4	1.933165	0.682322
150029	6/10/2013	CRANDLWR-03 Riffle	14	7	0.886552	0.335935
Mean			17.16667	5.833333	1.600349	0.553691

Genera richness by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
150025	6/11/2013	CRANDUP-01 Multi	1	12	9	0	0	0	4	4	0	0	1
150028	6/11/2013	CRANDUP-01 Riffle	3	13	9	0	0	0	4	6	1	0	1
150027	6/11/2013	CRANDMD-02 Multi	2	11	2	0	0	0	0	17	1	0	0
150026	6/11/2013	CRANDMD-02 Riffle	3	10	2	0	0	0	1	20	1	0	1
150030	6/10/2013	CRANDLWR-03 Multi	1	11	4	0	0	0	1	15	1	0	1
150029	6/10/2013	CRANDLWR-03 Riffle	1	7	4	0	0	0	3	5	1	0	1
Mean			1.8	10.7	5.0	0.0	0.0	0.0	2.2	11.4	0.8	0.0	0.8

Total Abundance by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
150025	6/11/2013	CRANDUP-01 Multi	15	693	474	0	0	0	52	208	0	0	35
150028	6/11/2013	CRANDUP-01 Riffle	20	414	234	0	0	0	32	142	9	0	1
150027	6/11/2013	CRANDMD-02 Multi	26	567	9	0	0	0	0	17	543	0	0
150026	6/11/2013	CRANDMD-02 Riffle	23	762	24	0	0	0	5	20	4	0	4
150030	6/10/2013	CRANDLWR-03 Multi	2	222	720	0	0	0	4	15	104	0	143
150029	6/10/2013	CRANDLWR-03 Riffle	1	59	811	0	0	0	9	5	3	0	1
Mean			15	453	379	0	0	0	17	68	111	0	31

Biotic Indices

Sample ID	Collection Date	Station	Hilsenhoff Biotic Index		USFS Community CTQd
			Index	Indication	
150025	6/11/2013	CRANDUP-01 Multi	4.263333	Potential slight organic pollution	76
150028	6/11/2013	CRANDUP-01 Riffle	4.073333	Potential slight organic pollution	72
150027	6/11/2013	CRANDMD-02 Multi	2.383333	Potential slight organic pollution	103
150026	6/11/2013	CRANDMD-02 Riffle	5.646667	Likely has moderate organic pollution	97
150030	6/10/2013	CRANDLWR-03 Multi	3.266667	Potential slight organic pollution	91
150029	6/10/2013	CRANDLWR-03 Riffle	3.856667	Potential slight organic pollution	81
Mean			3.915		86.666667

The Hilsenhoff Biotic Index (HBI) summarizes the overall polution tolerance of the taxa collected. Sampling locations with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 are considered polluted.

Sample ID	Collection Date	Station	Intolerant Taxa				Tolerant Taxa			
			Richness	Percent	Abundance	Percent	Richness	Percent	Abundance	Percent
150025	6/11/2013	CRANDUP-01 Multi	4	17	321	20	1	4	15	1
150028	6/11/2013	CRANDUP-01 Riffle	5	23	169	19	1	5	9	1
150027	6/11/2013	CRANDMD-02 Multi	0	0	0	0	0	0	0	0
150026	6/11/2013	CRANDMD-02 Riffle	1	8	15	2	0	0	0	0
150030	6/10/2013	CRANDLWR-03 Multi	1	7	9	1	0	0	0	0
150029	6/10/2013	CRANDLWR-03 Riffle	1	6	9	1	0	0	0	0
Mean			2.0	10	87.2	7	0.3	1	4.0	0

Functional Feeding Groups

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
150025	6/11/2013	CRANDUP-01 Multi	2	9	2	9	3	14	6	27	6	27	3	14
150028	6/11/2013	CRANDUP-01 Riffle	3	13	3	13	1	4	7	30	7	30	2	9
150027	6/11/2013	CRANDMD-02 Multi	1	8	0	0	0	0	4	31	5	38	3	23
150026	6/11/2013	CRANDMD-02 Riffle	1	7	0	0	1	7	5	36	5	36	2	14
150030	6/10/2013	CRANDLWR-03 Multi	2	12	0	0	2	12	5	29	6	35	2	12
150029	6/10/2013	CRANDLWR-03 Riffle	1	7	1	7	3	21	5	36	3	21	1	7
Mean			1.7	9.3	1.0	4.9	1.7	9.7	5.3	31.6	5.3	31.4	2.2	13.1

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
150025	6/11/2013	CRANDUP-01 Multi	50	3	92	6	52	3	966	61	399	25	25	2
150028	6/11/2013	CRANDUP-01 Riffle	68	8	96	11	3	0	503	56	215	24	18	2
150027	6/11/2013	CRANDMD-02 Multi	20	1	0	0	0	0	1104	82	193	14	26	2
150026	6/11/2013	CRANDMD-02 Riffle	14	2	0	0	4	0	764	89	57	7	20	2
150030	6/10/2013	CRANDLWR-03 Multi	74	6	0	0	161	13	928	72	122	9	2	0
150029	6/10/2013	CRANDLWR-03 Riffle	7	1	11	1	7	1	850	90	68	7	0	0
Mean			38.8	3.4	33.2	2.9	37.8	2.9	852.5	75.0	175.7	14.4	15.2	1.3

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:

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]

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.

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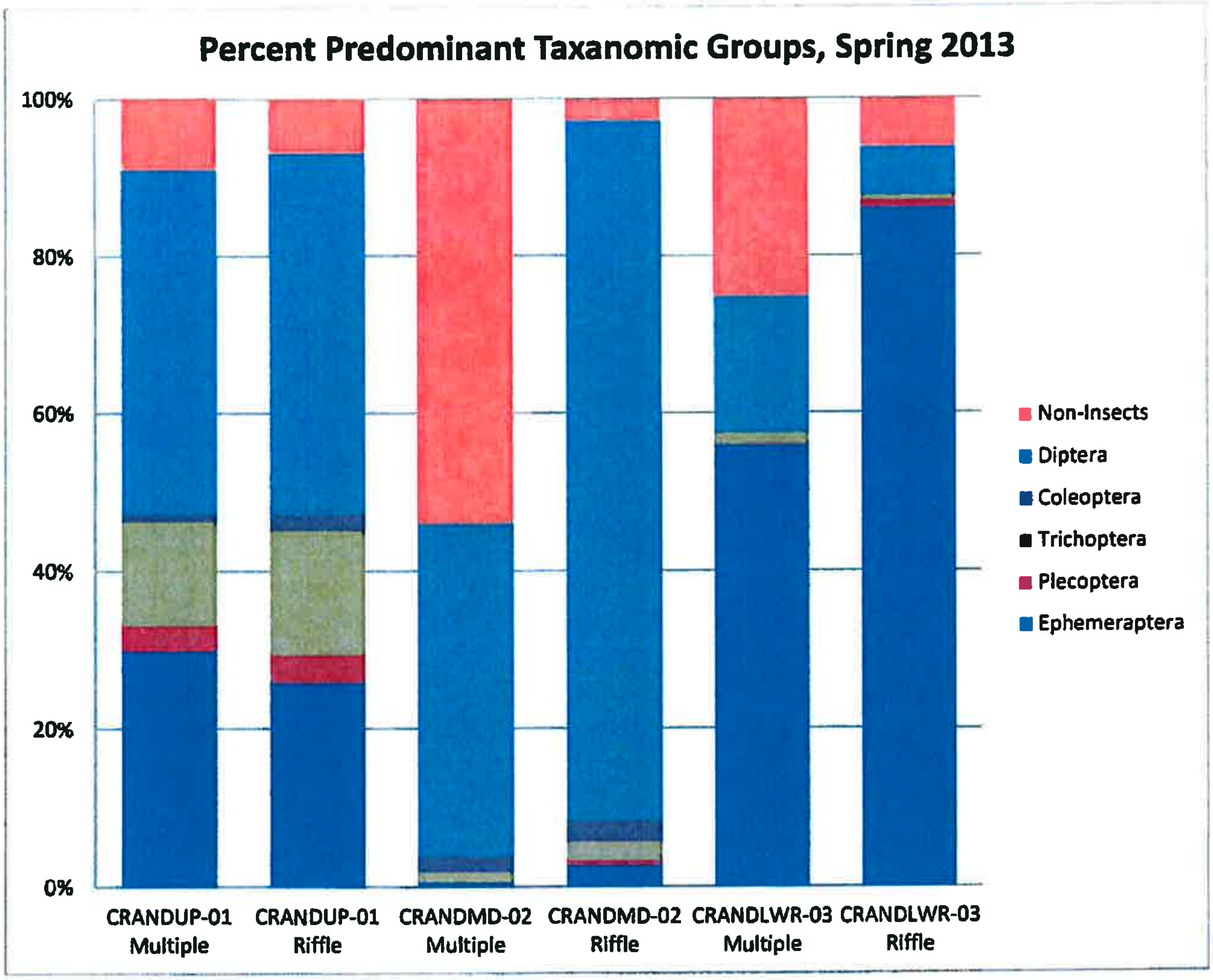
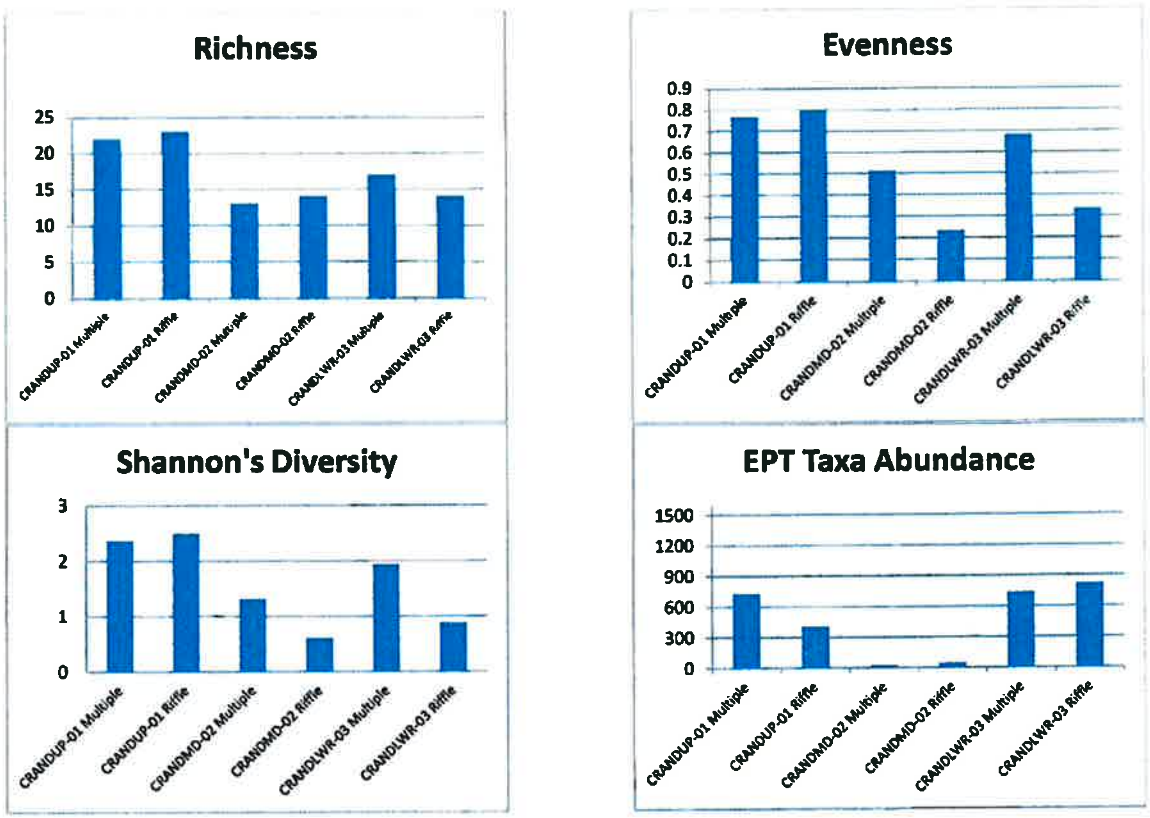
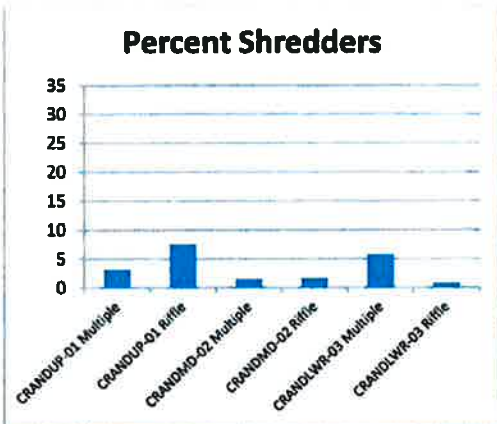
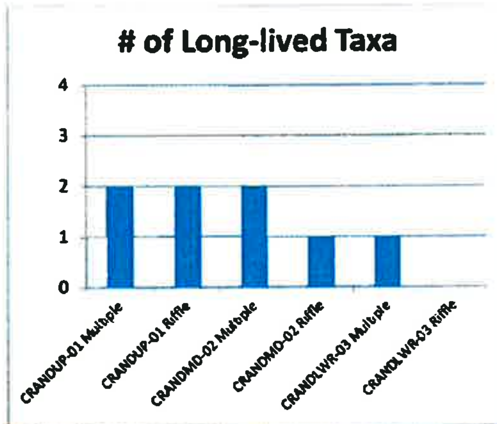
APPENDIX 2

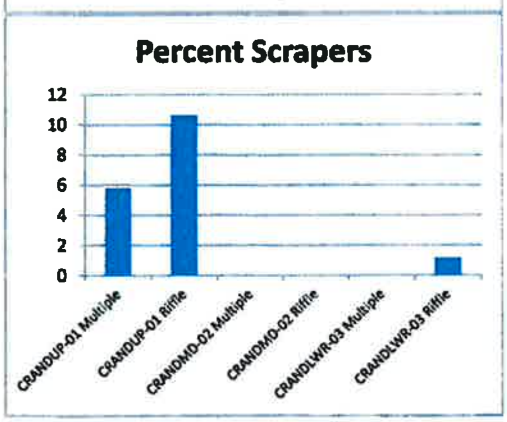
MACROINVERTEBRATE METRICS

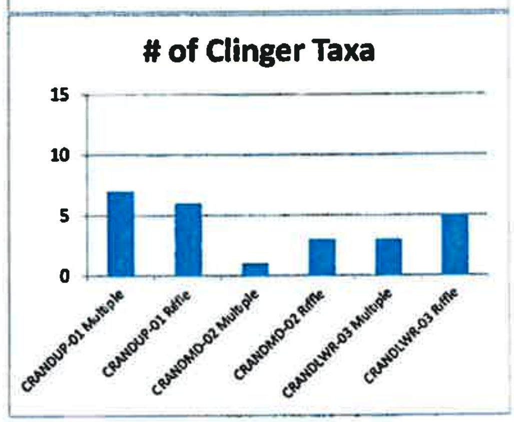

Percent Predominant Taxanomic Groups, Spring 2013
100%
80%
60%
40%
20%
0%
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle
Non-Insects
Diptera
Coleoptera
Trichoptera
Plecoptera
Ephemeraptera

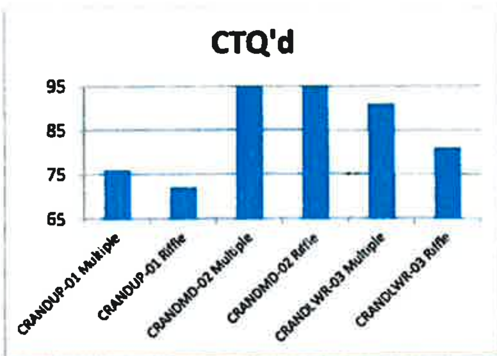

Richness
25
20
15
10
5
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle
Evenness
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle
Shannon's Diversity
3
2
1
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle
EPT Taxa Abundance
1500
1200
900
600
300
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

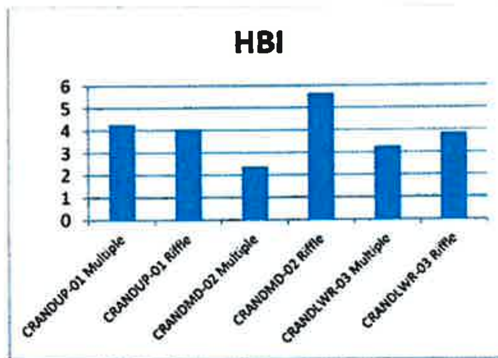

Percent Shredders
35
30
25
20
15
10
5
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

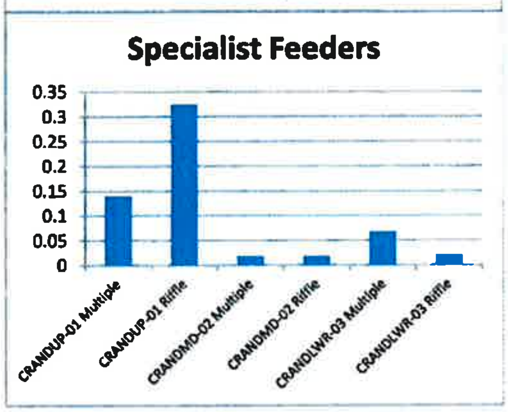

# of Long-lived Taxa
4
3
2
1
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

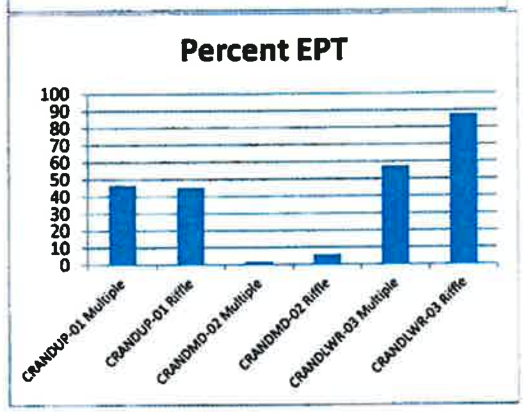

Percent Scrapers
12
10
8
6
4
2
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

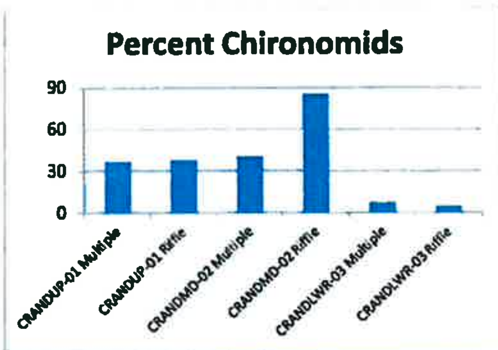

# of Clinger Taxa
15
10
5
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

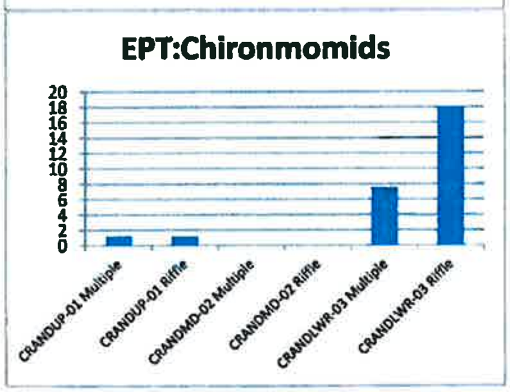

CTQ'd
95
85
75
65
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

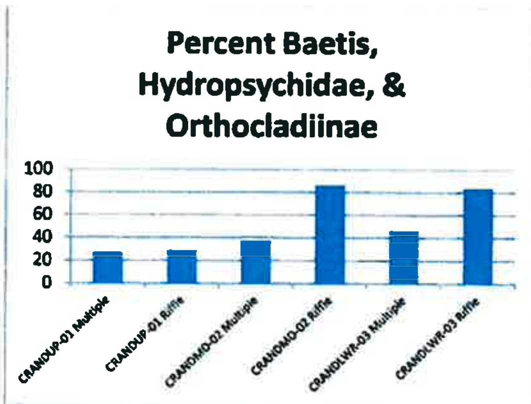

HBI
6
5
4
3
2
1
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

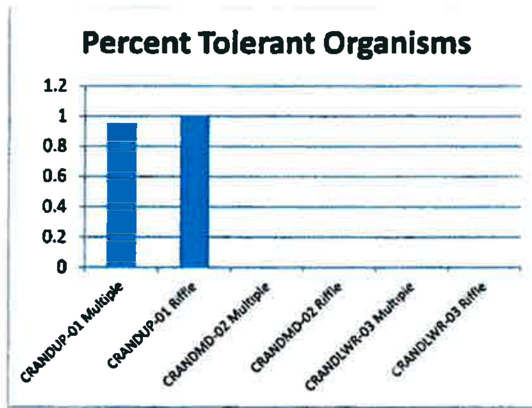

Specialist Feeders
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

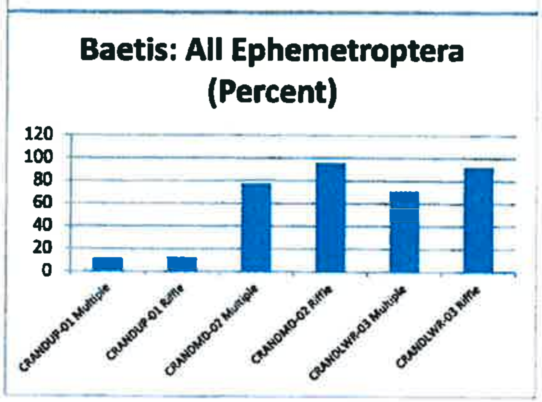

Percent EPT
100
90
80
70
60
50
40
30
20
10
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

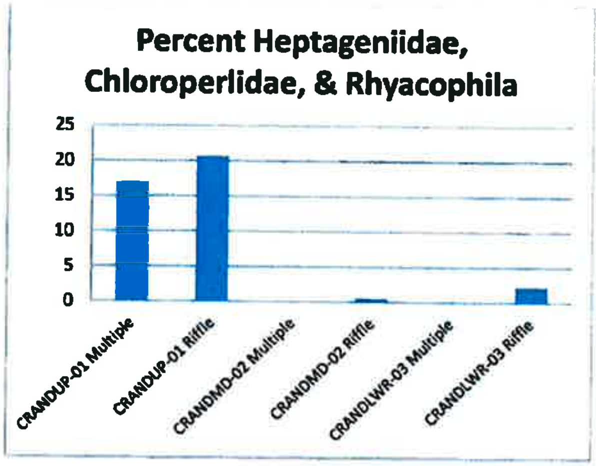

Percent Chironomids
90
60
30
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

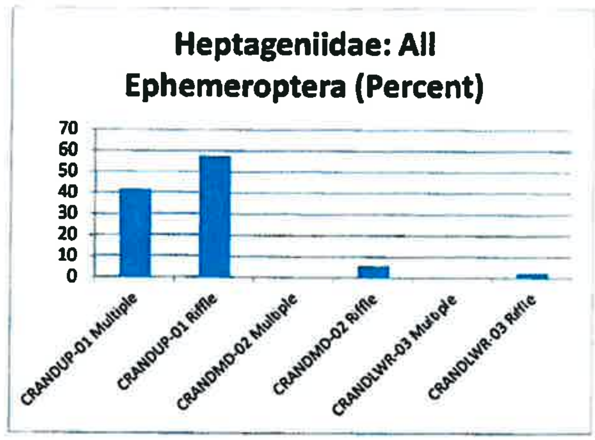

EPT:Chironmomids
20
18
16
14
12
10
8
6
4
2
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

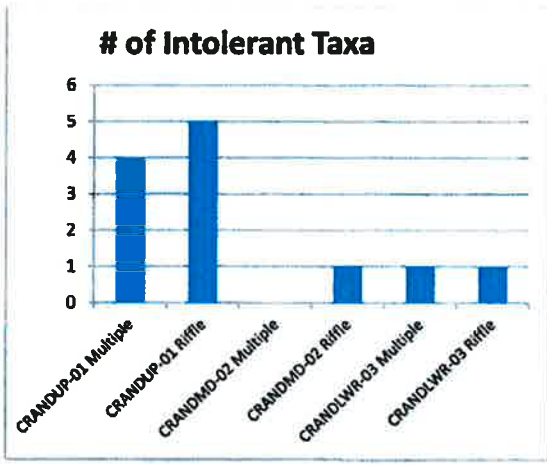

Percent Baetis, Hydropsychidae, & Orthocladiinae
100
80
60
40
20
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle


Percent Tolerant Organisms
1.2
1
0.8
0.6
0.4
0.2
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

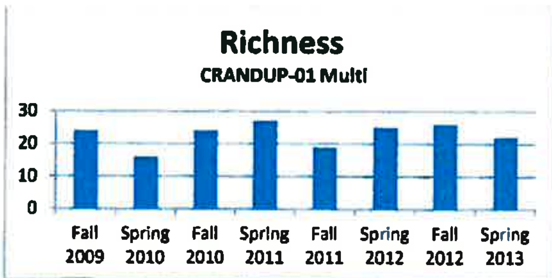

Baetis: All Ephemetroptera (Percent)
120
100
80
60
40
20
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle


Percent Heptageniidae, Chloroperlidae, & Rhyacophila
25
20
15
10
5
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle

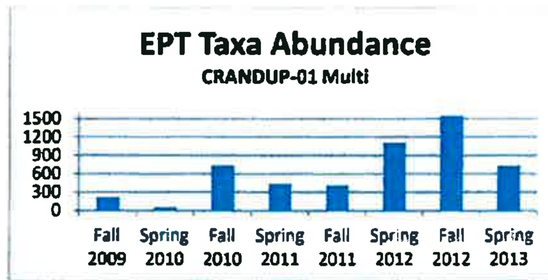

Heptageniidae: All Ephemeroptera (Percent)
70
60
50
40
30
20
10
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle



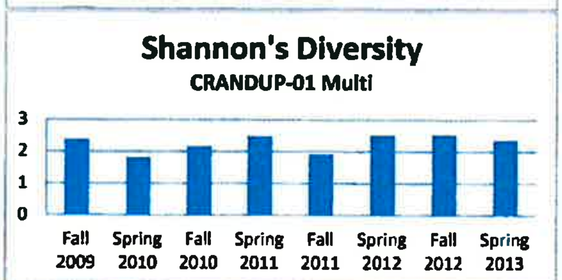
# of Intolerant Taxa
6
5
4
3
2
1
0
CRANDUP-01 Multiple
CRANDUP-01 Riffle
CRANDMD-02 Multiple
CRANDMD-02 Riffle
CRANDLWR-03 Multiple
CRANDLWR-03 Riffle



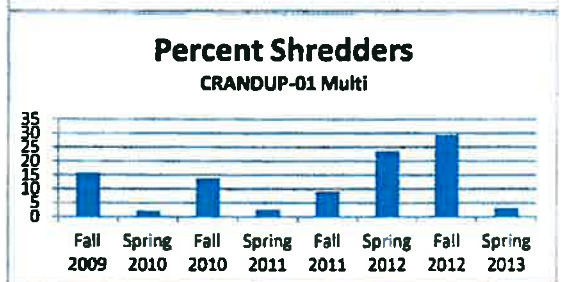
Richness
CRANDUP-01 Multi
30
20
10
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



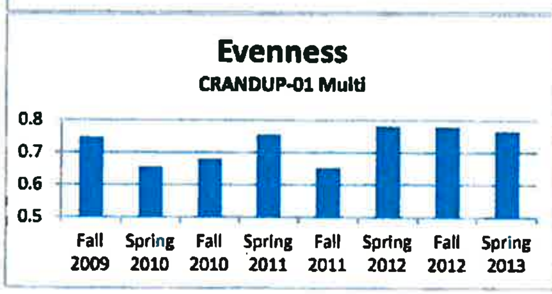
EPT Taxa Abundance
CRANDUP-01 Multi
1500
1200
900
600
300
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



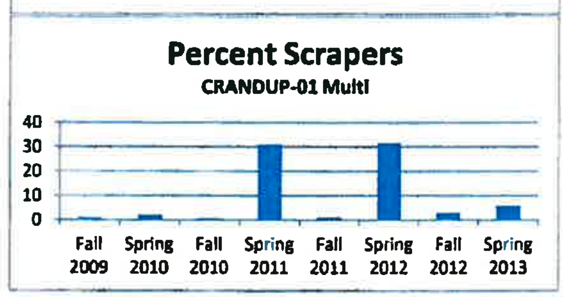
Shannon's Diversity
CRANDUP-01 Multi
3
2
1
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



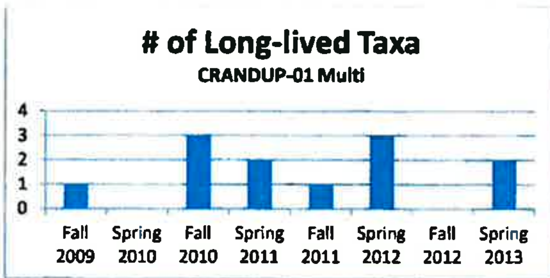
Percent Shredders
CRANDUP-01 Multi
35
30
25
20
15
10
5
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

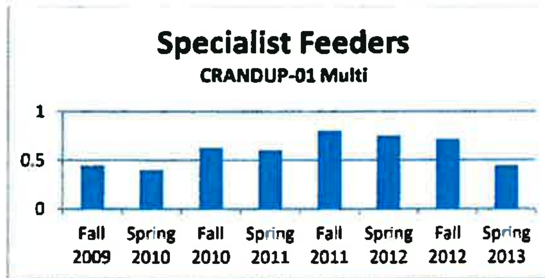


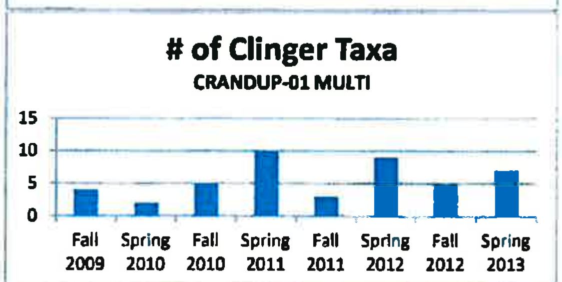
Evenness
CRANDUP-01 Multi
0.8
0.7
0.6
0.5
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

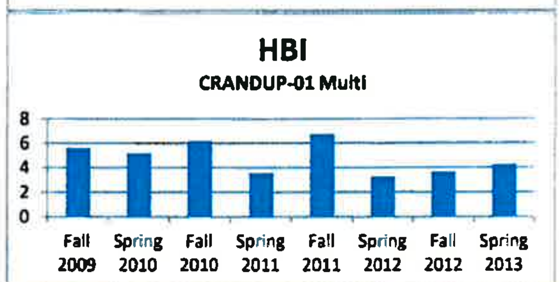


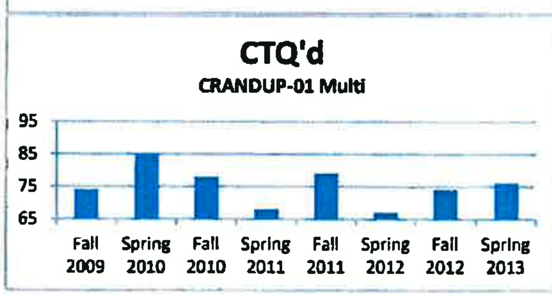
Percent Scrapers
CRANDUP-01 Multi
40
30
20
10
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

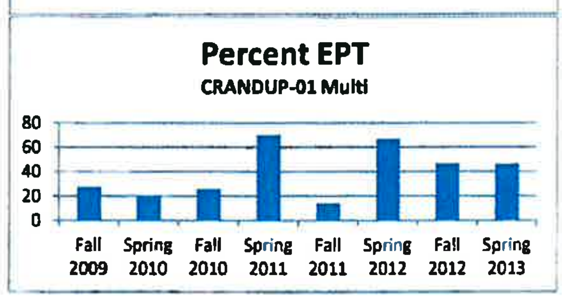

# of Long-lived Taxa
CRANDUP-01 Multi
4
3
2
1
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

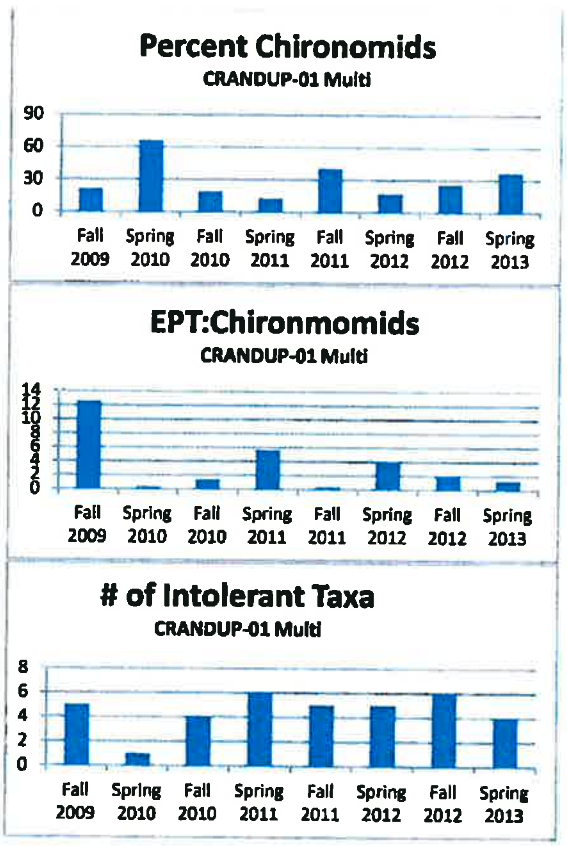

Specialist Feeders
CRANDUP-01 Multi
1
0.5
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


# of Clinger Taxa
CRANDUP-01 MULTI
15
10
5
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

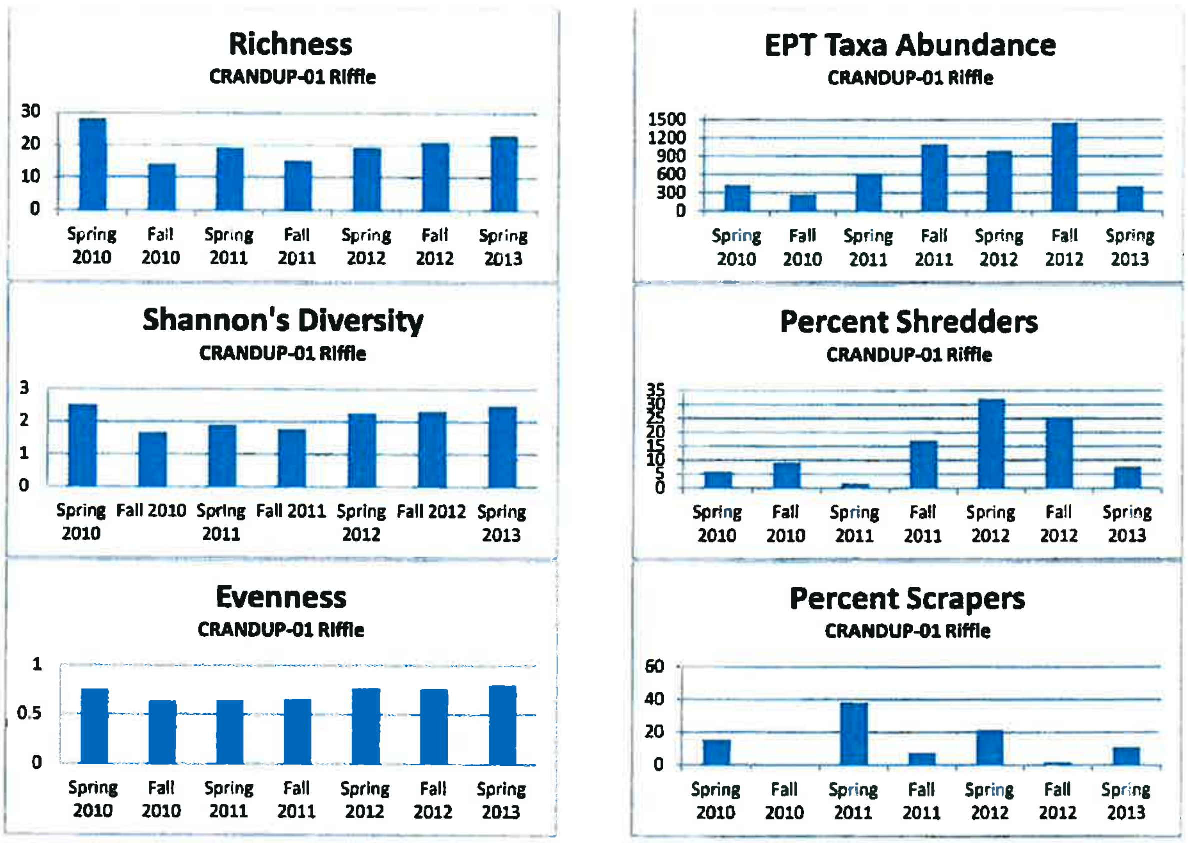

HBI
CRANDUP-01 Multi
8
6
4
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


CTQ'd
CRANDUP-01 Multi
95
85
75
65
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

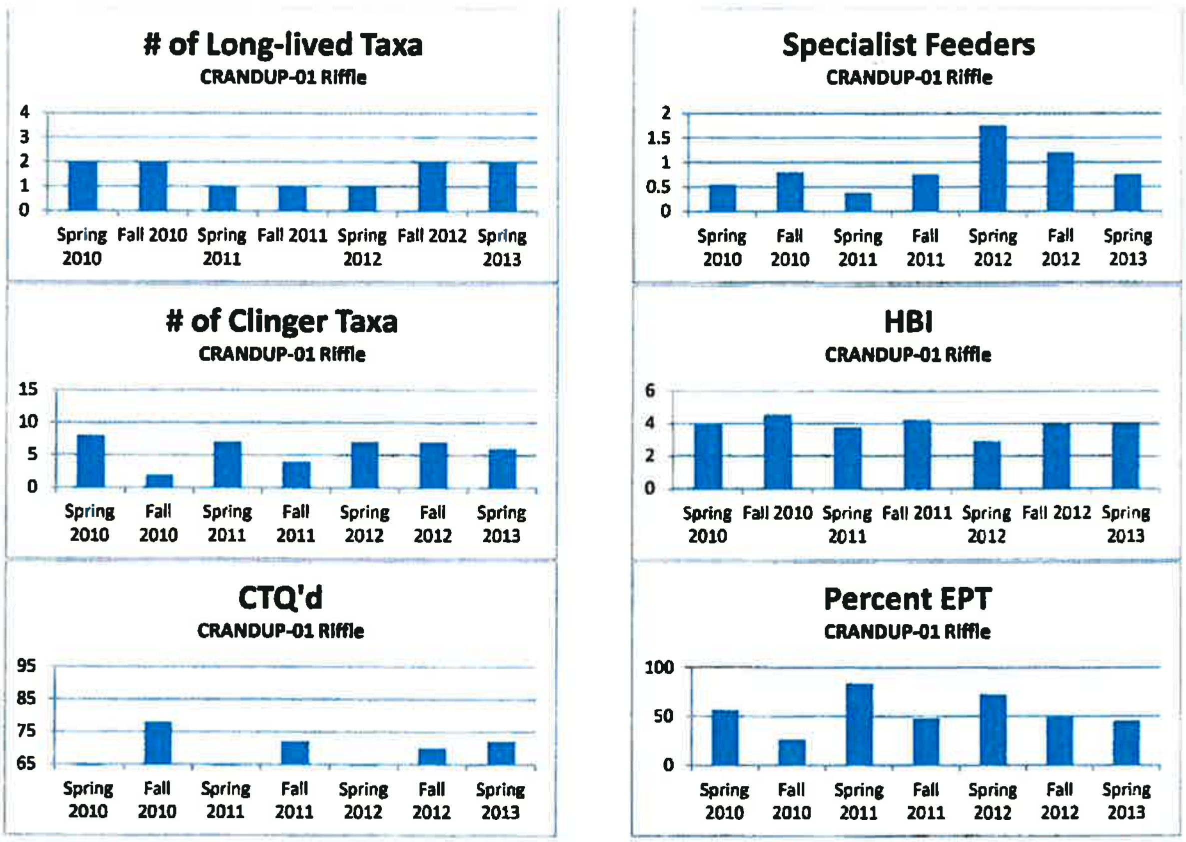

Percent EPT
CRANDUP-01 Multi
80
60
40
20
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



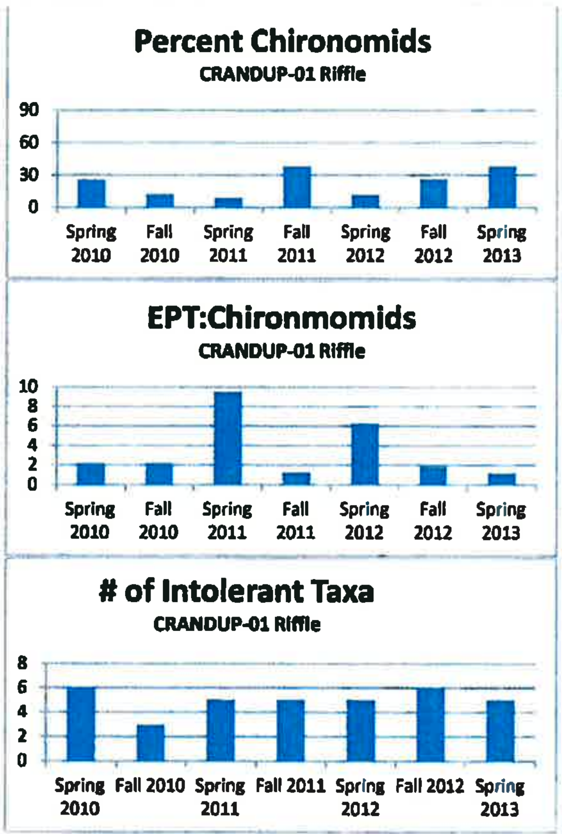
Percent Chironomids
CRANDUP-01 Multi
90
60
30
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
EPT:Chironmomids
CRANDUP-01 Multi
14
12
10
8
6
4
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
# of Intolerant Taxa
CRANDUP-01 Multi
8
6
4
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

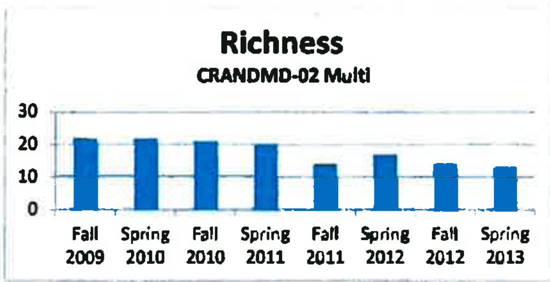


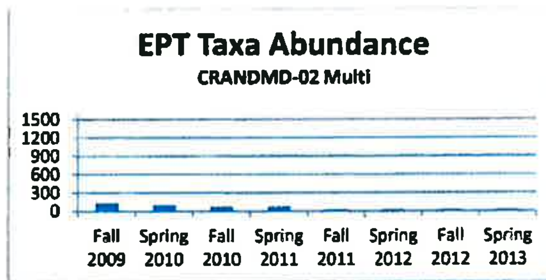
Richness
CRANDUP-01 Riffle
30
20
10
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
EPT Taxa Abundance
CRANDUP-01 Riffle
1500
1200
900
600
300
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
Shannon's Diversity
CRANDUP-01 Riffle
3
2
1
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
Percent Shredders
CRANDUP-01 Riffle
35
30
25
20
15
10
5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
Evenness
CRANDUP-01 Riffle
1
0.5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
Percent Scrapers
CRANDUP-01 Riffle
60
40
20
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

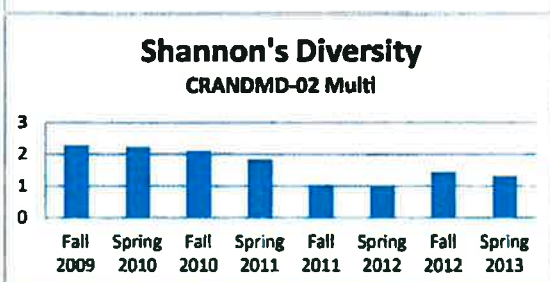


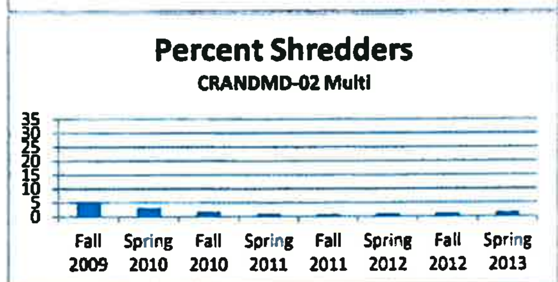
# of Long-lived Taxa
CRANDUP-01 Riffle
4
3
2
1
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
Specialist Feeders
CRANDUP-01 Riffle
2
1.5
1
0.5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
# of Clinger Taxa
CRANDUP-01 Riffle
15
10
5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
HBI
CRANDUP-01 Riffle
6
4
2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
CTQ'd
CRANDUP-01 Riffle
95
85
75
65
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
Percent EPT
CRANDUP-01 Riffle
100
50
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

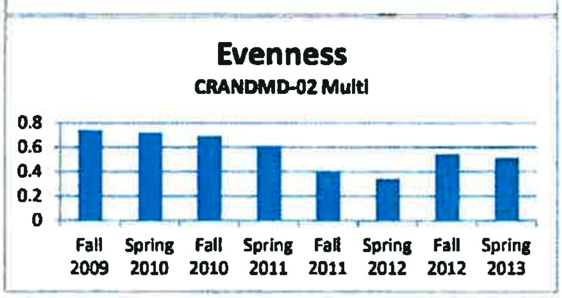

Percent Chironomids
CRANDUP-01 Riffle
90
60
30
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
EPT:Chironmomids
CRANDUP-01 Riffle
10
8
6
4
2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
# of Intolerant Taxa
CRANDUP-01 Riffle
8
6
4
2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

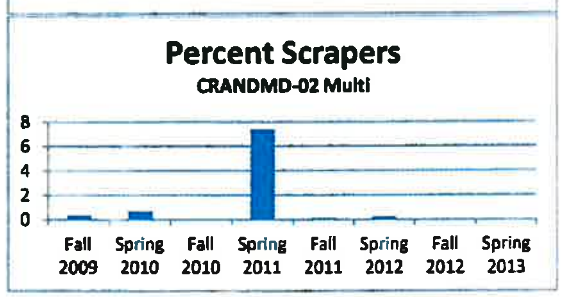

Richness
CRANDMD-02 Multi
30
20
10
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

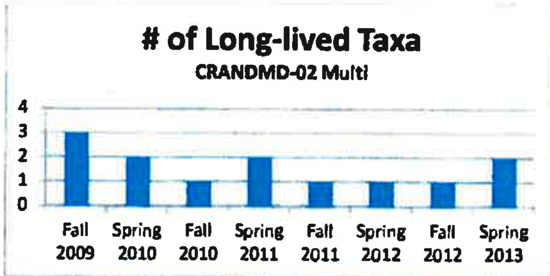

EPT Taxa Abundance
CRANDMD-02 Multi
1500
1200
900
600
300
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

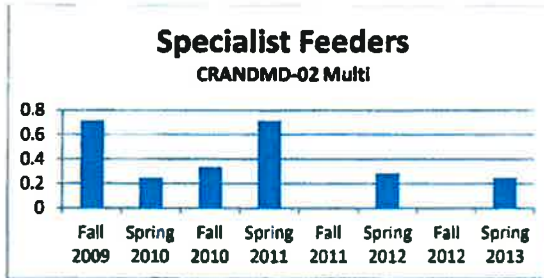

Shannon's Diversity
CRANDMD-02 Multi
3
2
1
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

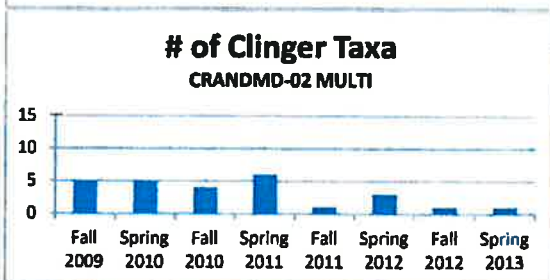

Percent Shredders
CRANDMD-02 Multi
35
30
25
20
15
10
5
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

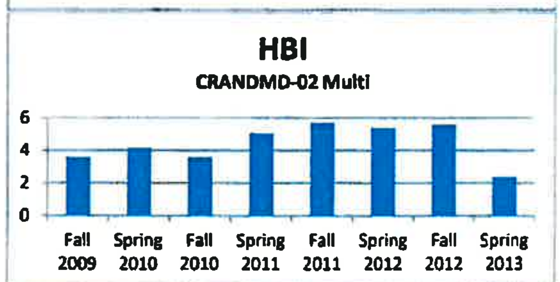

Evenness
CRANDMD-02 Multi
0.8
0.6
0.4
0.2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

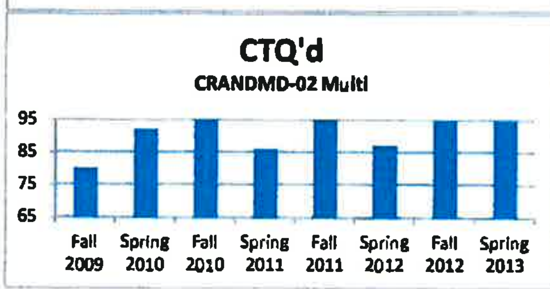

Percent Scrapers
CRANDMD-02 Multi
8
6
4
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

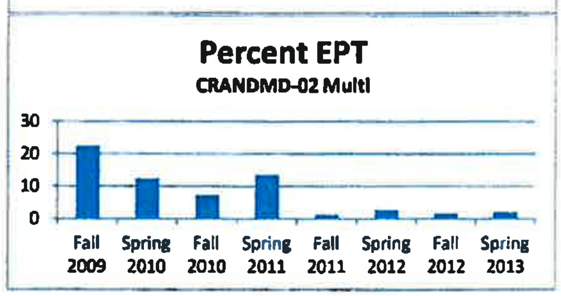

# of Long-lived Taxa
CRANDMD-02 Multi
4
3
2
1
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

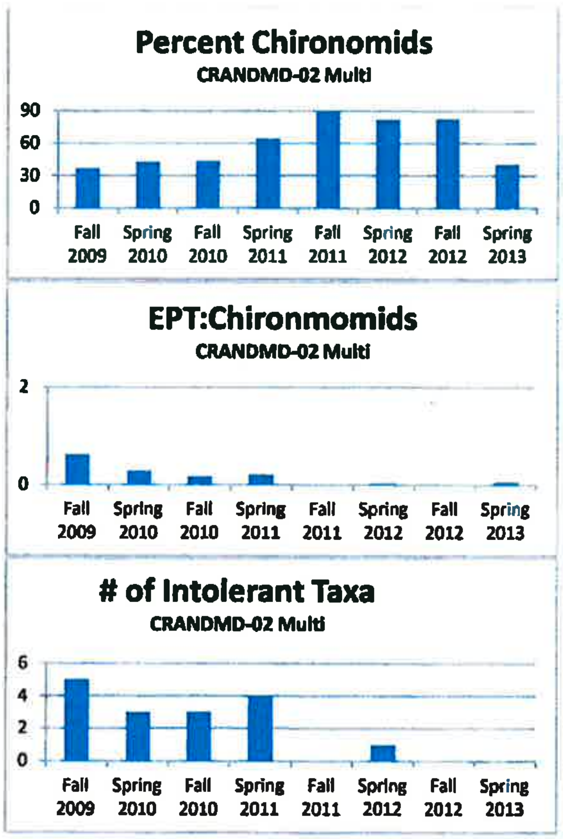

Specialist Feeders
CRANDMD-02 Multi
0.8
0.6
0.4
0.2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

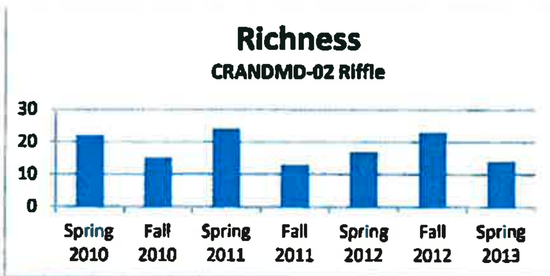

# of Clinger Taxa
CRANDMD-02 MULTI
15
10
5
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

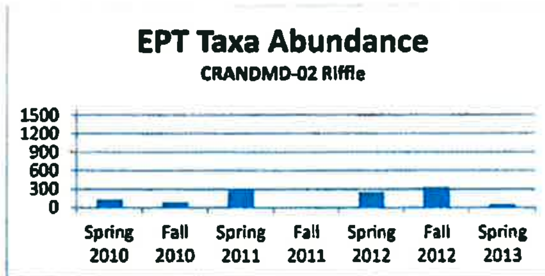

HBI
CRANDMD-02 Multi
6
4
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

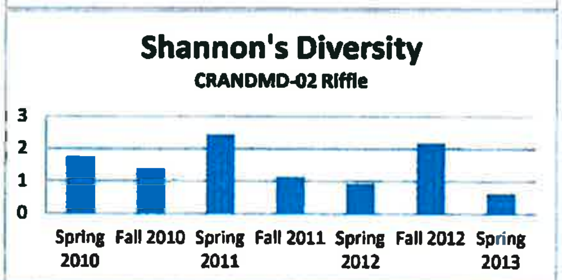

CTQ'd
CRANDMD-02 Multi
95
85
75
65
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

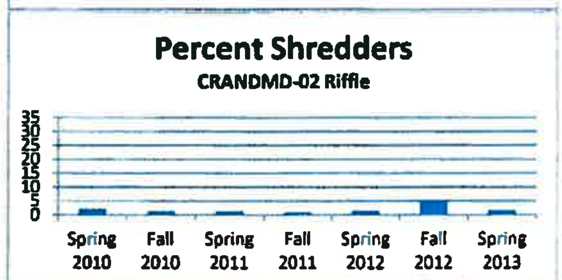

Percent EPT
CRANDMD-02 Multi
30
20
10
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

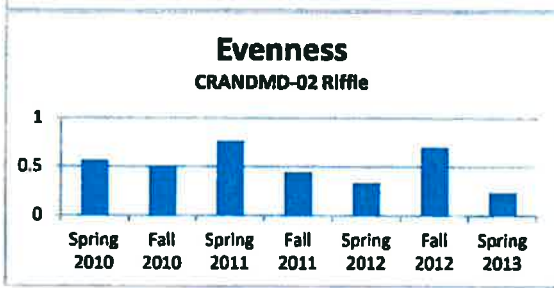

Percent Chironomids
CRANDMD-02 Multi
90
60
30
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
EPT:Chironmomids
CRANDMD-02 Multi
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
# of Intolerant Taxa
CRANDMD-02 Multi
6
4
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

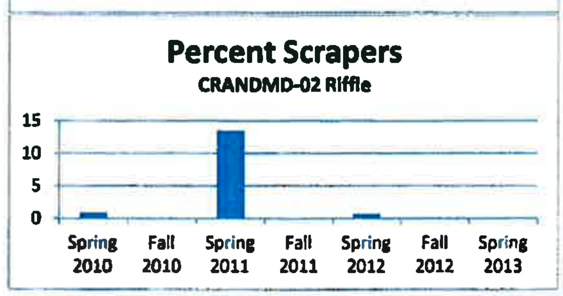

Richness
CRANDMD-02 Riffle
30
20
10
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

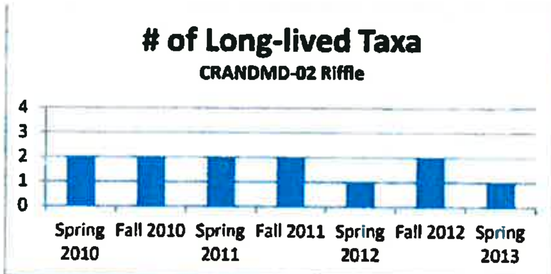

EPT Taxa Abundance
CRANDMD-02 Riffle
1500
1200
900
600
300
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


Shannon's Diversity
CRANDMD-02 Riffle
3
2
1
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


Percent Shredders
CRANDMD-02 Riffle
35
30
25
20
15
10
5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

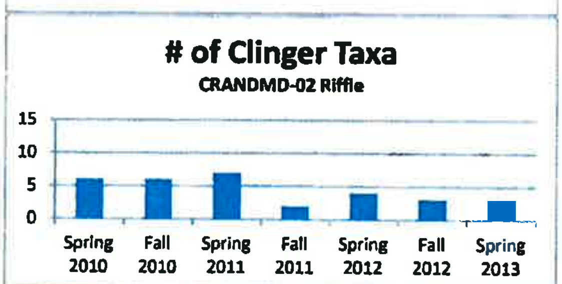

Evenness
CRANDMD-02 Riffle
1
0.5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


Percent Scrapers
CRANDMD-02 Riffle
15
10
5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

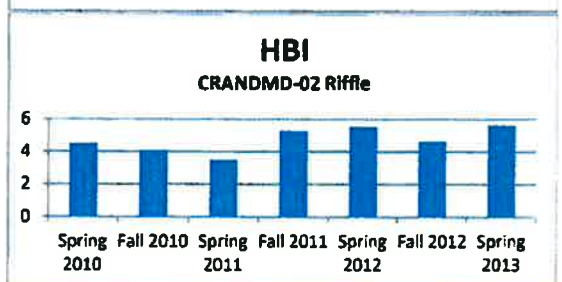


# of Long-lived Taxa
CRANDMD-02 Riffle
4
3
2
1
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

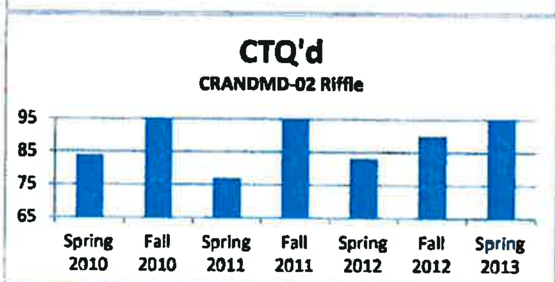
Specialist Feeders
CRANDMD-02 Riffle
0.6
0.4
0.2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



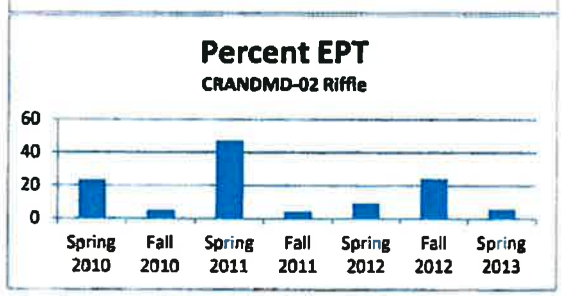
# of Clinger Taxa
CRANDMD-02 Riffle
15
10
5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



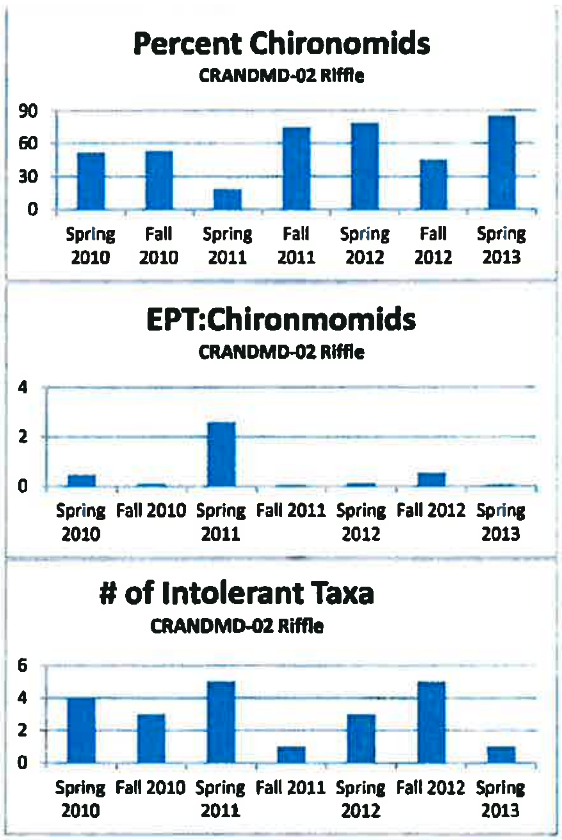
HBI
CRANDMD-02 Riffle
6
4
2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

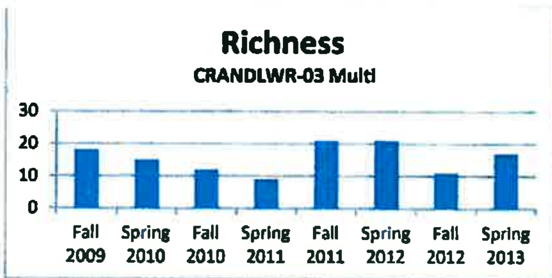


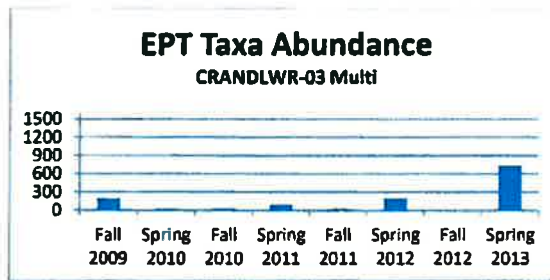
CTQ'd
CRANDMD-02 Riffle
95
85
75
65
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

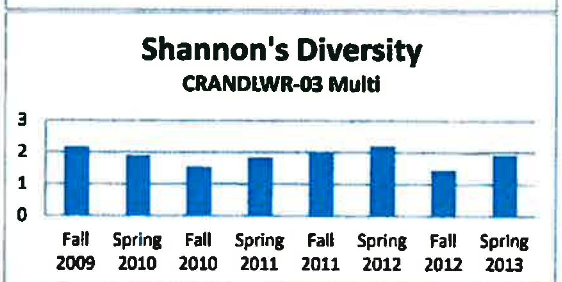


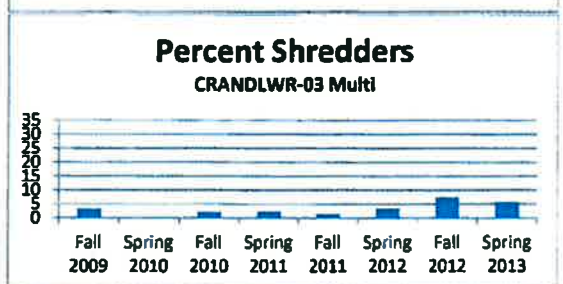
Percent EPT
CRANDMD-02 Riffle
60
40
20
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

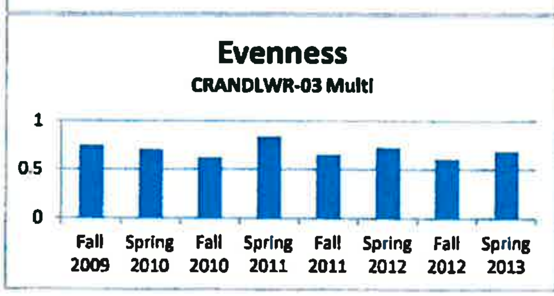

Percent Chironomids
CRANDMD-02 Riffle
90
60
30
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
EPT:Chironmomids
CRANDMD-02 Riffle
4
2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013
# of Intolerant Taxa
CRANDMD-02 Riffle
6
4
2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

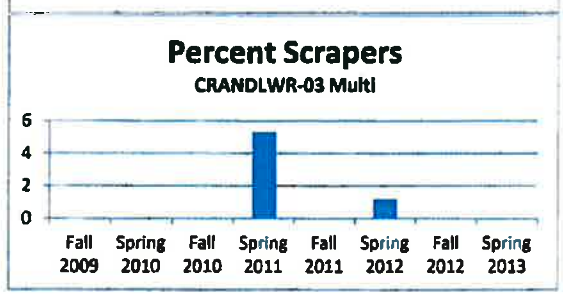

Richness
CRANDLWR-03 Multi
30
20
10
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

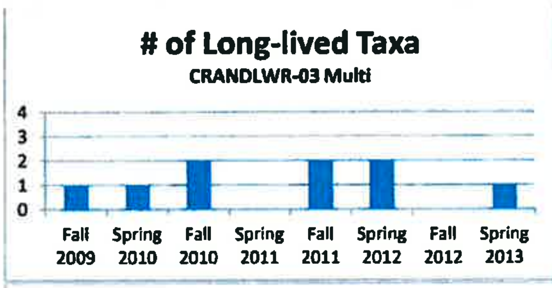

EPT Taxa Abundance
CRANDLWR-03 Multi
1500
1200
900
600
300
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

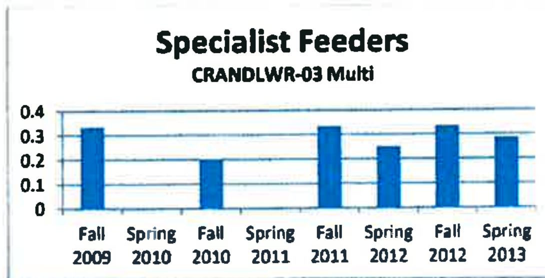

Shannon's Diversity
CRANDLWR-03 Multi
3
2
1
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

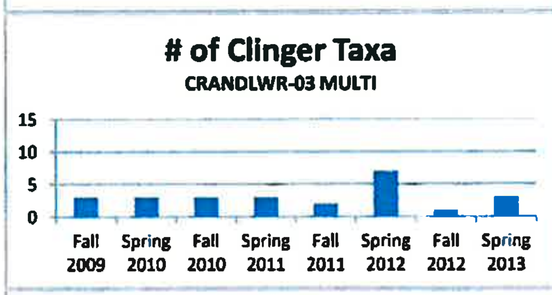

Percent Shredders
CRANDLWR-03 Multi
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

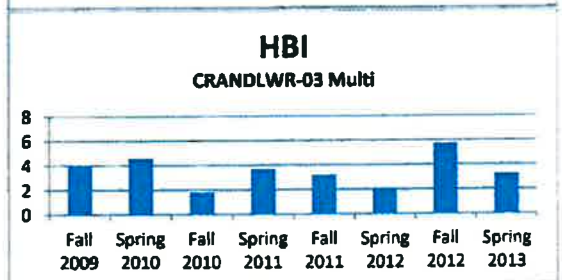

Evenness
CRANDLWR-03 Multi
1
0.5
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

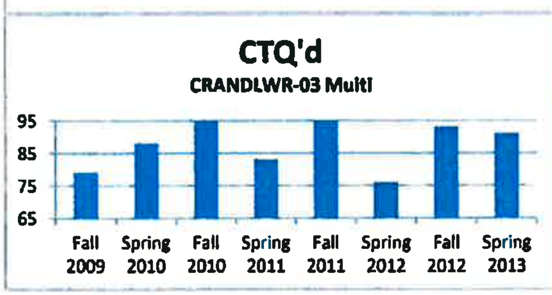

Percent Scrapers
CRANDLWR-03 Multi
6
4
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

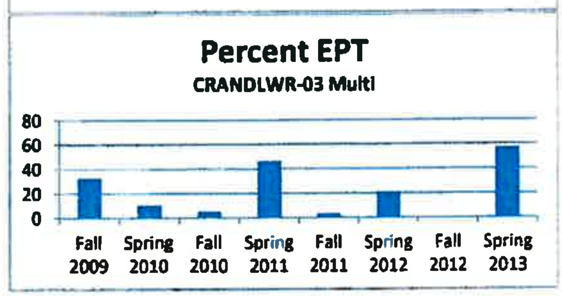

# of Long-lived Taxa
CRANDLWR-03 Multi
4
3
2
1
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

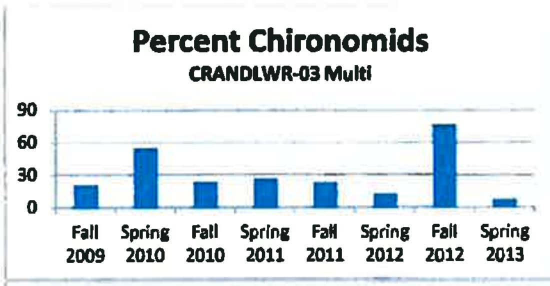

Specialist Feeders
CRANDLWR-03 Multi
0.4
0.3
0.2
0.1
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

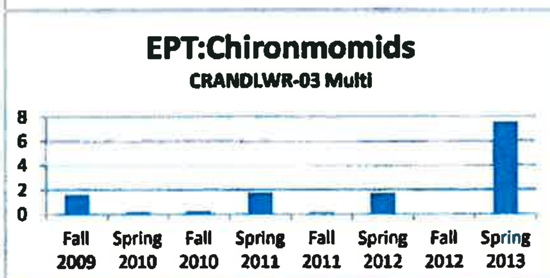

# of Clinger Taxa
CRANDLWR-03 MULTI
15
10
5
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

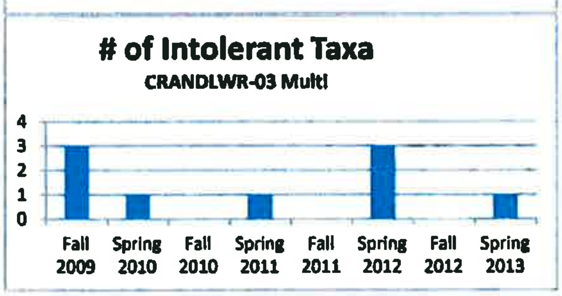

HBI
CRANDLWR-03 Multi
8
6
4
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

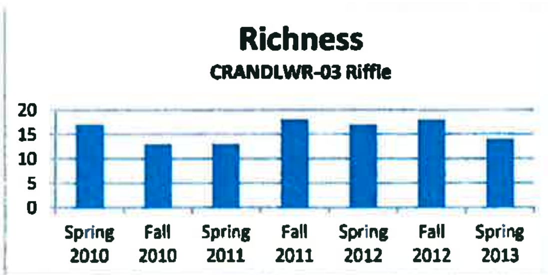

CTQ'd
CRANDLWR-03 Multi
95
85
75
65
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

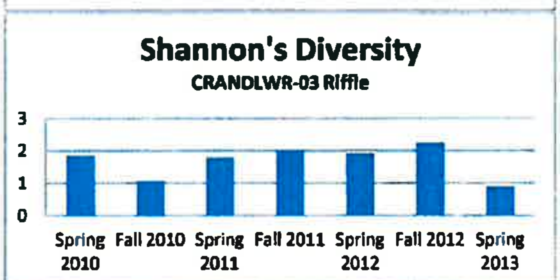

Percent EPT
CRANDLWR-03 Multi
80
60
40
20
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

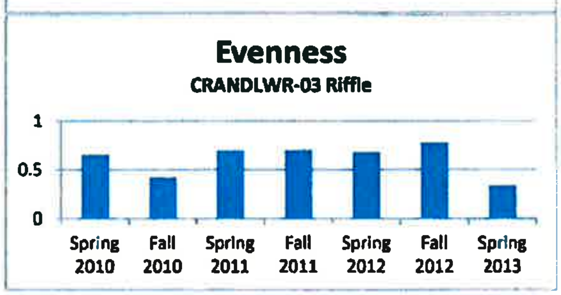

Percent Chironomids
CRANDLWR-03 Multi
90
60
30
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

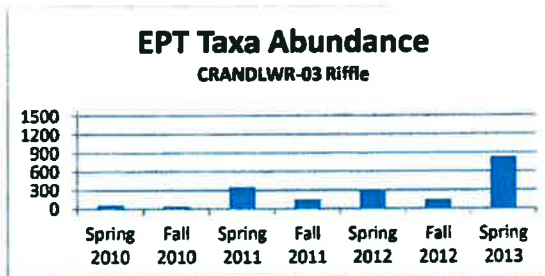

EPT:Chironmomids
CRANDLWR-03 Multi
8
6
4
2
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

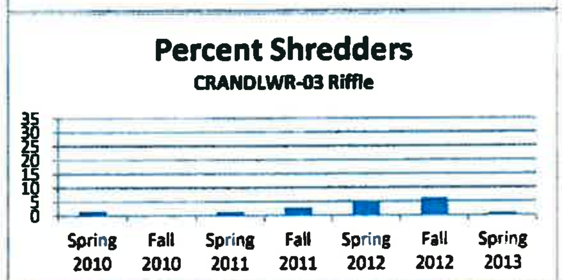

# of Intolerant Taxa
CRANDLWR-03 Multi
4
3
2
1
0
Fall 2009
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

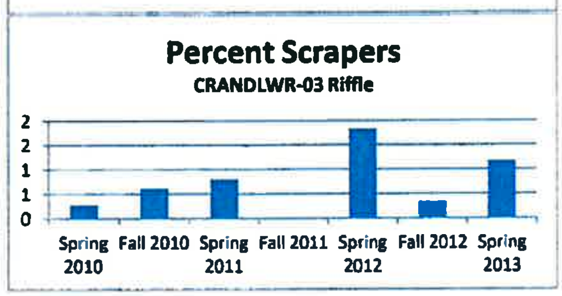

Richness
CRANDLWR-03 Riffle
20
15
10
5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

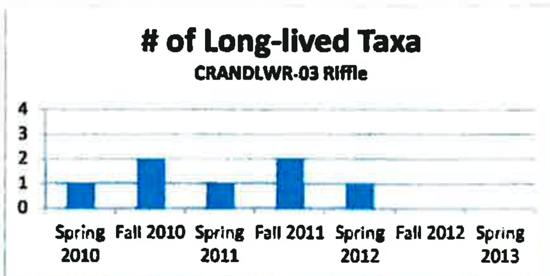

Shannon's Diversity
CRANDLWR-03 Riffle
3
2
1
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


Evenness
CRANDLWR-03 Riffle
1
0.5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

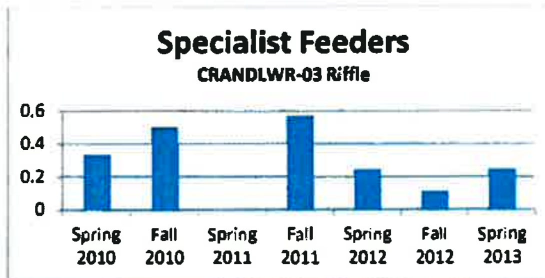

EPT Taxa Abundance
CRANDLWR-03 Riffle
1500
1200
900
600
300
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


Percent Shredders
CRANDLWR-03 Riffle
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

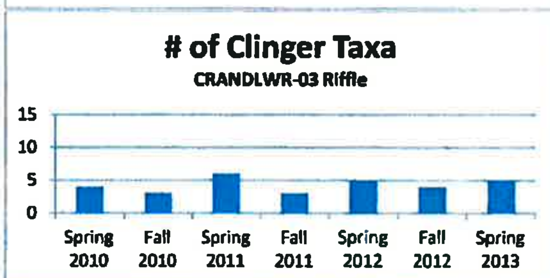

Percent Scrapers
CRANDLWR-03 Riffle
2
2
1
1
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



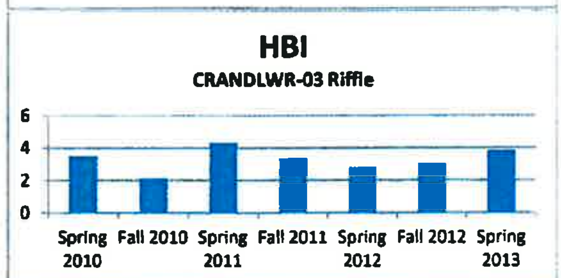
# of Long-lived Taxa
CRANDLWR-03 Riffle
4
3
2
1
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



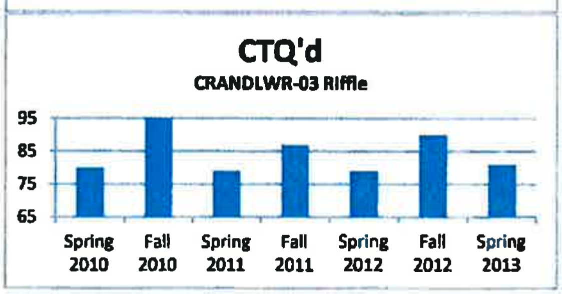
Specialist Feeders
CRANDLWR-03 Riffle
0.6
0.4
0.2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



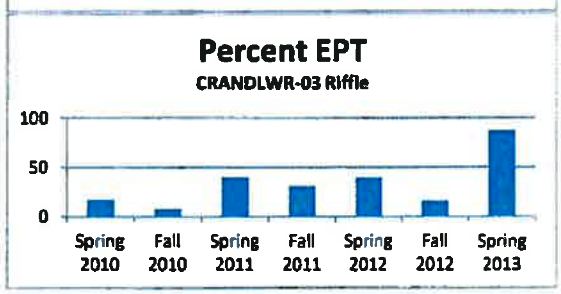
# of Clinger Taxa
CRANDLWR-03 Riffle
15
10
5
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



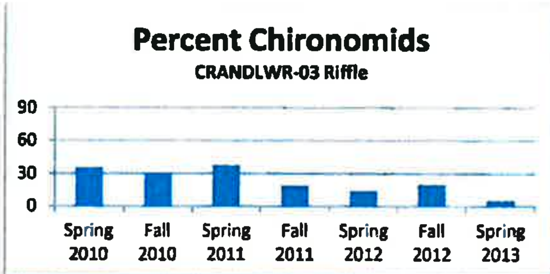
HBI
CRANDLWR-03 Riffle
6
4
2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

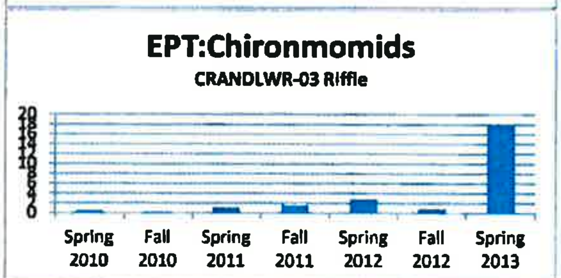


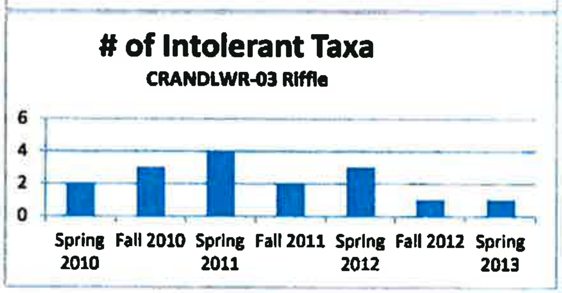
CTQ'd
CRANDLWR-03 Riffle
95
85
75
65
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013



Percent EPT
CRANDLWR-03 Riffle
100
50
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


Percent Chironomids
CRANDLWR-03 Riffle
90
60
30
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


EPT:Chironmomids
CRANDLWR-03 Riffle
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013


# of Intolerant Taxa
CRANDLWR-03 Riffle
6
4
2
0
Spring 2010
Fall 2010
Spring 2011
Fall 2011
Spring 2012
Fall 2012
Spring 2013

Taxa Lists for Individual Samples

Following is the taxonomic list and the number of individuals found of each species for the 6 samples collected on June 11, 2013. The count is the total number of individuals found, identified, and retained for future reference. The samples column refers to the amount of samples contained that taxon.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Samples	Count
Annelida	Clitellata						5	310
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		Arrenurus		2	2
			Lebertiidae		Lebertia		6	141
			Sperchonidae		Sperchon		5	21
							5	79
	Insecta	Coleoptera	Dytiscidae	Hydroporinae	Oreodytes		3	3
			Elmidae		Narpus	concolor	4	27
			Elmidae		Optioservus	quadrimaculatus	4	22
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		5	31
			Ceratopogonidae				2	5
			Chironomidae				6	33
			Chironomidae	Chironominae			6	170
			Chironomidae	Orthocladiinae			6	1145
			Chironomidae	Tanypodinae			3	11
			Empididae	Hemerodromiinae	Chelifera		2	8
			Empididae		Neoplasta		5	24
			Empididae		Wiedemannia		2	5
			Empididae				1	1
			Empididae	Hemerodromiinae			1	6
			Psychodidae		Pericoma		2	13
			Ptychopteridae		Ptychoptera		1	1
			Simuliidae	Simuliinae	Simulium		3	13
			Stratiomyidae		Caloparyphus		1	1
			Stratiomyidae		Euparyphus		1	4
			Tabanidae		Tabanus		1	4
			Tabanidae				1	1
			Tipulidae	Limoniinae	Antocha	monticola	2	5
			Tipulidae		Dicranota		4	8
			Tipulidae	Limoniinae	Limnophila		3	8
			Tipulidae	Limoniinae	Ormosia		1	1
			Tipulidae	Tipulinae	Tipula		5	56
			Tipulidae				1	1
		Ephemeroptera	Ameletidae		Ameletus		2	19
			Baetidae		Baetis		6	845
			Baetidae		Diphetor	hageni	5	216
			Baetidae				2	7
			Ephemerellidae		Drunella		2	8
			Ephemerellidae		Ephemerella		1	1
			Heptageniidae		Cinygmula		3	59
			Heptageniidae		Epeorus		4	103
			Heptageniidae				2	23
			Leptophlebiidae		Paraleptophlebia		1	1
			Leptophlebiidae				2	27

Taxonomic list continued.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Samples	Count
		Plecoptera	Chloroperlidae	Chloroperlinae	Suwallia		1	2
			Nemouridae		Zapada	cinctipes	1	2
			Nemouridae		Zapada		1	6
			Nemouridae		Zapada		1	7
			Nemouridae				1	5
			Perlodidae	Isoperlinae	Isoperla		5	29
			Perlodidae				2	4
							1	2
		Trichoptera	Hydropsychidae	Hydropsychinae	Hydropsyche		1	1
			Hydropsychidae	Arctopsychinae	Parapsyche	elsis	1	4
			Hydropsychidae	Arctopsychinae	Parapsyche		1	1
			Limnephilidae	Limnephilinae	Hesperophylax		5	21
			Limnephilidae	Limnephilinae	Psychoglypha		1	1
			Limnephilidae				4	30
			Rhyacophilidae		Rhyacophila	angelita group	2	3
			Rhyacophilidae		Rhyacophila	vofixa group	2	91
			Rhyacophilidae		Rhyacophila		3	67
			Uenoidae		Oligophlebodes		1	1
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		5	85
Nemata							2	2
Platyhelminthes	Turbellaria						2	5
OTU Taxa:	64	Genera:	39	Families:	28			3838

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected June 11, 2013 at the station CRANDUP-01, Crandall Creek, Upstream, Emery County, Utah. The sample was collected from the reachwide habitat using a Kick Net. The total area sampled was .46 square meters. Of the collected sample, 87.5% was identified and retained. A total of 626 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150025. OTU= Operational Taxonomic Unit

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes					Adult	17
			Lebertiidae		Lebertia		Adult	72
			Sperchonidae		Sperchon		Adult	12
	Insecta	Coleoptera	Elmidae		Optioservus		Adult	15
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	25
			Chironomidae	Chironominae			Larvae	209
			Chironomidae	Orthocladiinae			Larvae	358
			Chironomidae	Tanypodinae			Larvae	12
			Empididae	Hemerodromiinae			Larvae	15
			Empididae		Neoplasta		Larvae	17
			Empididae		Wiedemannia		Larvae	10
			Empididae				Larvae	2
			Psychodidae		Pericoma		Larvae	15
			Ptychopteridae		Ptychoptera		Larvae	2
			Simuliidae	Simuliinae	Simulium		Larvae	5
			Tipulidae	Tipulinae	Tipula		Larvae	22
		Ephemeroptera	Ameletidae		Ameletus		Larvae	29
			Baetidae		Baetis		Larvae	50
			Baetidae		Diphetor		Larvae	157
			Ephemerellidae		Drunella	cinctipes	Larvae	5
			Ephemerellidae		Ephemerella		Larvae	2
			Heptageniidae				Larvae	2
			Heptageniidae		Cinygmula		Larvae	56
			Heptageniidae		Epeorus		Larvae	116
			Leptophlebiidae				Larvae	57
		Plecoptera					Larvae	5
			Nemouridae		Zapada		Larvae	15
			Perlodidae				Larvae	2
			Perlodidae	Isoperlinae	Isoperla		Larvae	30
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche	hageni	Larvae	12
			Limnephilidae				Larvae	12
			Rhyacophilidae		Rhyacophila		Larvae	87
			Rhyacophilidae		Rhyacophila		Larvae	96
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	35
Nemata							Adult	2
Platyhelminthes	Turbellaria						Adult	2
Total:	OTU Taxa:	36	Genera:	22	Families:	26		1580

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected June 11, 2013 at the station CRANDUP-01, Crandall Creek, Upstream, Emery County, Utah. The sample was collected from the targeted riffle habitat using a Kick Net. The total area sampled was .74 square meters. Of the collected sample, 100% was identified and retained. A total of 668 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150028. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	9
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		Arrenurus		Adult	1
			Lebertiidae		Lebertia		Adult	38
			Sperchonidae		Sperchon		Adult	5
							Adult	5
	Insecta	Coleoptera	Dytiscidae	Hydroporinae	Oreodytes		Adult	1
			Elmidae		Narpus	concolor	Larvae	1
			Elmidae		Optioservus	quadrimaculatus	Adult	18
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	15
			Ceratopogonidae				Larvae	5
			Chironomidae	Chironominae			Larvae	93
			Chironomidae	Orthocladiinae			Larvae	231
			Chironomidae				Pupae	12
			Chironomidae				Larvae	7
			Empididae	Hemerodromiinae	Chelifera		Larvae	7
			Empididae		Neoplasta		Larvae	5
			Empididae		Wiedemannia		Larvae	1
			Psychodidae		Pericoma		Larvae	9
			Tipulidae	Limoniinae	Limnophila		Larvae	3
			Tipulidae	Limoniinae	Ormosia		Larvae	1
			Tipulidae	Tipulinae	Tipula		Larvae	22
			Tipulidae		Dicranota		Larvae	1
		Ephemeroptera	Ameletidae		Ameletus		Larvae	14
			Baetidae		Baetis		Larvae	26
			Baetidae		Diphetor	hageni	Larvae	36
			Baetidae				Larvae	1
			Ephemerellidae		Drunella		Larvae	8
			Heptageniidae		Cinygmula		Larvae	43
			Heptageniidae		Epeorus		Larvae	70
			Heptageniidae				Larvae	30
			Leptophlebiidae				Larvae	5
		Plecoptera	Nemouridae		Zapada		Larvae	9
			Nemouridae				Larvae	7
			Perlodidae	Isoperlinae	Isoperla		Larvae	12
			Perlodidae				Larvae	4
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche		Larvae	1
			Limnephilidae	Limnephilinae	Hesperophylax		Larvae	12
			Limnephilidae				Larvae	18
			Rhyacophilidae		Rhyacophila		Larvae	36
			Rhyacophilidae		Rhyacophila	vofixa group	Larvae	73
			Uenoidae		Oligophlebodes		Larvae	1
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	1
OTU Taxa:	42	Genera:	28	Families:	23			897

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected June 11, 2013 at the station CRANDMD-02, Crandall Creek, Midstream, Emery County, Utah. The sample was collected from the reachwide habitat using a Kick Net. The total area sampled was .46 square meters. Of the collected sample, 100% was identified and retained. A total of 618 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150027. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	543
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	93
			Sperchonidae		Sperchon		Adult	7
							Adult	70
	Insecta	Coleoptera	Dytiscidae	Hydroporinae	Oreodytes		Adult	2
			Elmidae		Narpus	concolor	Larvae	24
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	4
			Ceratopogonidae				Larvae	2
			Chironomidae	Chironominae			Larvae	15
			Chironomidae	Orthocladiinae			Larvae	500
			Chironomidae	Tanypodinae			Larvae	11
			Chironomidae				Pupae	17
			Stratiomyidae		Euparyphus		Larvae	9
			Tabanidae				Larvae	2
			Tipulidae	Tipulinae	Tipula		Larvae	2
			Tipulidae		Dicranota		Larvae	2
			Tipulidae				Larvae	2
		Ephemeroptera	Baetidae		Baetis		Larvae	7
			Baetidae		Diphetor	hageni	Larvae	2
		Trichoptera	Limnephilidae	Limnephilinae	Hesperophylax		Larvae	2
			Limnephilidae	Limnephilinae	Psychoglypha		Larvae	2
			Limnephilidae				Larvae	13
Nemata							Adult	2
Platyhelminthes	Turbellaria						Adult	9
OTU Taxa:	24	Genera:	12	Families:	11			1342

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected June 11, 2013 at the station CRANDMD-02, Crandall Creek, Midstream, Emery County, Utah. The sample was collected from the targeted riffle habitat using a Kick Net. The total area sampled was .74 square meters. Of the collected sample, 100% was identified and retained. A total of 636 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150026. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata					Adult	4	4
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia	Adult	15	15
			Sperchonidae		Sperchon	Adult	1	1
	Insecta	Coleoptera	Dytiscidae	Hydroporinae	Oreodytes	Adult	1	1
			Elmidae		Narpus	Larvae	19	19
			Elmidae		Optioservus	Adult	3	3
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia	Larvae	8	8
			Chironomidae	Chironominae		Larvae	9	9
			Chironomidae	Orthocladiinae		Larvae	718	718
			Chironomidae			Pupae	7	7
			Empididae	Hemerodromiinae	Chelifera	Larvae	4	4
			Empididae		Neoplasta	Larvae	1	1
			Stratiomyidae		Caloparyphus	Larvae	1	1
			Tipulidae	Limoniinae	Limnophila	Larvae	4	4
			Tipulidae	Tipulinae	Tipula	Larvae	3	3
			Tipulidae		Dicranota	Larvae	7	7
		Ephemeroptera	Baetidae		Baetis	Larvae	23	23
			Heptageniidae		Epeorus	Larvae	1	1
		Plecoptera	Perlodidae	Isoperlinae	Isoperla	Larvae	5	5
		Trichoptera	Limnephilidae	Limnephilinae	Hesperophylax	Larvae	3	3
			Limnephilidae			Larvae	8	8
			Rhyacophilidae		Rhyacophila	Larvae	7	7
			Rhyacophilidae		Rhyacophila	Larvae	3	3
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium	Adult	4	4
OTU Taxa:	24	Genera:	18	Families:	15			859

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected June 11, 2013 at the station CRANDLWR-03, Crandall Creek, Lower, Emery County, Utah. The sample was collected from the reachwide habitat using a Kick Net. The total area sampled was .46 square meters. Of the collected sample, 100% was identified and retained. A total of 592 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150030. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	104
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		Arrenurus		Adult	2
			Lebertiidae		Lebertia		Adult	48
			Sperchonidae		Sperchon		Adult	17
							Adult	9
	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	2
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	4
			Chironomidae	Chironominae			Larvae	4
			Chironomidae	Orthocladiinae			Larvae	87
			Chironomidae	Tanypodinae			Larvae	2
			Chironomidae				Pupae	4
			Empididae		Neoplasta		Larvae	17
			Simuliidae	Simuliinae	Simulium		Larvae	17
			Tabanidae		Tabanus		Larvae	9
			Tipulidae	Limoniinae	Antocha	monticola	Larvae	9
			Tipulidae	Limoniinae	Limnophila		Larvae	7
			Tipulidae	Tipulinae	Tipula		Larvae	61
		Ephemeroptera	Baetidae		Baetis		Larvae	504
			Baetidae		Diphetor	hageni	Larvae	200
			Baetidae				Larvae	13
			Leptophlebiidae		Paraleptophlebia		Larvae	2
		Plecoptera	Perlodidae	Isoperlinae	Isoperla		Larvae	4
		Trichoptera	Limnephilidae	Limnephilinae	Hesperophylax		Larvae	13
			Rhyacophilidae		Rhyacophila	angelita group	Larvae	2
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	143
OTU Taxa:	**25**	Genera:	**18**	Families:	**16**			**1284**

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected June 11, 2013 at the station CRANDLWR-03, Crandall Creek, Lower, Emery County, Utah. The sample was collected from the targeted riffle habitat using a Kick Net. The total area sampled was .74 square meters. Of the collected sample, 100% was identified and retained. A total of 698 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150029. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	3
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	11
							Adult	43
	Insecta	Coleoptera	Elmidae		Optioservus	quadrimaculatus	Adult	1
		Diptera	Chironomidae	Chironominae			Larvae	1
			Chironomidae	Orthocladiinae			Larvae	39
			Chironomidae				Pupae	5
			Empididae		Neoplasta		Larvae	5
			Simuliidae	Simuliinae	Simulium		Larvae	4
			Tipulidae	Limoniinae	Antocha	monticola	Larvae	1
			Tipulidae		Dicranota		Larvae	1
		Ephemeroptera	Baetidae		Baetis		Larvae	749
			Baetidae		Diphetor	hageni	Larvae	45
			Heptageniidae		Cinygmula		Larvae	11
			Heptageniidae		Epeorus		Larvae	7
		Plecoptera	Chloroperlidae	Chloroperlinae	Suwallia		Larvae	3
			Nemouridae		Zapada	cinctipes	Larvae	3
			Perlodidae	Isoperlinae	Isoperla		Larvae	4
		Trichoptera	Hydropsychidae	Hydropsychinae	Hydropsyche		Larvae	1
			Limnephilidae	Limnephilinae	Hesperophylax		Larvae	4
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	1
OTU Taxa:	21	Genera:	16	Families:	14			942

2013

ANNUAL REPORT

MACROINVERTEBRATE

STUDY

Crandall Canyon Mine Macroinvertebrate Study September 2013

December 2013

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1.0 INTRODUCTION

EIS Environmental & Engineering Consulting (EIS) collected benthic macroinvertebrate samples from Crandall Creek on September 20 and 23, 2013. The creek is located near Huntington, Utah. From 2009 to 2013, 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). Please note that there were some discrepancies within the data provided by the BugLab and what JBR had reported. This was 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. These metrics will typically be lower with this new way of computation (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 to monitor water quality and provide reports documenting the survey results. Eight surveys have been completed since 2009 (JBR 2012). This report provides the results of the Fall survey of 2013 completed by EIS. The samples were collected September

20th and 23rd, 2013. The samples were then shipped to the BugLab in Logan, Utah for processing.

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 September 20th, 2013 - Upstream

CRANDMD-02 September 20th, 2013 - Upstream

CRANDLWR-03 September 20th, 2013 - 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 (Miller and Judson 2013) 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 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 and C. 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 (Davis et al 2001).

Percent *Baetis,* Hydropsychidae, and Orthocladinae; Ratio of *Baetis* to all Ephemeroptera– These two similar measures express the documented higher tolerances of *Baetis,* Hydropsychidae, and Orthocladinae, than other members of their families. Mize and Deacon (2002) among others have used the presence of these taxa when assessing environmental conditions specific to mining (some studies have found the opposite conclusion with *Baetis;* however, the majority appear to consider it one of the more tolerant of the mayflies).

Percent Heptageniidae, Chloroperlidae, and *Rhyacophila;* Ratio of Heptageniidae to all Ephemeroptera– Similarly to the above-noted tolerant taxa, Heptageniidae, Chloroperlidae, and *Rhyacophila* were considered by Mize and Deacon (2002) when assessing elevated trace metals impacts. Heptageniidae, Chloroperlidae, and *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 (Miller 2013) are incorporated into the tables of Appendix A. The report includes a summarization of the raw and standardized data for the samples collected in September of 2013. EIS has incorporated that data into readable tables and includes multiple diversity and biotic indices. It does not discuss or interpret the study results, as this section will review that task. Appendix B provides numerous graphs to show a visual comparison of the community composition between the different reaches and habitat or sample types (multi and riffle) for just the recent sample set collected in the Fall of 2013. Appendix C also provides numerous graphs for visual temporal comparison but for all the samples since 2009.

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 2013 sample set for comparison of potential differences between the habitat types and spatial variation for the new data (Figures 2b-24b). The graphs of Appendix C include all the data gathered since Fall 2009. The first set of graphs contains this historical data and is differentiated by the multi-habitat and target riffle samples for comparison (Figures 1c-23c). The last group of charts also contains data since 2009; however the values from both the multi and riffle sample were combined to obtain an average value to see any potential trends throughout the years (Figures 24c-42c).

A total of 42 operational taxonomic units (OTU) were identified in the Fall sample set. There were 26 families and 28 genera present and all of the insect orders most commonly found in macroinvertebrate communities were found in each reach, orders Coleoptera, Diptera, Ephemeroptera, Plecoptera, and Trichoptera. Non-insect invertebrates were also identified in all samples. Ephemeroptera was the most dominate order in the multi habitat in the upper reach, making up 34 percent of the sample. While the riffle sample of the same reach was dominated by the order Diptera at 44 percent. In the middle reach, in both multi and riffle samples the dominate order was Diptera with 36 and 38 percent, respectively. In the lower reach, in both multi and riffle samples the dominate order was Ephemerotptera with 34 and 45 percent, respectively (Figure 1b, Table 1b). A dominance of any single order greater than 50 percent suggests environmental stress, none of the fall samples met this criteria.

In addition, all the samples had higher proportions of the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) when compared to previous years. These orders are commonly considered sensitive to pollution (Karr & Chu 1999) and the fluctuation in their abundance can be an indicator of stream health. In the upper reach, EPT made up a majority of the taxa in the multi habitat, at 60.8 percent. The riffle habitat consisted of 36.8 percent EPT (Figure 9b). In the middle reach directly below the mine, the Diptera order still had a high dominance, however the EPT increased to 26.6 and 38.7 percent of abundance in multi-habitat and riffle samples, compared to 1.6 and 24.3 percent in Fall 2012 or 1.1 and 4.4 in Fall 2011 (Figure 8c). In the lower reach, EPT was the highest at 66.4 and 63 percent, respectively (Figure 9b). The increase of the sensitive macroinvertebrate species can be an indication of improved conditions in all reaches. The composition of the taxa in the stream is also becoming more even. The evenness value measures the distribution of taxa within a community and ranges from 0-1. The value approaches zero as a particular taxa becomes more dominate. In the upper reach, the multi habitat had a value of 0.84 and the riffle 0.86. The middle reach had values of 0.77 in the multi and 0.78 in the riffle. And lastly, the lower reach had values of 0.75 in multi and 0.71 in the riffle (Figure 4b).

The richness, evenness, and Shannon's Diversity were overall higher in the upper reach than the middle and lower reach. Although Crandall Creek as a whole continues to provide less than ideal habitat for a macroinvertebrate community, all samples contained at least two distinct taxa that are considered intolerant to pollution. The upper reach had the highest number of intolerant taxa in both habitat types with 7, the middle reach had 4, and the lower had 2 (Figure 14b). The richness was higher in the upstream reach with an average value of 26, and the middle and lower reaches had a value of 21.5 (Figure 2b). Because the number of distinct taxa appears to be fluctuating within all reaches and both habitat types year to year, there is no real discernible trend. As for the most recent fall sample set, it does appear that the richness across all the six samples is becoming more even. There were more distinct taxa in the upper reach than the middle and lower reaches, but there was not as much as a difference as in previous years.

The two tolerance indices that were calculated by the BugLab were the Hilsenhoff Biotic Index (HBI) and the USFS community tolerant quotient (CTQd) also indicated conditions were improving. When comparing the upstream to the middle and lower reaches, the HBI was fairly consistent across the three reaches, at average values of 3.3, 3.13, and 3.29, respectively (Figure 6b). These values in previous years were also much higher (as mentioned in section 3.4, the lower the HBI value the unpolluted the stream). For example in the Fall 2012 samples the corresponding values were 3.82, 5.11, 4.37 and the Fall of 2011 the values were 5.48, 5.29, and 3.26 (Figure 28c). The CTQd, which ranges from 20 in the highest quality streams to 100 in the poorest, was high across all samples collected even the upper reach that should show no signs of degradation due to mining. The values ranged from 75 in the upper reach to 89 in the lower reach (Figure 7b). These values have fluctuated throughout the years in all reaches, but have always remained high.

Although Crandall Creek may not be in the most optimal conditions as a whole, all of the sites appear to have a somewhat diverse assemblage of taxa. This sample set had a higher abundance of the least tolerant taxa (HBI ≤ 2) than that of the most tolerant taxa (HBI ≥ 8) than in previous years indicating that while the conditions may not be ideal, it is still supporting sensitive aquatic taxa.

The stream habitat and substrate appeared to be similar to those noted during previous studies. The lower reach has more cemented and embedded substrate than the middle and upper reaches and has less suitable habitat for invertebrates. As JBR had mentioned, these habitat differences also have impact on the macroinvertebrate community. The discharged mine water may not be the only cause for decreased abundance of macroinvertebrates. 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. The catastrophic impacts to Huntington Creek from major flooding resulting from a major wildfire in the upper drainage areas should also be considered. The high flows have directly impacted macroinvertebrate populations in Huntington Creek that are sources for movement into Crandall Creek.

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 C display the differences between the two habitats within each year as well as just within the new data collected in the Fall of 2013 (Figures1c-23c). Overall, there does not seem to be any distinguishable trend between the multiple habitat and the targeted riffle habitats. For most metrics, the multi-habitat and riffle samples at a given site were rather similar. In a few cases the one type of habitat may have indicated a better macroinvertebrate habitat than the other, but it was not consistent year to year. In addressing any trends or spatial differences, both riffle and multi-habitat results were used.

For example, the richness in the upstream reach in the multi-habitat was 27 and in the riffle it was 25. In the middle reach, the multi sample had 21 distinct taxa and the riffle had 22. The lower reach had 21 taxa in the multi and 22 in the riffle samples (Figure 2b). The evenness values also didn't reveal any distinct variances in one habitat over the other. In the upper reach multi-habitat the evenness was 0.85 while the riffle was 0.75 however the in the middle reach the values were 0.76 in the multi and 0.78 in the riffle and lower were 0.75 and 0.70, respectively (Figure 4b).

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 is upstream of any potential impact from the mines discharge. CRANDMD-02 (middle) is immediately below the discharge, and CRNDLWR-03 (lower) is further downstream. The graphs provided in Appendices B and C provides a visual means to examine the spatial variation within the creek. There is a considerable amount of variation year to year and within each reach. As mentioned in Section 4.0, Crandall Creek appears to not be in the most ideal condition as a whole, with the middle reach being the least optimal.

In all reaches, the data fluctuates from year to year making it difficult to observe any trends, other than those discussed in Section 4.0. The richness in upper reach in the Fall 2009 sample was 24. It has decreased and increased over time and currently there is 23 distinct taxa in this sample. The same is occurring with the middle reach. In 2009 the richness was 22, after fluctuating it remains about the same, at 21.5 in this sample (Figures 24c-42c).

The lowest reach may be improving based on the change of species composition, notably the change from order Diptera to Ephemeroptera has remained. The EPT taxa abundance has gone up from about 33 percent in 2009 to 66 percent. The overall abundance has increased from 590 in 2009 to 699 (Figure 31c). There is no evident trend as of yet among the other metrics used; such as richness, evenness, and Shannon's Diversity due to a high degree of variability as depicted in Appendix C.

4.3 Temporal Variation in Macroinvertebrate Community

EIS was able to obtain the standardized data from the BugLab dating back to 2009 to assess temporal variations. Other than what is mentioned in previous paragraphs, the data does not show any other formidable overall trends. As some of these metrics and indices indicate improvement, others show continued degradation, while some are similar. There are some noticeable changes from season to season, likely due to stream flow rates and macroinvertebrate life cycles.

5.0 CONCLUSION

The samples for the 2013 Fall Macroinvertebrate Study were collected on September 20 and 23, 2013 from the 3 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. 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 that the relative abundance and types of taxa differ between the sampled reaches and generally show reduced habitat quality and less than optimal conditions in all sampled locations. There is too much variance from year to year and season to season to see any notable trends. The substrate and habitat also differs between reaches and should be taken into consideration. The changes in stream morphology due to increased beaver dams in the middle reach should also be considered, as well as the environmental impacts from the fire in 2012 and catastrophic flooding in Huntington Canyon as a result.

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APPENDIX A

BUGLAB REPORT

Report prepared for:

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December 18, 2013

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	of individuals identified
150594	CRANDUP-01	9/20/2013	Reachwide	Kick net	0.46	100	663
150595	CRANDUP-01	9/20/2013	Targeted Riffle	Kick net	0.74	100	727
150596	CRANDMD-02	9/20/2013	Reachwide	Kick net	0.46	100	211
150597	CRANDMD-02	9/20/2013	Targeted Riffle	Kick net	0.74	100	220
150598	CRANDLWR-03	9/23/2013	Reachwide	Kick net	0.46	100	530
150599	CRANDLWR-03	9/23/2013	Targeted Riffle	Kick net	0.74	100	182

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
150594	9/20/2013	CRANDUP-01 Multi	1441	876	Baetidae	10.55
150595	9/20/2013	CRANDUP-01 Riffle	982	361	Chironomidae	37.58
150596	9/20/2013	CRANDMD-02 Multi	459	122	Chironomidae	27.89
150597	9/20/2013	CRANDMD-02 Riffle	297	115	Chironomidae	21.89
150598	9/23/2013	CRANDLWR-03 Multi	1152	765	Baetidae	33.59
150599	9/23/2013	CRANDLWR-03 Riffle	246	155	Baetidae	44.31
Mean			762.8	399.0		29.30

Diversity Indices

Table 4a. Richness totals for taxa, genera, families, and EPT. Shannon diversity index and evenness values.

Sample ID	Collection Date	Station	Total taxa richness	Total genera richness*	Total family richness*	EPT taxa richness*	Shannon diversity index	Evenness
150594	9/20/2013	CRANDUP-01 Multi	42	28	26	20	2.794247	0.847811
150595	9/20/2013	CRANDUP-01 Riffle	44	29	23	21	2.432213	0.755609
150596	9/20/2013	CRANDMD-02 Multi	29	15	20	12	2.33784	0.767884
150597	9/20/2013	CRANDMD-02 Riffle	31	21	19	10	2.421419	0.783366
150598	9/23/2013	CRANDLWR-03 Multi	38	22	20	16	2.290898	0.752465
150599	9/23/2013	CRANDLWR-03 Riffle	31	21	20	14	2.191269	0.708909
Mean			35.8	22.7	21.3	15.5	2.411314	0.769341

*Based off raw data, qualitative data versus the standardized quantitative data.

Table 5a. Diversity indicies based on standardized OTU

Sample ID	Collection Date	Station	Total taxa richness	EPT taxa richness	Shannon diversity index	Evenness
150594	9/20/2013	CRANDUP-01 Multi	27	11	2.794247	0.847811
150595	9/20/2013	CRANDUP-01 Riffle	25	11	2.432213	0.755609
150596	9/20/2013	CRANDMD-02 Multi	21	7	2.33784	0.767884
150597	9/20/2013	CRANDMD-02 Riffle	22	6	2.421419	0.783366
150598	9/23/2013	CRANDLWR-03 Multi	21	7	2.290898	0.752465
150599	9/23/2013	CRANDLWR-03 Riffle	22	8	2.191269	0.708909
Mean			23	8	2.411314	0.769341

Table 6a. Genera richness by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
150594	9/20/2013	CRANDUP-01 Multi	2	13	7	0	0	0	8	5	1	0	1
150595	9/20/2013	CRANDUP-01 Riffle	2	12	8	0	0	0	10	3	1	0	1
150596	9/20/2013	CRANDMD-02 Multi	2	10	6	0	0	0	4	2	1	0	0
150597	9/20/2013	CRANDMD-02 Riffle	1	15	4	0	0	0	4	2	1	0	1
150598	9/20/2013	CRANDLWR-03 Multi	1	14	6	0	0	0	3	7	1	0	1
150599	9/20/2013	CRANDLWR-03 Riffle	2	12	5	0	0	0	3	6	0	0	1
Mean			1.7	12.7	6.0	0.0	0.0	0.0	5.3	4.2	0.8	0.0	0.8

Table 7a. Total Abundance by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
150594	9/20/2013	CRANDUP-01 Multi	7	272	500	0	0	0	280	116	57	0	41
150595	9/20/2013	CRANDUP-01 Riffle	5	436	231	0	0	0	95	56	20	0	43
150596	9/20/2013	CRANDMD-02 Multi	17	165	80	0	0	0	21	32	65	0	0
150597	9/20/2013	CRANDMD-02 Riffle	15	112	88	0	0	0	23	14	5	0	3
150598	9/20/2013	CRANDLWR-03 Multi	9	170	399	0	0	0	38	344	109	0	46
150599	9/20/2013	CRANDLWR-03 Riffle	3	53	116	0	0	0	15	38	0	0	30
Mean			9	201	236	0	0	0	79	100	43	0	27

Biotic Indices

Table 8a. Hilsenhoff Biotic Index and CTQd

Sample ID	Collection Date	Station	Hilsenhoff Biotic Index: Index	Hilsenhoff Biotic Index: Indication	USFS Community CTQd
150594	9/20/2013	CRANDUP-01 Multi	2.746667	Potential slight organic pollution	75
150595	9/20/2013	CRANDUP-01 Riffle	3.926667	Potential slight organic pollution	80
150596	9/20/2013	CRANDMD-02 Multi	2.880435	Potential slight organic pollution	88
150597	9/20/2013	CRANDMD-02 Riffle	3.390863	Potential slight organic pollution	86
150598	9/23/2013	CRANDLWR-03 Multi	3.22	Potential slight organic pollution	89
150599	9/23/2013	CRANDLWR-03 Riffle	3.363636	Potential slight organic pollution	86
Mean			3.254711		84

The Hilsenhoff Biotic Index (HBI) summarizes the overall polution tolerance of the taxa collected. Sampling locations with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 are considered polluted.

USFS Community Tolerant Quotient values vary from about 20 to 100 where the lower the value the better quality of water. Each taxa are assigned a quotient value from 2 to 108. The lower values are given to taxa that tend to be found only in high quality unpolluted water and the higher values to taxa that can be found in severly polluted water.

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

Sample ID	Collection Date	Station	Intolerant Taxa: Richness	Intolerant Taxa: Percent	Intolerant Taxa: Abundance	Intolerant Taxa: Percent	Tolerant Taxa: Richness	Tolerant Taxa: Percent	Tolerant Taxa: Abundance	Tolerant Taxa: Percent
150594	9/20/2013	CRANDUP-01 Multi	7	26	546	38	1	4	67	5
150595	9/20/2013	CRANDUP-01 Riffle	7	28	223	23	1	4	31	3
150596	9/20/2013	CRANDMD-02 Multi	4	19	37	8	0	0	0	0
150597	9/20/2013	CRANDMD-02 Riffle	4	18	38	13	1	5	4	1
150598	9/23/2013	CRANDLWR-03 Multi	2	10	46	4	1	5	2	0
150599	9/23/2013	CRANDLWR-03 Riffle	2	9	15	6	0	0	0	0
Mean			4.3	18	150.8	15	0.7	3	17.3	2

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
150594	9/20/2013	CRANDUP-01 Multi	3	11	1	4	3	11	3	11	9	33	8	30
150595	9/20/2013	CRANDUP-01 Riffle	4	16	2	8	1	4	1	4	8	32	9	36
150596	9/20/2013	CRANDMD-02 Multi	5	24	0	0	0	0	0	0	8	38	8	38
150597	9/20/2013	CRANDMD-02 Riffle	3	14	0	0	1	5	1	5	9	41	8	36
150598	9/23/2013	CRANDLWR-03 Multi	2	10	0	0	4	19	4	19	6	29	5	24
150599	9/23/2013	CRANDLWR-03 Riffle	2	9	3	14	3	14	3	14	8	36	3	14
Mean			3.2	13.9	1.0	4.2	2.0	8.7	2.0	8.7	8.0	34.9	6.8	29.6

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
150594	9/20/2013	CRANDUP-01 Multi	191	13	161	11	52	4	624	43	409	28	4	0
150595	9/20/2013	CRANDUP-01 Riffle	81	8	77	8	43	4	558	57	209	21	14	1
150596	9/20/2013	CRANDMD-02 Multi	50	11	24	5	0	0	161	35	217	47	7	2
150597	9/20/2013	CRANDMD-02 Riffle	26	9	9	3	3	1	150	51	93	31	16	5
150598	9/23/2013	CRANDLWR-03 Multi	300	26	2	0	117	10	591	51	135	12	7	1
150599	9/23/2013	CRANDLWR-03 Riffle	24	10	1	0	54	22	124	50	39	16	4	2
Mean			112.0	12.8	45.7	4.6	44.8	6.9	368.0	47.9	183.7	26.0	8.7	1.8

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]

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.

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APPENDIX B

MACROINVERTEBRATE METRICS FALL 2013

Figure 1b. Percent Predominant Taxonomic Groups Fall 2013 Samples

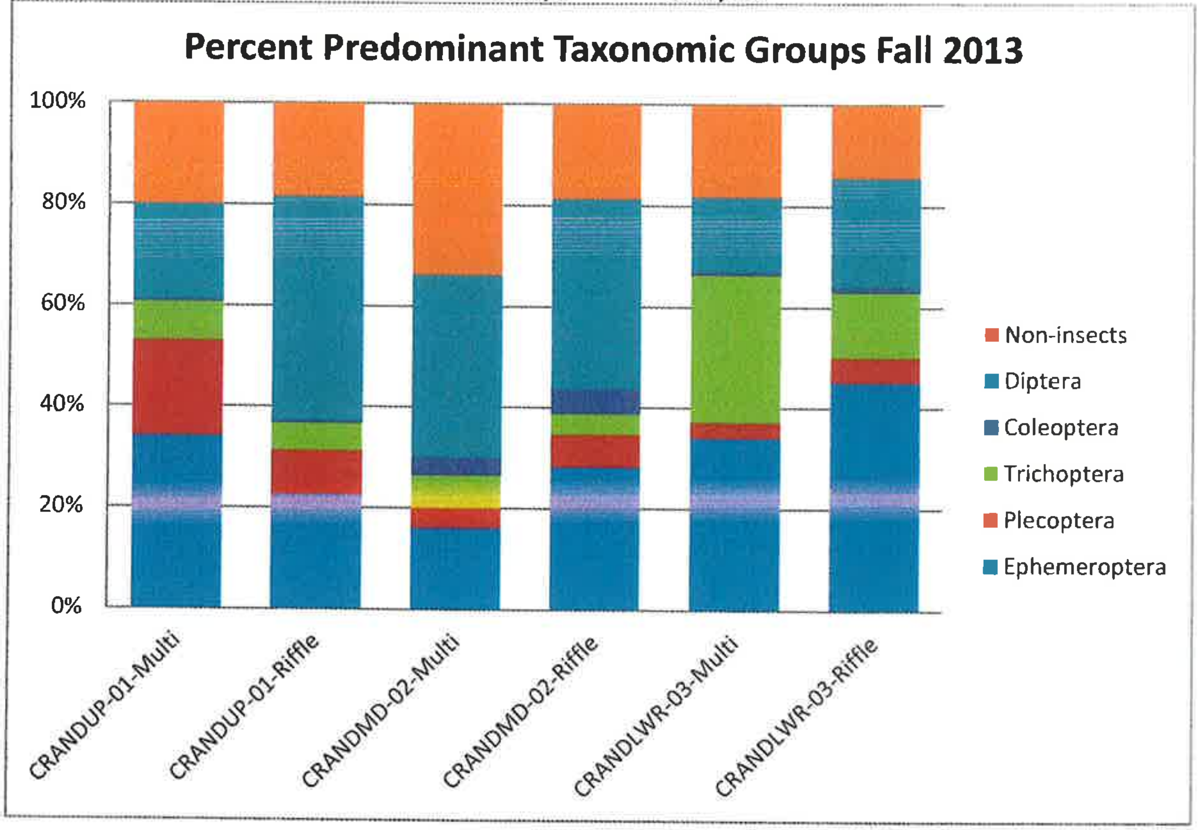


Table 1b. Percent Predominant Taxonomic Groups in the Fall 2013 Samples

	CRANDUP-01-Multi	CRANDUP-01-Riffle	CRANDMD-02-Multi	CRANDMD-02-Riffle	CRANDLWR-03-Multi	CRANDLWR-03-Riffle
Non-insects	20	18	34	19	18	14
Diptera	19	44	36	38	15	22
Coleoptera	0	1	4	5	1	1
Trichoptera	8	5	7	4	29	13
Plecoptera	19	9	4	6	3	5
Ephemeroptera	34	23	16	28	34	45
Elmidae	0	0	1	5	0	0
Chironomidae	9	38	28	22	8	6
Crustacea	0	0	0	0	0	0
Oligochaete	4	2	14	2	9	0
Mollusca	3	4	0	1	4	12

Figure 2b. Richness

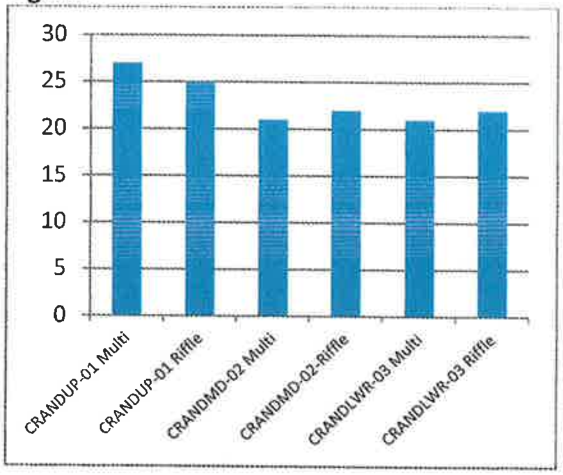


Figure 3b. Shannon's Diversity

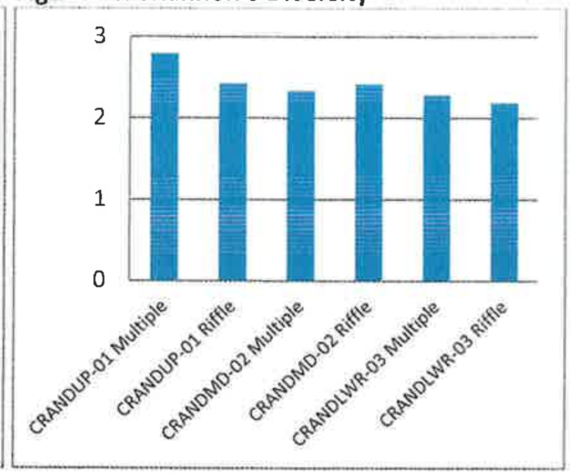


Figure 4b. Evenness

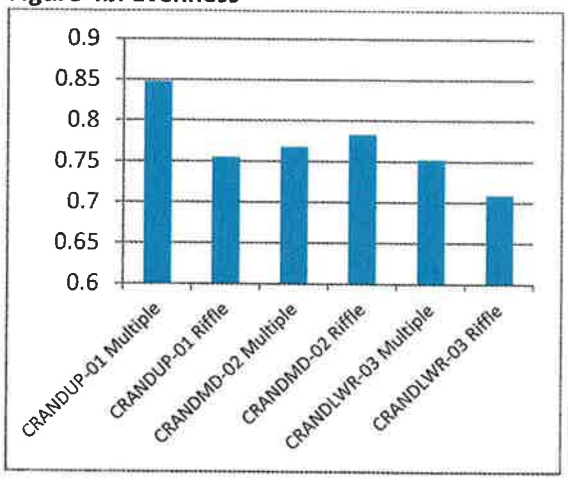


Figure 5b. Abundance

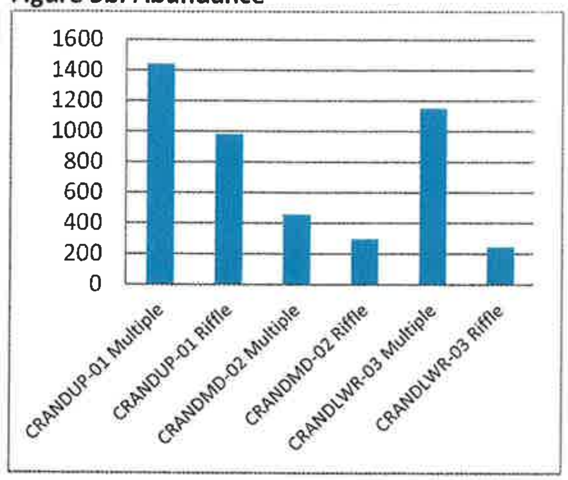


Figure 6b. HBI

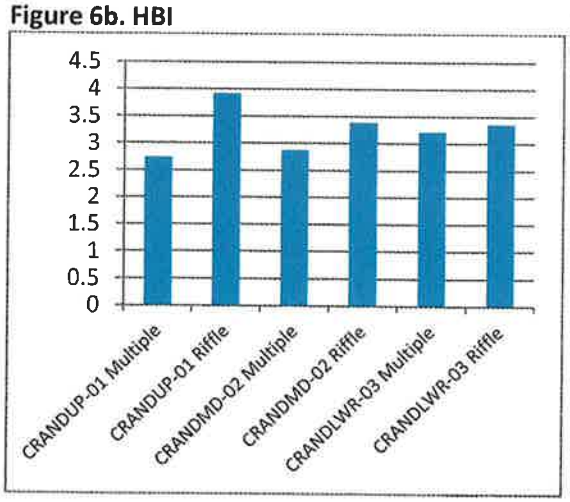


Figure 7b. CTQd

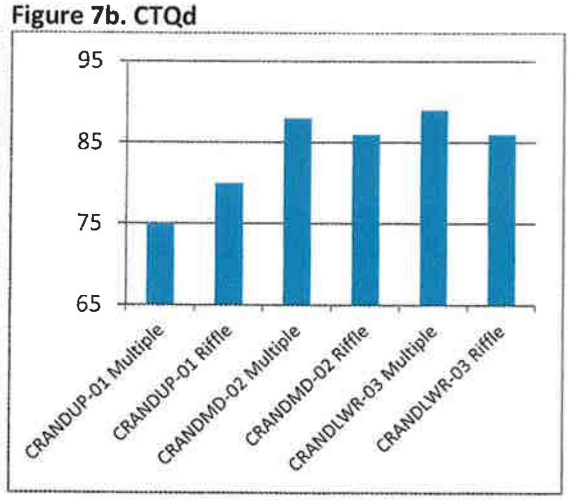


Figure 8b. EPT Taxa Abundance

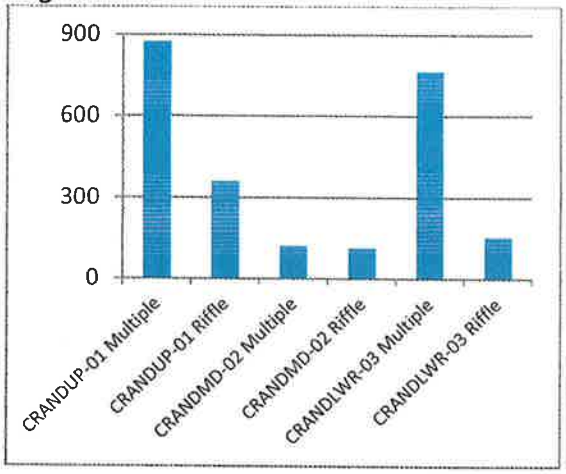


Figure 9b. Percent EPT

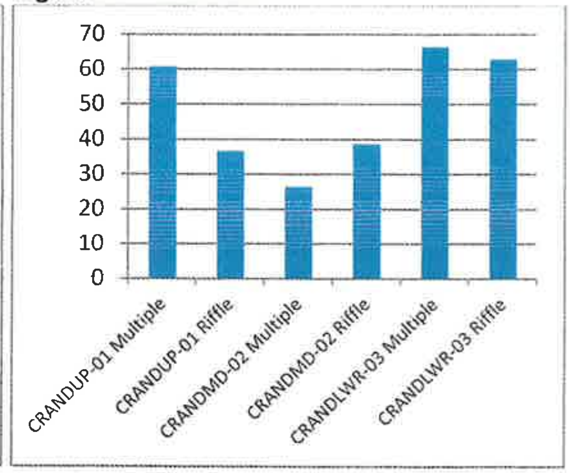


Figure 10b. Percent Chironomids

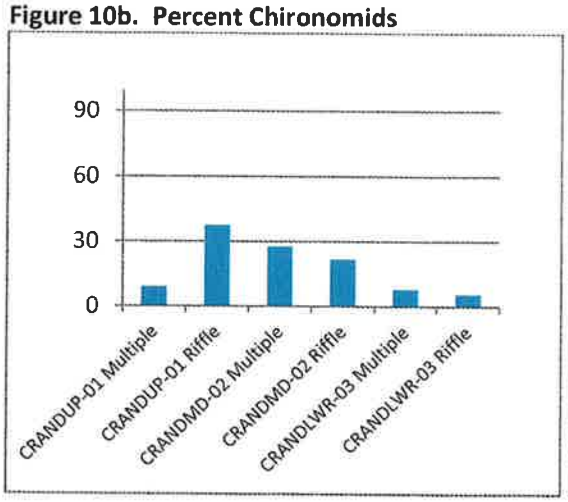


Figure 11b. Ratio of EPT to Chironmonids

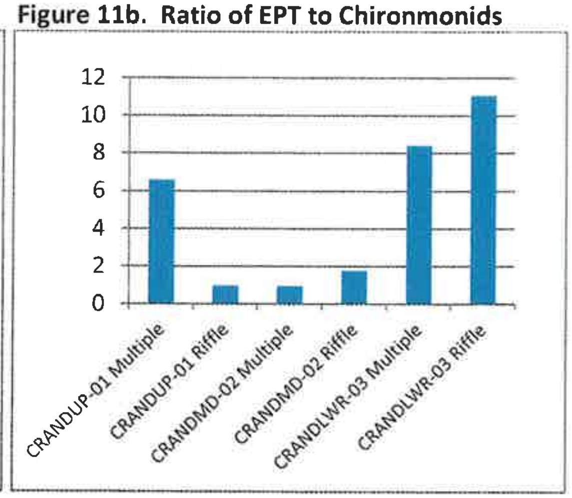


Figure 12b. Number of Tolerant Taxa

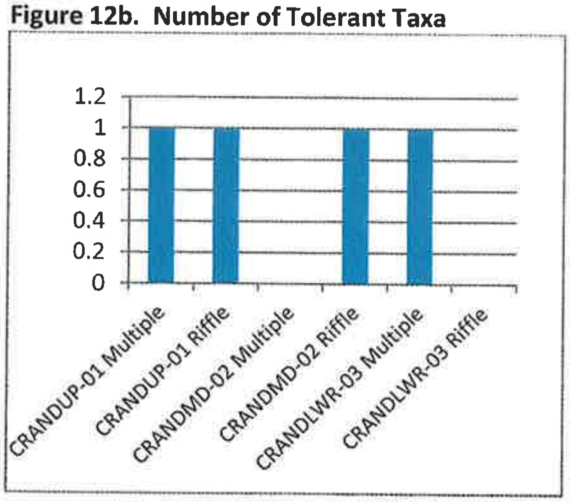


Figure 13b. Percent Tolerant Organisms

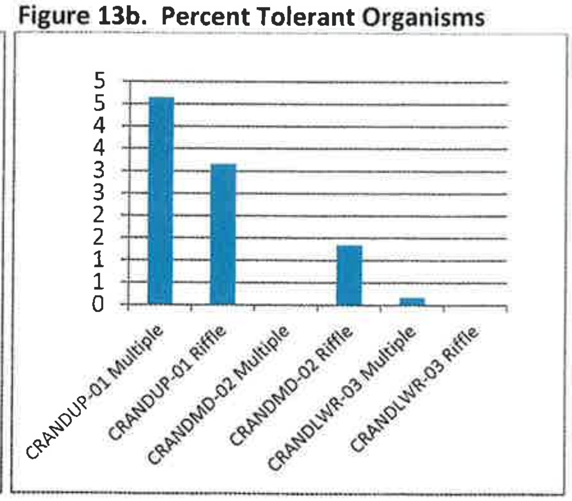


Figure 14b. Number of Intolerant Taxa

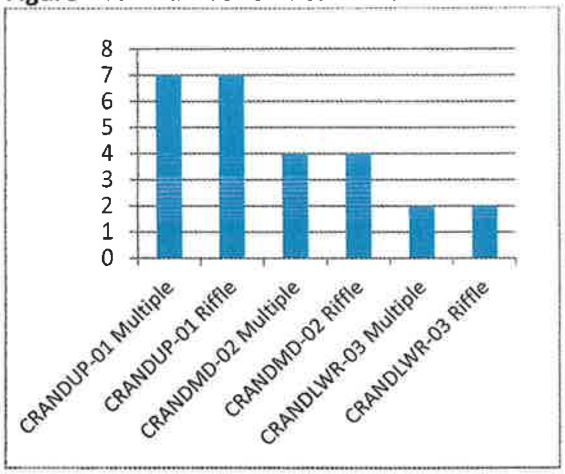


Figure 15b. Percent Intolerant Organisms

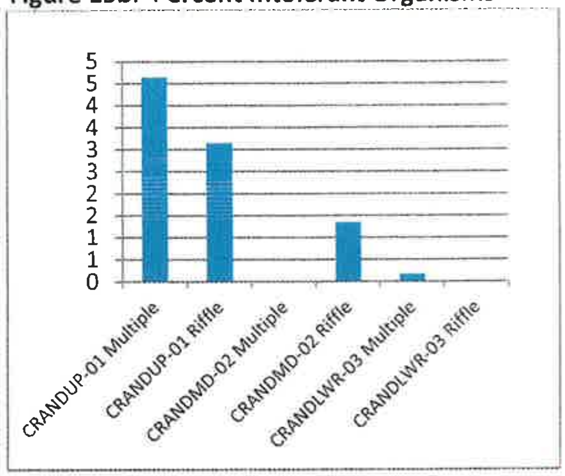


Figure 16b. Specialist Feeders: Generalist Feeders

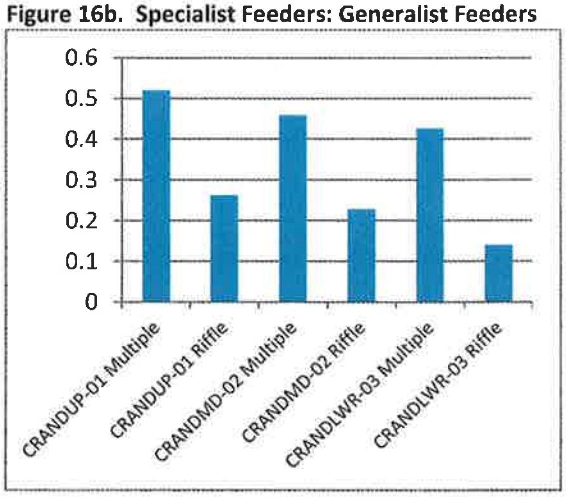


Figure 17b. Percent Shredders

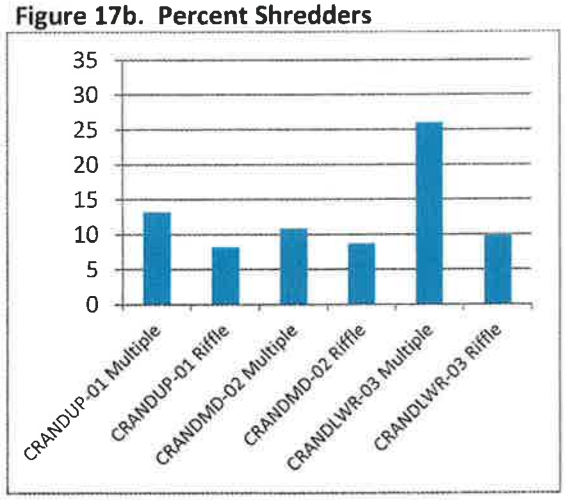


Figure 18b. Percent Scrapers

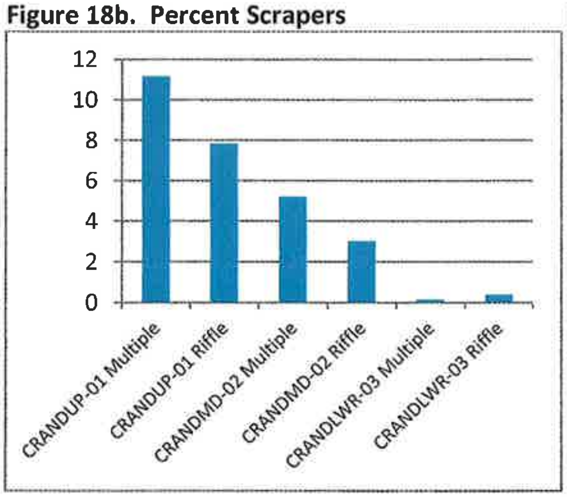


Figure 19b. Number of Long-Lived Taxa

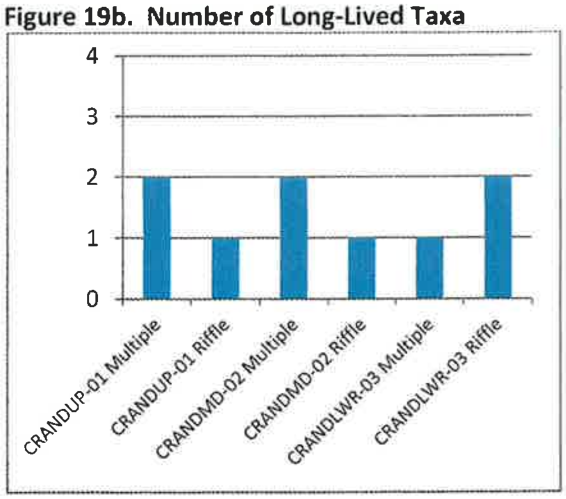


Figure 20b. Number of Clinger Taxa

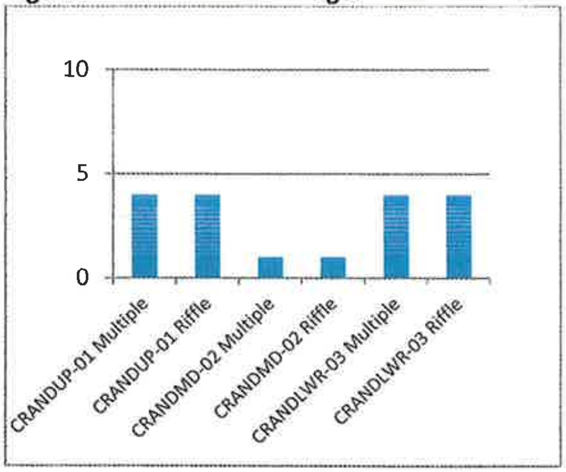


Figure 21b. Baetis:All Ephemetroptera (Percent)

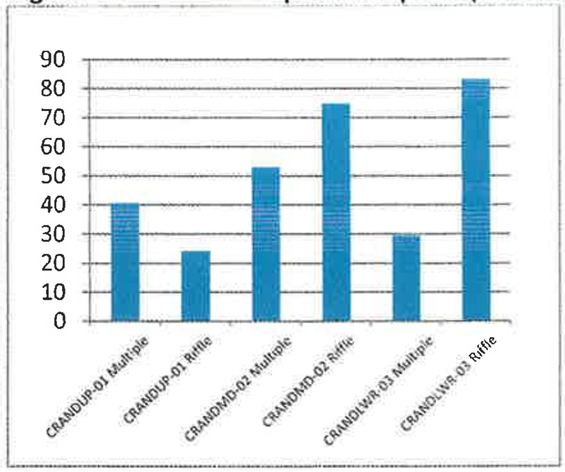


Figure 22b. Baetis, Hydropsychidae & Orthocladiinae (Percent)

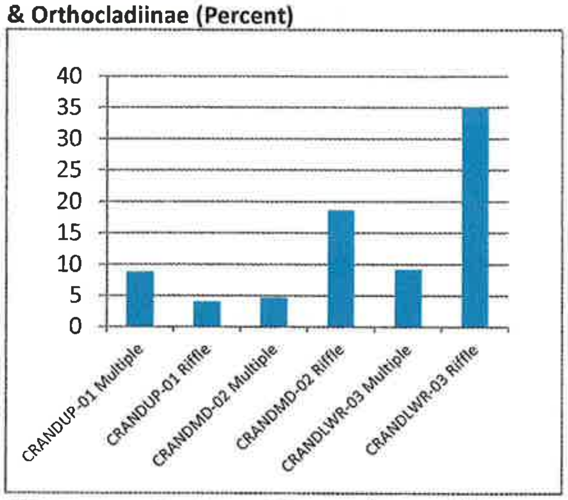


Figure 23b. Heptageniidae: All Ephemeroptera (Percent)

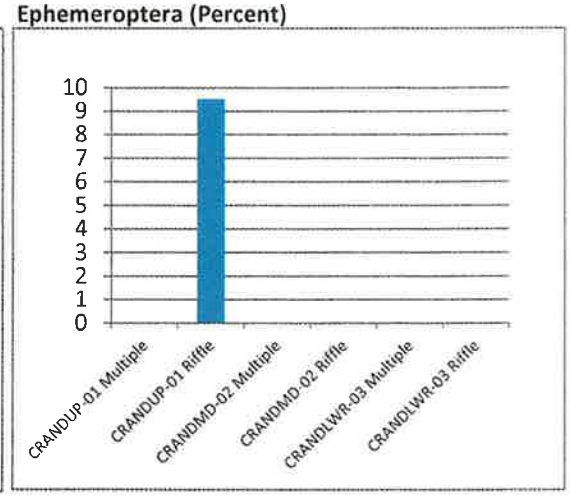
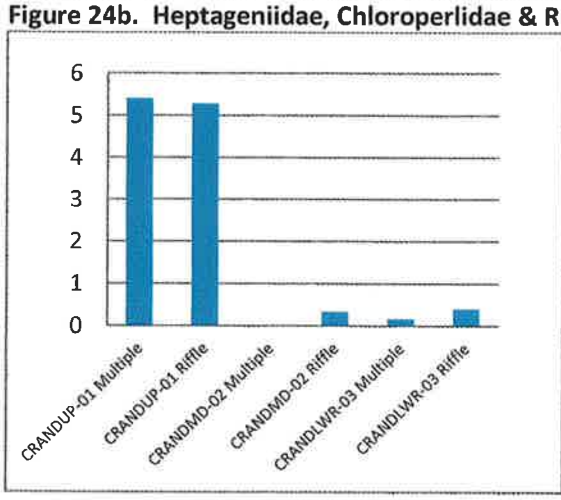


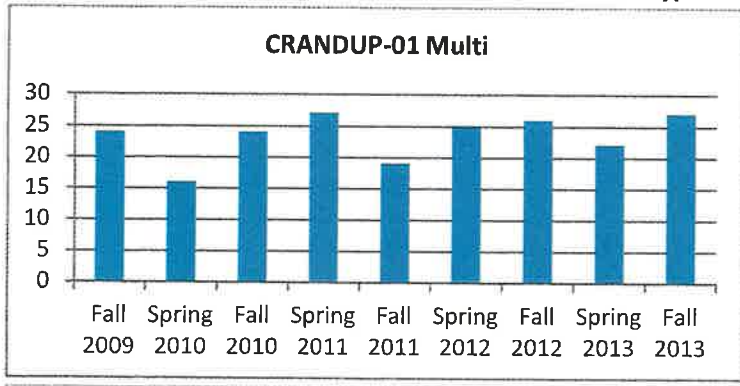
Figure 24b. Heptageniidae, Chloroperlidae & Rhyacophila (Percent)

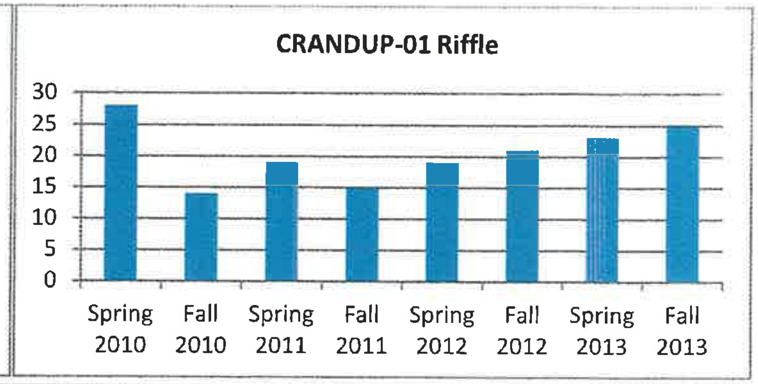


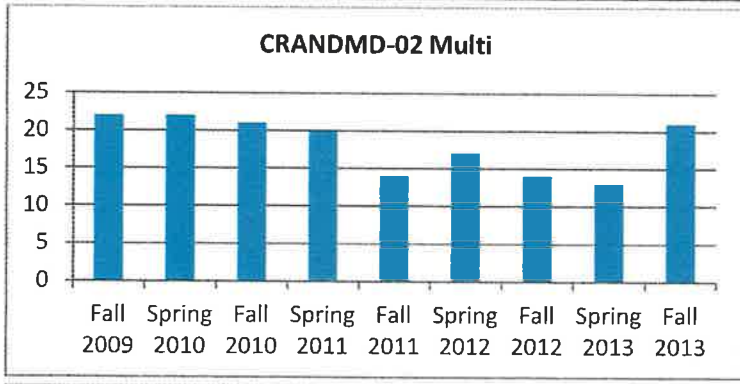
APPENDIX C

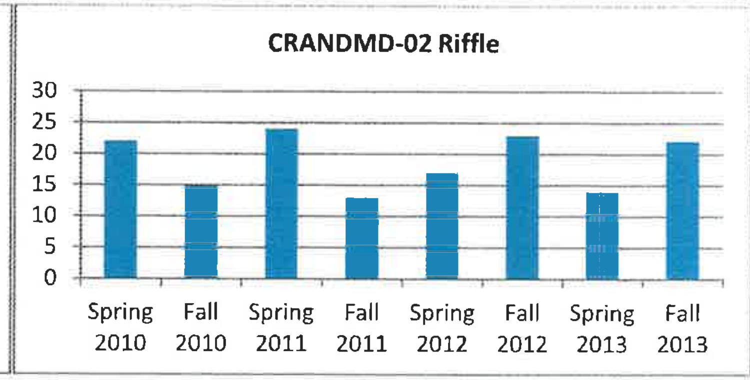
MACROINVERTEBRATE FIGURES FALL 2009- FALL 2013

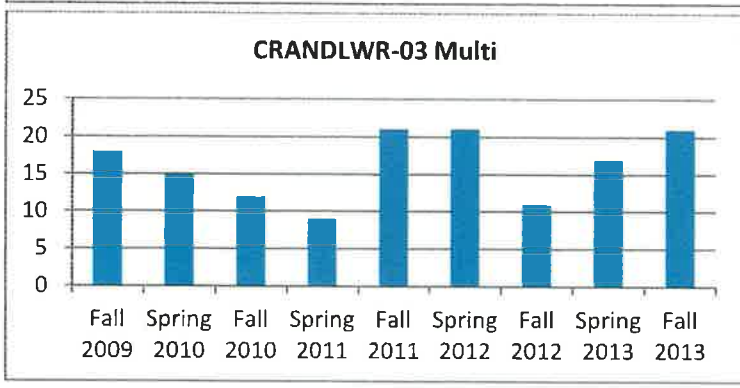
Figures 1c. Richness values for each reach and habitat type from 2009-2013

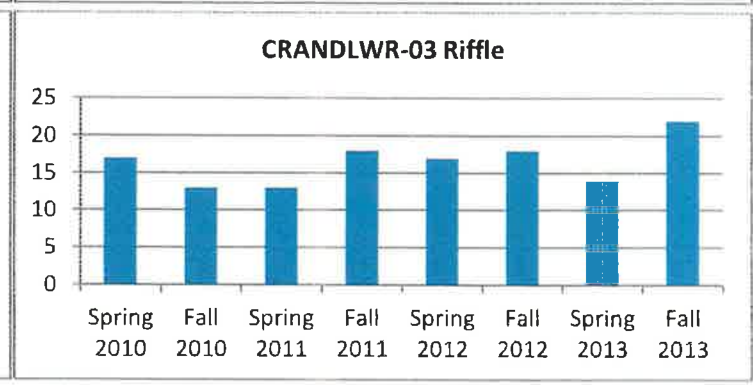




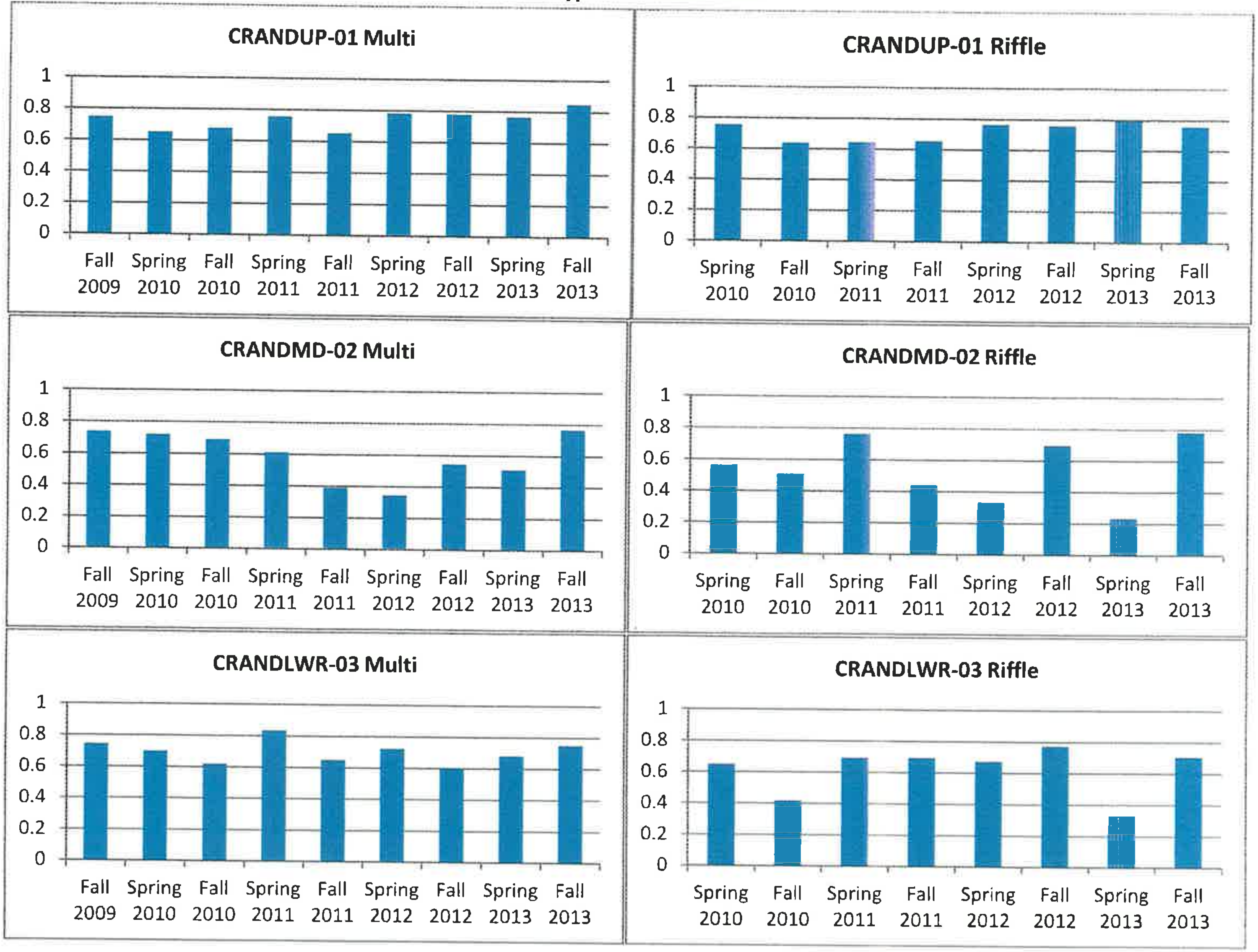




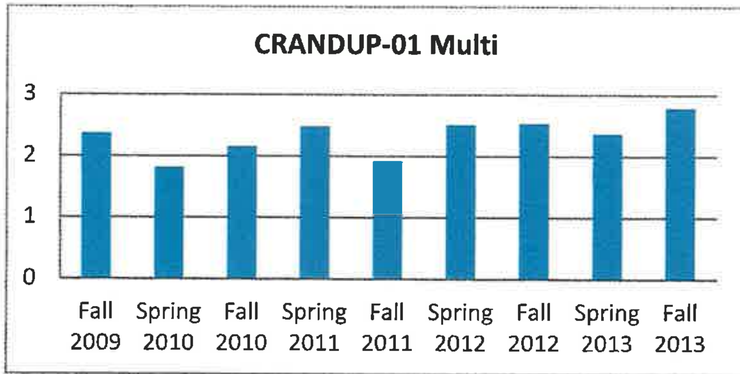


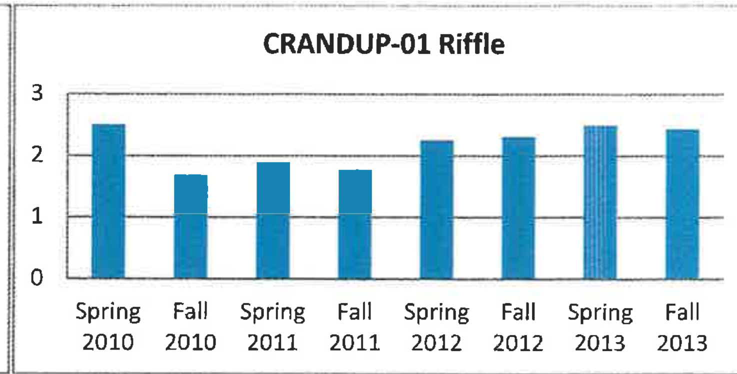


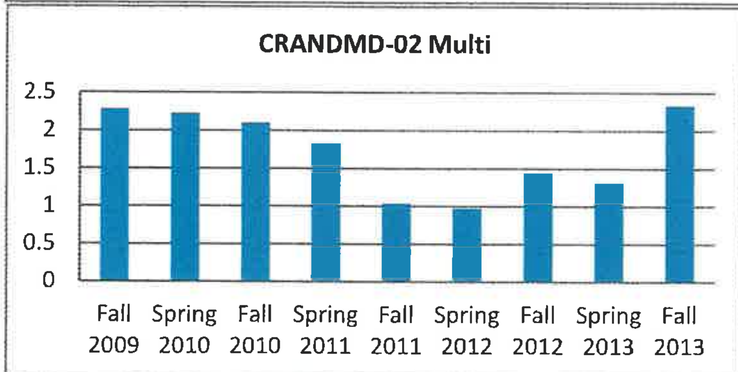
Figures 2c. Evenness values for each reach and habitat type from 2009-2013

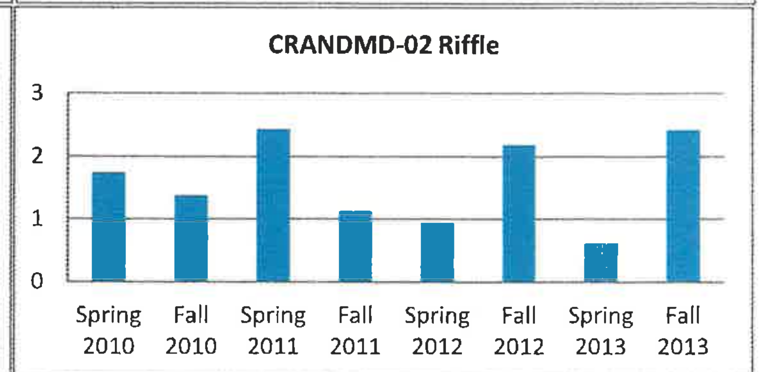


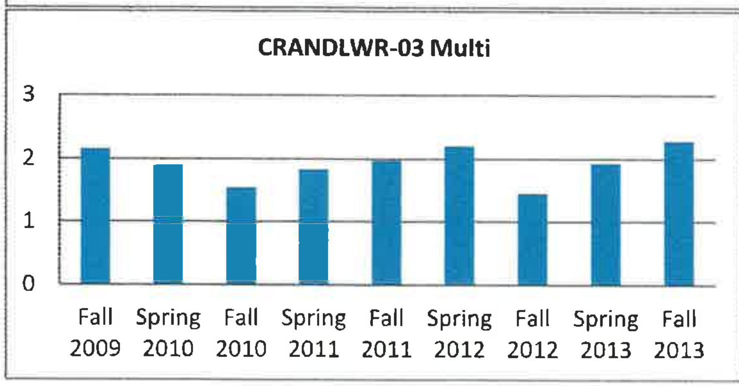
Figures 3c. Shannon's Diversity values for each reach and habitat type from 2009-2013

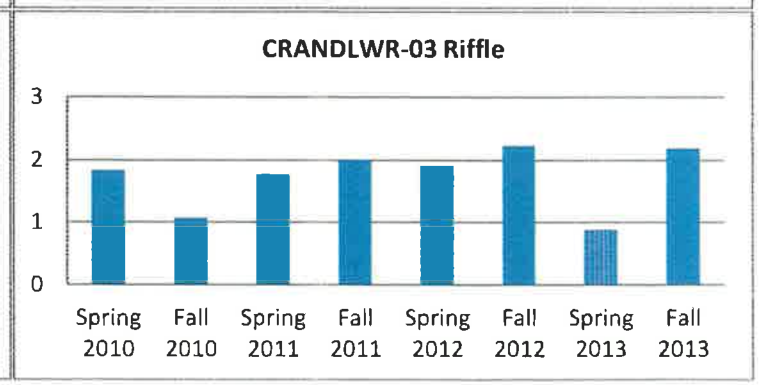




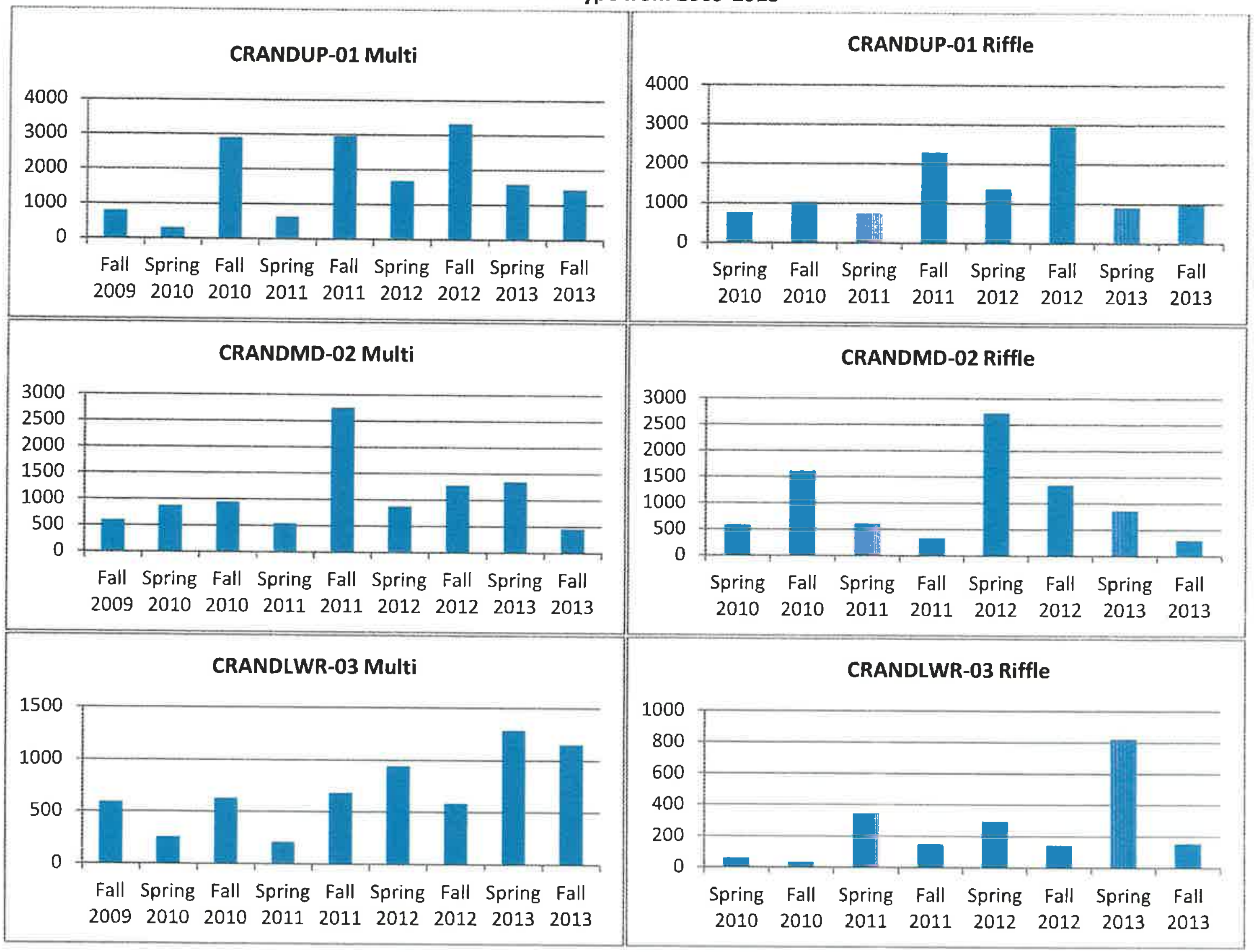




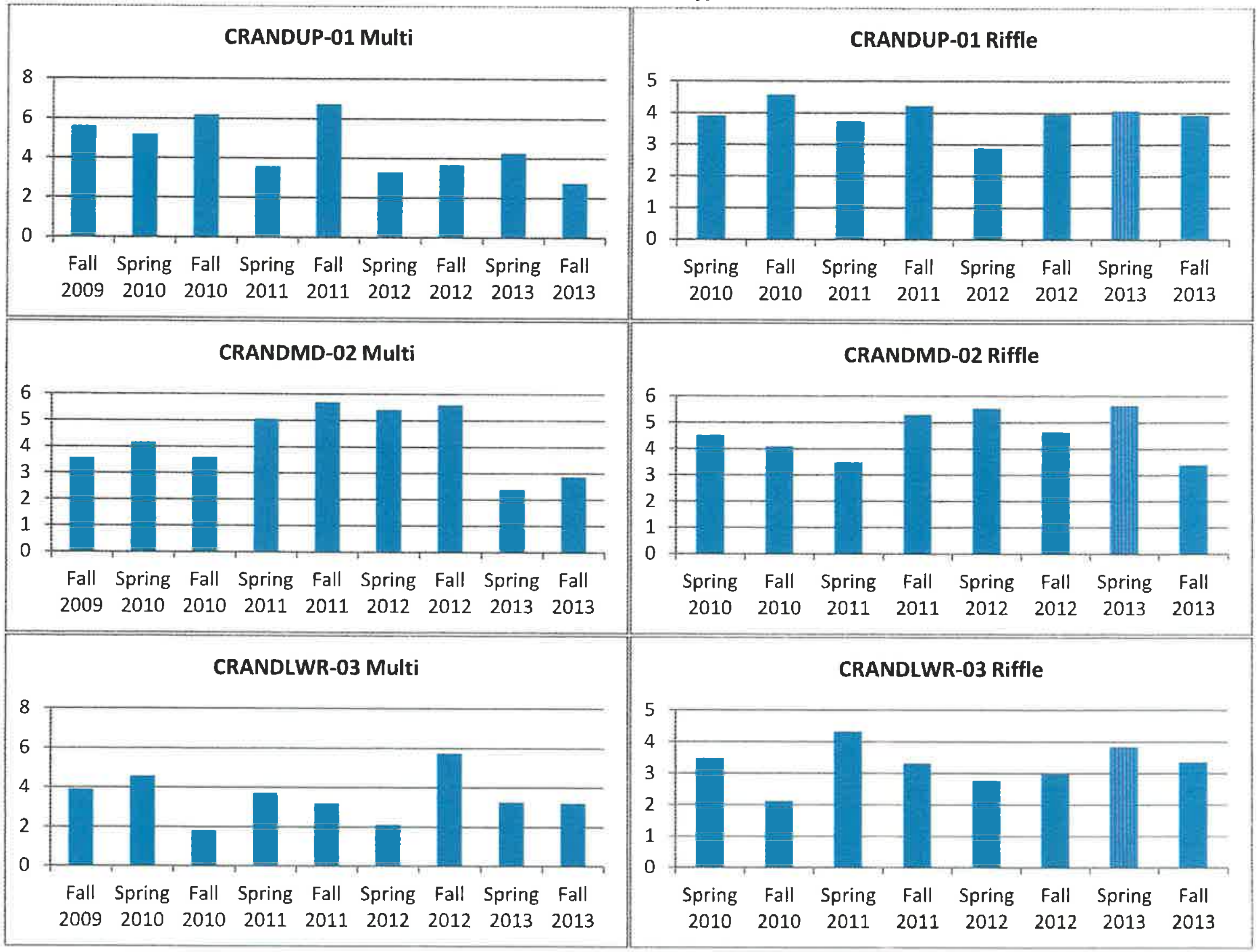




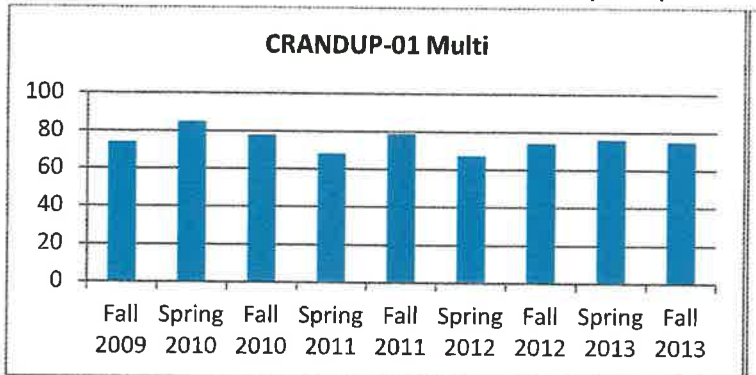
Figures 4c. Abundance values for each reach and habitat type from 2009-2013

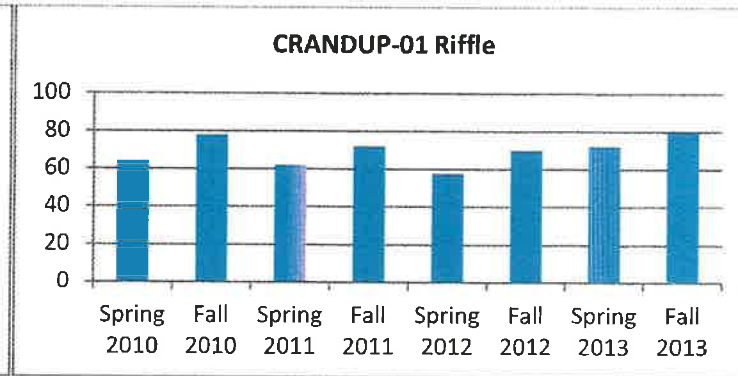


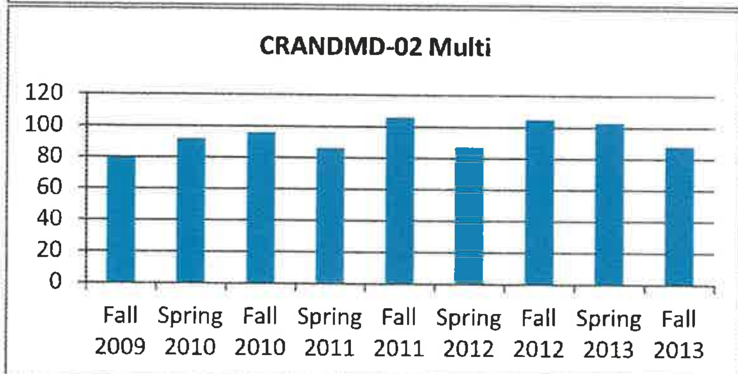
Figures 5c. Hilsenhoff Biotic Index values for each reach and habitat type from 2009-2013

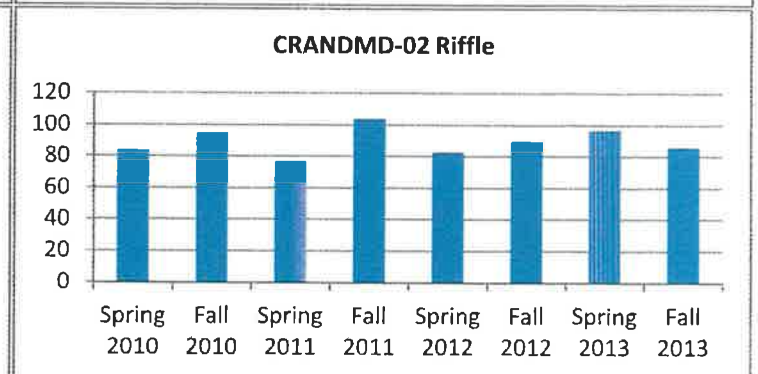


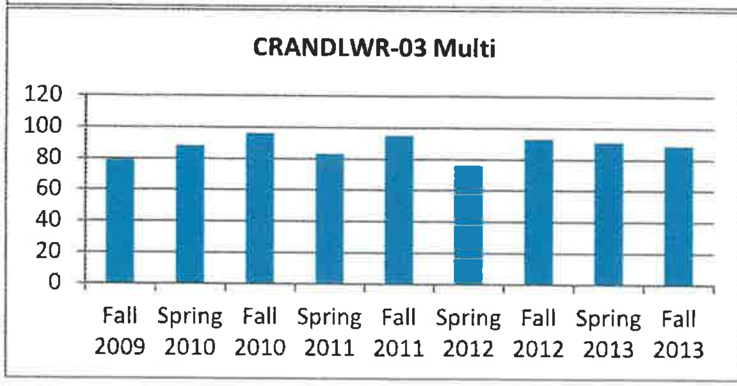
Figures 6c. USFS Community Tolerance Quotient (CTQd) values for each reach and habitat type from 2009-2013

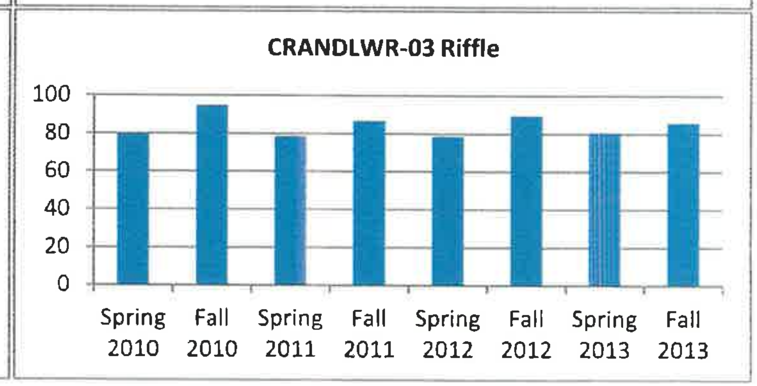




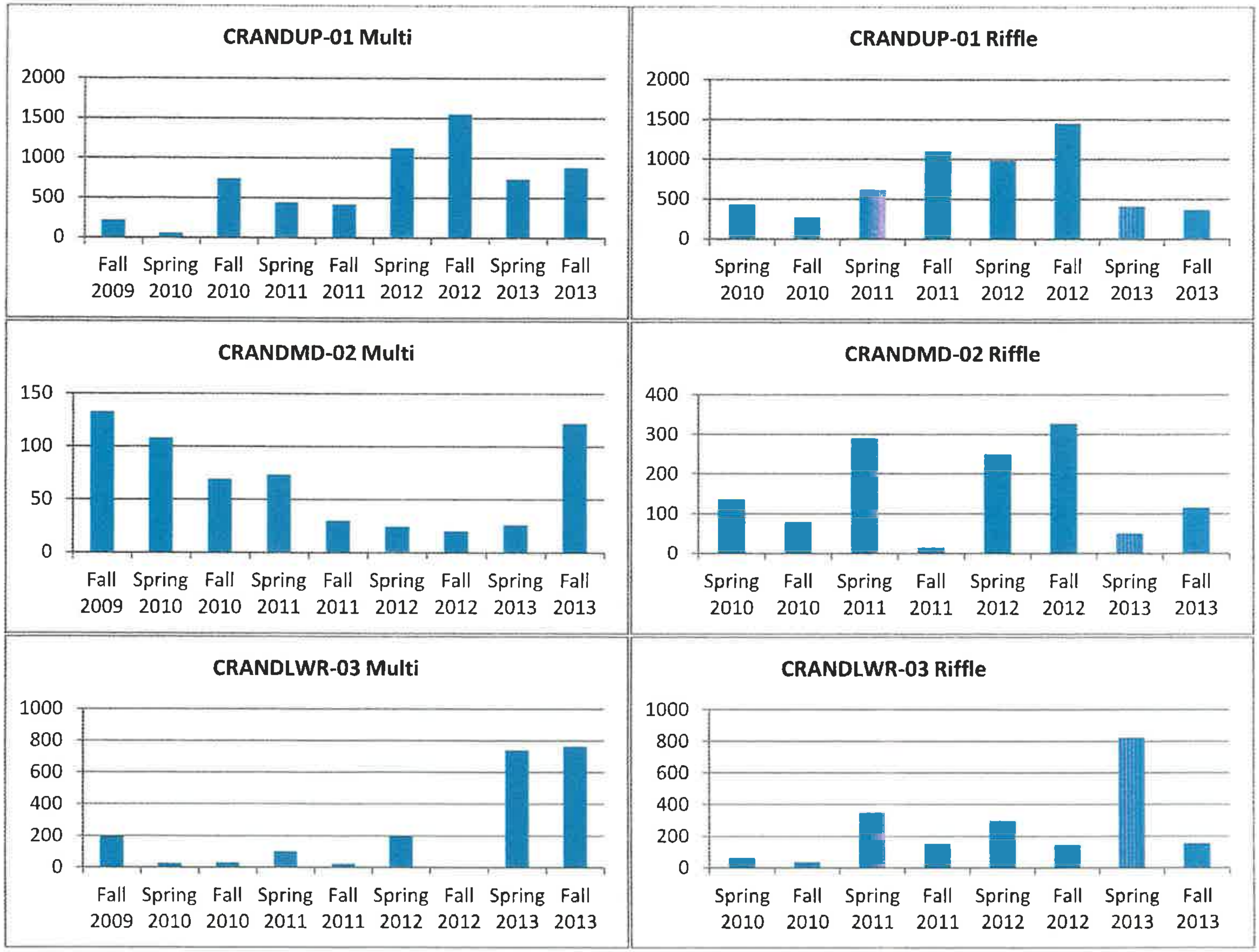




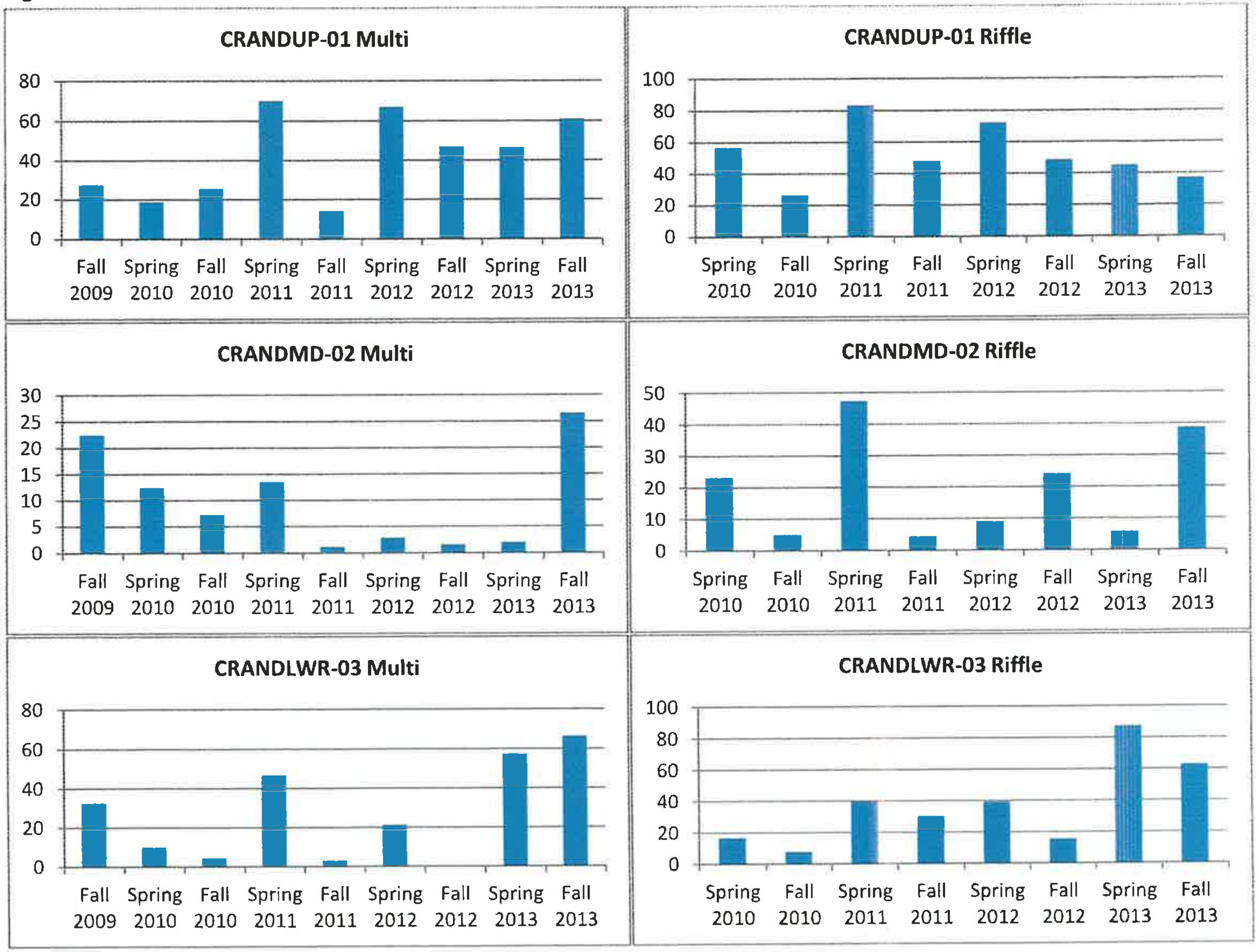




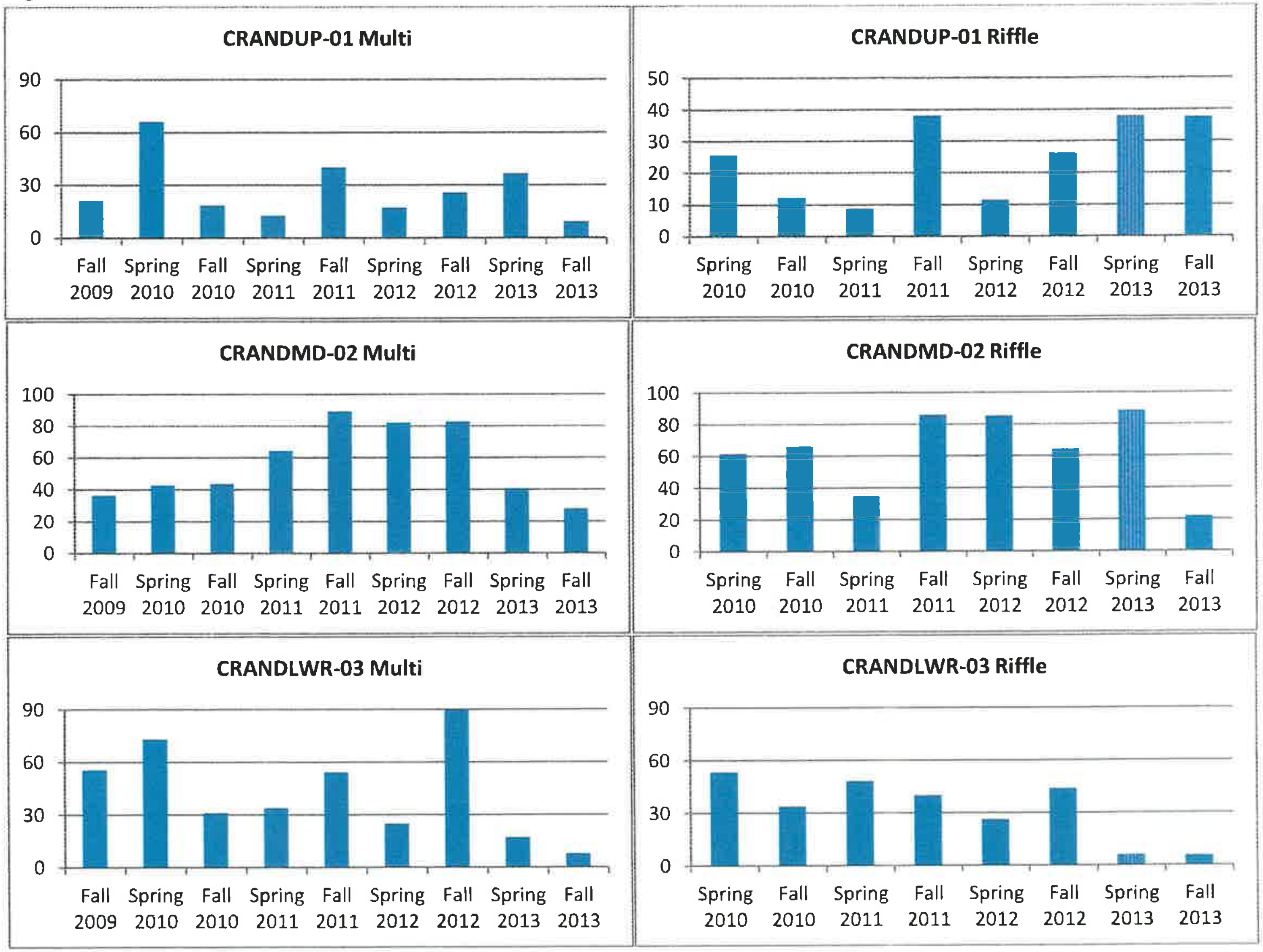
Figures 7c. EPT taxa abundance values for each reach and habitat type from 2009-2013



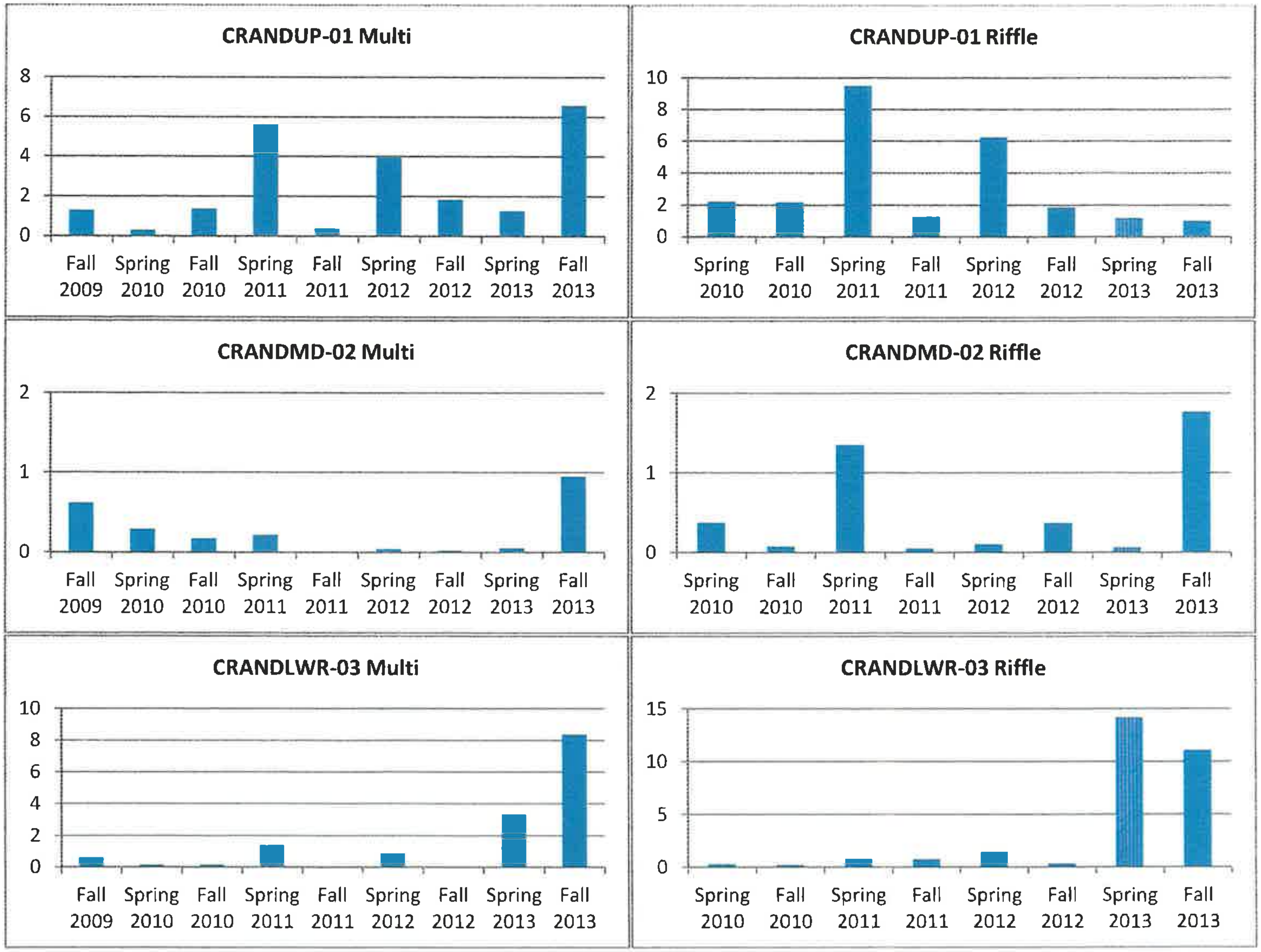
Figures 8c. Percent EPT for each reach and habitat type from 2009-2013



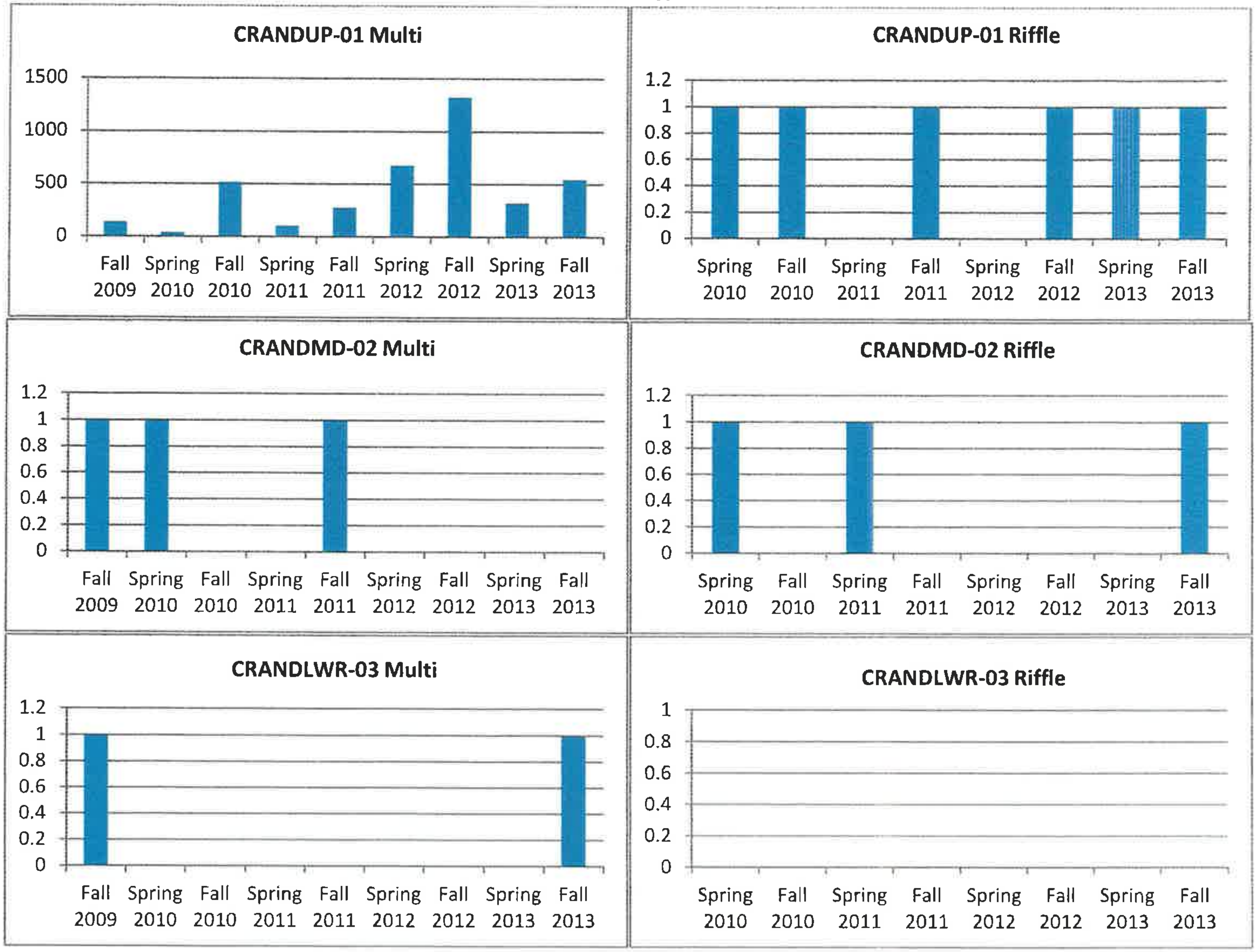
Figures 9c. Percent Chironomids for each reach and habitat type from 2009-2013



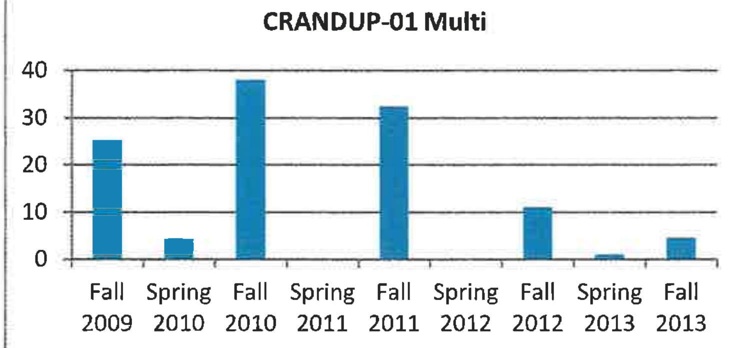
Figures 10c. Ratio of EPT to Chironmoids values for each reach and habitat type from 2009-2013

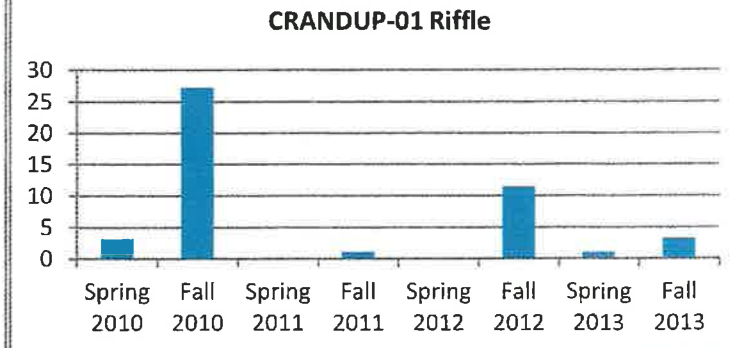


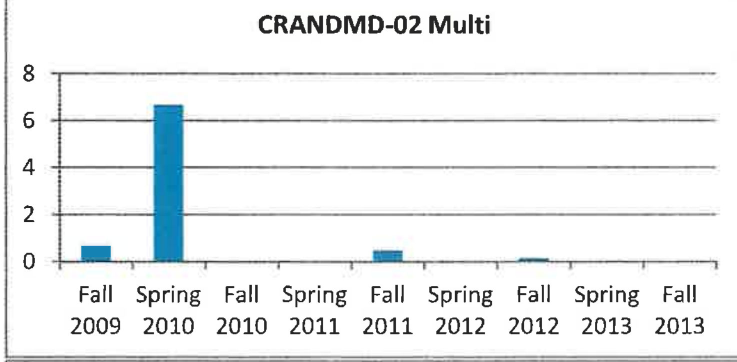
Figures 11c. Number of tolerant taxa for each reach and habitat type from 2009-2013

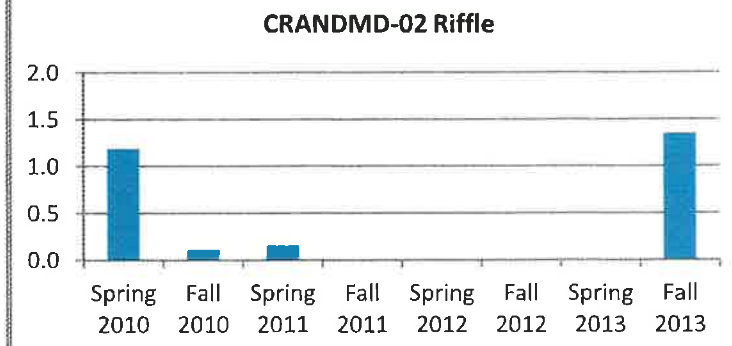


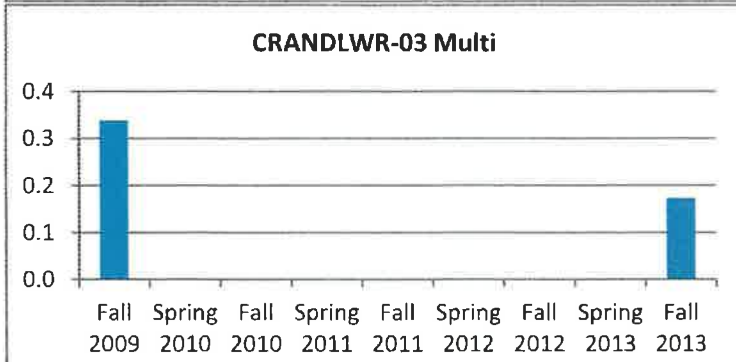
Figures 12c. Percent tolerant organisms for each reach and habitat type from 2009-2013

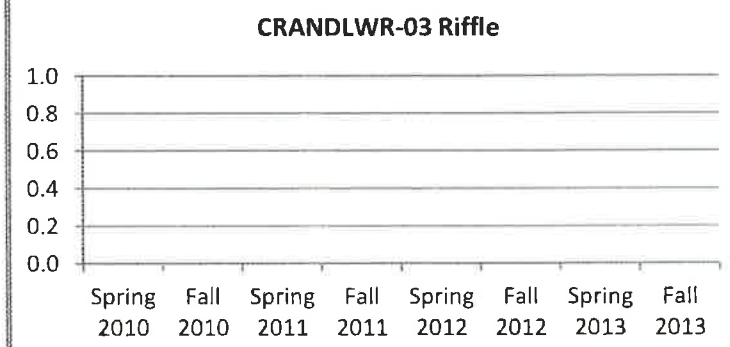




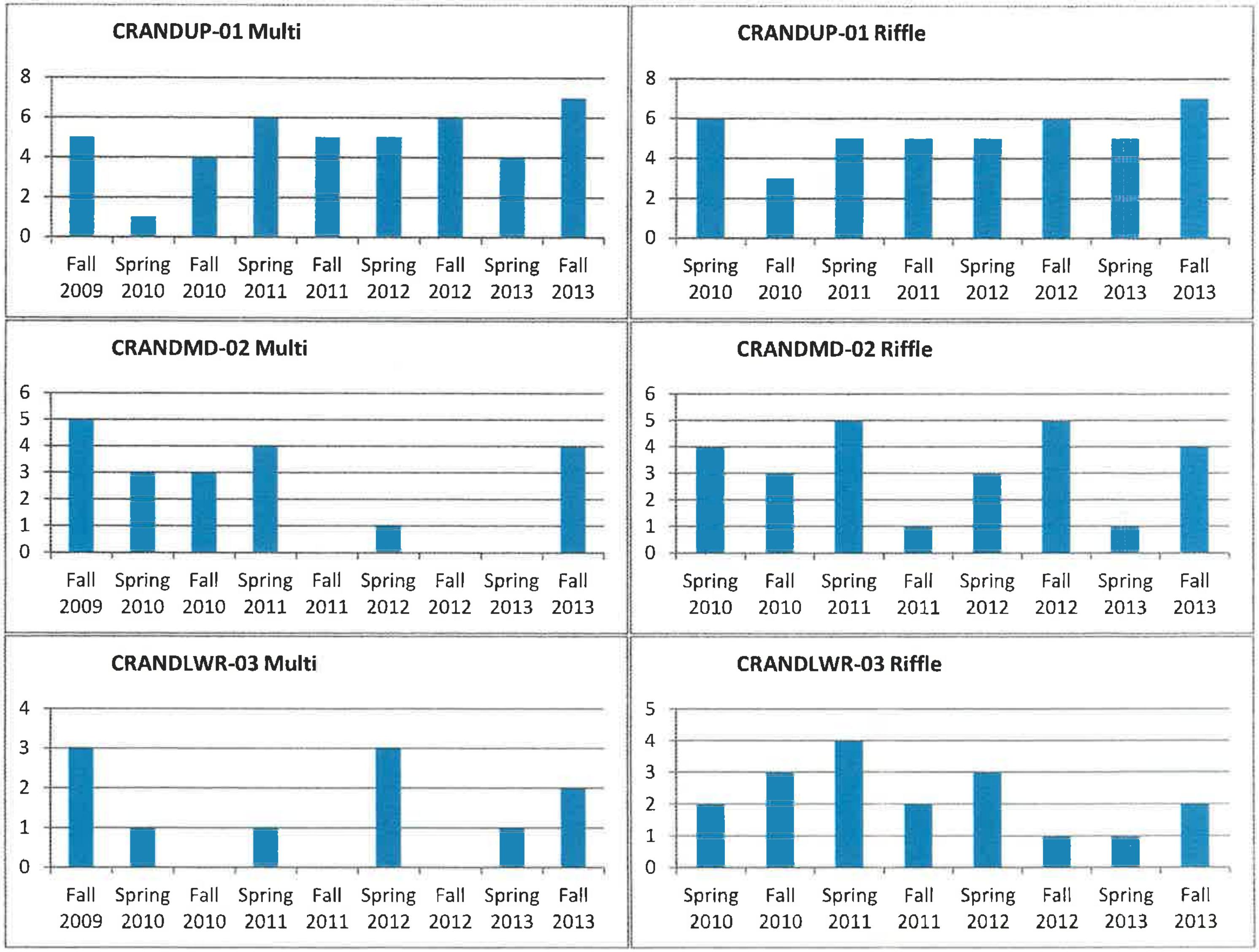




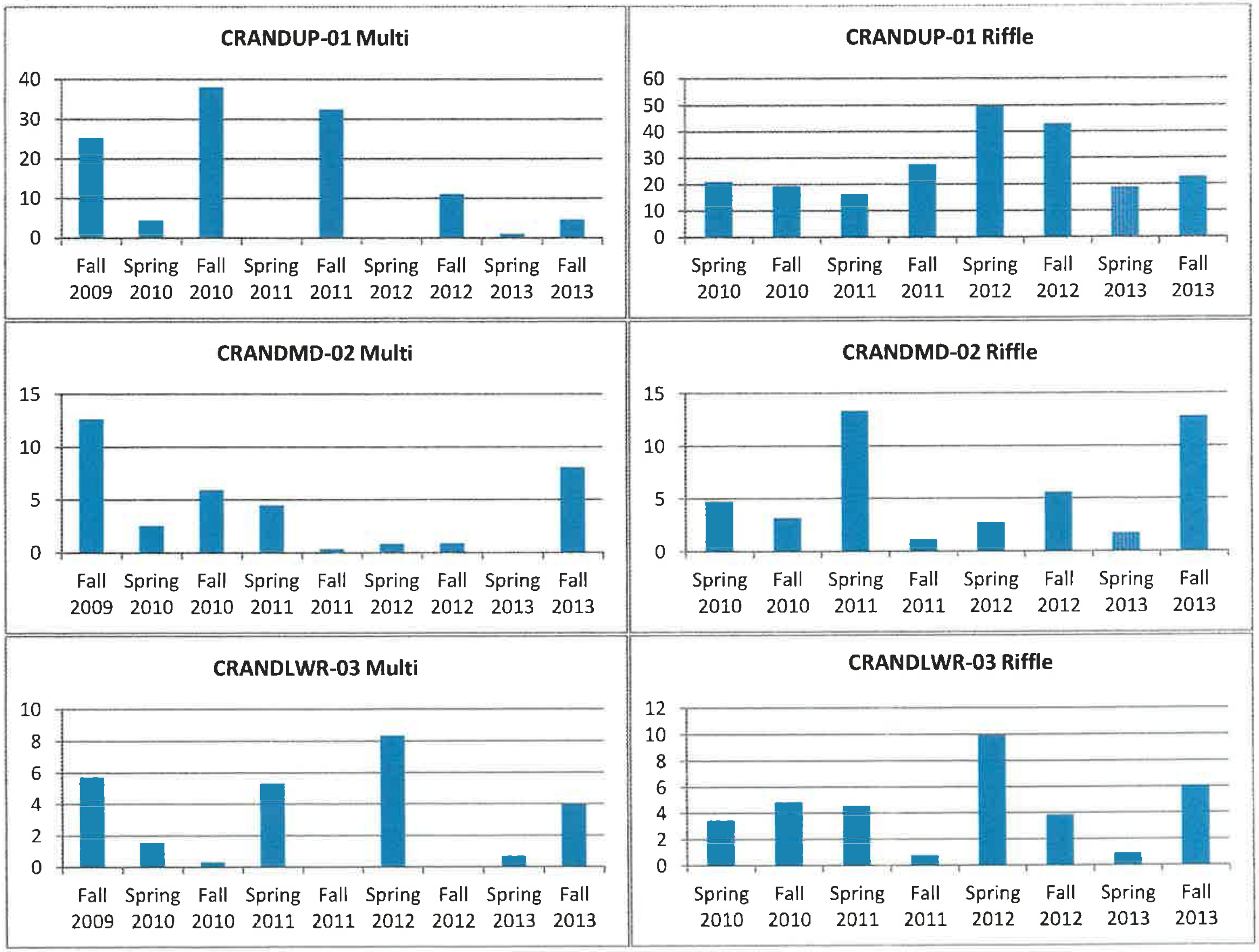




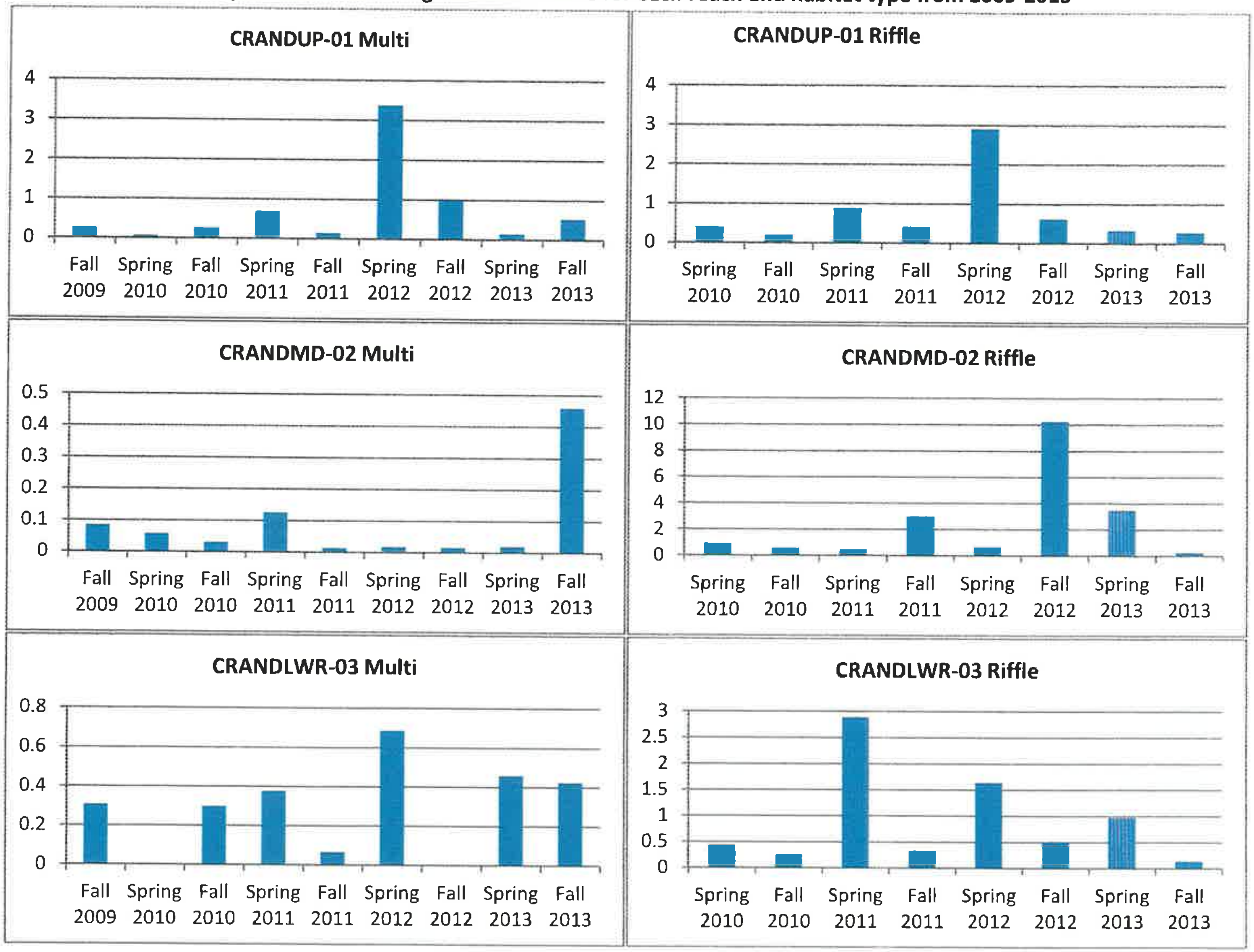
Figures 13c. Number of intolerant taxa for each reach and habitat type from 2009-2013



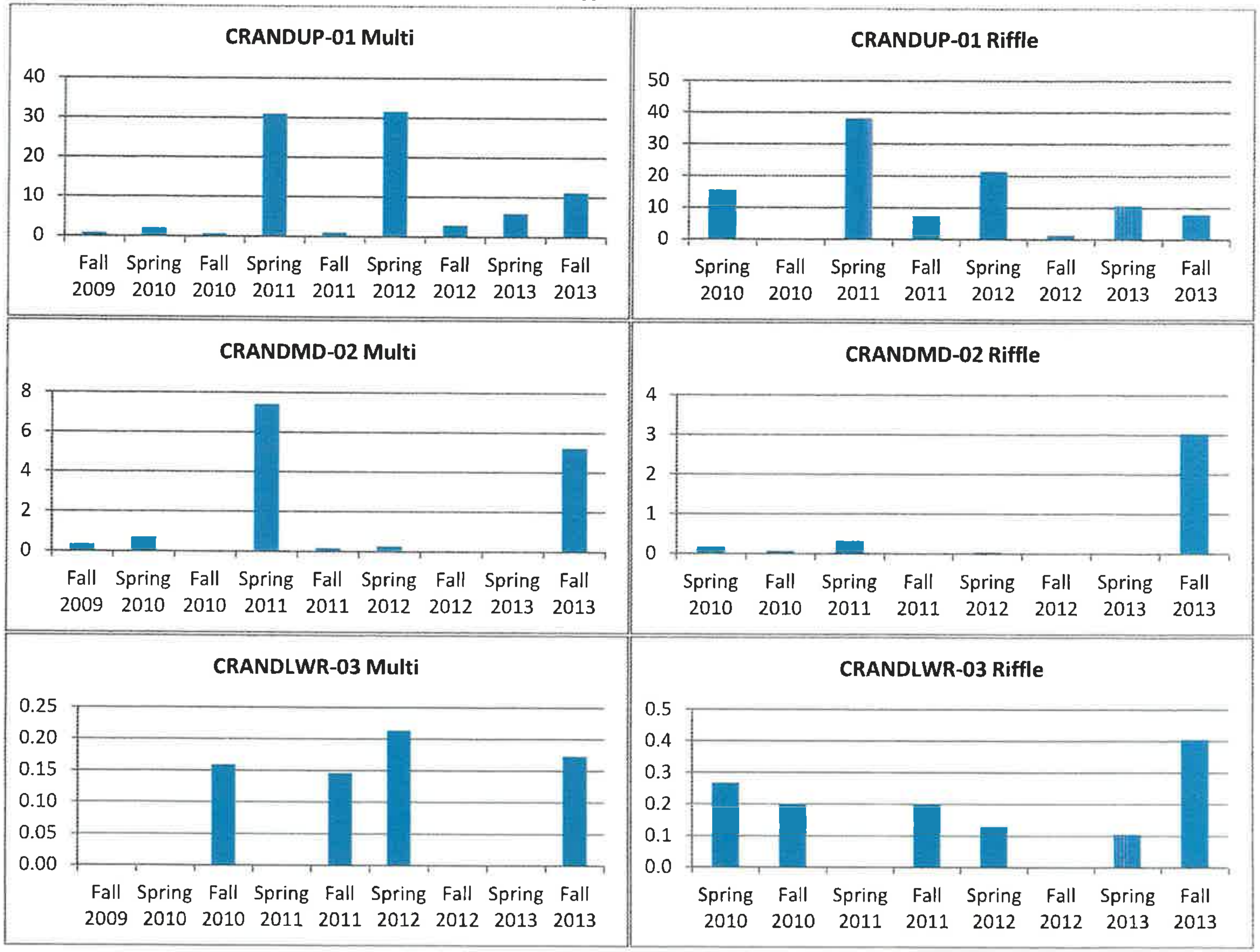
Figures 14c. Percent intolerant organisms for each reach and habitat type from 2009-2013



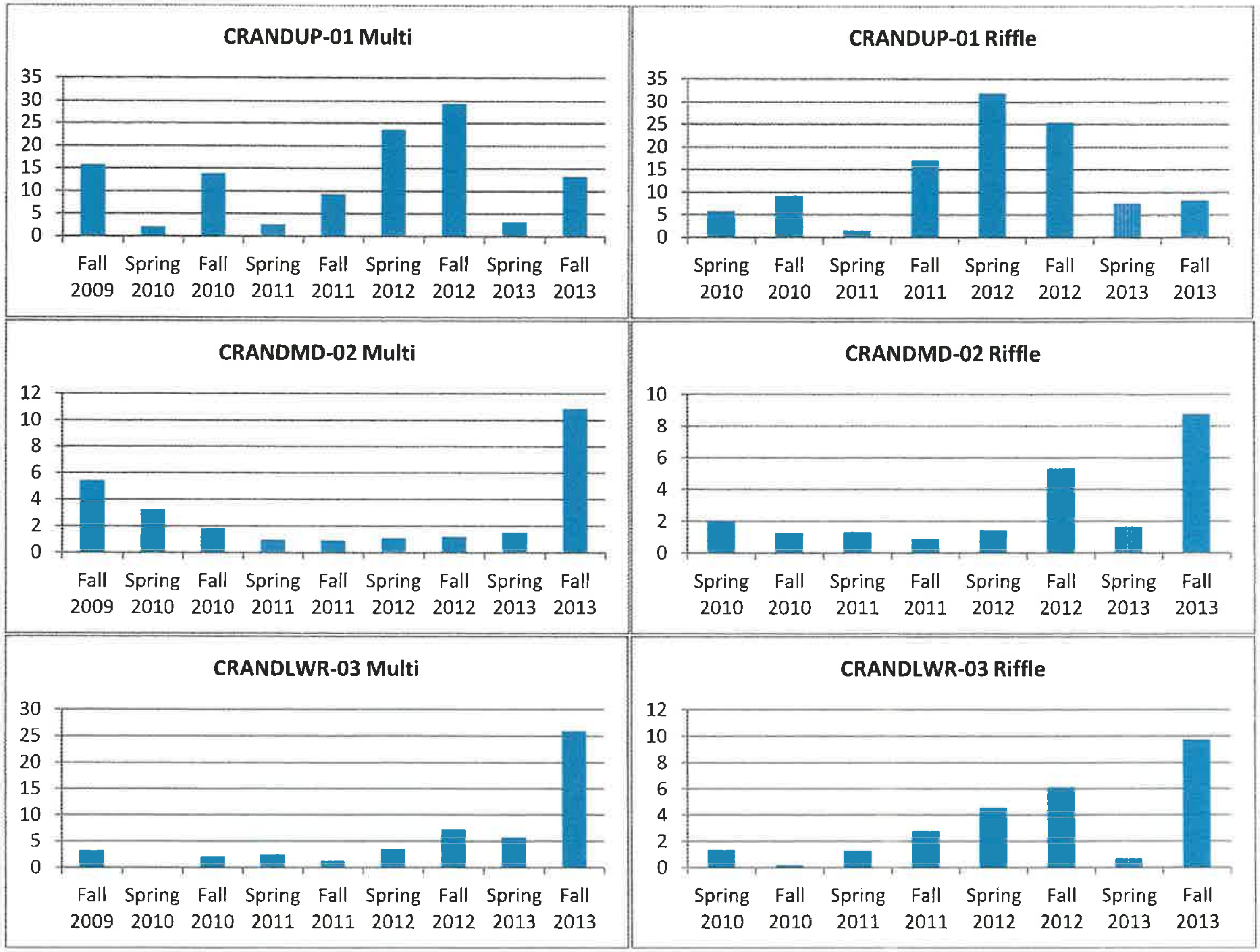
Figures 15c. Ratio of specialist feeders to generalist feeders for each reach and habitat type from 2009-2013



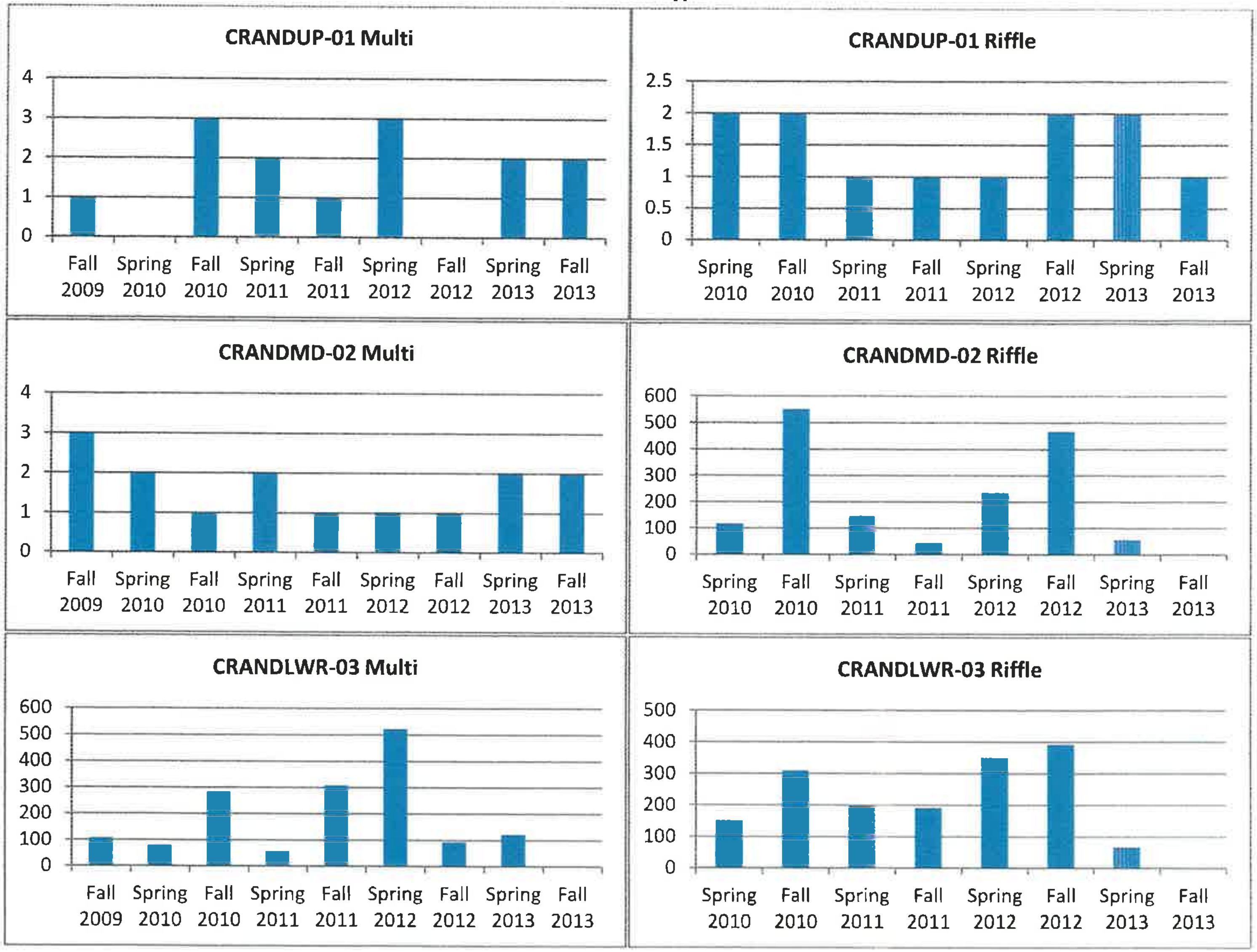
Figures 16c. Percent scrapers for each reach and habitat type from 2009-2013



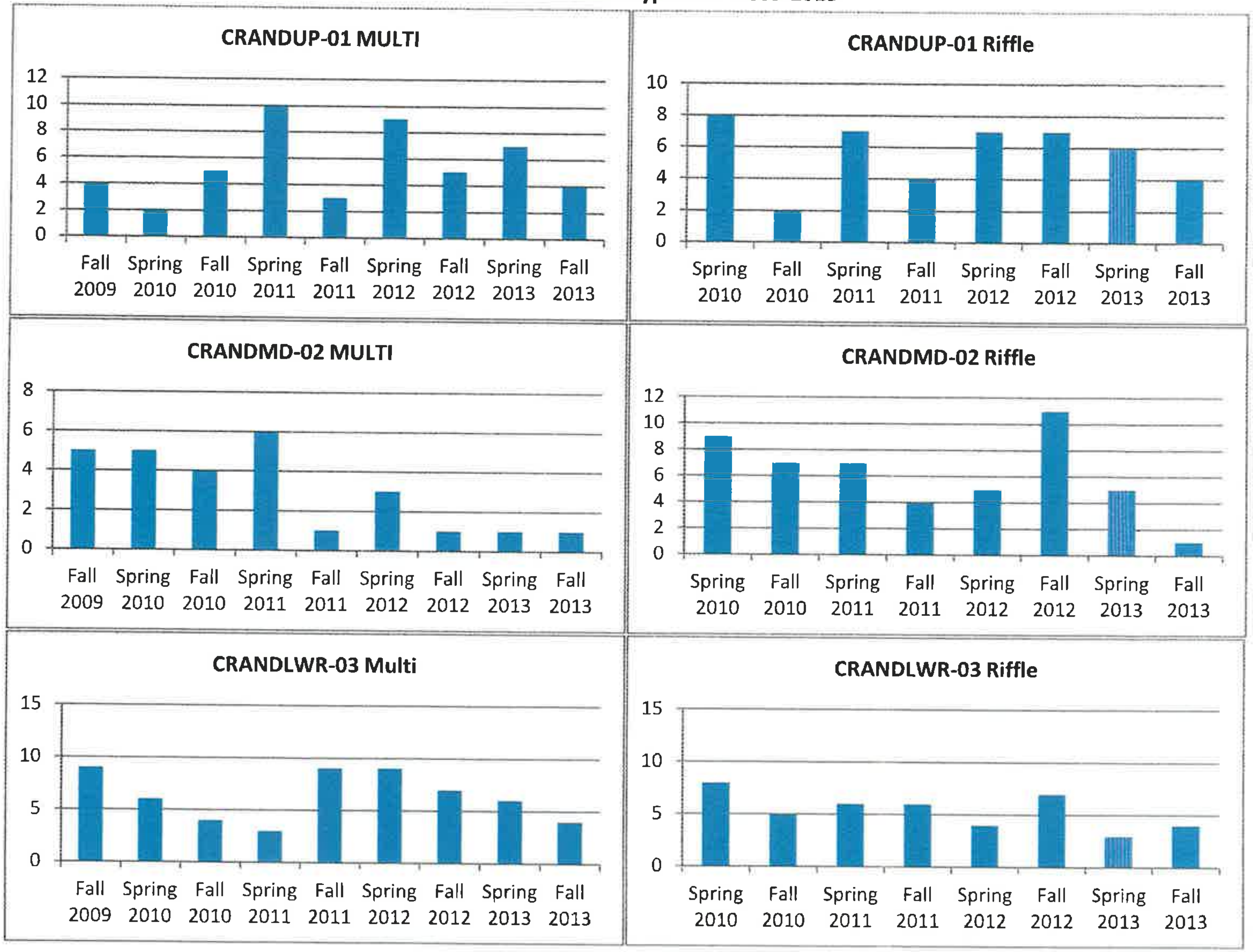
Figures 17c. Percent shredders for each reach and habitat type from 2009-2013



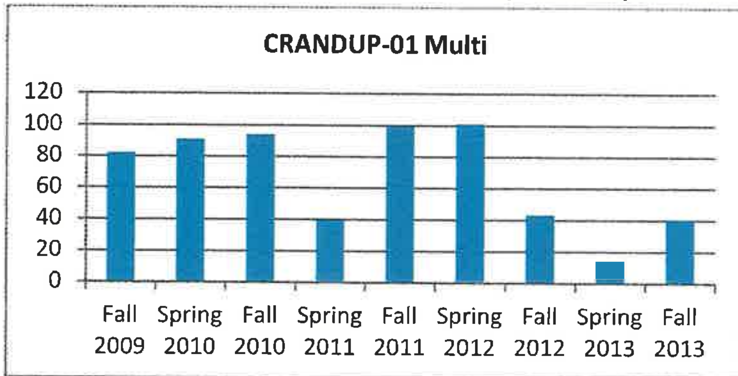
Figures 18c. Number of long-lived taxa for each reach and habitat type from 2009-2013

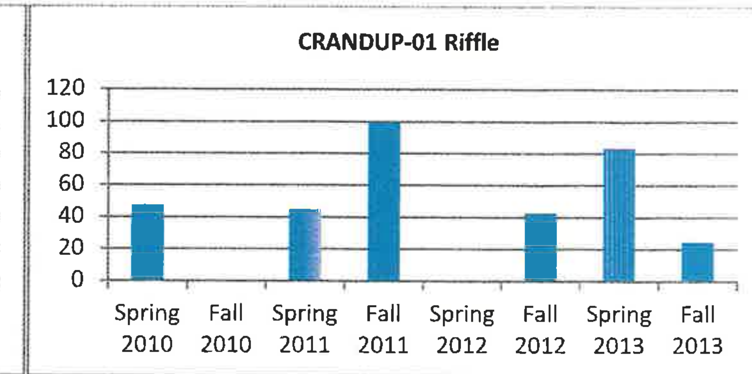


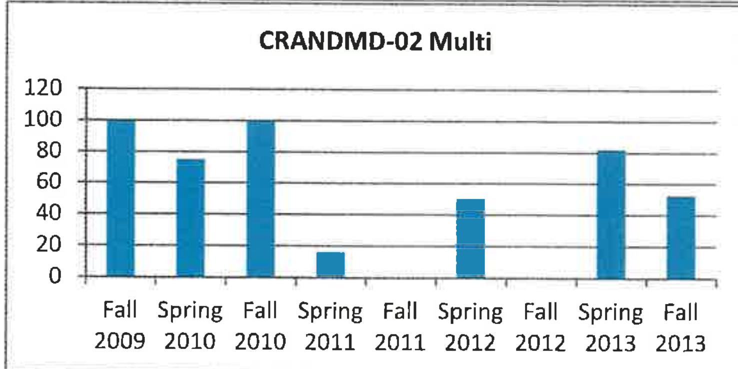
Figures 19c. Number of clinger taxa for each reach and habitat type from 2009-2013

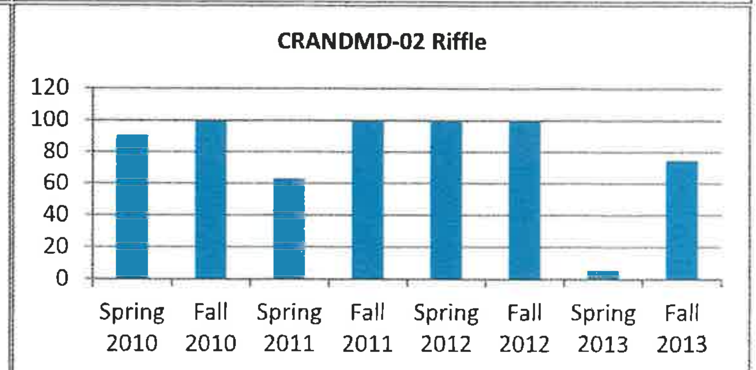


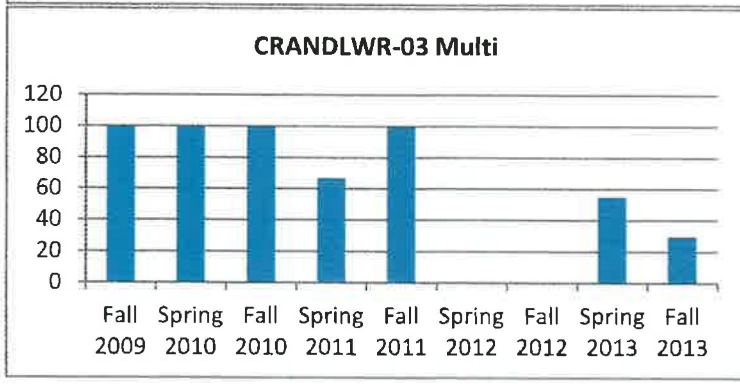
Figures 20c. Percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2009-2013

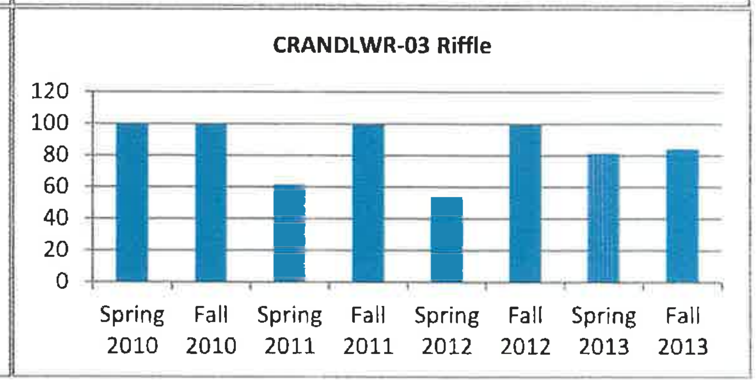




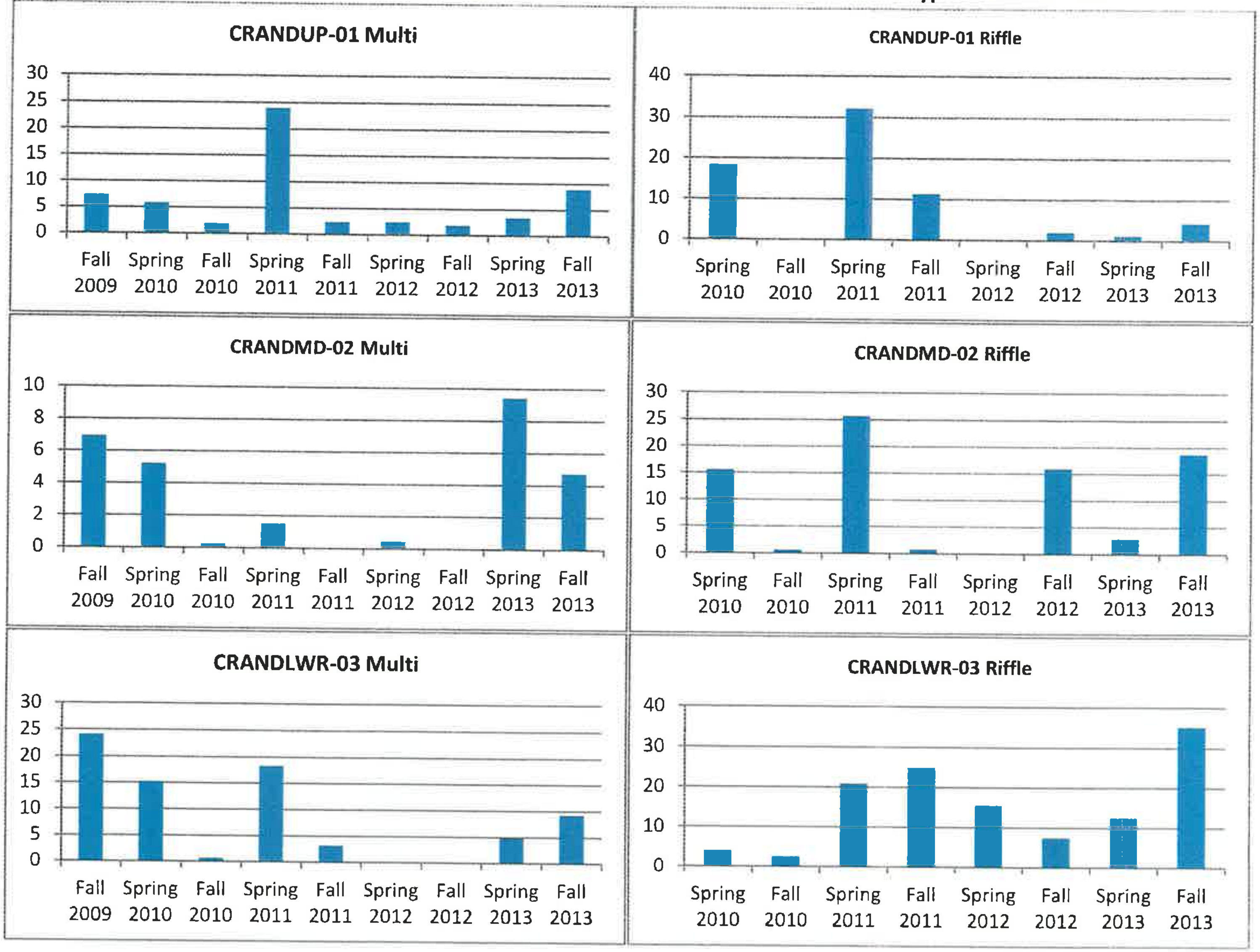




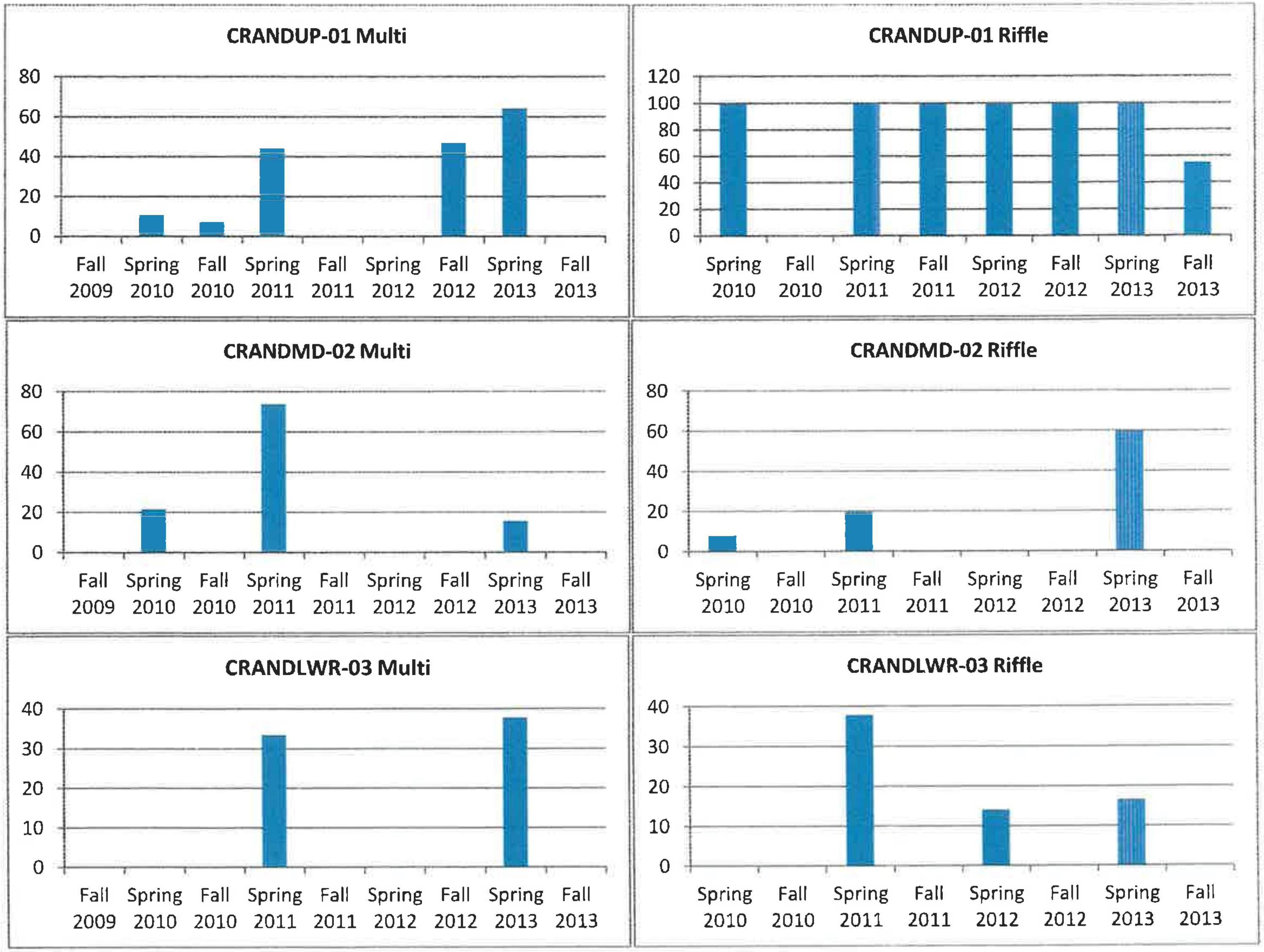




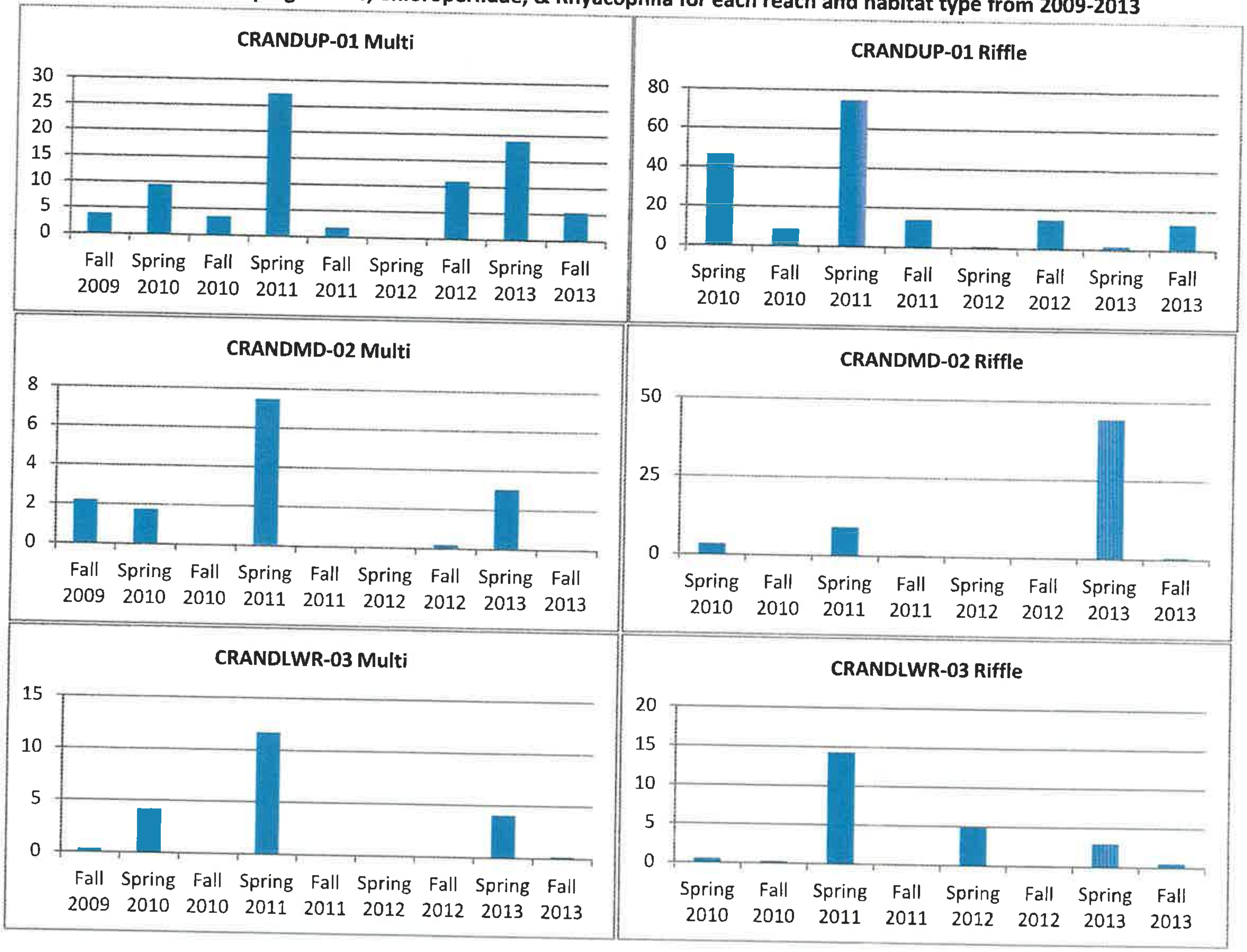
Figures 21c. Percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2013



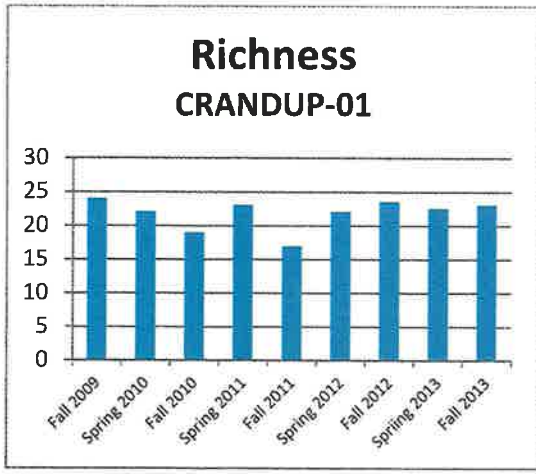
Figures 22c. Percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2013

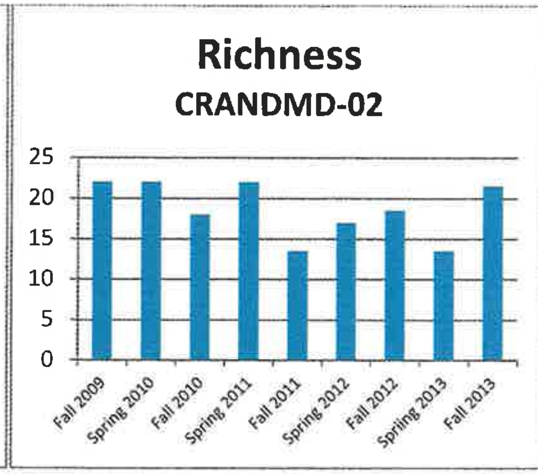


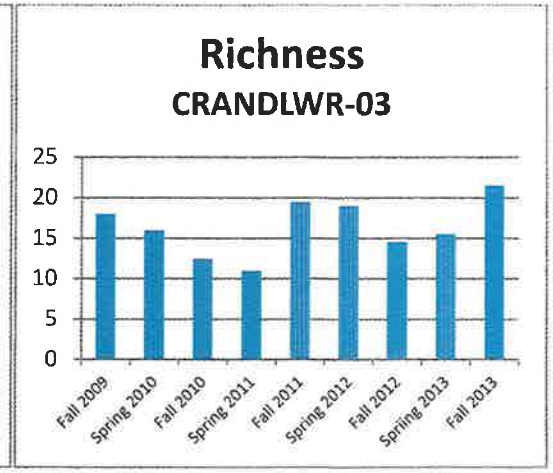
Figures 23c. Percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2013



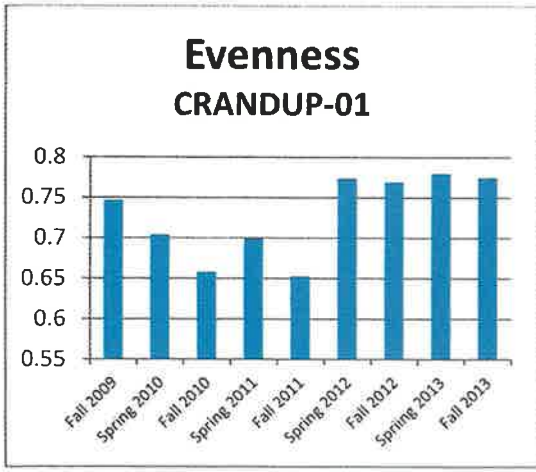
Figures 24c. Average richness in each reach from Fall 2009- Fall 2013

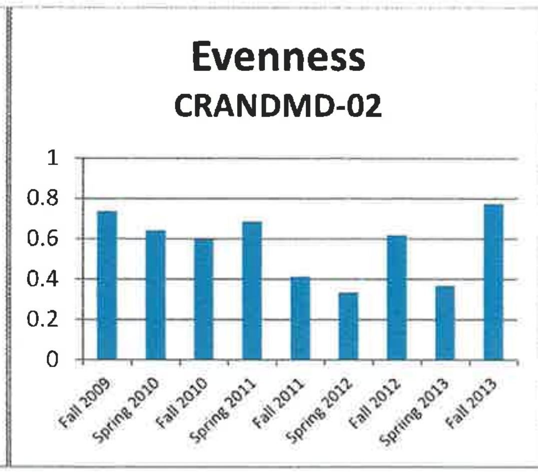


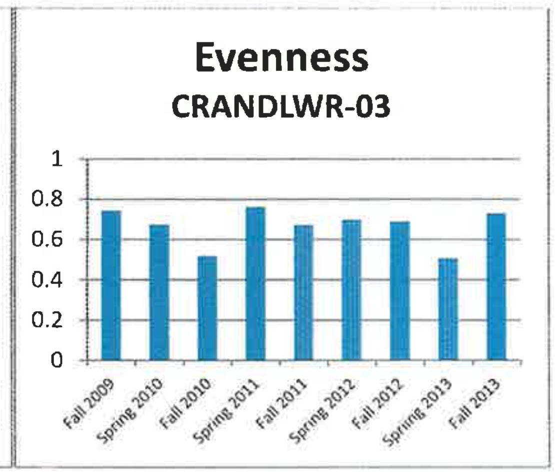




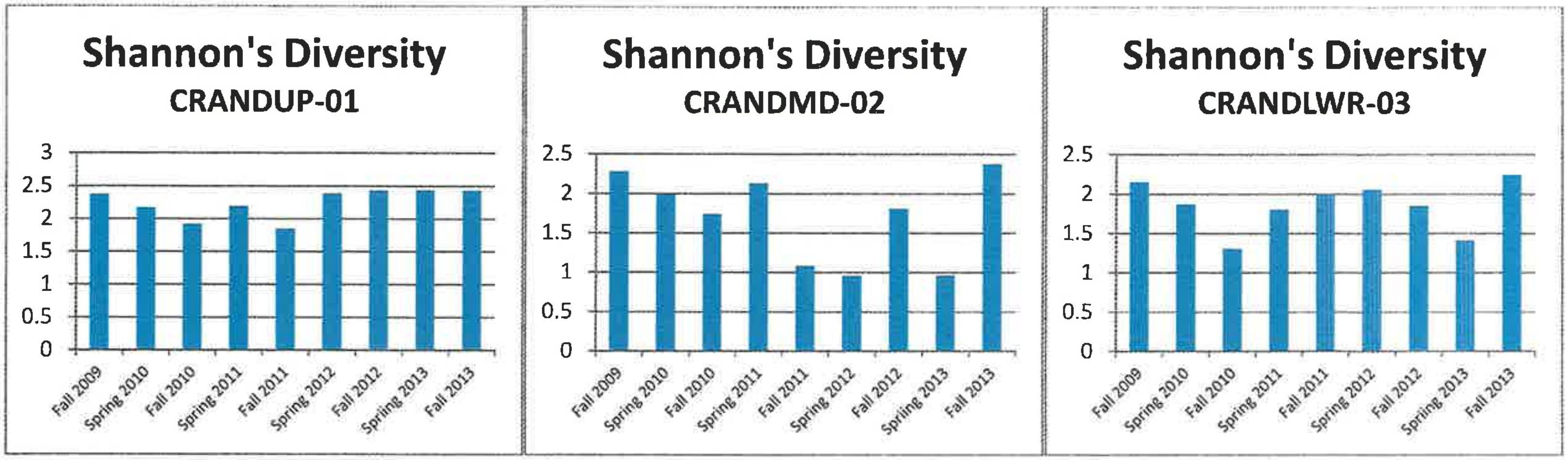
Figures 25c. Average evenness in each reach from Fall 2009- Fall 2013



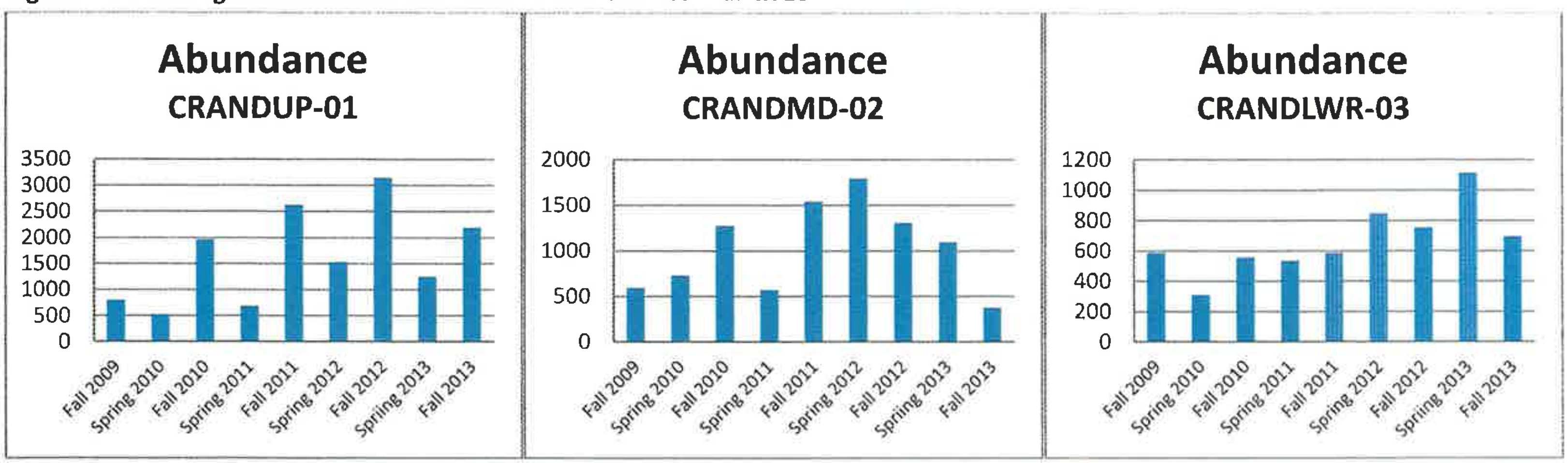




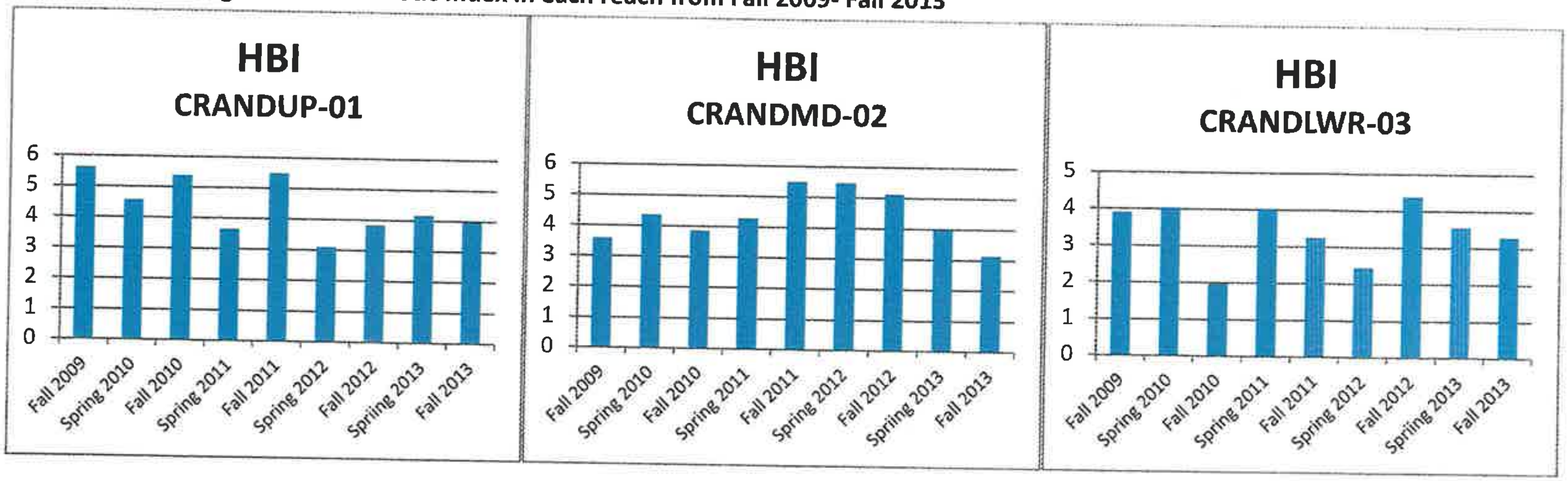
Figures 26c. Average Shannon's Diversity in each reach from Fall 2009- Fall 2013



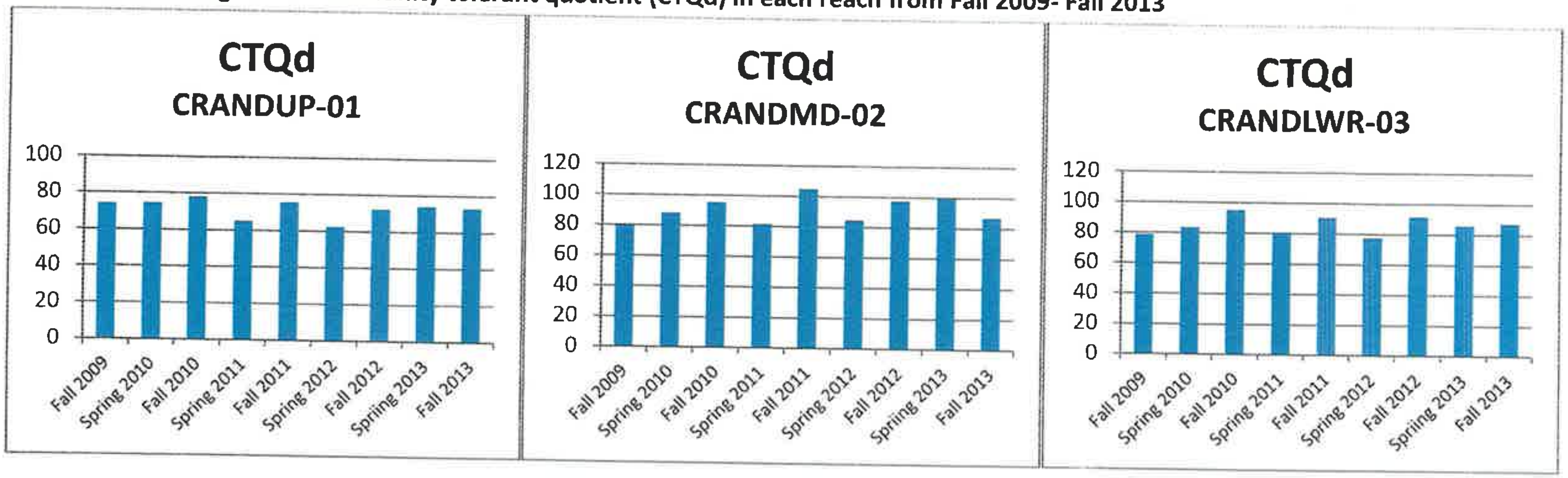
Figures 27c. Average abundance in each reach from Fall 2009- Fall 2013



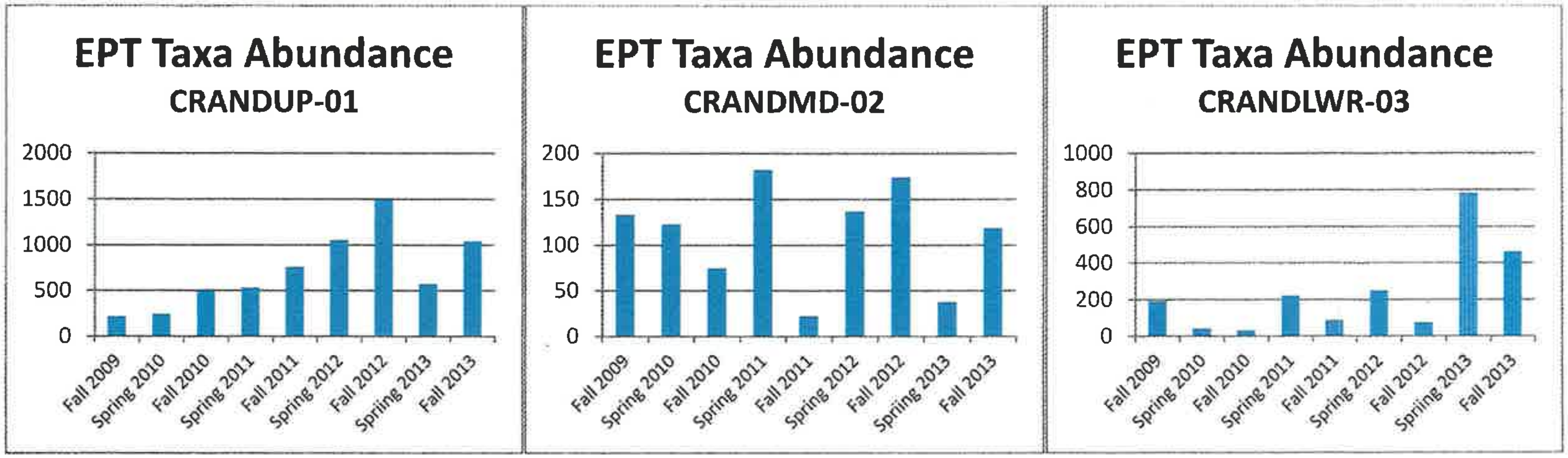
Figures 28c. Average Hilsenhoff Biotic Index in each reach from Fall 2009- Fall 2013



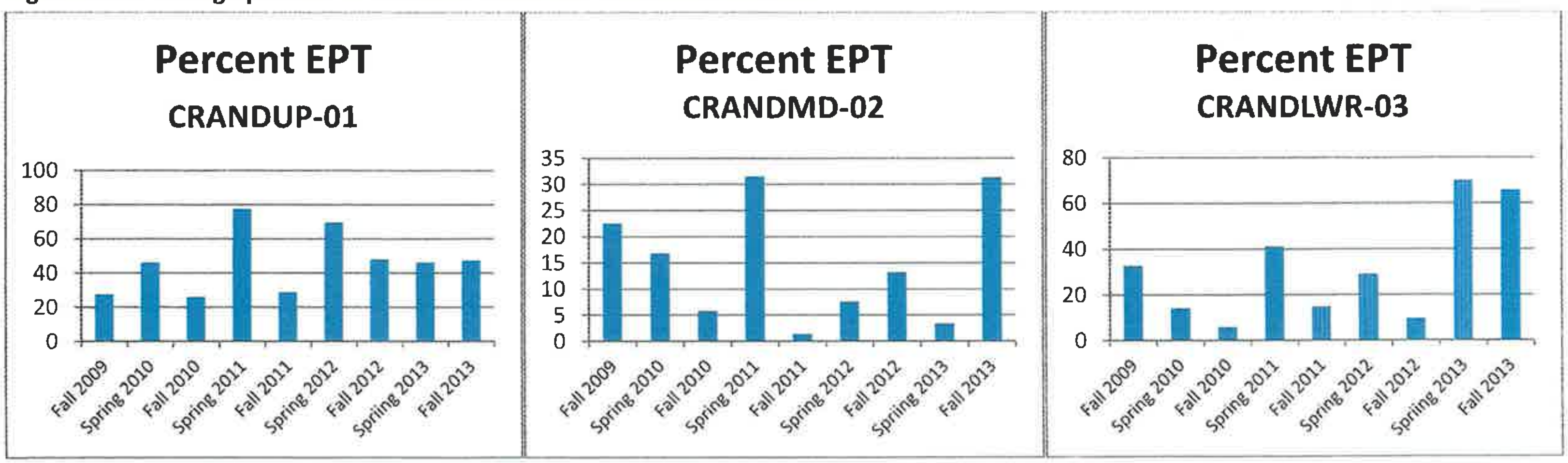
Figures 29c. Average USFS community tolerant quotient (CTQd) in each reach from Fall 2009- Fall 2013



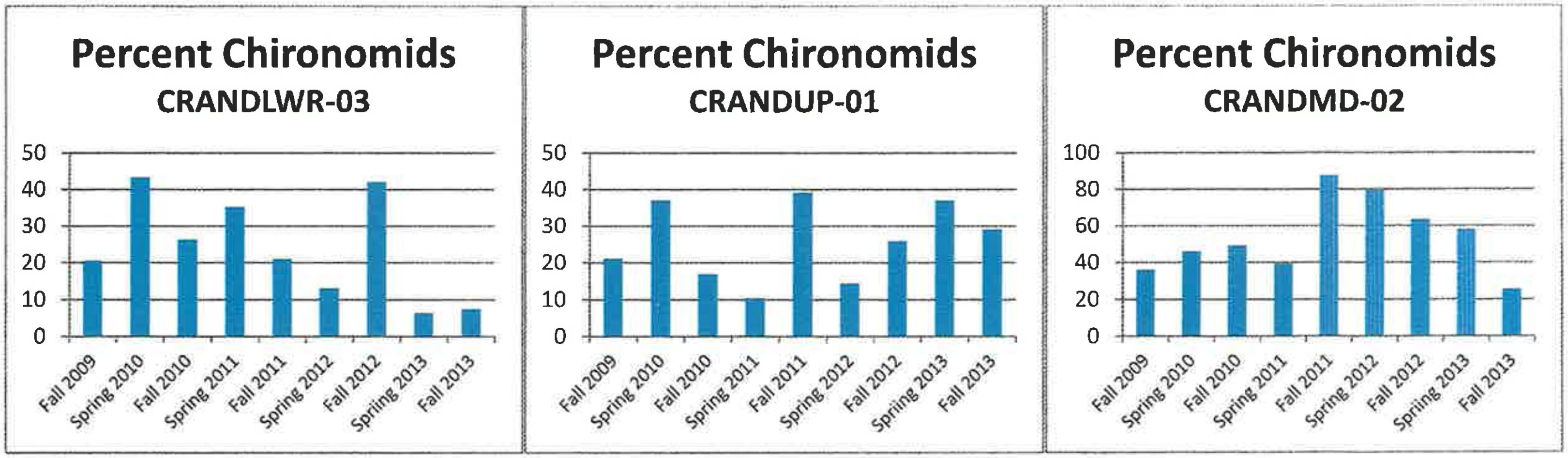
Figures 30c. Average EPT taxa abuncance in each reach from Fall 2009- Fall 2013



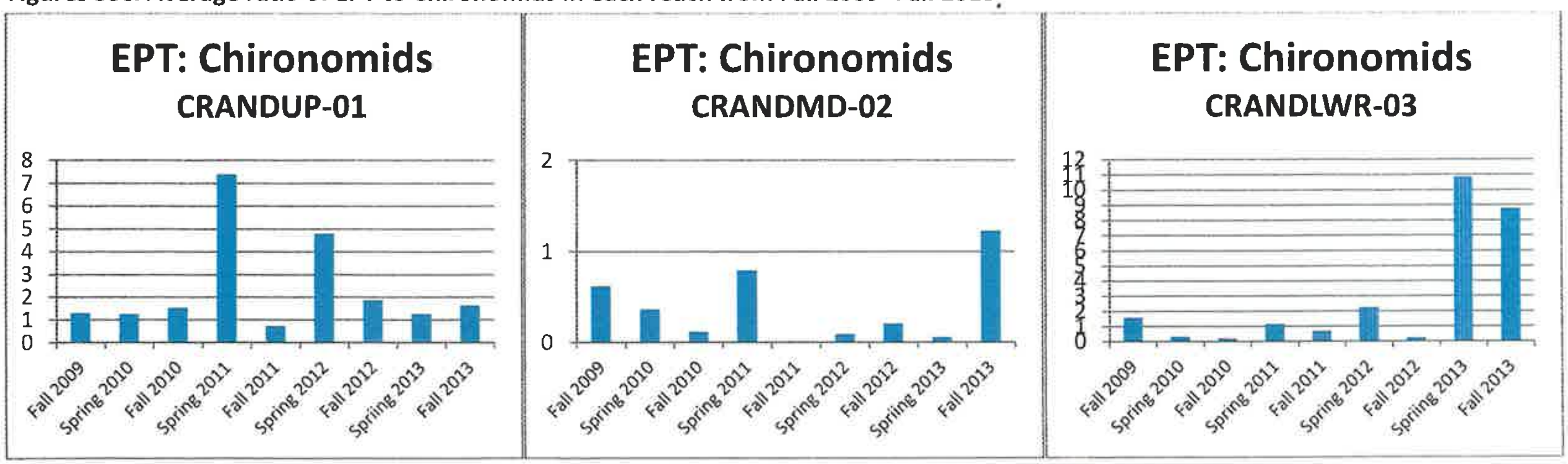
Figures 31c. Average percent EPT in each reach from Fall 2009- Fall 2013



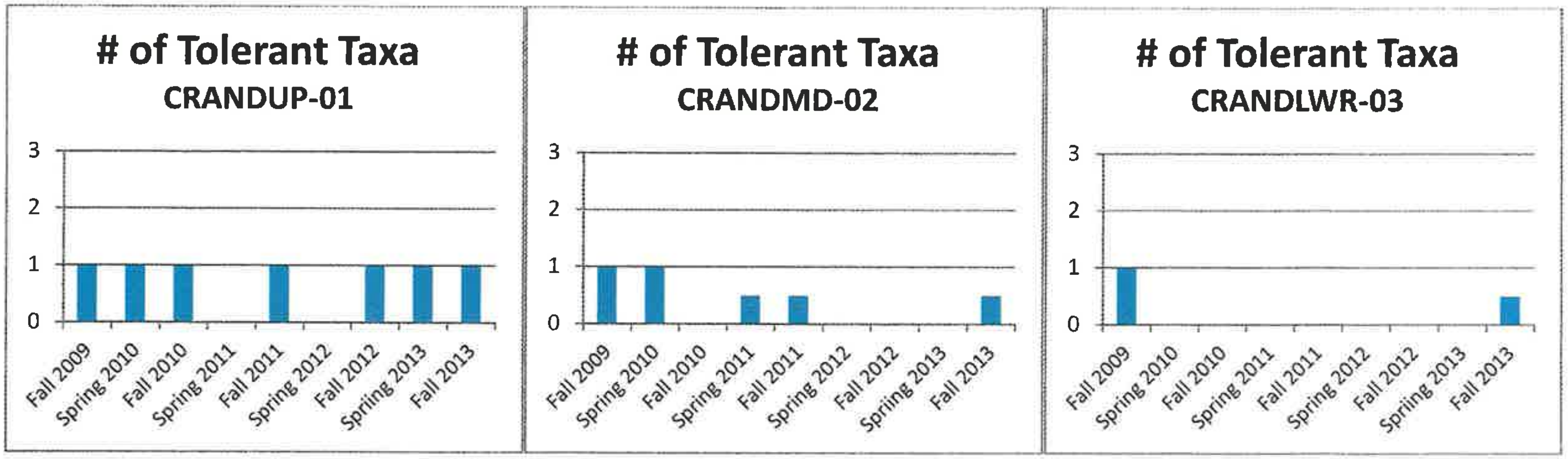
Figures 32c. Average percent Chironomids in each reach from Fall 2009- Fall 2013



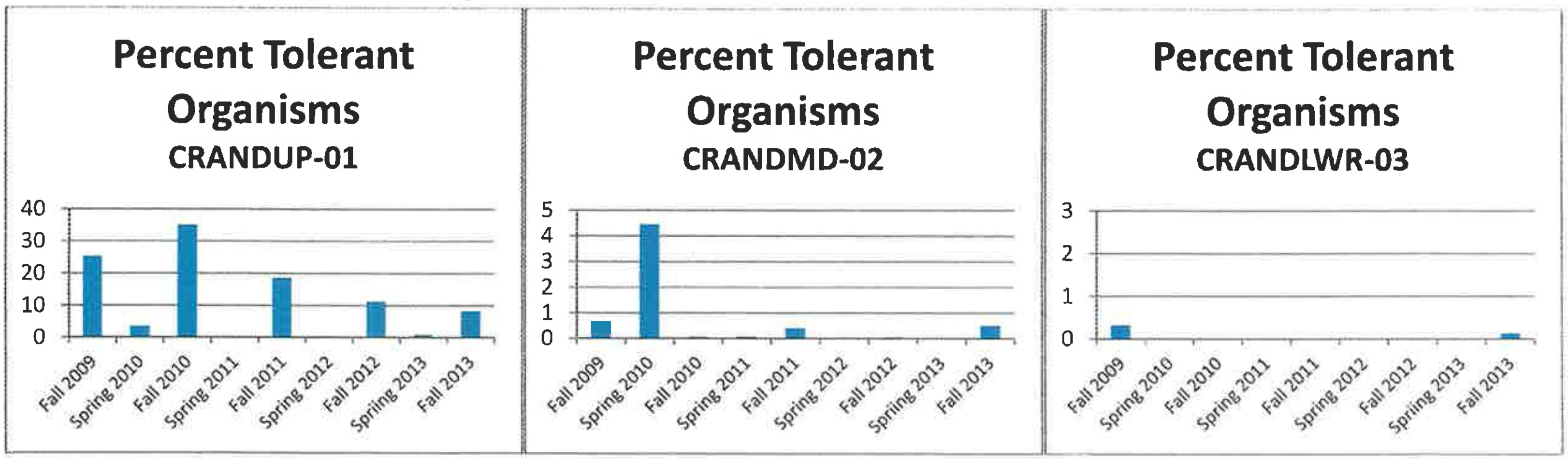
Figures 33c. Average ratio of EPT to Chironomids in each reach from Fall 2009- Fall 2013



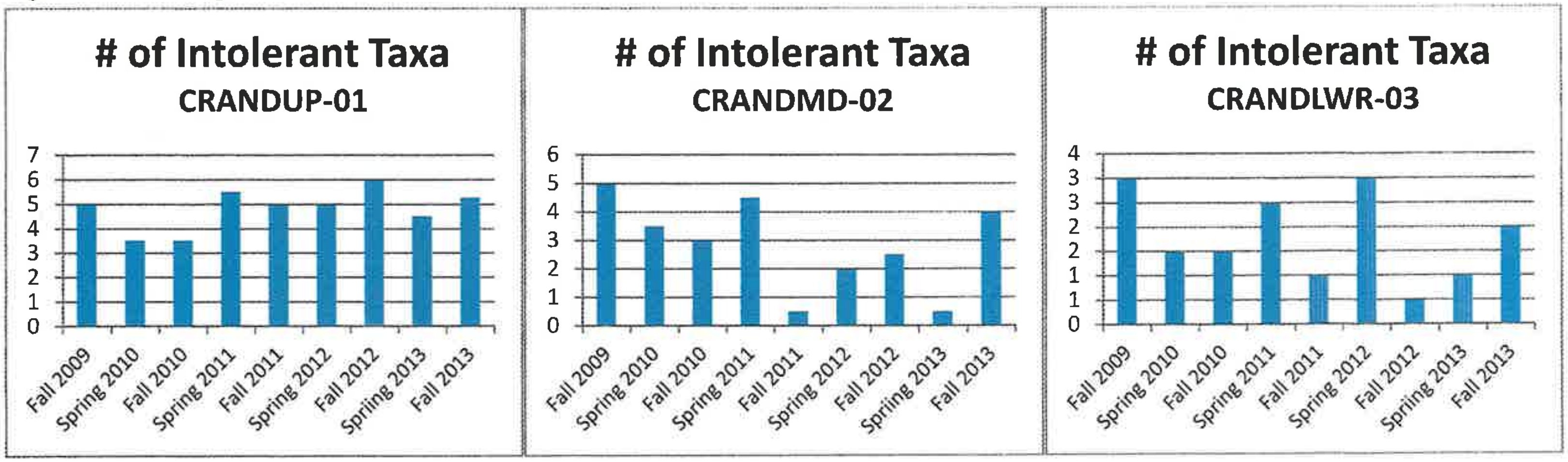
Figures 34c. Average number of tolerant taxa in each reach from Fall 2009- Fall 2013



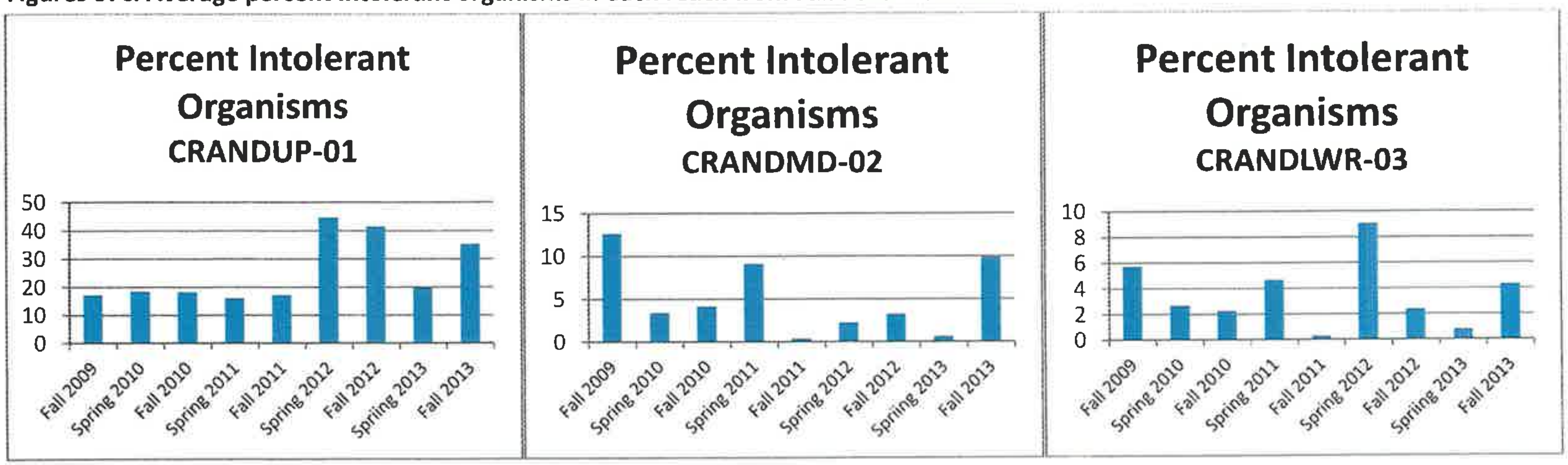
Figures 35c. Average percent tolerant organisms in each reach from Fall 2009- Fall 2013



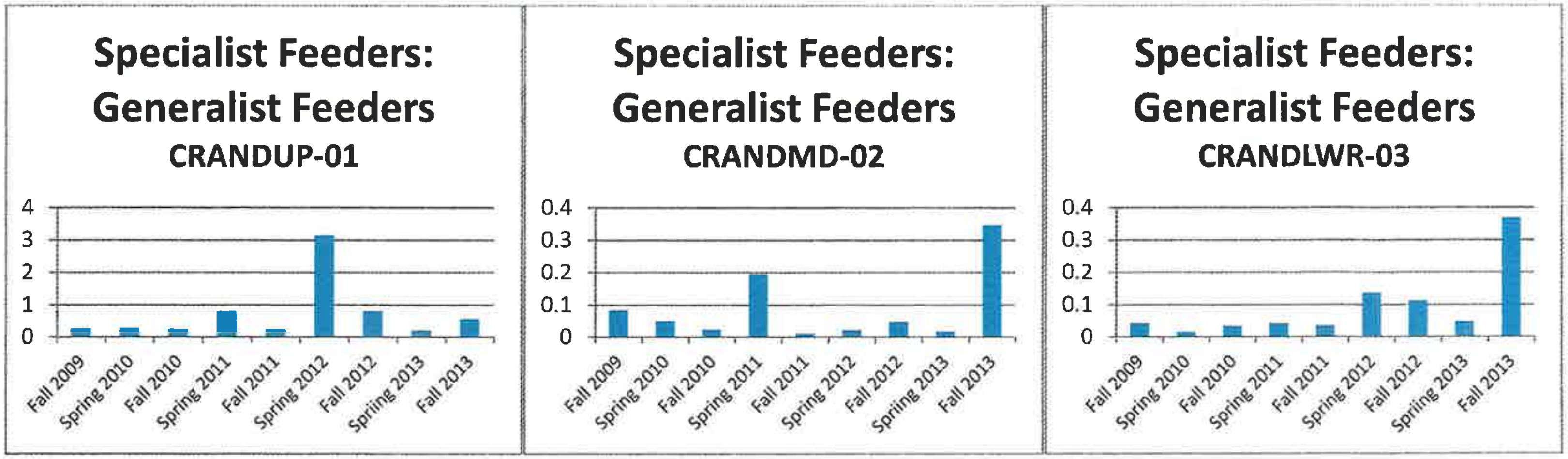
Figures 36c. Average number of intolerant taxa in each reach from Fall 2009- Fall 2013



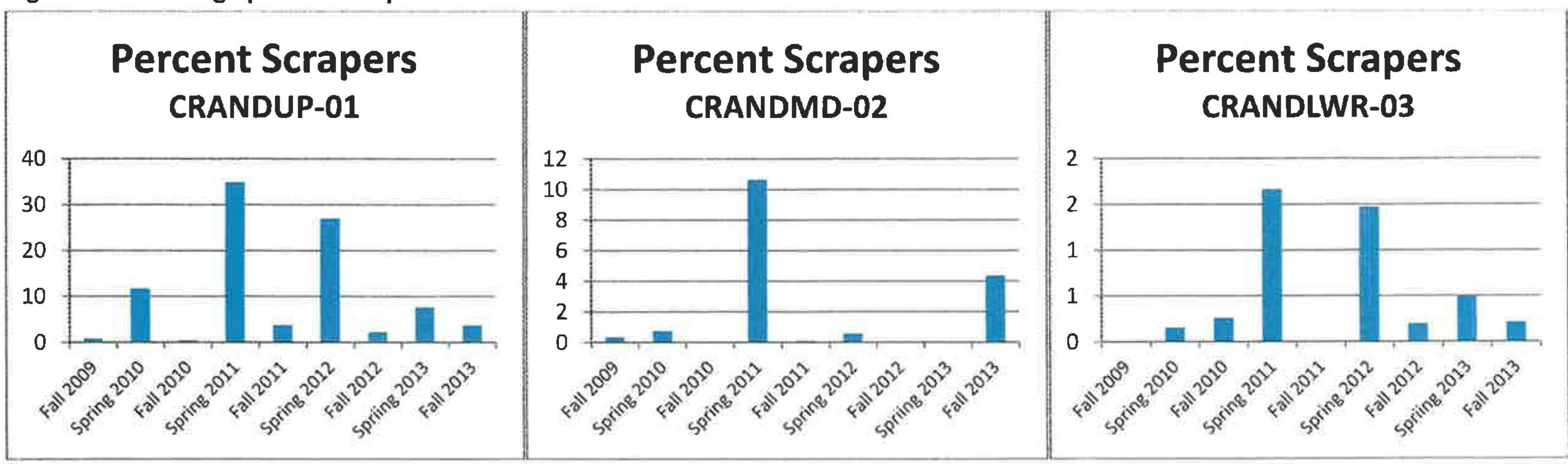
Figures 37c. Average percent intolerant organisms in each reach from Fall 2009- Fall 2013



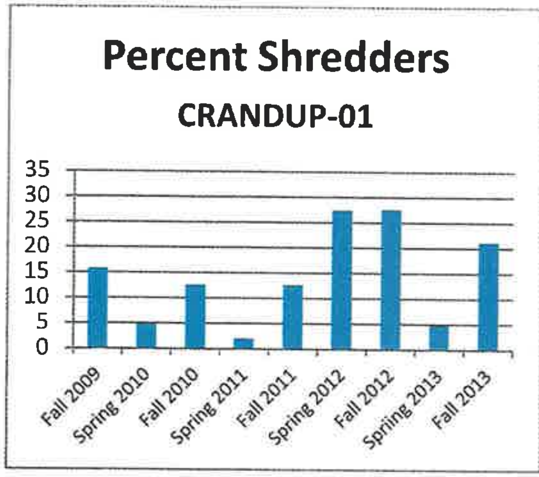
Figures 38c. Average ratio of specialist feeders to generalist feeders in each reach from Fall 2009- Fall 2013

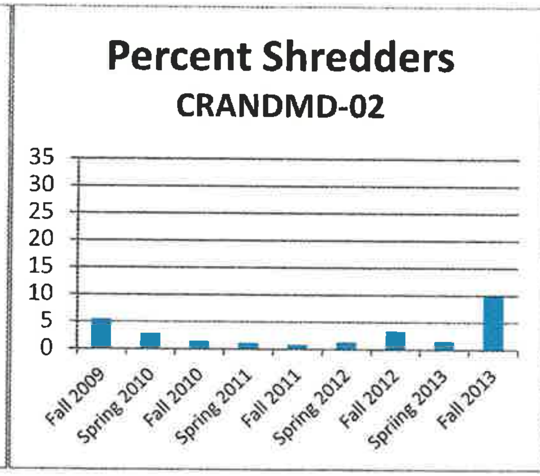


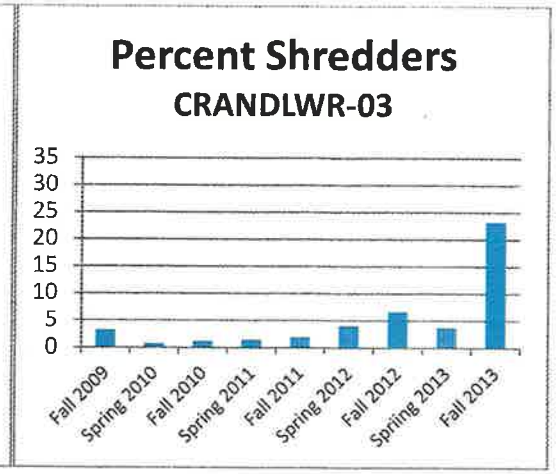
Figures 39c. Average percent scrapers in each reach from Fall 2009- Fall 2013



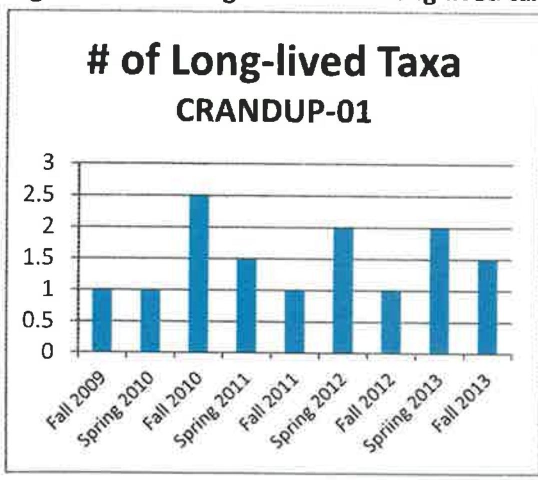
Figures 40c. Average percent shredders in each reach from Fall 2009- Fall 2013

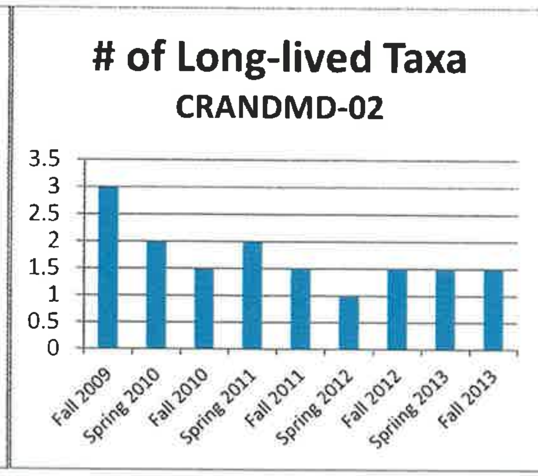


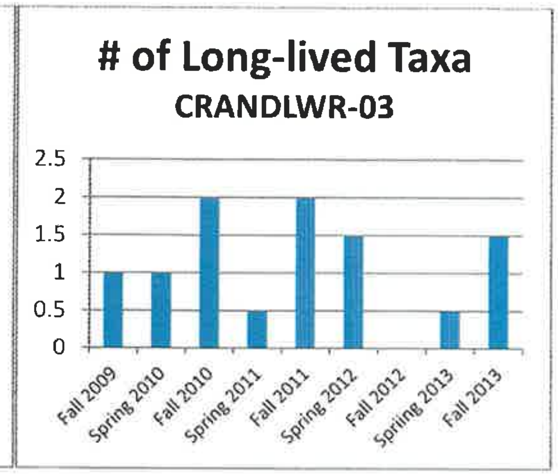




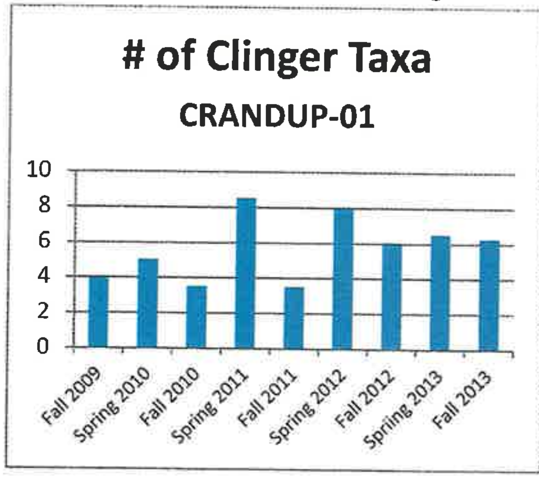
Figures 41c. Average number of long-lived taxa in each reach from Fall 2009- Fall 2013

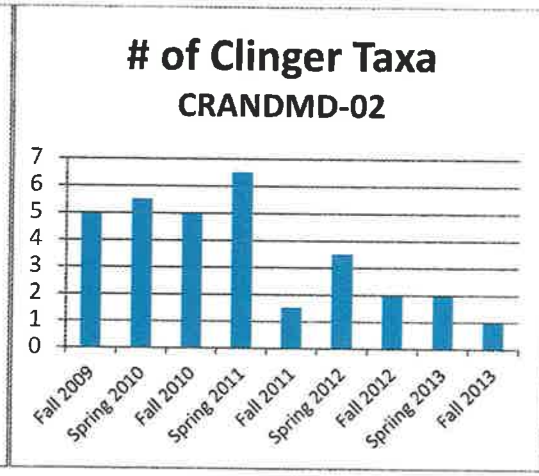


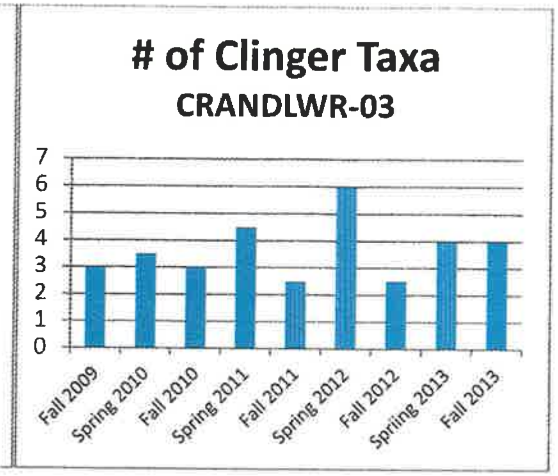




Figures 42c. Average number of clinger taxa reach from Fall 2009- Fall 2013







Taxa Lists for Individual Samples

Following is the taxonomic list and the number of individuals found of each species for the 6 samples collected on September 20 & 23, 2013. The count is the total number of individuals found, identified, and retained for future reference.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	57
Arthropoda	Arachnida	Trombidiformes					Adult	2
			Lebertiidae		Lebertia		Adult	93
			Sperchonidae		Sperchon		Adult	30
	Insecta	Coleoptera	Dytiscidae				Larvae	2
		Coleoptera	Elmidae		Narpus	concolor	Larvae	4
		Diptera	Ceratopogonidae	Dasyheleinae	Dasyhelea		Larvae	2
			Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	28
		Diptera	Chironomidae	Chironominae			Larvae	24
			Chironomidae	Orthocladiinae			Larvae	76
			Chironomidae	Tanypodinae			Larvae	33
			Empididae				Pupae	2
			Empididae	Hemerodromiinae	Chelifera		Larvae	7
			Psychodidae		Pericoma		Larvae	67
			Simuliidae	Simuliinae	Simulium		Larvae	2
			Stratiomyidae		Caloparyphus		Larvae	113
			Tipulidae		Dicranota		Larvae	11
			Tipulidae	Limoniinae	Limnophila		Larvae	7
			Tipulidae	Tipulinae	Tipula		Larvae	9
		Ephemeroptera	Baetidae		Baetis		Larvae	128
			Baetidae		Diphetor	hageni	Larvae	24
			Ephemerellidae				Larvae	28
			Ephemerellidae		Drunella	grandis	Larvae	150
			Heptageniidae				Larvae	152
			Leptophlebiidae		Paraleptophlebia		Larvae	9
			Ameletidae		Ameletus		Larvae	35
		Plecoptera	Capniidae	Capniinae			Larvae	2
			Chloroperlidae		Sweltsa		Larvae	7
			Nemouridae				Larvae	7
			Nemouridae		Zapada		Larvae	102
			Nemouridae		Zapada		Larvae	4
			Nemouridae		Zapada	cinctipes	Larvae	2
			Perlodidae				Larvae	9
			Perlodidae		Megarcys	signata	Larvae	2
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche		Larvae	17
			Limnephilidae				Larvae	2
			Uenoidae		Oligophlebodes		Larvae	7
			Rhyacophilidae		Rhyacophila		Larvae	4
			Rhyacophilidae		Rhyacophila	vofixa gro	Larvae	76
	Arachnida	Trombidiformes	Sperchonidae		Sperchonopsis		Adult	2
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	41
Platyhelminthes	Turbellaria						Adult	61
Total:	OTU Taxa:	**42**	Genera:	**28**	Families:	**26**		**1441**

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected September 20, 2013 at the station CRANDUP-01, Crandall Creek, Upstream, Emery County, Utah. The sample was collected from the reachwide habitat using a Kick Net. The total area sampled was 0.46 square meters. Of the collected sample, 100% was identified and retained. A total of 663 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150594. OTU= Operational Taxonomic Unit

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes					Adult	17
			Lebertiidae		Lebertia		Adult	72
			Sperchonidae		Sperchon		Adult	12
	Insecta	Coleoptera	Elmidae		Optioservus		Adult	15
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	25
			Chironomidae	Chironominae			Larvae	209
			Chironomidae	Orthocladiinae			Larvae	358
			Chironomidae	Tanypodinae			Larvae	12
			Empididae	Hemerodromiinae			Larvae	15
			Empididae		Neoplasta		Larvae	17
			Empididae		Wiedemannia		Larvae	10
			Empididae				Larvae	2
			Psychodidae		Pericoma		Larvae	15
			Ptychopteridae		Ptychoptera		Larvae	2
			Simuliidae	Simuliinae	Simulium		Larvae	5
			Tipulidae	Tipulinae	Tipula		Larvae	22
		Ephemeroptera	Ameletidae		Ameletus		Larvae	29
			Baetidae		Baetis		Larvae	50
			Baetidae		Diphetor		Larvae	157
			Ephemerellidae		Drunella	cinctipes	Larvae	5
			Ephemerellidae		Ephemerella		Larvae	2
			Heptageniidae				Larvae	2
			Heptageniidae		Cinygmula		Larvae	56
			Heptageniidae		Epeorus		Larvae	116
			Leptophlebiidae				Larvae	57
		Plecoptera					Larvae	5
			Nemouridae		Zapada		Larvae	15
			Perlodidae				Larvae	2
			Perlodidae	Isoperlinae	Isoperla		Larvae	30
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche	hageni	Larvae	12
			Limnephilidae				Larvae	12
			Rhyacophilidae		Rhyacophila		Larvae	87
			Rhyacophilidae		Rhyacophila		Larvae	96
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	35
Nemata							Adult	2
Platyhelminthes	Turbellaria						Adult	2
Total:	OTU Taxa:	**36**	Genera:	**22**	Families:	**26**		**1580**

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected September 20, 2013 at the station CRANDUP-01, Crandall Creek, Upstream, Emery County, Utah. The sample was collected from the targeted riffle habitat using a Kick Net. The total area sampled was 0.74 square meters. Of the collected sample, 100% was identified and retained. A total of 727 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150595. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	20
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		Arrenurus		Adult	4
			Hygrobatidae		Lebertia		Adult	5
			Lebertiidae		Lebertia		Adult	76
			Sperchonidae		Sperchon		Adult	16
	Insecta	Coleoptera	Dytiscidae		Oreodytes		Larvae	1
			Elmidae		Optioservus	quadrimaculatus	Adult	4
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	11
			Chironomidae	Chironominae	Narpus	concolor	Larvae	86
			Chironomidae	Orthocladiinae	Optioservus	quadrimaculatus	Larvae	268
			Chironomidae	Tanypodinae			Larvae	15
			Empididae				Pupae	1
			Empididae	Hemerodromiinae	Chelifera		Larvae	4
			Empididae		Neoplasta		Larvae	3
			Psychodidae		Pericoma		Larvae	31
			Tipulidae		Dicranota		Larvae	5
			Tipulidae	Limoniinae	Limnophila		Larvae	1
			Tipulidae		Pedicia		Larvae	1
			Tipulidae	Tipulinae	Tipula		Larvae	9
		Ephemeroptera	Baetidae		Baetis		Larvae	41
			Baetidae		Diphetor	hageni	Larvae	18
			Ephemerellidae		Drunella	grandis	Larvae	3
			Ephemerellidae				Larvae	11
			Heptageniidae				Larvae	45
			Heptageniidae		Cinygmula		Larvae	16
			Leptophlebiidae		Paraleptophlebia		Larvae	76
			Ameletidae		Ameletus		Larvae	15
			Capniidae	Capniinae			Larvae	8
			Chloroperlidae		Plumiperla		Larvae	1
			Chloroperlidae		Sweltsa		Larvae	1
			Nemouridae		Zapada		Larvae	3
			Nemouridae		Zapada		Larvae	1
			Nemouridae		Zapada	cinctipes	Larvae	42
			Perlodidae				Larvae	23
			Perlodidae		Megarcys	signata	Larvae	3
			Perlodidae	Perlodinae	Diura	knowltoni	Larvae	1
		Trichoptera	Limnephilidae				Larvae	14
			Limnephilidae	Limnephilinae	Hesperophylax		Larvae	4
			Rhyacophilidae		Rhyacophila	vofixa group	Larvae	35
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	43
Nemata							Adult	7
Platyhelmint	Turbellaria						Adult	8
OTU Taxa:	**44**	Genera:	**29**	Families:	**23**			**982**

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected September 20, 2013 at the station CRANDMD-02, Crandall Creek, Midstream, Emery County, Utah. The sample was collected from the reachwide habitat using a Kick Net. The total area sampled was 0.46 square meters. Of the collected sample, 100% was identified and retained. A total of 211 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150596. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	65
Arthropoda	Arachnida	Trombidiformes					Adult	9
Arthropoda	Arachnida	Trombidiformes	Hygrobatidae				Adult	4
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	61
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hydroporinae	Oreodytes		Adult	13
Arthropoda	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	4
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae			Larvae	9
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae			Larvae	35
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae			Larvae	85
Arthropoda	Insecta	Diptera	Empididae	Hemerodromiinae	Chelifera		Larvae	4
Arthropoda	Insecta	Diptera	Tabanidae				Larvae	4
Arthropoda	Insecta	Diptera	Tipulidae		Dicranota		Larvae	2
Arthropoda	Insecta	Diptera	Tipulidae	Tipulinae	Tipula		Larvae	4
Arthropoda	Insecta	Ephemeroptera	Baetidae				Larvae	4
Arthropoda	Insecta	Ephemeroptera	Baetidae		Baetis		Larvae	22
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae				Larvae	4
Arthropoda	Insecta	Ephemeroptera	Heptageniidae				Larvae	24
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae		Paraleptophlebia		Larvae	15
Arthropoda	Insecta	Plecoptera	Capniidae	Capniinae			Larvae	11
Arthropoda	Insecta	Plecoptera	Leuctridae				Larvae	2
Arthropoda	Insecta	Plecoptera	Perlodidae				Larvae	2
Arthropoda	Insecta	Trichoptera	Limnephilidae				Larvae	24
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilinae	Hesperophylax		Larvae	7
Arthropoda	Insecta	Diptera	Ceratopogonidae	Forcipomyiinae	Atrichopogon		Larvae	2
Arthropoda	Insecta	Diptera	Stratiomyidae		Caloparyphus		Larvae	2
Arthropoda	Insecta	Ephemeroptera	Baetidae		Diphetor	hageni	Larvae	4
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	17
Arthropoda	Insecta	Plecoptera	Nemouridae		Zapada	cinctipes	Larvae	2
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		Arrenurus		Adult	15
OTU Taxa:	**29**	Genera:	**15**	Families:	**20**			**459**

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected September 20, 2013 at the station CRANDMD-02, Crandall Creek, Midstream, Emery County, Utah. The sample was collected from the targeted riffle habitat using a Kick Net. The total area sampled was 0.74 square meters. Of the collected sample, 100% was identified and retained. A total of 220 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150597. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	5
Arthropoda	Arachnida	Trombidiformes					Adult	4
			Lebertiidae		Lebertia		Adult	34
			Sperchonidae		Sperchon		Adult	9
Arthropoda	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	15
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	11
			Ceratopogonidae	Forcipomyiinae	Atrichopogon		Larvae	1
			Chironomidae				Pupae	5
			Chironomidae	Chironominae			Larvae	1
			Chironomidae	Orthocladiinae			Larvae	46
			Chironomidae	Tanypodinae			Larvae	12
			Empididae		Neoplasta		Larvae	3
			Empididae	Hemerodromiinae	Chelifera		Larvae	9
			Psychodidae		Pericoma		Larvae	4
			Stratiomyidae		Caloparyphus		Larvae	12
			Stratiomyidae		Euparyphus		Larvae	1
			Tabanidae		Tabanus		Larvae	1
			Tipulidae		Dicranota		Larvae	1
			Tipulidae	Limoniinae	Limnophila		Larvae	1
			Tipulidae	Tipulinae	Tipula		Larvae	1
		Ephemeroptera	Baetidae		Baetis		Larvae	55
			Baetidae		Diphetor	hageni	Larvae	1
			Heptageniidae				Larvae	9
			Leptophlebiidae		Paraleptophlebia		Larvae	18
		Plecoptera	Capniidae	Capniinae			Larvae	11
			Chloroperlidae		Sweltsa		Larvae	1
			Nemouridae		Zapada	cinctipes	Larvae	3
			Perlodidae				Larvae	4
		Trichoptera	Limnephilidae				Larvae	11
			Rhyacophilidae		Rhyacophila		Larvae	1
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	3
OTU Taxa:	31	Genera:	21	Families:	19			297

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected September 23, 2013 at the station CRANDLWR-03, Crandall Creek, Lower, Emery County, Utah. The sample was collected from the reachwide habitat using a Kick Net. The total area sampled was 0.46 square meters. Of the collected sample, 100% was identified and retained. A total of 530 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150598. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	109
Arthropoda	Arachnida	Trombidiformes					Adult	2
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	11
Arthropoda	Arachnida	Trombidiformes	Hydryphantidae		Protzia		Adult	2
Arthropoda	Arachnida	Trombidiformes	Sperchonidae		Sperchon		Adult	20
Arthropoda	Insecta	Coleoptera	Elmidae				Larvae	9
Arthropoda	Insecta	Diptera	Chironomidae				Pupae	4
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae			Larvae	17
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae			Larvae	54
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae			Larvae	15
Arthropoda	Insecta	Diptera	Empididae	Hemerodromiinae	Chelifera		Larvae	2
Arthropoda	Insecta	Diptera	Psychodidae		Pericoma		Larvae	2
Arthropoda	Insecta	Diptera	Simuliidae				Pupae	2
Arthropoda	Insecta	Diptera	Simuliidae	Simuliinae	Simulium		Larvae	20
Arthropoda	Insecta	Diptera	Tipulidae	Limoniinae	Antocha	monticola	Larvae	2
Arthropoda	Insecta	Diptera	Tipulidae		Dicranota		Larvae	17
Arthropoda	Insecta	Diptera	Tipulidae	Tipulinae	Tipula		Larvae	20
Arthropoda	Insecta	Ephemeroptera	Baetidae				Larvae	26
Arthropoda	Insecta	Ephemeroptera	Baetidae		Baetis		Larvae	107
Arthropoda	Insecta	Ephemeroptera	Baetidae		Callibaetis		Larvae	4
Arthropoda	Insecta	Ephemeroptera	Heptageniidae				Larvae	2
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae				Larvae	4
Arthropoda	Insecta	Plecoptera	Chloroperlidae		Sweltsa		Larvae	2
Arthropoda	Insecta	Plecoptera	Perlodidae				Larvae	20
Arthropoda	Insecta	Plecoptera	Perlodidae	Isoperlinae	Isoperla		Larvae	13
Arthropoda	Insecta	Trichoptera	Brachycentridae		Brachycentrus		Larvae	7
Arthropoda	Insecta	Trichoptera	Hydropsychidae				Larvae	4
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae	Hydropsyche		Larvae	39
Arthropoda	Insecta	Trichoptera	Hydroptilidae				Larvae	2
Arthropoda	Insecta	Trichoptera	Hydroptilidae				Pupae	2
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	Hydroptila		Larvae	2
Arthropoda	Insecta	Trichoptera	Limnephilidae				Larvae	272
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilinae	Hesperophylax		Larvae	9
Cnidaria	Hydrozoa						Adult	20
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	46
Arthropoda	Insecta	Diptera	Tipulidae	Limoniinae	Ormosia		Larvae	2
Arthropoda	Insecta	Ephemeroptera	Baetidae		Diphetor	hageni	Larvae	250
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	4
Arthropoda	Insecta	Diptera	Empididae		Neoplasta		Larvae	7
OTU Taxa:	**38**	Genera:	**22**	Families:	**20**			**1152**

The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected September 23, 2013 at the station CRANDLWR-03, Crandall Creek, Lower, Emery County, Utah. The sample was collected from the targeted riffle habitat using a Kick Net. The total area sampled was 0.74 square meters. Of the collected sample, 100% was identified and retained. A total of 182 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 150599. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	3
Arthropoda	Arachnida	Trombidiformes	Sperchonidae		Sperchon		Adult	3
Arthropoda	Insecta	Coleoptera	Haliplidae		Brychius		Larvae	1
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae			Larvae	12
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae			Larvae	1
Arthropoda	Insecta	Diptera	Dixidae		Dixa		Larvae	1
Arthropoda	Insecta	Diptera	Empididae	Hemerodromiinae	Chelifera		Larvae	1
Arthropoda	Insecta	Diptera	Simuliidae	Simuliinae	Simulium		Larvae	1
Arthropoda	Insecta	Diptera	Tabanidae				Larvae	4
Arthropoda	Insecta	Diptera	Tabanidae		Tabanus		Larvae	1
Arthropoda	Insecta	Diptera	Tipulidae				Larvae	3
Arthropoda	Insecta	Diptera	Tipulidae		Dicranota		Larvae	8
Arthropoda	Insecta	Diptera	Tipulidae		Hexatoma		Larvae	1
Arthropoda	Insecta	Diptera	Tipulidae	Tipulinae	Tipula		Larvae	15
Arthropoda	Insecta	Ephemeroptera	Baetidae				Larvae	5
Arthropoda	Insecta	Ephemeroptera	Baetidae		Baetis		Larvae	86
Arthropoda	Insecta	Ephemeroptera	Baetidae		Callibaetis		Larvae	1
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae				Larvae	1
Arthropoda	Insecta	Plecoptera	Chloroperlidae		Sweltsa		Larvae	1
Arthropoda	Insecta	Plecoptera	Perlodidae				Larvae	5
Arthropoda	Insecta	Plecoptera	Perlodidae	Isoperlinae	Isoperla		Larvae	5
Arthropoda	Insecta	Trichoptera	Hydropsychidae				Larvae	3
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychinae	Hydropsyche		Larvae	20
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae	Hydroptila		Larvae	1
Arthropoda	Insecta	Trichoptera	Limnephilidae				Larvae	4
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilinae	Hesperophylax		Larvae	3
Arthropoda	Insecta	Trichoptera	Rhyacophilidae		Rhyacophila		Larvae	1
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	30
Arthropoda	Insecta	Ephemeroptera	Baetidae		Diphetor	hageni	Larvae	16
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	3
Arthropoda	Insecta	Coleoptera	Elmidae		Optioservus	quadrimaculatus	Adult	1

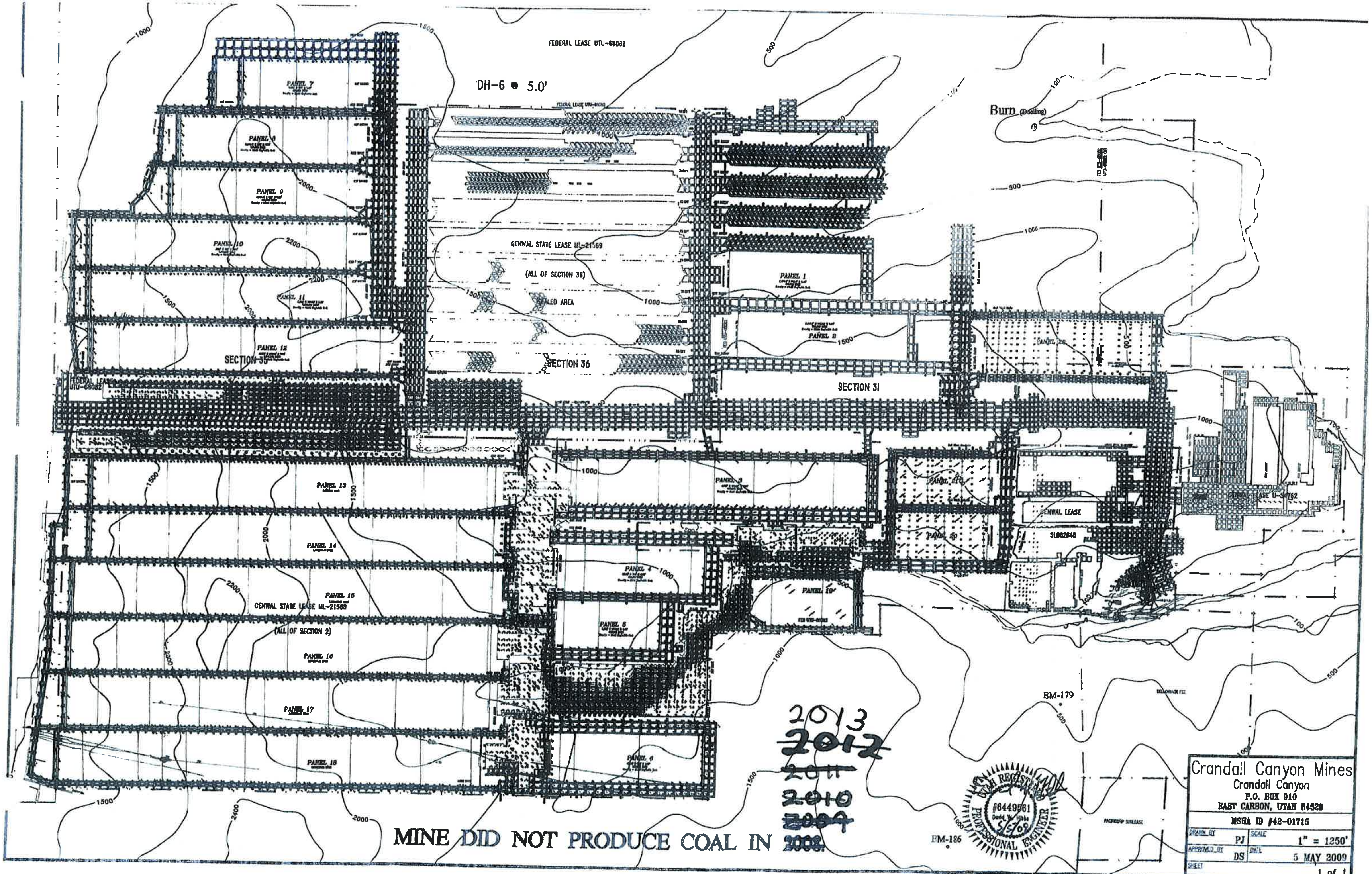
OTU Taxa:	31	Genera:	21	Families:	20

2013

ANNUAL REPORT

MINE

MAP


FEDERAL LEASE UTU-68082
DH-6 ● 5.0'
Burn
PANEL 7
PANEL 8
PANEL 9
PANEL 10
PANEL 11
PANEL 12
SECTION 35
FEDERAL LEASE UTU-68082
GENWAL STATE LEASE ML-21569
(ALL OF SECTION 36)
SEALED AREA
SECTION 36
PANEL 1
PANEL 2
SECTION 31
PANEL 3
GENWAL LEASE
SL062648
PANEL 13
PANEL 14
PANEL 4
PANEL 15
GENWAL STATE LEASE ML-21568
(ALL OF SECTION 2)
PANEL 5
PANEL 16
PANEL 17
PANEL 18
PANEL 6
BM-179
BM-186
2013
2012
2011
2010
2009
MINE DID NOT PRODUCE COAL IN 2008.
PROFESSIONAL ENGINEER
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