GENWAL™ RESOURCES, INC.

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

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

March 2, 2015

Attn: Daron Haddock
Permit Supervisor

Re: Crandall Canyon Mines, C/015/032
2014 Annual Report

Dear Mr. Haddock,

Attached you will find the 2014 Annual Report for the Crandall Canyon Mines.

If you have any questions, or need any additional information regarding this submittal, please contact me directly at 435-888-4000.

Sincerely,

David Hibbs
UtahAmerican Energy, Inc.
President/Chief Engineer

2014

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	
Operator Name		Phone Number	
Mailing Address		Email	
City			
State		Zip Code	

		DOGM File Location or Annual Report Location
Excess Spoil Piles	☐ Required ☒ Not Required	
Refuse Piles	☐ Required ☒ Not Required	
Impoundments	☒ Required ☐ Not Required	Sediment Pond annual certification is included.
Other:		

OPERATOR COMMENTS

REVIEWER COMMENTS ☐ Met Requirements ☐ Did Not meet Requirements

COMMITMENTS AND CONDITIONS

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

Title: MACROINVERTEBRATE SAMPLING
Objective: To monitor macroinvertebrate populations in Crandall Creek
Frequency: 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

Macroinvertebrate Study results included in Annual Report.

Reviewer Comments ☐ Met Requirements ☐ Did Not Meet Requirements

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

Operator Comments

Included in Annual Report.

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)

REVIEWER COMMENTS

REPORTING OF OTHER TECHNICAL DATA

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

Please list attachments:

Reviewer Comments

MAPS

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

Map Name	Map Number	Included		Confidential	
		Yes	No	Yes	No
Annual subsidence map	Not Required	☐	☒	☐	☒
Mine Map	Included at end of Report	☒	☐	☐	☒
		☐	☐	☐	☐
		☐	☐	☐	☐
		☐	☐	☐	☐

Reviewer Comments ☐ Met Requirements ☐ Did Not Meet Requirements

2014

Annual Report

Sediment Information

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT		Page 1 of

Permit Number	ACT/015/032	**Report Date**	November 4th, 2014
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 4th, 2014
Inspected By	Karin Odendahl
Reason for Inspection (Annual, Quarterly or Other Periodic Inspection, Critical Installation, or Completion of Construction)	4th Quarter, 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:

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

Pond is evaporating as designed. At time of inspection pond had approximately 2 feet of water.

Approximate sediment level is 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.

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 functioning as designed and is currently dry. 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:** [signature] **Date:** 11·4·14

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.

P.E. Stamp: REGISTERED PROFESSIONAL ENGINEER #152606 R. JAY MARSHALL STATE OF UTAH 11/19/14

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

Signature: R. Jay Marshall Date: 11/19/14

P.E. Number & State: 152606 Utah

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT		

Permit Number	Permit Number: 015/032	**Report Date**	November 4th 2014
Mine Name	Crandall Canyon Mine		
Company Name	UtahAmerican Energy, Inc.		
Impoundment Identification	**Impoundment Name**	Lower Sediment Pond	
	Impoundment Number	None	
	UPDES Permit Number	UT0024368	
	MSHA ID Number	None for the Pond	

IMPOUNDMENT INSPECTION

Inspection Date	November 4th 2014
Inspected By	Karin Odendahl
Reason for Inspection (Annual, Quarterly or Other Periodic Inspection, Critical Installation, or Completion of Construction)	4th Quarter, Annual

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

No appearance of instability, structural weakness, or any other hazardous condition was observed at the time of inspection.

Required for an impoundment which functions as a SEDIMENTATION POND.

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

Sediment Elevations:

60%	7769.0'
100%	7770.0'

Sediment levels are below clean-out limit. Sediment level is approximately 7760'

3. Principle and emergency spillway elevations.

Principle	7780.81'
Emergency	7781.81'

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

Water is below maximum water elevation, highwater markers are visible.

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

No observable problems exist at the inlets or outlets.

Vegetation surrounding the pond is healthy.

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

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

Qualification Statement	I hereby certify that; I am experienced in the construction of impoundments; I am qualified and authorized under the direction of a Registered Professional Engineer to inspect the condition and appearance of impoundments in accordance with the certified and approved designs for this structure; that the impoundment has been maintained in accordance with approved design and meet or exceed the minimum design requirements under all applicable federal, state and local regulations; and, that inspections and inspection reports are made by myself and include any appearances of instability, structural weakness or other hazardous conditions of the structure affecting stability. **Signature:** [signature] **Date:** 11·4·14

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

Three cleanout stakes were installed according to the approved plan. The green color is from the bottom of the pond up to the 60% cleanout elevation of 7769'. The yellow color goes from the bottom of the 60% cleanout level of 7769' to the maximum cleanout level of 7770'. Above the 7770' mark to the top of the pipe 7773.2' is red in color. This color scheme clearly shows the cleanout elevations and the do not exceed water elevation of 7773.2.

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

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.

[P.E. Cert. Stamp]

REGISTERED PROFESSIONAL ENGINEER #152606 R. JAY MARSHALL 11/19/17 STATE OF UTAH

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

Signature: R Jay Marshall Date: 11/19/17

P.E. Number & State: 152606 Utah

2014

Annual Report

Subsidence Information

UtahAmerican Energy, Inc.

Crandall Canyon Mine - Subsidence Survey

11/3/2014

YEAR			2004	2007	2008	2009	2010	2011	2012	2013	2014
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (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	10439.44
B	413095.74	2080610.92	10426.40	10425.43	10425.40	10425.41	10425.38	10425.41	10425.40	10425.37	10425.40
C	412995.22	2080594.07	10412.27	10411.20	10411.23	10411.23	10411.16	10411.18	10411.17	10411.20	10411.16
D	412897.30	2080578.76	10400.21	10399.21	10399.25	10399.18	10399.23	10399.24	10399.21	10399.27	10399.23
E	412795.72	2080563.91	10385.11	10384.15	10384.18	10384.13	10384.16	10384.17	10384.18	10384.15	10384.14
J	412296.72	2080487.65	10323.47	10323.29	10323.20	10323.15	10323.26	10323.18	10323.19	10323.22	10323.22
N	411898.88	2080428.44	10313.15	10313.15	10313.13	10313.16	10313.16	10313.16	10313.10	10313.17	10313.15
O	411798.12	2080415.52	10316.56	10316.49	10316.50	10316.56	10316.52	10316.56	10316.57	10316.55	10316.53
P	411700.03	2080403.24	10321.64	10321.65	10321.65	10321.69	10321.66	10321.65	10321.64	10321.63	10321.65
Q	411599.74	2080390.76	10326.61	---	---	---	---	10326.53	10326.53	10326.56	10326.55
R	411550.40	2080383.83	10330.17	---	---	---	---	10330.15	10330.08	10330.11	10330.09
S	411501.07	2080376.56	10333.65	---	---	---	---	10333.51	10333.57	10333.54	10333.52
T	411399.27	2080366.35	10342.83	---	---	---	---	10342.74	10342.75	10342.77	10342.74
U	411299.82	2080354.19	10349.80	---	---	---	---	10349.68	10349.64	10349.69	10349.68
V	411247.57	2080350.11	10353.81	---	---	---	---	10353.84	10353.77	10353.80	10353.81
W	411198.08	2080343.54	10358.03	---	---	---	---	10357.94	10357.98	10357.93	10357.96
X	411147.67	2080337.97	10360.97	---	---	---	---	10360.78	10360.89	10360.83	10360.81
Y	411097.90	2080332.61	10365.90	---	---	---	---	10365.78	10365.84	10365.85	10365.85
Z	411044.53	2080331.80	10371.01	---	---	---	---	10370.93	10371.01	10370.98	10370.99
AA	410994.37	2080331.13	10376.37	---	---	---	---	10376.27	10376.36	10376.34	10376.30
EE	410741.97	2080325.86	10430.72	---	---	---	---	10430.86	10430.97	10430.91	10430.94
GG	410619.62	2080334.65	10435.38	---	---	---	---	10435.09	10435.41	10435.40	10435.43
HH	410508.23	2080321.51	10435.17	---	---	---	---	10435.63	10435.11	10435.18	10435.15
II	410458.36	2080312.15	10433.84	---	---	---	---	10434.29	10433.84	10433.88	10433.82
JJ	410409.35	2080302.79	10433.25	---	---	---	---	10433.73	10433.20	10433.23	10433.20
KK	410359.98	2080292.88	10432.40	---	---	---	---	10432.87	10432.42	10432.40	10432.43
LL	410265.30	2080265.04	10428.65	---	---	---	---	10428.57	10428.47	10428.49	10428.46
NN	409769.08	2080125.54	10347.00	---	---	---	---	10346.66	10346.71	10346.68	10346.70
OO	409498.68	2080210.27	10284.52	---	---	---	---	10284.27	10284.26	10284.29	10284.25
PP	409291.54	2080286.75	10262.98	---	---	---	---	10263.41	10263.41	10263.38	10263.39

WARE SURVEYING & ENGINEERING

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

Phone: 435-613-1266 | 1344 North 1000 West

Email: waresurveying@emerytelcom.net | Price, Utah 84501

UtahAmerican Energy, Inc.

Crandall Canyon Mine

East Mountain Reclaimed Slide Area

11/3/2014

YEAR			2012	2013	2014	
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION DIFFERENCE
Benchmark	413145.90	2079155.88	9986.04	9986.04	9986.04	
1	413105.83	2079216.62	9987.03	9987.03	9987.06	-0.03
2	413079.15	2079242.82	9985.59	9985.45	9985.47	-0.02
3	413068.96	2079262.42	9982.58	9982.37	9981.89	0.48
4	413056.95	2079275.88	9980.12	9979.90	9979.56	0.34
5	413035.54	2079293.43	9979.24	9979.32	9979.33	-0.01
6	413009.81	2079312.22	9977.00	9976.78	9976.80	-0.02
7	413011.56	2079280.20	9967.21	9966.96	9966.95	0.01
8	413027.60	2079264.79	9963.57	9963.59	9963.59	0.00
9	413034.15	2079256.20	9964.10	9964.16	9964.10	0.06
10	413040.75	2079245.24	9963.48	9963.28	9963.28	0.00
11	413044.33	2079234.13	9966.05	9965.95	9965.88	0.07
12	413048.37	2079223.30	9963.67	9963.62	9963.63	-0.01
13	413025.61	2079233.40	9954.87	9954.98	9954.97	0.01
14	413020.64	2079240.46	9955.37	9955.31	9955.29	0.02
15	413009.89	2079253.75	9955.08	9955.03	9955.00	0.03
16	412997.97	2079264.46	9957.58	9957.45	9957.46	-0.01
17	412994.73	2079233.22	9945.34	9945.34	9945.35	-0.01
18	413001.96	2079217.74	9940.01	9939.88	9939.91	-0.03
19	412986.19	2079204.91	9928.78	9928.58	9928.57	0.01
20	412960.88	2079205.24	9917.01	9916.98	9916.95	0.03

WARE SURVEYING & ENGINEERING

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

Phone: 435-820-4335

Email: waresurveying@emerytelcom.net

2014

Annual Report

Macro-Invertebrate Study #1

Crandall Canyon Mine Macroinvertebrate Study Spring 2014

November 2014

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 11th and 12th, 2014. 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 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 have lower values 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 (Spring and Fall) to monitor water quality and provide reports documenting the survey results. The first seven surveys were completed by JBR (JBR 2012). They included surveys from the Fall of 2009 until the Fall of 2012. EIS has since completed three more surveys starting in the Spring of 2013. This report provides the results of the Spring survey of 2014. The samples were collected June 11th and 12th, 2014. The samples were then shipped to the BugLab in Logan, Utah for processing, as per UDWQ requirements.

2.0 SITE LOCATIONS AND DESCRIPTION

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

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

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

CRANDUP-01 June 12th, 2014 - Upstream

CRANDMD-02 June 11th, 2014 - Upstream

CRANDLWR-03 June 11th, 2014 - 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, C, and D. Some of these graphs include a breakdown of predominant taxonomic groups, graphs of the different diversity and biotic indices, abundances, total taxa richness, EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa richness, individual taxa richness, Tolerant and Intolerant taxa richness, percent richness, Hilsenhoff Biotic Index, different functional feeding group richnesses, and abundances. As mentioned in previous reports, no one metrics can be used to explain the potential influences the mine may have on the creek. Multiple metrics were used as in previous years to compare data from site to site and year to year. Descriptions of why these values are beneficial are below and have been taken directly out of the Bug Labs report (Judson and Miller 2013)

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

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

EPT- A summary of the taxonomic richness and abundance within the insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT). These orders are commonly considered sensitive to pollution (Karr and Chu 1998, as referenced in Judson and Miller 2010).

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

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

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

Clinger taxa- The number of clinger taxa have been found by Karr and Chu (1998, as referenced in Judson and Miller 2010) to respond negatively to human disturbance. These taxa typically cling to the tops of rocks and are thought to be reduced by sedimentation or abundant algal growths.

Long-lived taxa- The number of long-lived taxa was calculated as the number of taxa collected that typically have 2-3 year life cycles. Disturbances and water quality and habitat impairment typically reduces the number of long-lived taxa (Karr and Chu 1998, as referenced in Judson and Miller 2010).

Biotic indices- Biotic indices use the indicator taxa concept. Taxa are assigned water quality tolerance values based on their tolerance to pollution. Scores are typically weighted by taxa relative abundance. In the US, the most commonly used biotic index is the Hilsenhoff Biotic Index (Hilsenhoff 1987 and 1988, as referenced in Judson and Miller 2010). The USFS and BLM throughout the western U.S. have also frequently used the USFS Community Tolerance Quotient.

Hilsenhoff Biotic Index -The Hilsenhoff Biotic Index (HBI) summarizes the overall pollution tolerances of the taxa collected. This index has been used to detect nutrient enrichment, high sediment loads, low dissolved oxygen, and thermal impacts. It is best at detecting organic pollution. Families were assigned an index value from 0 (taxa normally found only in high quality unpolluted water) to 10 (taxa found only in severely polluted waters). Family level values were taken from Hilsenhoff (1987 and 1988, as referenced in Judson and Miller 2010) and a family level HBI was calculated for each sampling location for which there were a sufficient number of individuals and taxa collected to perform the calculations. Sampling locations with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-

10 polluted. Rather than using mean HBI values for a sample, taxon HBI values can also be used to determine the number of pollution intolerant and tolerant taxa occurring at a site. In this report, taxa with HBI values <2 were considered intolerant clean water taxa and taxa with HBI values 2-8 were considered pollution tolerant taxa. The number of tolerant and intolerant taxa and the abundances of tolerant and intolerant taxa were calculated for each sampling location.

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

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

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

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

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

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

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

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

In addition, EIS used the BugLab's data set to calculate several other metrics that JBR also indicated being potentially useful for macroinvertebrate analysis. These are described below.

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

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

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

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

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

4.0 RESULTS & DISCUSSION

The results prepared by the BugLab (Miller 2013) are incorporated into the tables of the following appendices. As with assessment, multiple metrics and datasets should be relied upon to make a finding of whether any impact or nonimpact has occurred between the mine's groundwater discharge and Crandall Creek. This report evaluates this season's individual sample, assesses if spatial and habitat type has an influence among the three reaches sampled, and examines any temporal changes that may be occurring. Numerous metrics should be used in evaluating what may be happening in the creek. In this study, the natural variability of any of these metrics is not known due to limited number of samples sites, absence of replicates, and partial historical baseline information. Therefore, it is difficult to determine whether there is an impact between sites from analyzing only one metric. This section and its associated appendices will review these metrics within this season's individual sample, spatially among each reach and habitat type, and any temporal changes since 2009. Data is compared from the reference reach (CRANDUP-01) to the other two reaches. Additionally, a comparison between the middle reach directly below the mine (CRANDMD-02) and the lowest reach (CRANDLWR-03) can be made to assess the spatial limit and overall condition. The metrics evaluated include the various measurement types recommended by EPA (Barbour et al 1999). They include tolerance indices (HBI, CTQd), diversity (Shannon's), community composition (% EPT), and functional feeding groups (Percent Scraper/Shredders).

Appendix A of the report includes a summarization of the raw and standardized data for the samples collected in June of 2014. The following Appendices B, C, and D graph the previously mentioned metrics to show a visual comparison. Appendix B begins with a graph showing the distribution of the dominate orders within each reach and sample type (Figure 1b) as well as the numerical values (Table 1b). It is followed by numerous graphs that represent the Spring 2014 sample set and show a visual comparison of potential differences between the habitat types as well as spatial variation (Figures 2b-24b). The graphs of Appendix C include all the data gathered since Fall 2009 for temporal comparison among all the samples. They are differentiated by the multi-habitat and target riffle samples for further comparison (Figures 1c-23c). The graphs in Appendix D also contain data since the Fall of 2009; however the values from both the multi-habitats and riffle habitats sample were combined to obtain an average value assess any potential overall trends throughout the years (Figures 24c-42c).

A total of 66 operational taxonomic units (OTU) were identified in the Spring 2014 sample set. There were 34 families and 48 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. In the upper reach the dominate order in both the multi-habitat and riffle habitat were Ephemeroptera making up 50 and 64 percent of the sample, respectively. In the middle reach, Diptera was found to be the most dominate order in both the types of habitat, at 69 and 59 percent, respectively. In the lower reach the dominate order in the multi-habitat was Diptera at 46 percent. In the riffle habitat it was Ephemeroptera at 32 percent (Figure 1b and Table 1b). A dominance of any single order or taxon greater than 50 percent suggests environmental stress, in which the upper and middle reaches exhibited. However, in the upper reach, the dominate order was Ephemeroptera which is commonly considered to be sensitive to pollution (Karr and Chu 1998).

The orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) are commonly considered sensitive to pollution and fluctuation in their abundance can be an indicator of stream health (Karr & Chu 1999). In the upper reach, the orders EPT made up more than half of the taxa in the multi habitat, at 56.1 percent, and a majority of the riffle habitat at 72.3 percent EPT (Figure 9b). In the middle reach directly below the mine, EPT was similar to that of 2013 values, at 26.6 and 33.0 percent of abundance in multi-habitat and riffle samples. In the lower reach, EPT was 45.5 percent in the multi habitat and 39.4 percent in the riffle (Figure 9b). There is an overall increasing trend of these sensitive macroinvertebrate taxa in the upper and lower reaches, indicating improved conditions. The middle reach appears to be maintaining the same percentages as found in the 2012 samples. While it is not as high as the upper reach, it is still higher than percentages found in previous years. In the Fall 2012 the multi-habitat was 1.6 percent and the riffle was 24.3 percent. In the Spring 2012 sample they were 2.8 percent in the multi-habitat and 9.2 percent in the riffle (Figure 8c).

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 5 distinct taxa in each. The middle reach had 2 in each type of habitat. The lower reach multi-habitat had 2 distinct intolerant taxa and the riffle had 3 (Figure 14b). The richness was found to be the greatest in the upper reach with 18 distinct taxa found in each of the habitats the sampled. The middle reach multi-habitat had 16 distinct taxa and the riffle sample had 16. The richness in the lower reach multi-habitat was 13 and was 18 in the riffle habitat (Figure 2b). Because the number of distinct taxa appears to be fluctuating within all reaches and both habitat types year to year, more data is required to find a real discernible trend. These same results were found when evaluating many of the other metrics.

The differences in overall habitat among the three reaches likely influence the result of this study. The upper most reach and the lowest reach have similar substrate size compositions, which was largely bedrock overlaid with larger rocks. The lowest reach had a much more cemented substrate. The lack of interstitial spaces results in poorer habitat conditions for macroinvertebrates (Mize and Deacon 2002). These two reaches were also more narrow than the middle reach as well as had more of a vegetative overstory. It is also important to note the changes in the stream morphology of Crandall Creek when comparing data from previous years. The colonization of beaver and subsequent dams are continuing to change the creek, mainly in the middle reach. The catastrophic impacts to Huntington Creek from major flooding resulting from a major wildfire in 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. Therefore, the spatial comparisons discussed further should consider that there may be an indication of degradation that may be due to these physical attributes, to some extent

4.1 Comparison of Targeted Riffle and Multi-Habitat Samples

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

The graphs in Appendix B display the differences between the two habitats within this dataset (June 2014). As in previous years, 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. For example, the richness in the upstream reach in the multi-habitat was 18 and in the riffle it was the same, 18. In the middle reach, the multi-habitat sample had 16 distinct taxa and the riffle had 17. The lower reach had 13 taxa in the multi-habitat and 18 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 0.62 while the riffle was 0.52, the middle reach the values were 0.57 in the multi and 0.52 in the riffle and in the lower reach they were 0.69 and 0.77, respectively (Figure 4b). In a few cases the one type of habitat may have indicated a better macroinvertebrate habitat than the other. In this dataset, the multi-habitats had much higher abundance of macroinvertebrates than the riffle habitats in the middle section (Figure 5b). However, this is not the case in other years so it does not describe any apparent trend. In addressing any trends or spatial differences, both riffle and multi-habitat results were used.

Shannon's Diversity in upper multi-reach habitat was 1.78 and 1.51 in the riffle habitat. In the middle reach the multi-habitat was 1.58 and the riffle habitat it was 1.46. In the lower reach the multi-habitat was 1.78 and the riffle habitat was 2.24 (Figure 3b). The HBI, which the lower the value indicates less pollution, was 4.36 in the upper reach multi-habitat and 3.87 in the riffle. It was 5.15 and 4.84 in the middle reach, respectively. In the lowest reach, the HBI was 4.63 in the multi-habitat and 2.63 in the riffle (Figure 6b). The CTQd, which a lower the value indicates higher quality unpolluted water as well, was 83 in the upper reach multi-habitat and 75 in the riffle. In the middle reach these values were 96 and 89, respectively. In the lower reach the multi-habitat was 87 and the riffle was 92 (Figure 7b). Appendices A and B has more specific detail on all the values found and metrics graphed for visual comparison.

4.2 Spatial Variation in Macroinvertebrate Community

As mentioned in earlier parts of this report, there were 3 different reaches sampled in Crandall Creek. CRANDUP-01 (upper) is upstream of any potential impact from the mines discharge, CRANDMD-02 (middle) is immediately below the discharge, and CRNDLWR-03 (lower) is further downstream. While many of the metrics graphed indicated a decline in the macroinvertebrate, metrics such as Shannon's Diversity, Evenness, Abundance, and HBI indicated improvement in the middle or lower reaches (Appendix B).

The average richness in the upper reach was found to be 18, in the middle reach there were 16.5 distinct taxa found, and in the lower reach 15.5 (Figure 1d). The average evenness value was 0.57 in the upper reach, 0.54 in the middle reach and 0.73 in the lower reach (Figure 2d). The average Shannon's Diversity in the upper reach was 1.65, in the middle reach it was 1.52, and in the lower reach it was 2.01 (Figure 3d). The average abundance of individuals was 1380 in the upper reach, 3105.5 in the middle reach and 823.5 in the lower reach (Figure 4d). The HBI, in which the lower the value indicates less pollution in the stream, was 4.12 in the upper reach, 4.99 in the middle reach and 3.63 in the lower reach (Figure 5d). The CTQd, which a lower value also indicates higher quality unpolluted water, was 79 in the upper reach, 92.5 in the middle reach, and 89.5 in the lower reach (Figure 6d). Appendices C and D has more specific detail on all the values found and metrics graphed for visual comparison.

4.3 Temporal Variation in Macroinvertebrate Community

As previously mentioned, EIS was able to obtain the standardized data from the BugLab dating back to 2009 to assess temporal variations. The graphs in Appendices C and D provide a visual means to examine the temporal variation within the creek. In all reaches, the data fluctuates from year to year. This year, a trendline was added to the averaged overall data in Appendix D acquire any overall trends. The upper reach, which should not be impacted by the mines discharge, has great variability within each metric. For example the average richness in Fall 2009 was 24, it dropped to 17 in the Fall of 2011, went up to 26 in Fall of 2013 and currently dropped back down to 18 (Figure 1d). The evenness started at 0.75 in 2009, continued to decline to 0.65

in 2011, peaked to 0.80 in 2013 and dropped to the current value of 0.57. The lower the HBI index indicates higher quality water or better conditions, in 2009 the HBI was 5.61 and in this dataset it is 4.12. The CTQd value seems to be staying fairly consistent, in 2009 it was 74 and currently it is 79. About a third of the metrics indicate declining conditions, another third indicate fairly stable conditions, and the remaining third indicate increasing conditions.

The middle reach also has this variation occurring throughout the years. The middle reach is increasing in the number of macroinvertebrates found (Figure 4d), the taxa EPT is showing signs of improvement (Figure 7d), and the number of specialist feeders is also increasing (Figure 15d). The remaining metrics are highly variable or indicate an overall decline since 2009. The lower reach generally appears to be getting better in quality over time. While many of the metrics indicate a less than optimal habitat in the lower reach when compared to the upper reach, there are several that prove otherwise. The evenness, Shannon's Diversity, HBI, and a few species specific metrics had higher values when compared to the upper reach (Figures 1d-23d). As with any study, the more data acquired the more discernable the trends may be.

5.0 CONCLUSION

The samples for the 2013 Fall Macroinvertebrate Study were collected on June 11th and 12th, 2014 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 variability among all the sampled reaches and generally show reduced habitat quality and less than optimal conditions in all sampled locations. It does appear that the upper and the lower reach are increasing in quality standards or staying fairly stable since 2009. In the middle reach, the overall quality seems to be lower than the other two reaches; however multiple metrics indicate that it is improving compared to early years sampled. 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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Matthew has a B.S. in Biology from Utah State University. He has been a biologist at EIS since 2007 and also has working experience with the UDWR, the BLM, and as a research assistant at USU.

Mindi Lundberg, Biologist

Mindi has a B.S. in Conservation and Restoration Ecology from Utah State University. She also has a number of years' experience working with the UDWR, Utah State Parks, and has also held research assistant positions at USU before coming to EIS.

APPENDIX A

BUGLAB REPORT

Report prepared for:

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November 13, 2014

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
152958	CRANDUP-01	6/12/2014	Reachwide	Kick net	0.46	87.5	806
152959	CRANDUP-01	6/12/2014	Targeted Riffle	Kick net	0.74	100	528
152960	CRANDMD-02	6/11/2014	Reachwide	Kick net	0.46	37.5	920
152961	CRANDMD-02	6/11/2014	Targeted Riffle	Kick net	0.74	100	614
152962	CRANDLWR-03	6/11/2014	Reachwide	Kick net	0.46	100	494
152963	CRANDLWR-03	6/11/2014	Targeted Riffle	Kick net	0.74	100	424

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
152958	6/12/2014	CRANDUP-01 Multi	2046	1147	Baetidae	39.59
152959	6/12/2014	CRANDUP-01 Riffle	714	516	Baetidae	52.38
152960	6/11/2014	CRANDMD-02 Multi	5381	1429	Chironomidae	43.10
152961	6/11/2014	CRANDMD-02 Riffle	830	274	Chironomidae	50.96
152962	6/11/2014	CRANDLWR-03 Multi	1074	489	Baetidae	35.85
152963	6/11/2014	CRANDLWR-03 Riffle	573	226	Baetidae	31.06
Mean			1769.7	680.2		42.16

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
152958	6/12/2014	CRANDUP-01 Multi	42	28	26	16	1.780757	0.6161
152959	6/12/2014	CRANDUP-01 Riffle	44	29	23	13	1.515849	0.524448
152960	6/11/2014	CRANDMD-02 Multi	29	15	20	12	1.582175	0.570649
152961	6/11/2014	CRANDMD-02 Riffle	31	21	19	10	1.461412	0.515814
152962	6/11/2014	CRANDLWR-03 Multi	38	22	20	9	1.780177	0.69404
152963	6/11/2014	CRANDLWR-03 Riffle	31	21	20	10	2.236449	0.773758
Mean			35.8	22.7	21.3	11.66667	1.726136	0.615801

*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
152958	6/12/2014	CRANDUP-01 Multi	18	8	1.780757	0.6161
152959	6/12/2014	CRANDUP-01 Riffle	18	7	1.515849	0.524448
152960	6/11/2014	CRANDMD-02 Multi	16	4	1.582175	0.570649
152961	6/11/2014	CRANDMD-02 Riffle	17	7	1.461412	0.515814
152962	6/11/2014	CRANDLWR-03 Multi	13	7	1.780177	0.69404
152963	6/11/2014	CRANDLWR-03 Riffle	18	8	2.236449	0.773758
Mean			16.66667	7	1.726136	0.615801

Table 6a. Genera richness by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
152958	6/12/2014	CRANDUP-01 Multi	2	14	9	0	0	0	4	3	1	0	1
152959	6/12/2014	CRANDUP-01 Riffle	0	11	6	0	0	0	4	3	1	0	1
152960	6/11/2014	CRANDMD-02 Multi	1	12	5	0	0	0	3	4	1	0	0
152961	6/11/2014	CRANDMD-02 Riffle	1	9	5	0	0	0	1	4	1	0	0
152962	6/11/2014	CRANDLWR-03 Multi	2	6	3	0	0	0	2	4	0	0	1
152963	6/11/2014	CRANDLWR-03 Riffle	1	7	4	0	0	0	3	3	1	0	0
Mean			1.2	9.8	5.3	0.0	0.0	0.0	2.8	3.5	0.8	0.0	0.5

Table 7a. Total Abundance by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
152958	6/12/2014	CRANDUP-01 Multi	5	690	1025	0	0	0	44	77	32	0	57
152959	6/12/2014	CRANDUP-01 Riffle	0	162	458	0	0	0	22	36	1	0	12
152960	6/11/2014	CRANDMD-02 Multi	60	3689	1340	0	0	0	17	72	29	0	23
152961	6/11/2014	CRANDMD-02 Riffle	7	491	258	0	0	0	3	14	47	0	1
152962	6/11/2014	CRANDLWR-03 Multi	7	498	387	0	0	0	41	61	0	0	37
152963	6/11/2014	CRANDLWR-03 Riffle	3	111	181	0	0	0	35	9	68	0	134
Mean			14	940	608	0	0	0	27.1	44.8	29.6	0.0	44.1

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
152958	6/12/2014	CRANDUP-01 Multi	4.363333	Some organic pollution	83
152959	6/12/2014	CRANDUP-01 Riffle	3.866667	Potential slight organic pollution	75
152960	6/11/2014	CRANDMD-02 Multi	5.15	Some organic pollution	96
152961	6/11/2014	CRANDMD-02 Riffle	4.84	Some organic pollution	89
152962	6/11/2014	CRANDLWR-03 Multi	4.63	Some organic pollution	87
152963	6/11/2014	CRANDLWR-03 Riffle	2.633333	Potential slight organic pollution	92
Mean			4.247222		87.00

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	Percent	Abundance	Percent	Tolerant Taxa: Richness	Percent	Abundance	Percent
152958	6/12/2014	CRANDUP-01 Multi	5	28	134	7	0	0	2	0
152959	6/12/2014	CRANDUP-01 Riffle	5	28	62	9	0	0	0	0
152960	6/11/2014	CRANDMD-02 Multi	2	13	60	1	0	0	0	0
152961	6/11/2014	CRANDMD-02 Riffle	2	12	9	1	0	0	0	0
152962	6/11/2014	CRANDLWR-03 Multi	2	15	63	6	0	0	0	0
152963	6/11/2014	CRANDLWR-03 Riffle	3	17	38	7	0	0	0	0
Mean			3.2	19	61.0	5	0.0	0	0.3	0

Functional Feeding Groups

Table 10a. Taxa richness by functional feeding groups

Sample ID	Collection Date	Station	Shredders Richness	Shredders Percent	Scrapers Richness	Scrapers Percent	Collector-filterers Richness	Collector-filterers Percent	Collector-gatherers Richness	Collector-gatherers Percent	Predators Richness	Predators Percent	Unknown Richness	Unknown Percent
152958	6/12/2014	CRANDUP-01 Multi	1	4	1	4	2	7	2	7	7	26	14	52
152959	6/12/2014	CRANDUP-01 Riffle	1	4	1	4	2	8	2	8	9	36	10	40
152960	6/11/2014	CRANDMD-02 Multi	1	5	0	0	2	10	2	10	6	29	10	48
152961	6/11/2014	CRANDMD-02 Riffle	1	5	2	9	2	9	2	9	5	23	10	45
152962	6/11/2014	CRANDLWR-03 Multi	1	5	1	5	3	14	3	14	3	14	10	48
152963	6/11/2014	CRANDLWR-03 Riffle	2	9	1	5	3	14	3	14	5	23	8	36
Mean			1.2	5.1	1.0	4.4	2.3	10.3	2.3	10.3	5.8	25.0	10.3	44.8

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
152958	6/12/2014	CRANDUP-01 Multi	34	2	205	10	92	4	1411	69	298	15	6	0
152959	6/12/2014	CRANDUP-01 Riffle	9	1	78	11	34	5	503	70	89	12	1	0
152960	6/11/2014	CRANDMD-02 Multi	35	1	12	0	1177	22	3717	69	370	7	70	1
152961	6/11/2014	CRANDMD-02 Riffle	8	1	4	0	55	7	720	87	35	4	8	1
152962	6/11/2014	CRANDLWR-03 Multi	13	1	2	0	193	18	733	68	130	12	3	0
152963	6/11/2014	CRANDLWR-03 Riffle	26	5	1	0	173	30	309	54	47	8	17	3
Mean			20.8	1.7	50.3	3.7	287.3	14.3	1232.2	69.6	161.5	9.7	17.5	1.0

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 SPRING 2014

Figure 1b. Percent Predominant Taxonomic Groups Spring 2014 Samples

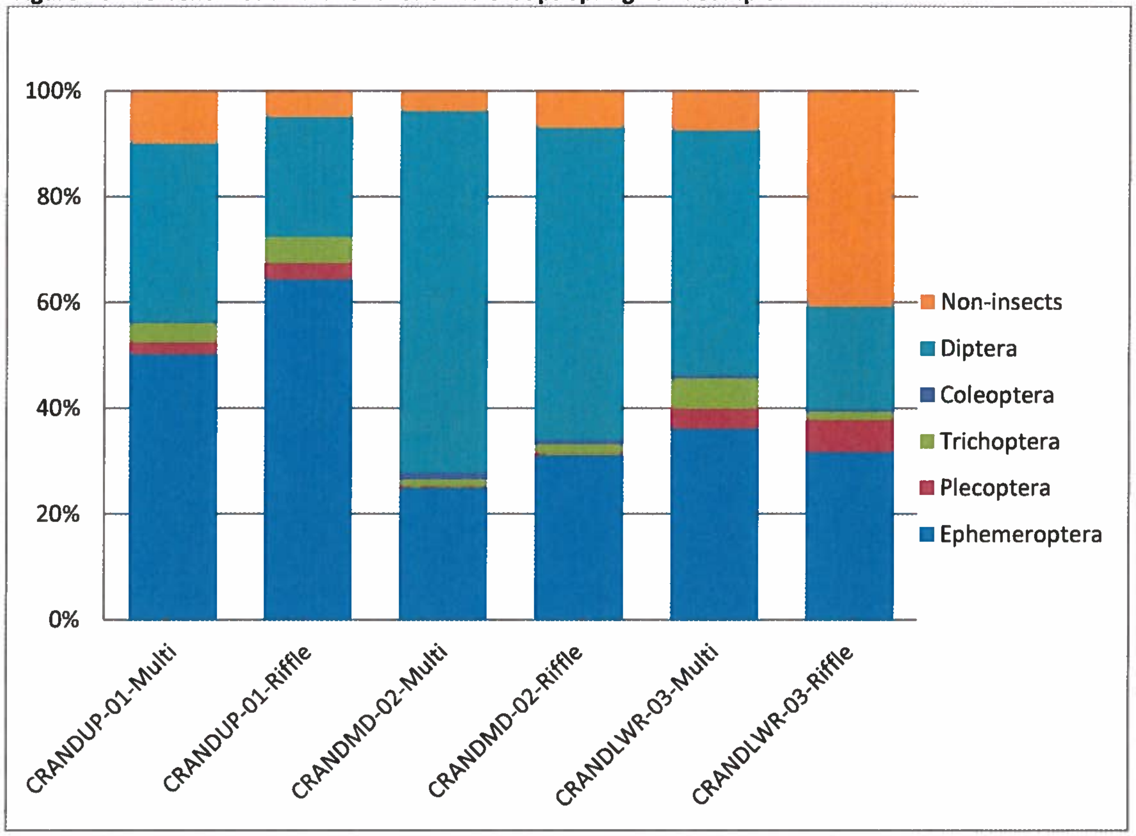


Table 1b. Percent Predominant Taxonomic Groups in the Spring 2014 Samples

	CRANDUP-01-Multi	CRANDUP-01-Riffle	CRANDMD-02-Multi	CRANDMD-02-Riffle	CRANDLWR-03-Multi	CRANDLWR-03-Riffle
Non-insects	10	5	4	7	7	41
Diptera	34	23	69	59	46	19
Coleoptera	0	0	1	1	1	1
Trichoptera	4	5	1	2	6	2
Plecoptera	2	3	0	0	4	6
Ephemeroptera	50	64	25	31	36	32

Figure 2b. Richness

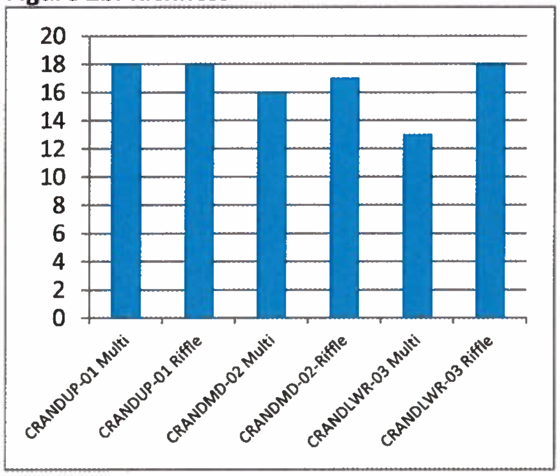


Figure 3b. Shannon's Diversity

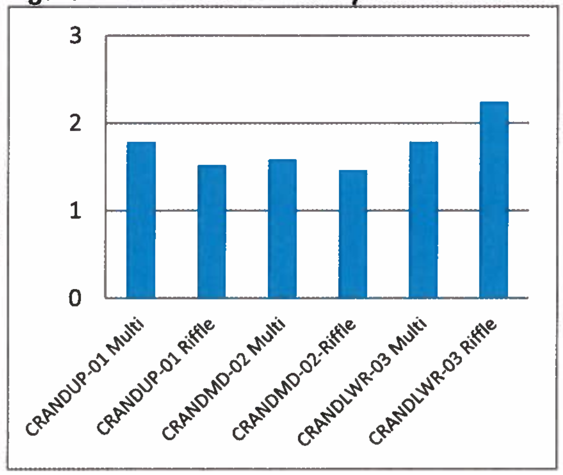


Figure 4b. Evenness

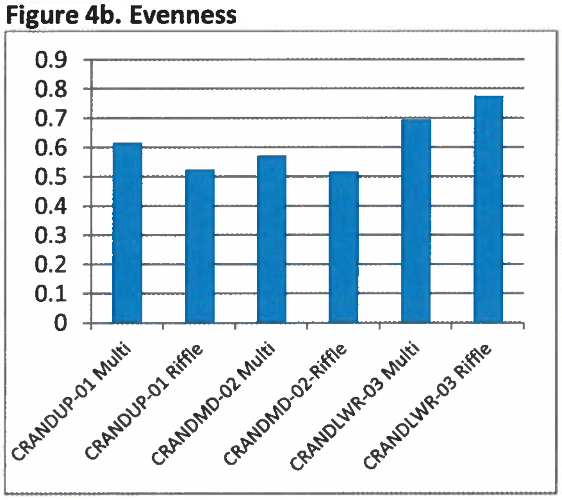


Figure 5b. Abundance

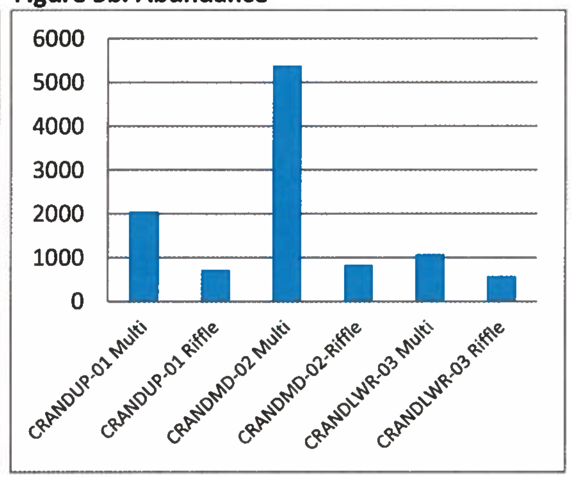


Figure 6b. HBI

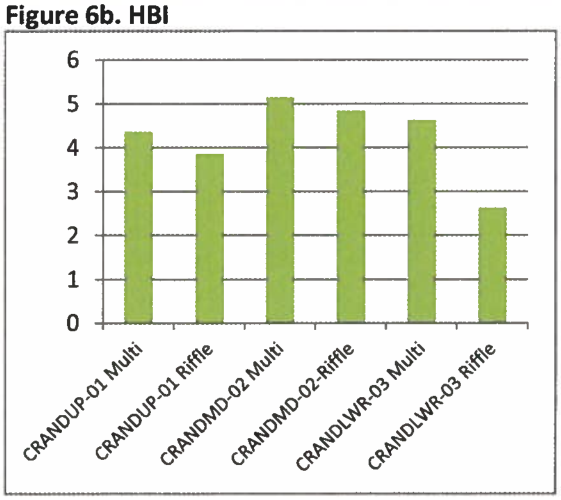


Figure 7b. CTQd

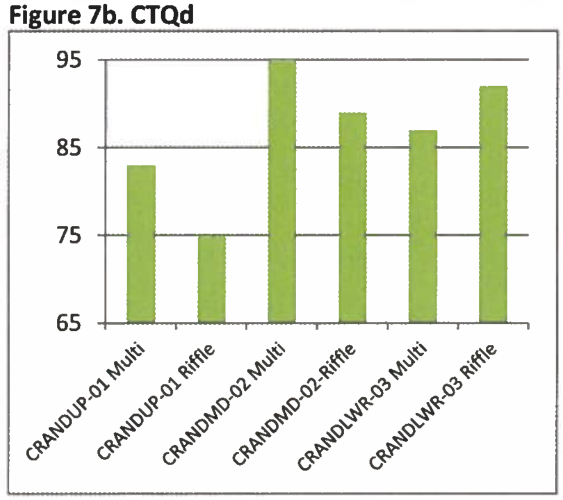


Figure 8b. EPT Taxa Abundance

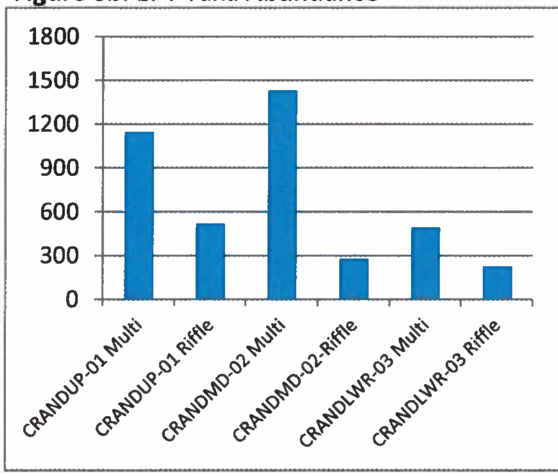


Figure 9b. Percent EPT

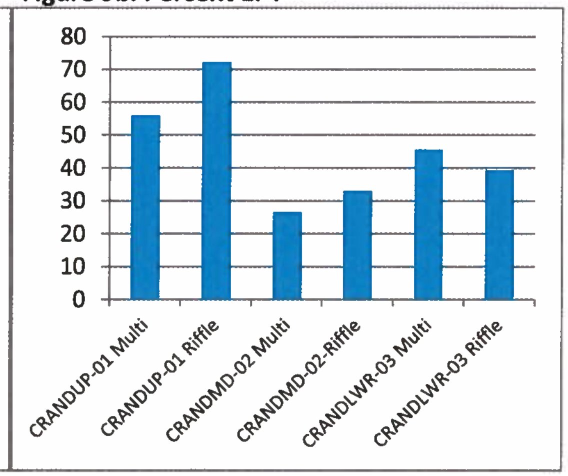


Figure 10b. Percent Chironomids

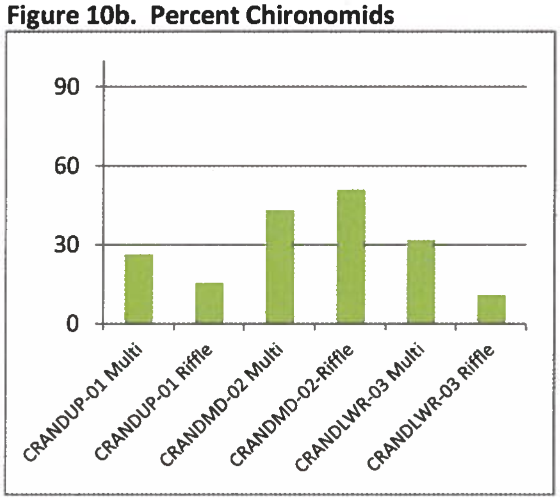


Figure 11b. Ratio of EPT to Chironmonids

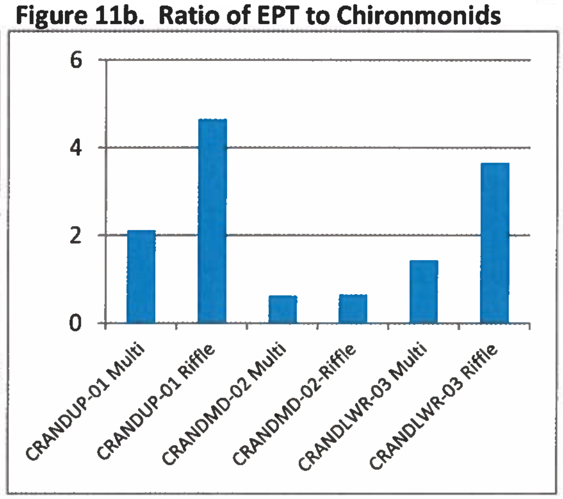


Figure 12b. Number of Tolerant Taxa

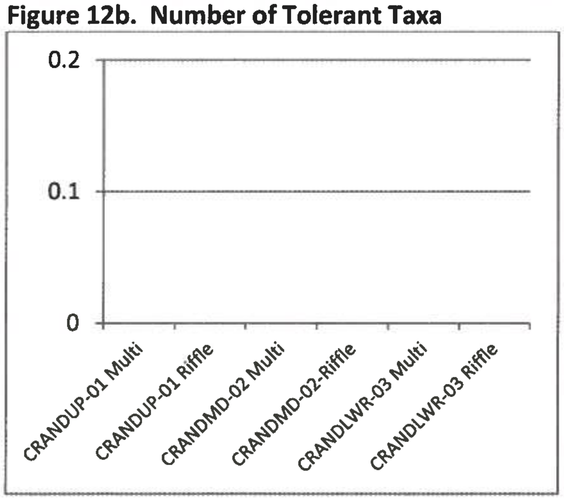


Figure 13b. Percent Tolerant Organisms

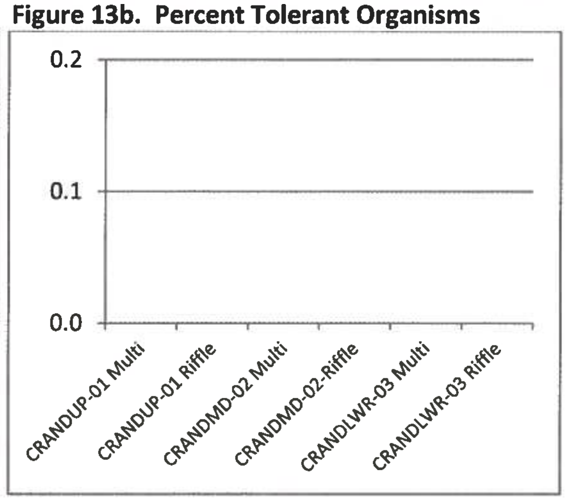


Figure 14b. Number of Intolerant Taxa

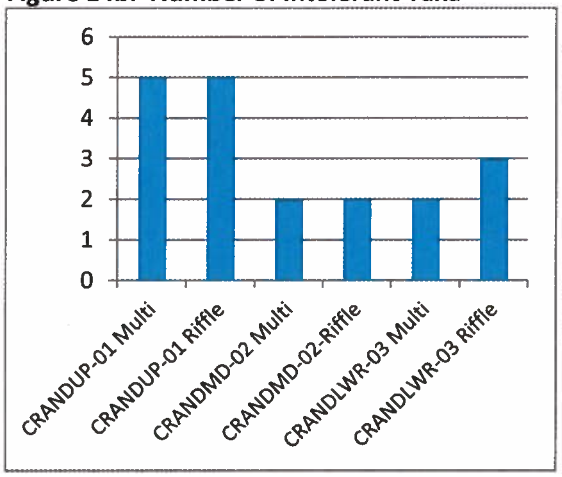


Figure 15b. Percent Intolerant Organisms

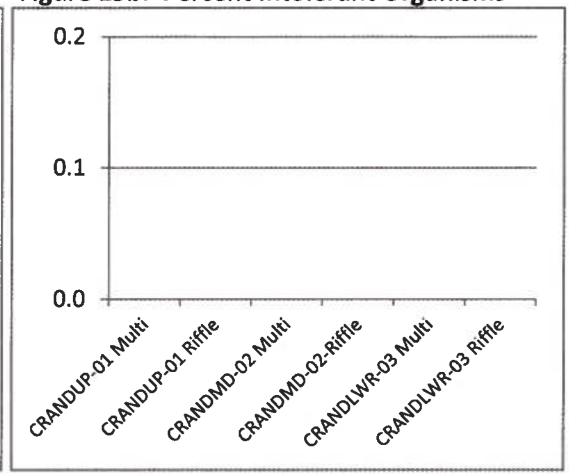


Figure 16b. Specialist Feeders: Generalist Feeders

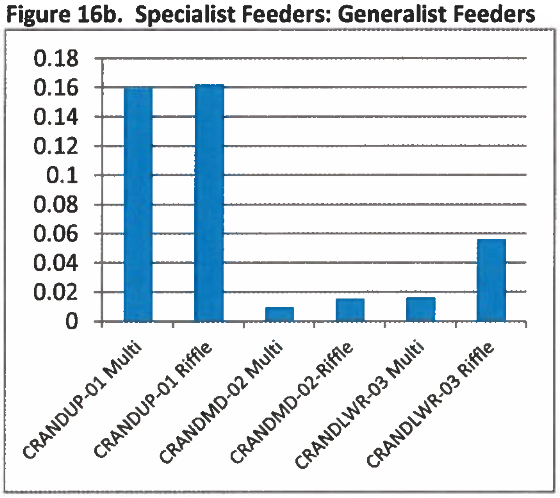


Figure 17b. Percent Shredders

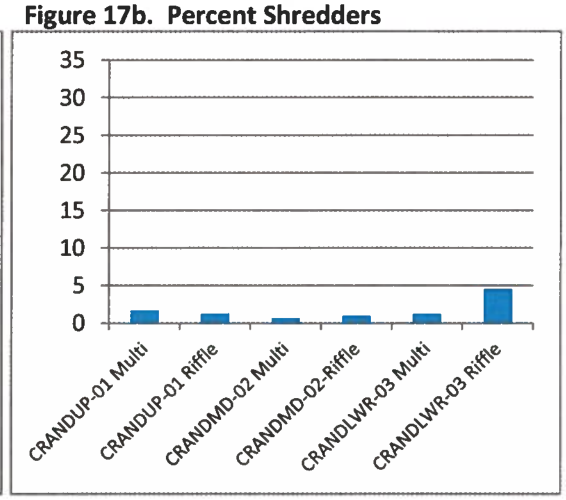


Figure 18b. Percent Scrapers

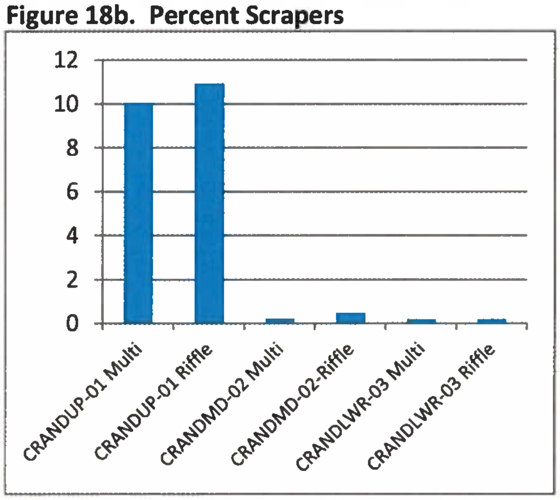


Figure 19b. Number of Long-Lived Taxa

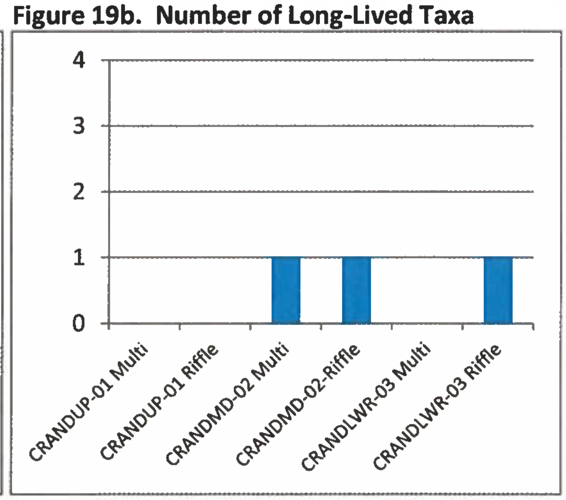


Figure 20b. Number of Clinger Taxa

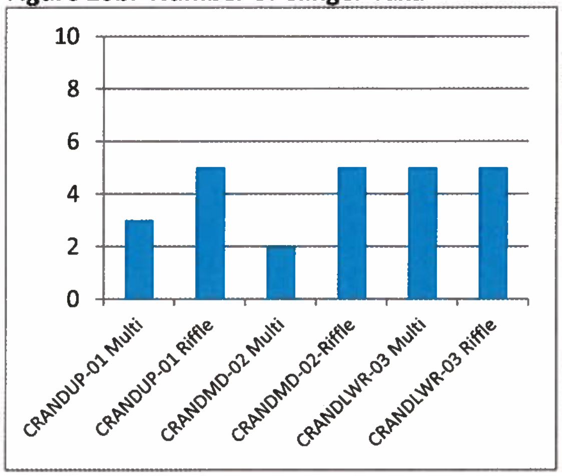


Figure 21b. Baetis:All Ephemetroptera (Percent)

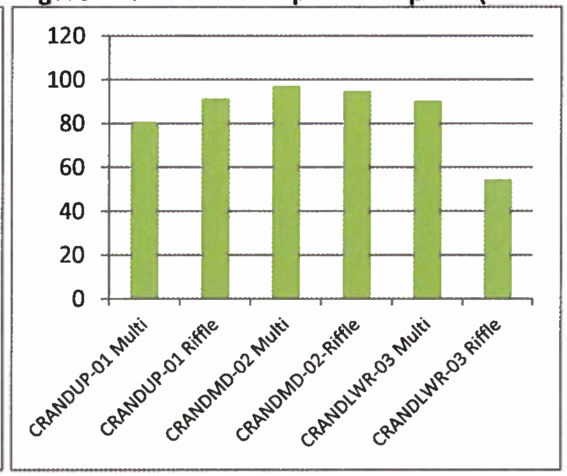


Figure 22b. Baetis, Hydropsychidae & Orthocladiinae (Percent)

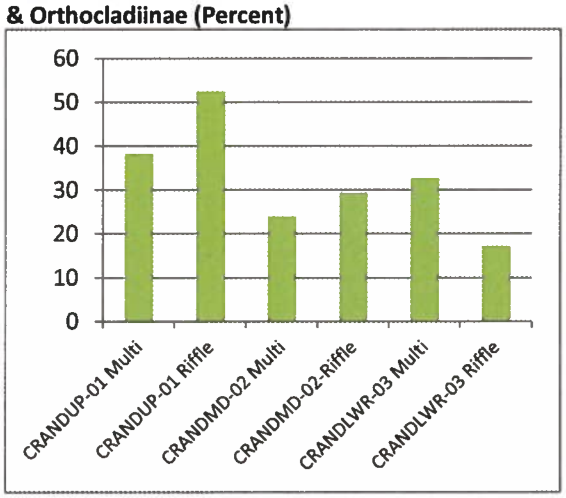


Figure 23b. Heptageniidae: All Ephemeroptera (Percent)

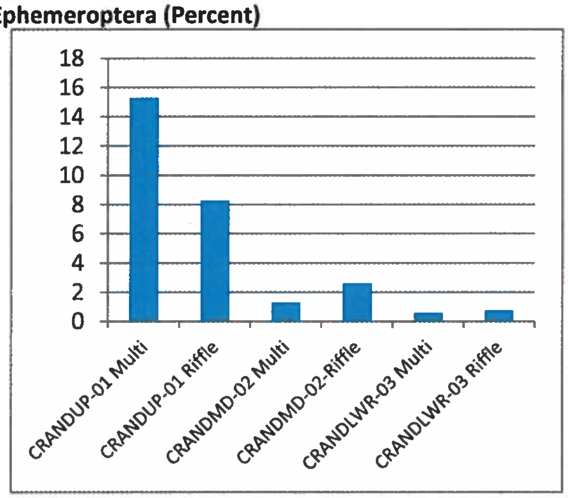
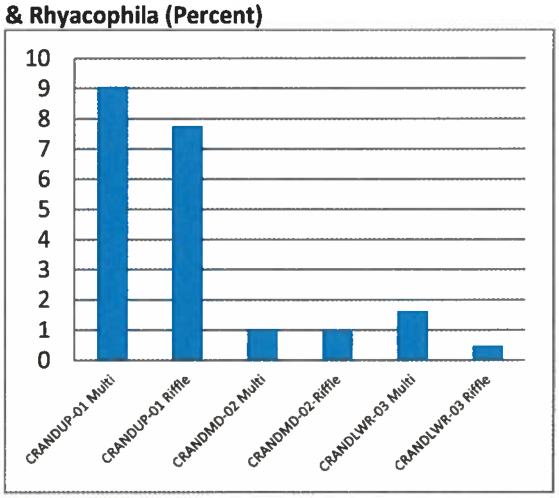


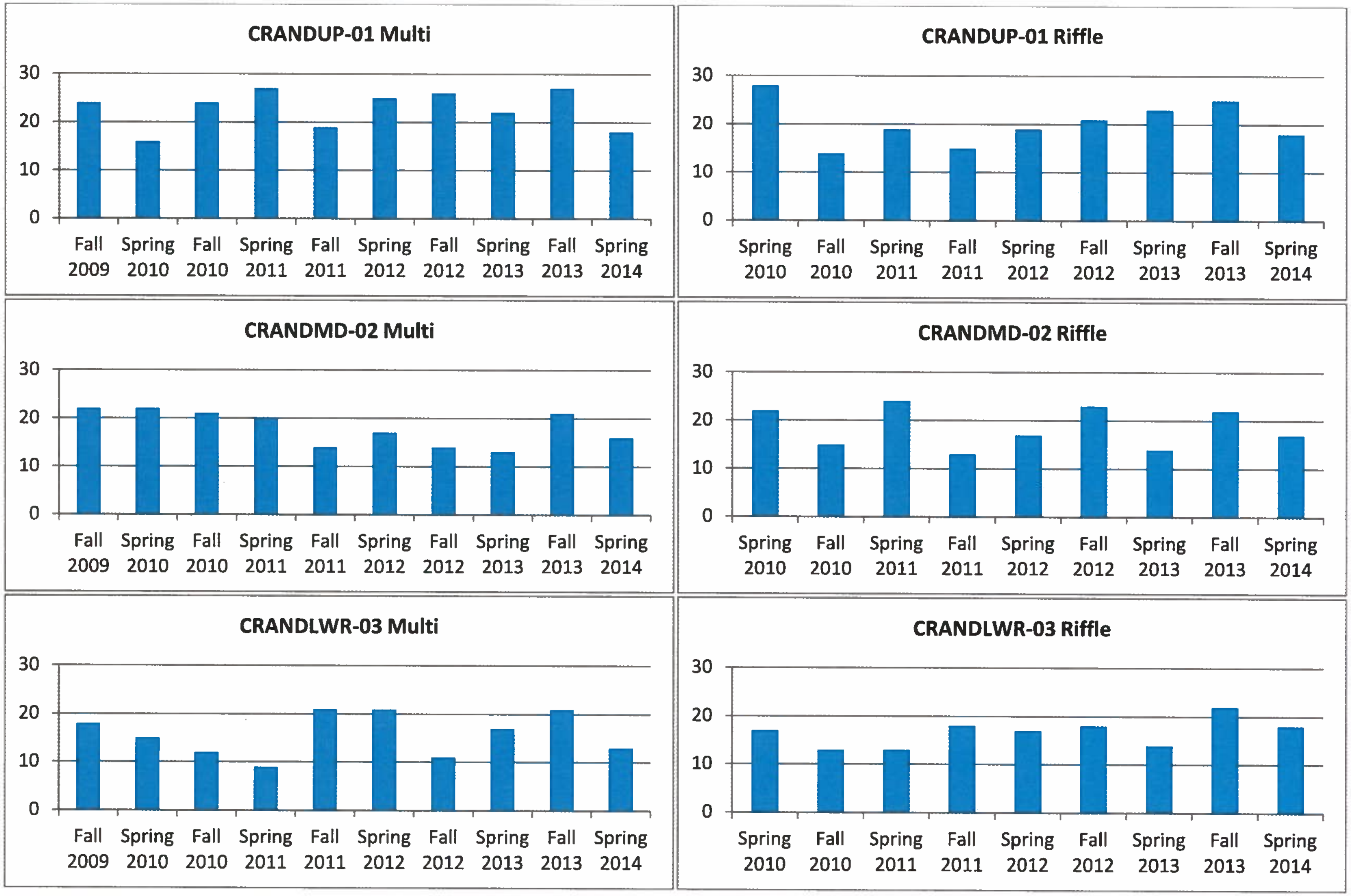
Figure 24b. Heptageniidae, Chloroperlidae & Rhyacophila (Percent)



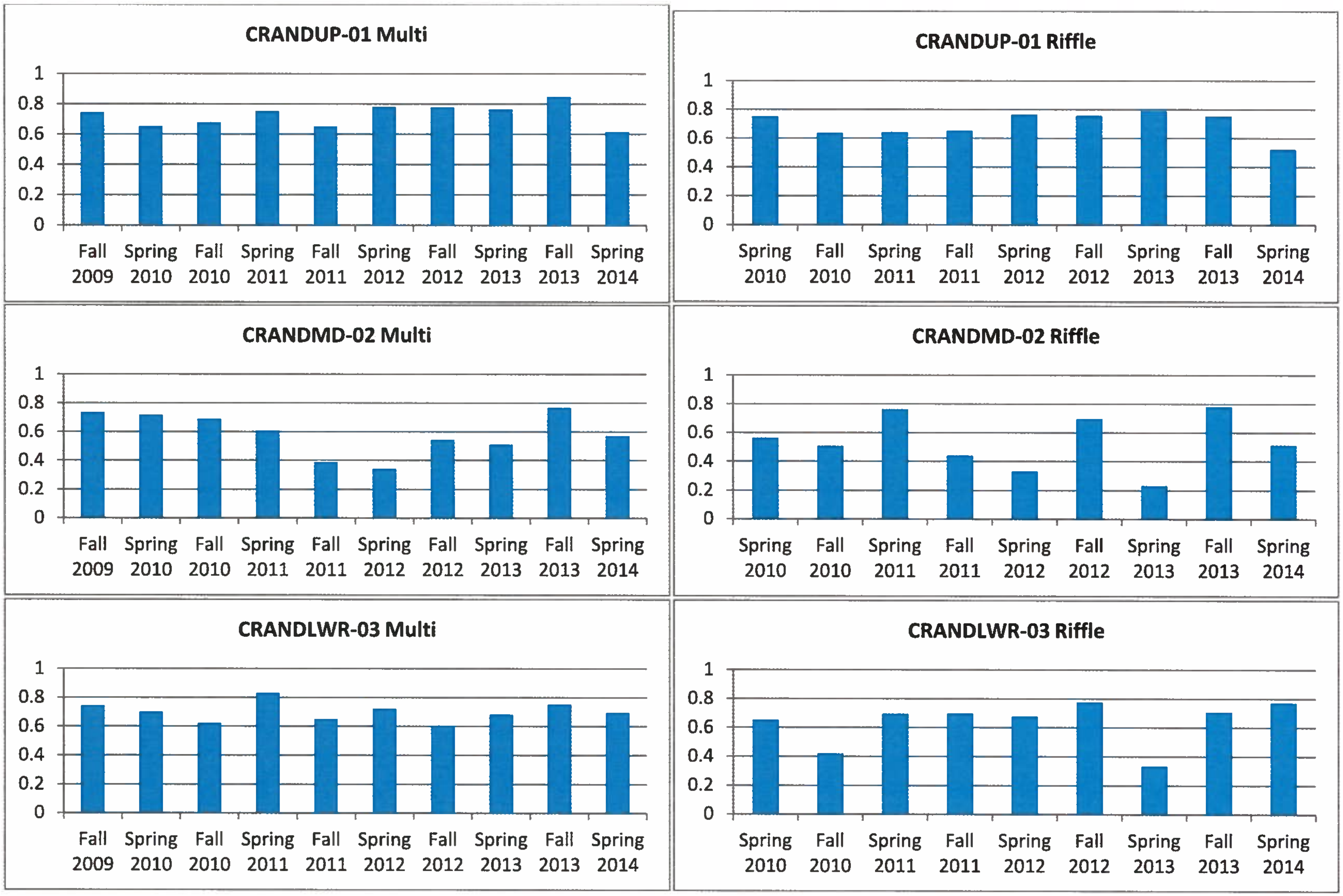
APPENDIX C

MACROINVERTEBRATE FIGURES FALL 2009- SPRING 2014

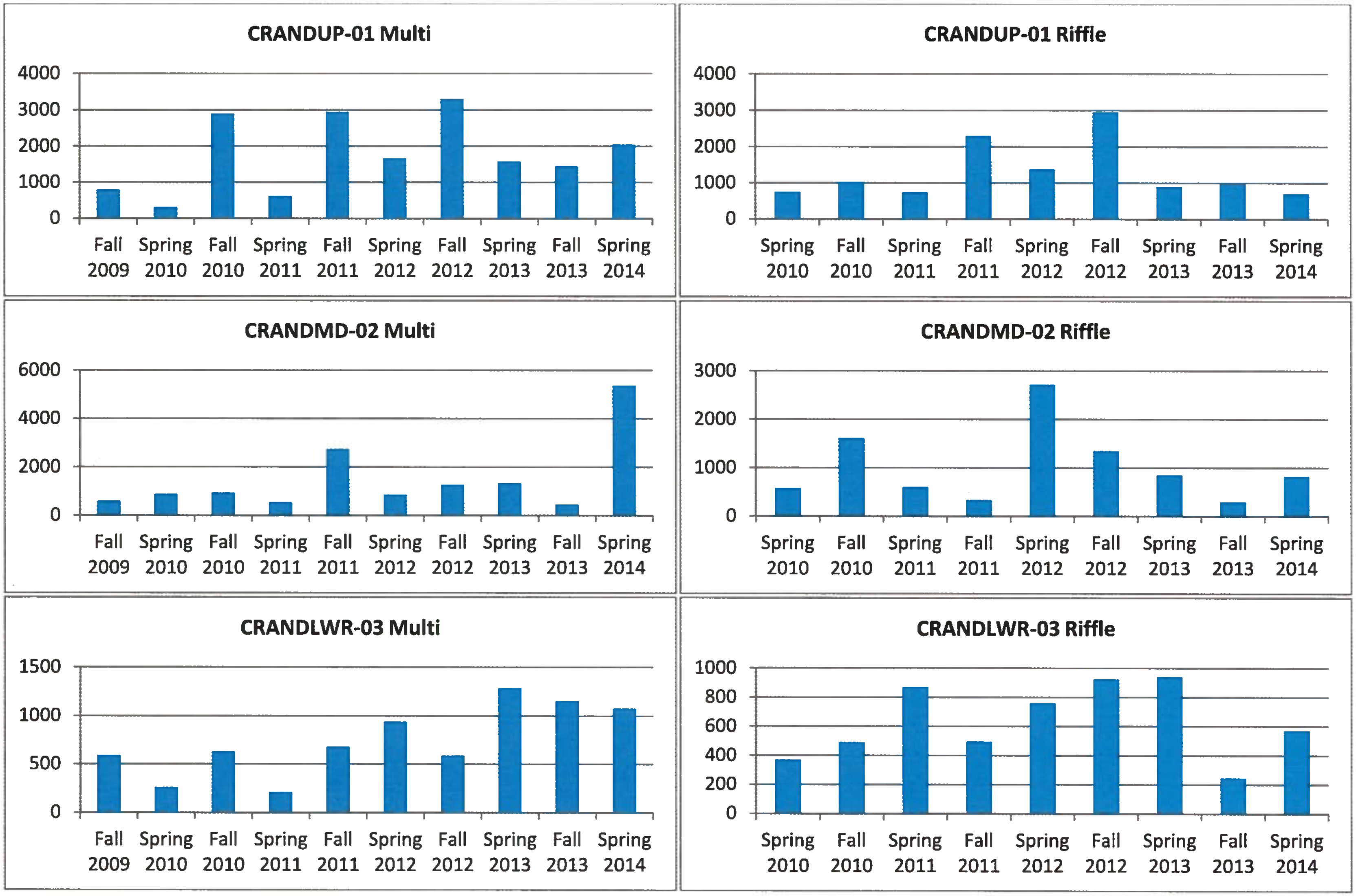
Figures 1c. Richness values for each reach and habitat type from 2009-2014



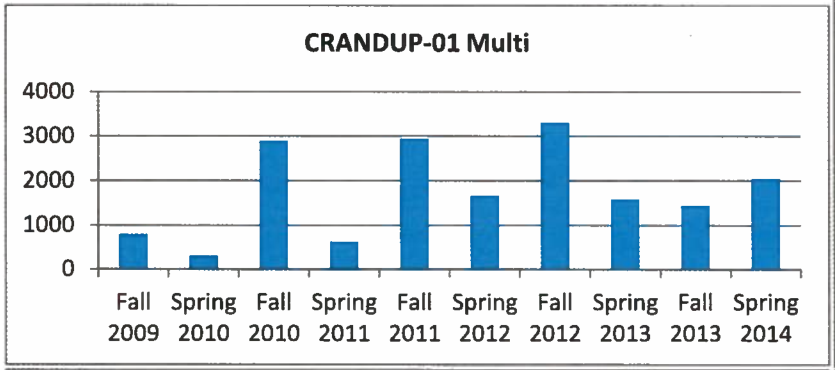
Figures 2c. Evenness values for each reach and habitat type from 2009-2014

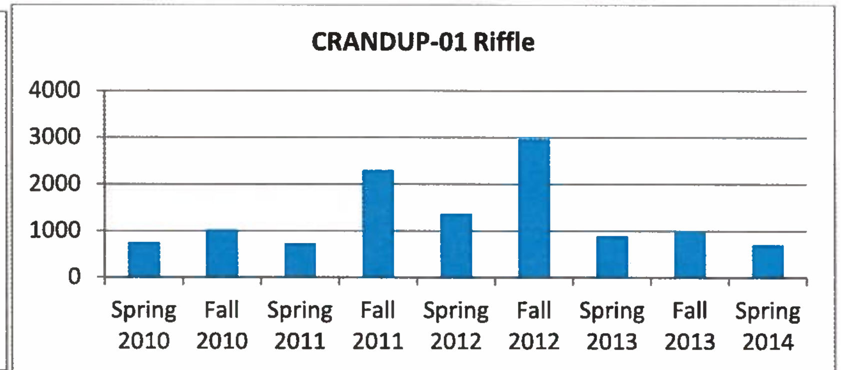


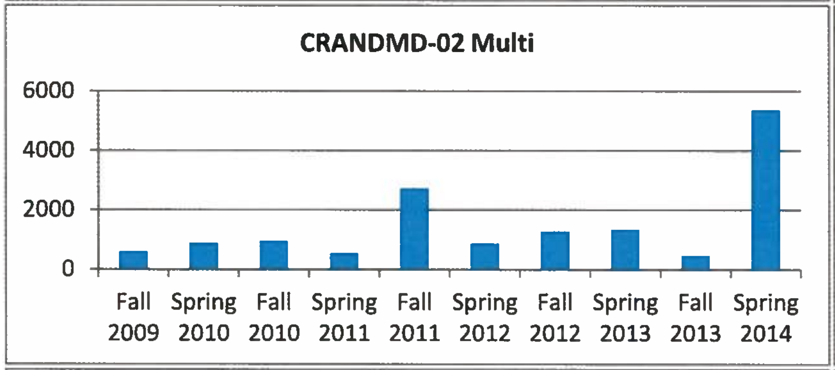
Figures 3c. Shannon's Diversity values for each reach and habitat type from 2009-2014

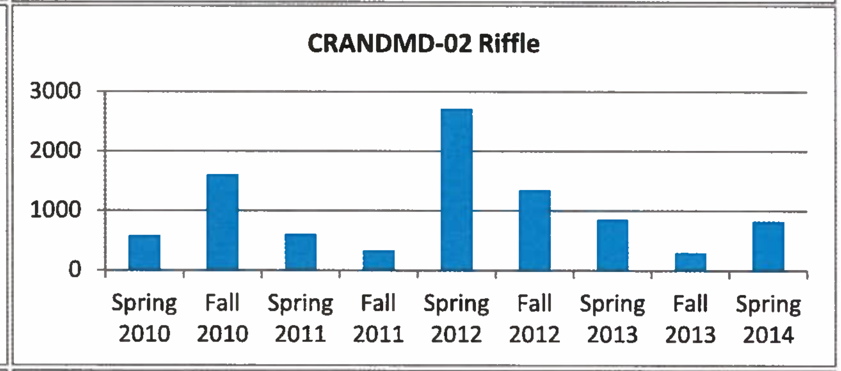


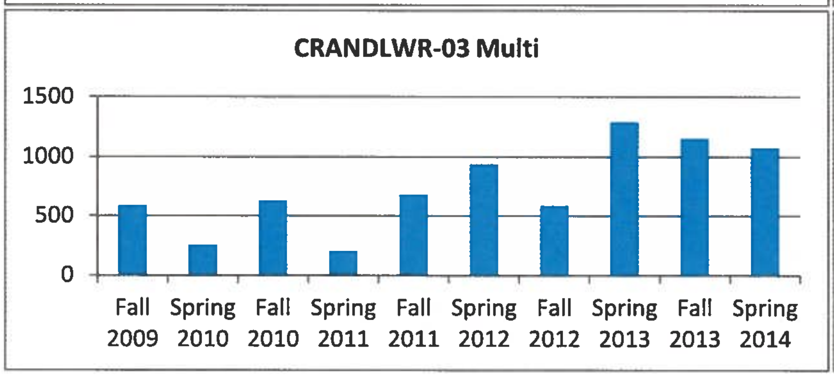
Figures 4c. Abundance values for each reach and habitat type from 2009-2014

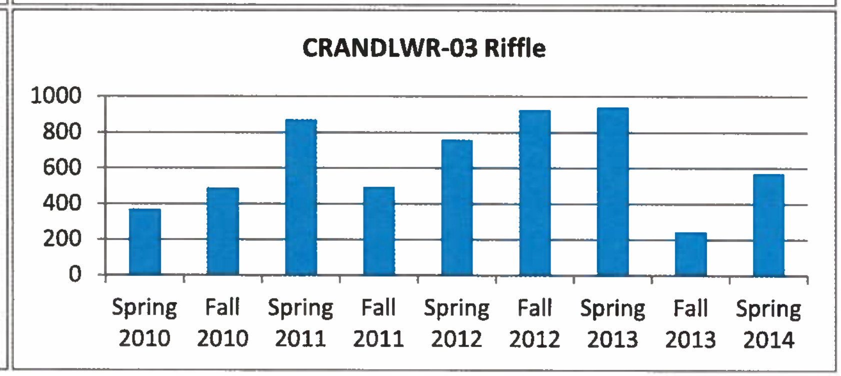




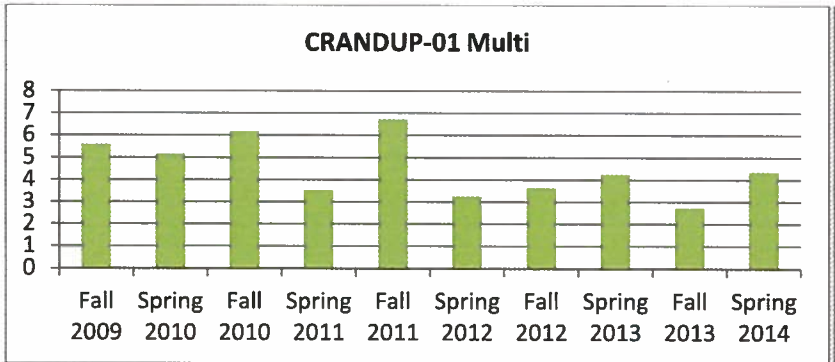


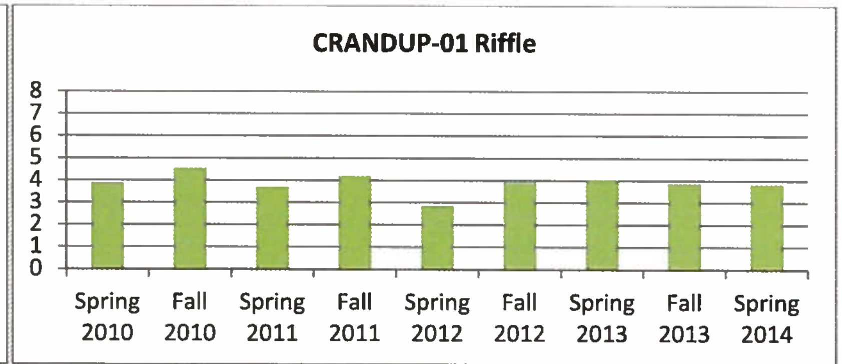


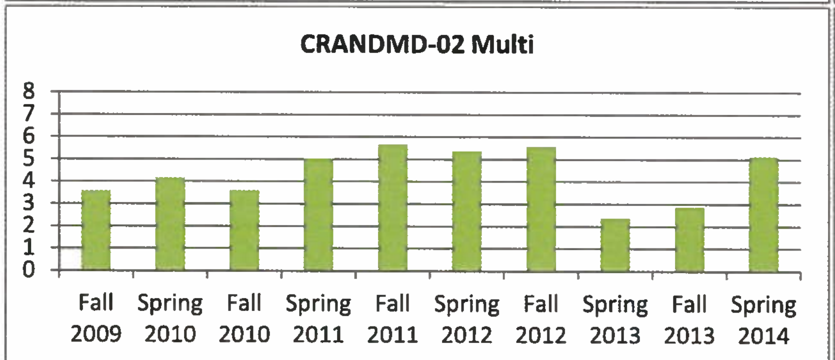


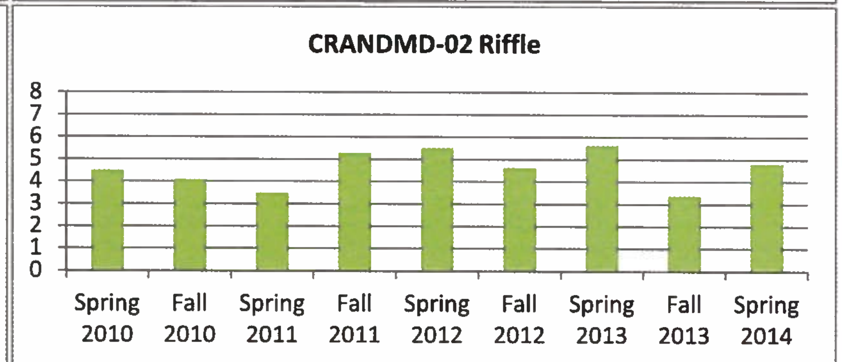


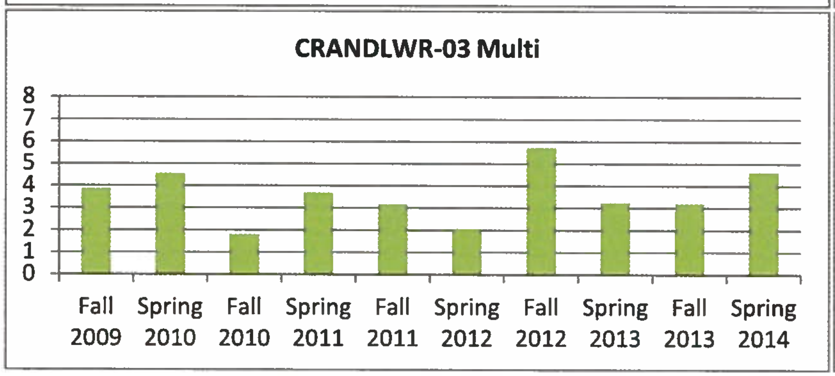
Figures 5c. Hilsenhoff Biotic Index values for each reach and habitat type from 2009-2014

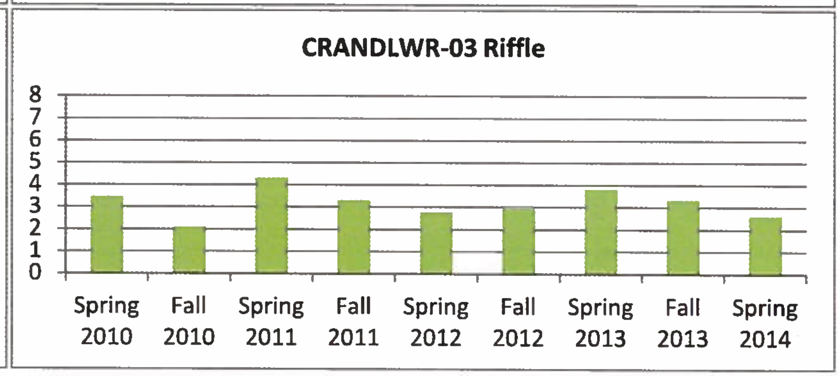




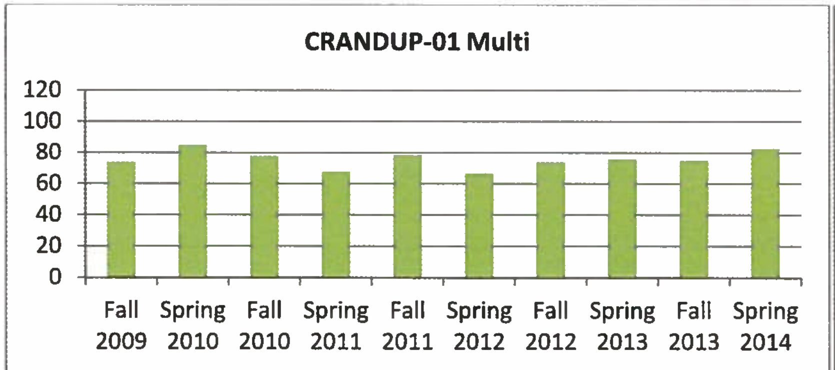


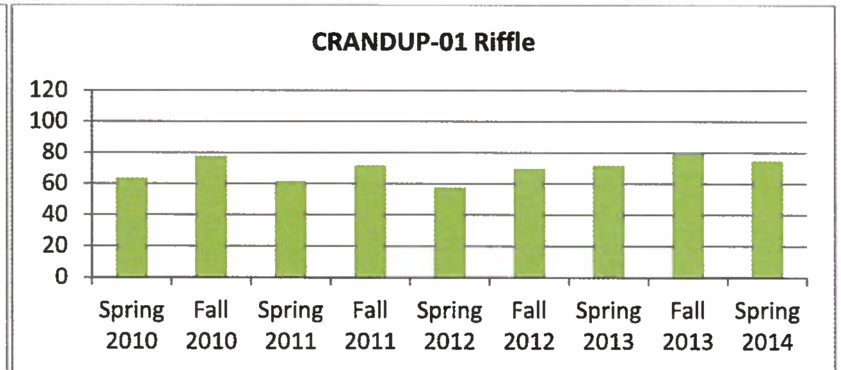


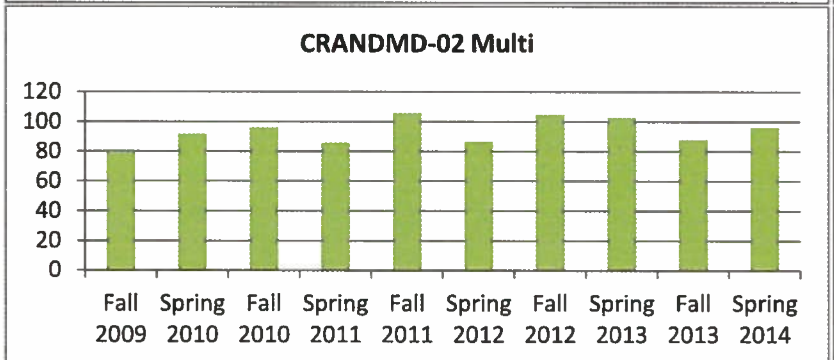


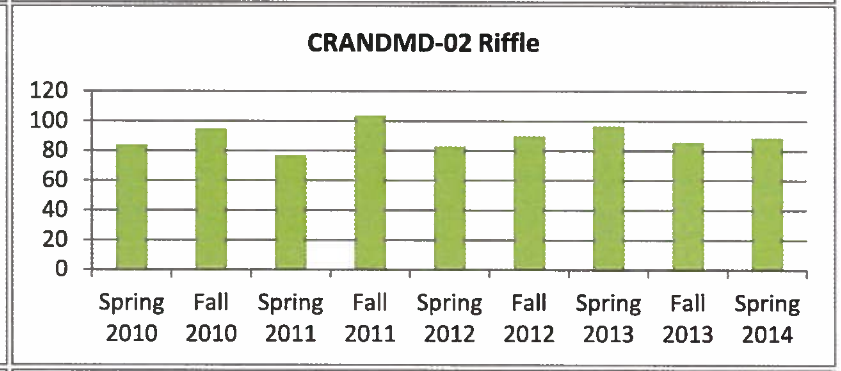


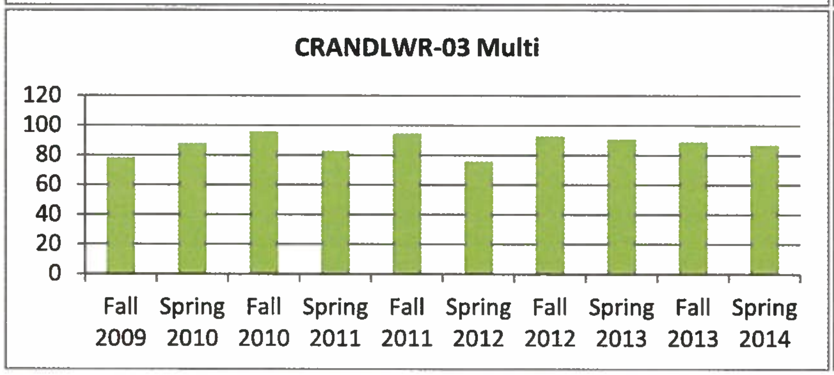
Figures 6c. USFS Community Tolerance Quotient (CTQd) values for each reach and habitat type from 2009-2014

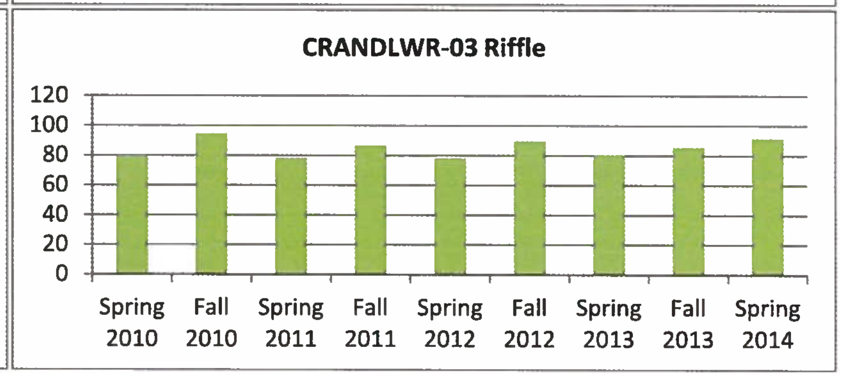




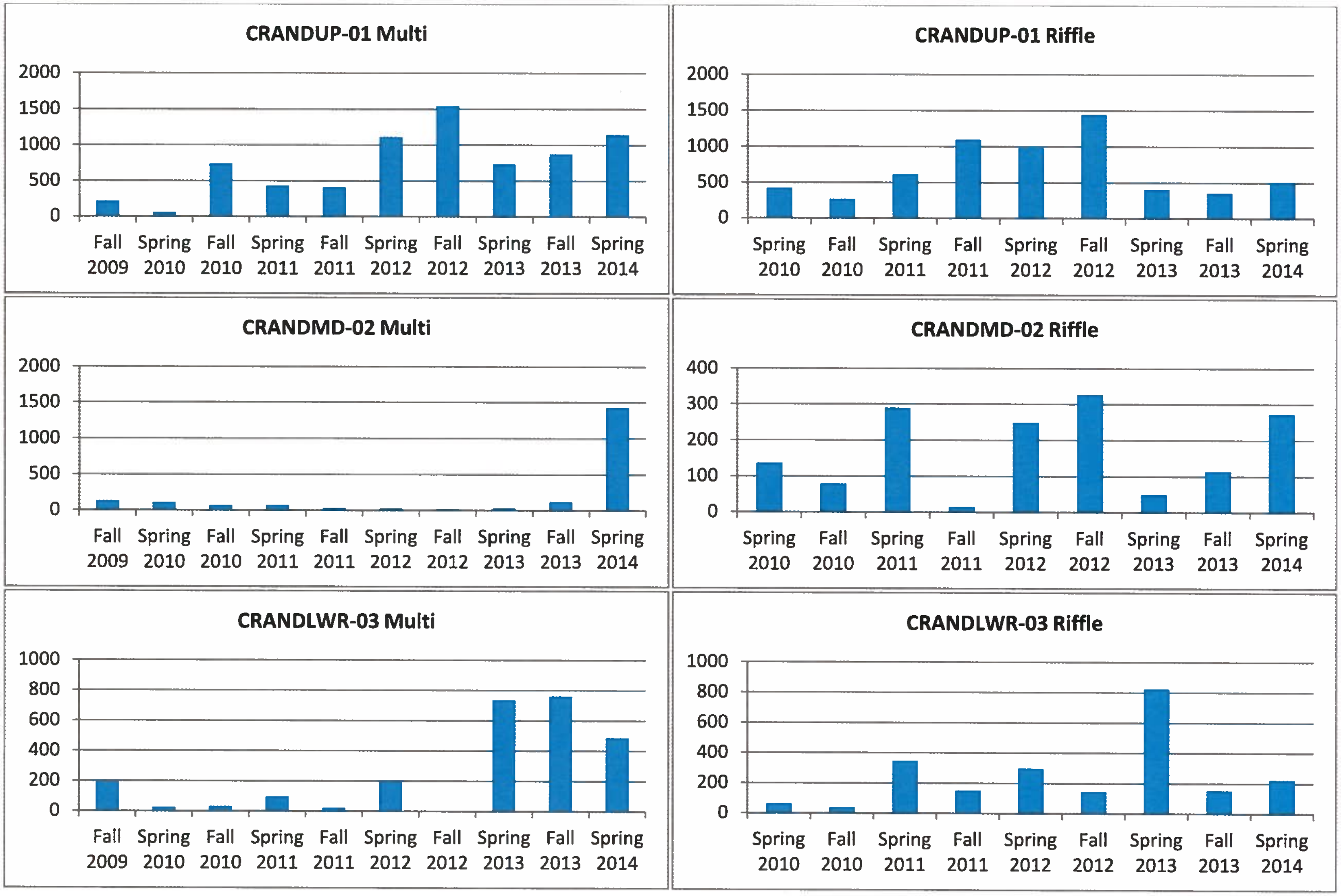




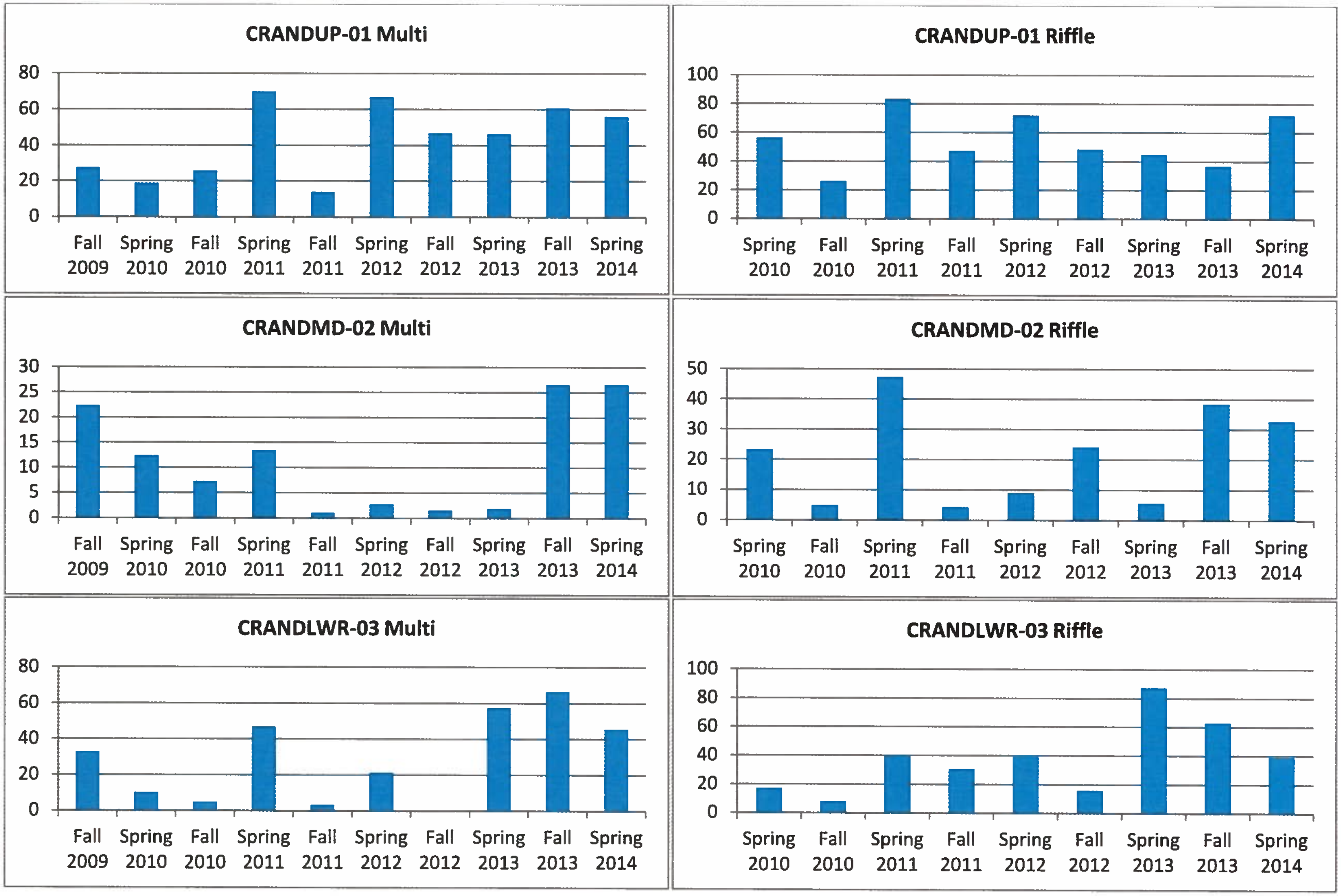




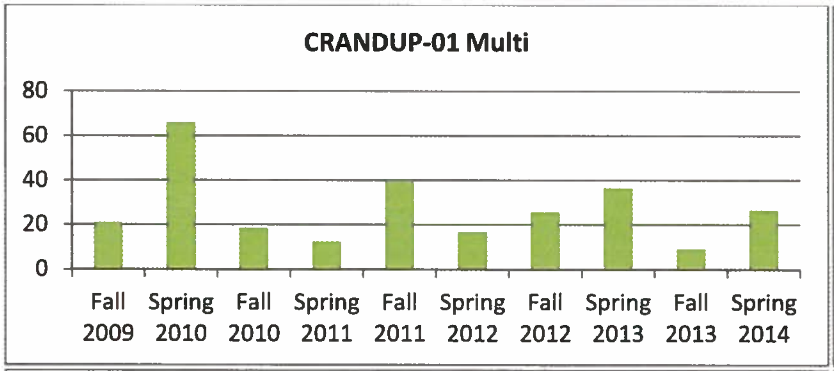
Figures 7c. EPT taxa abundance values for each reach and habitat type from 2009-2014

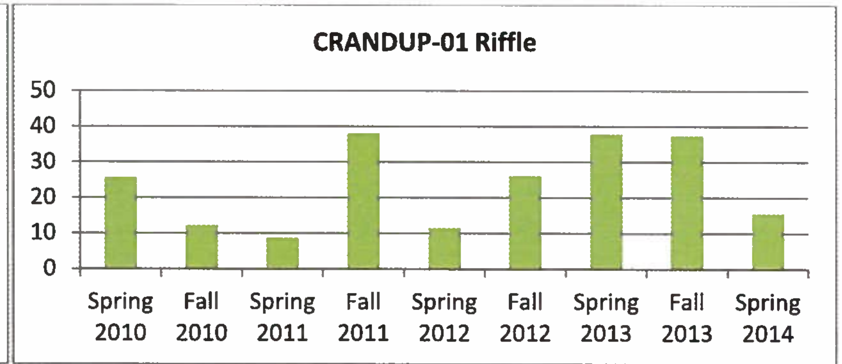


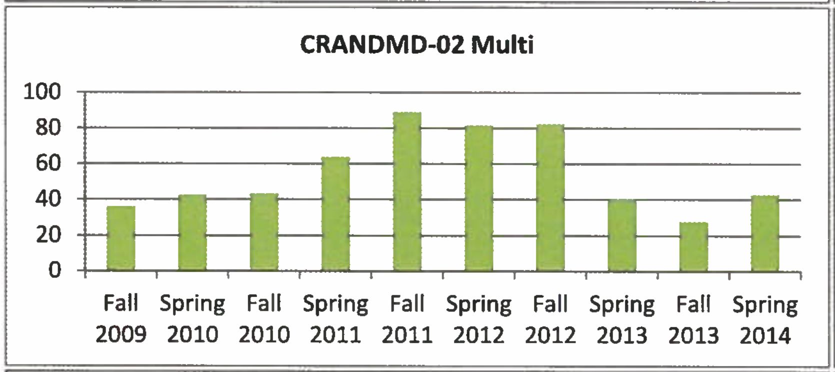
Figures 8c. Percent EPT for each reach and habitat type from 2009-2014

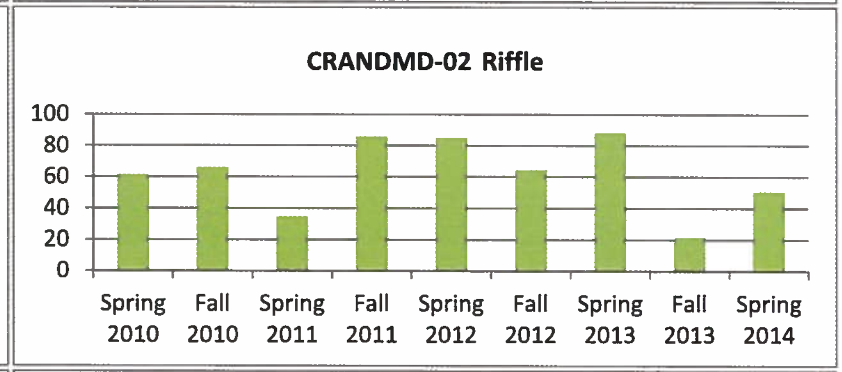


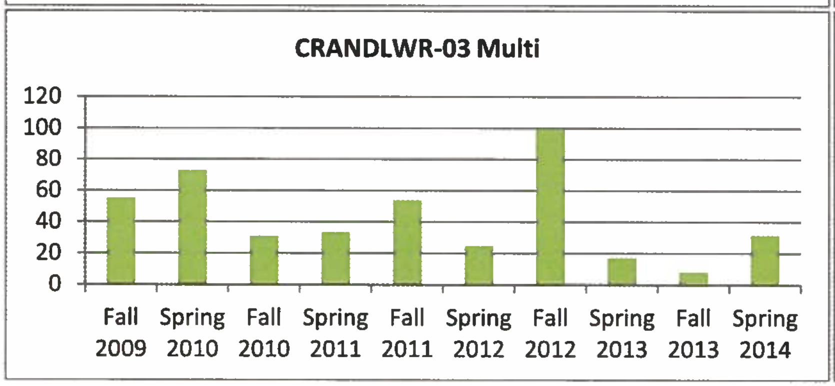
Figures 9c. Percent Chironomids for each reach and habitat type from 2009-2014

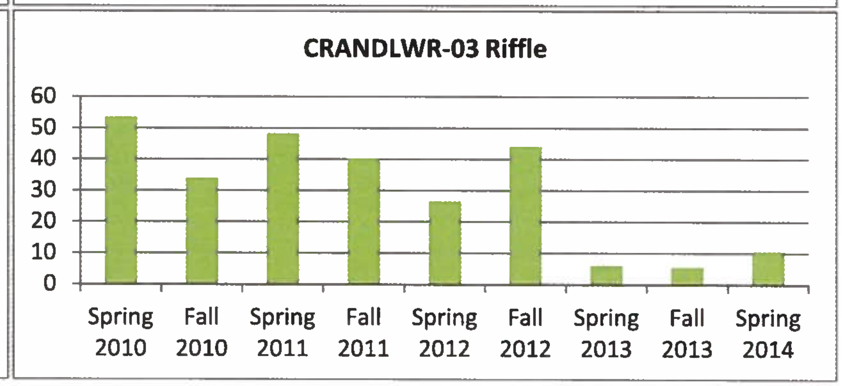




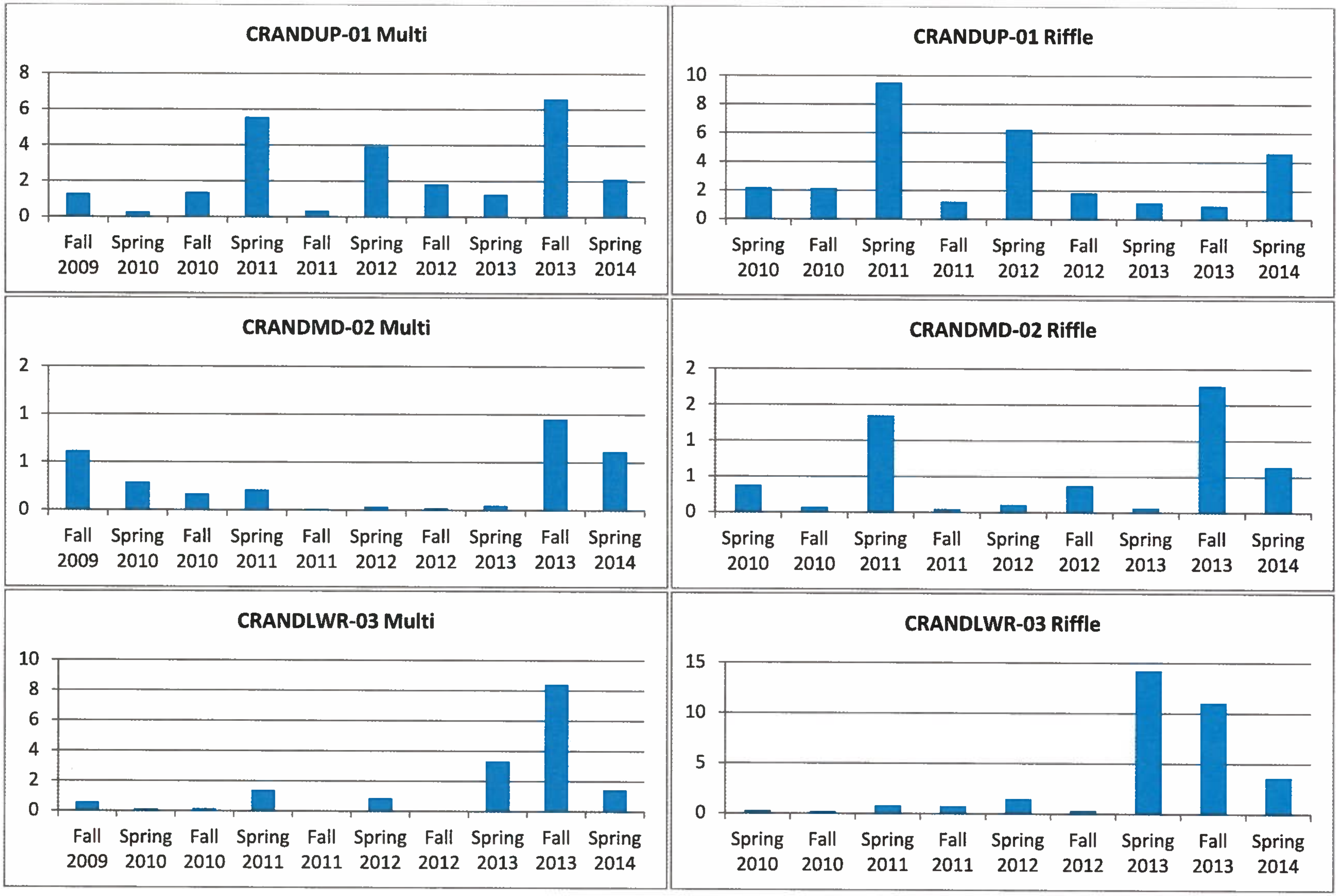




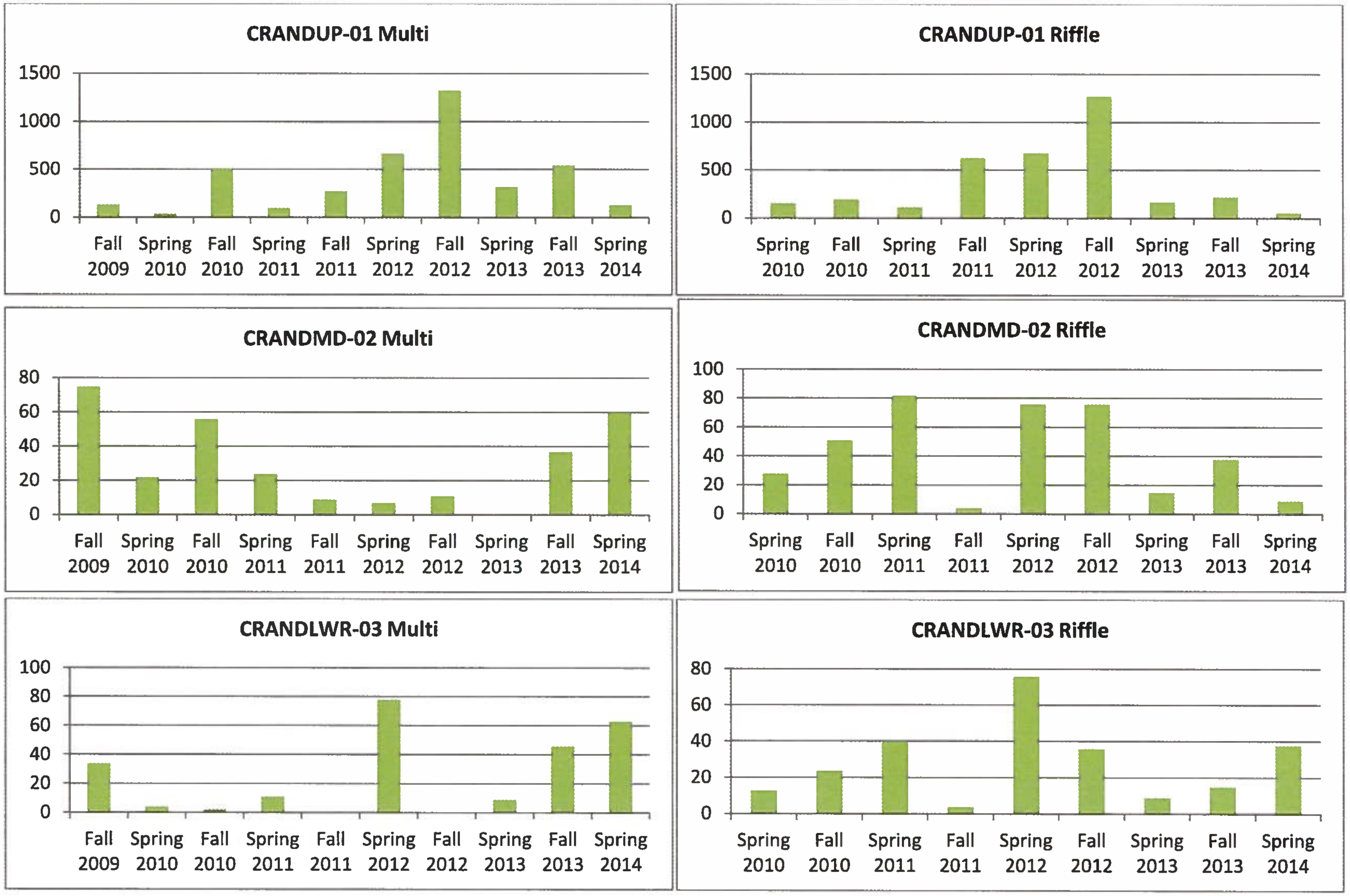




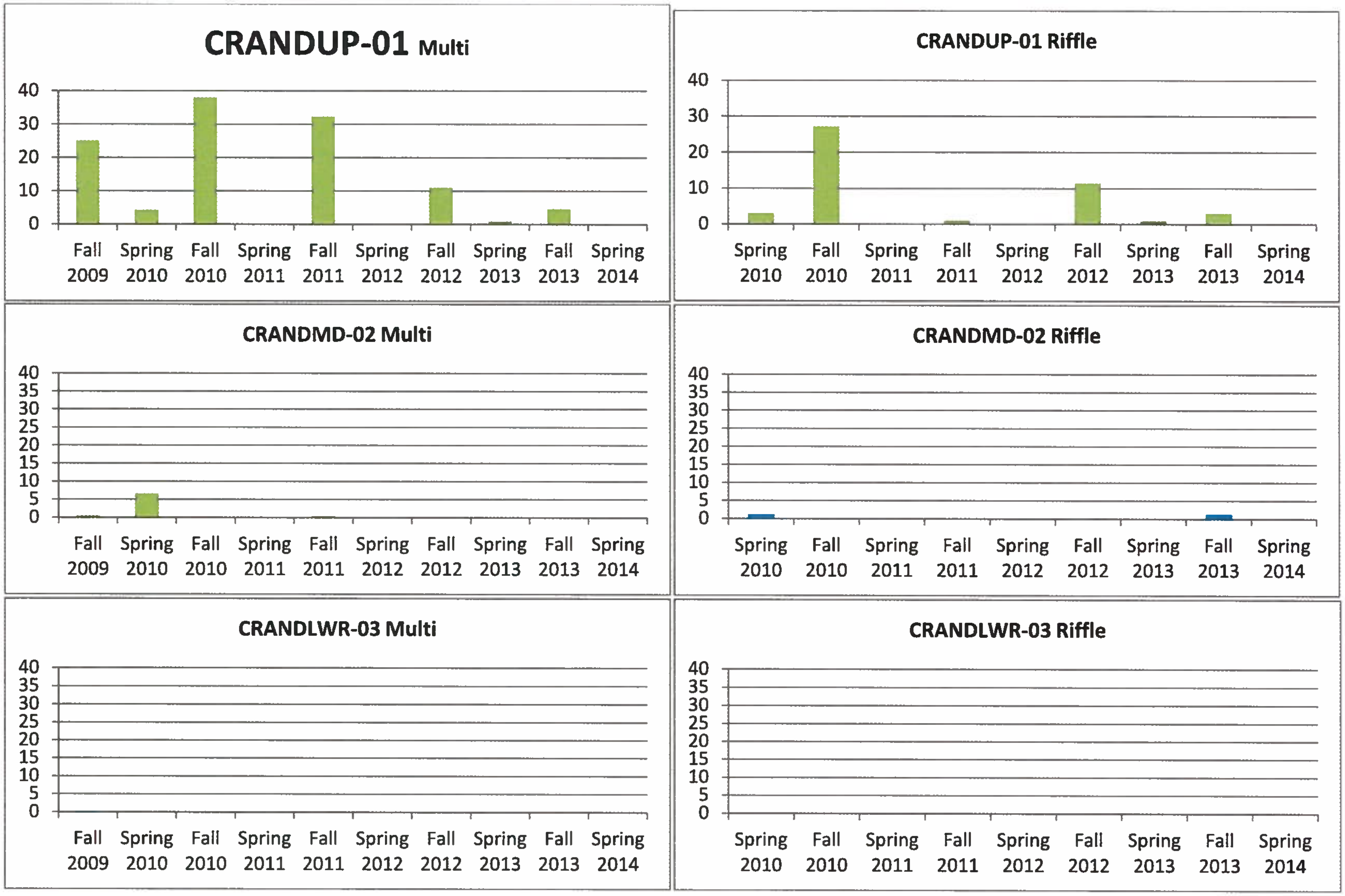
Figures 10c. Ratio of EPT to Chironmoids values for each reach and habitat type from 2009-2014



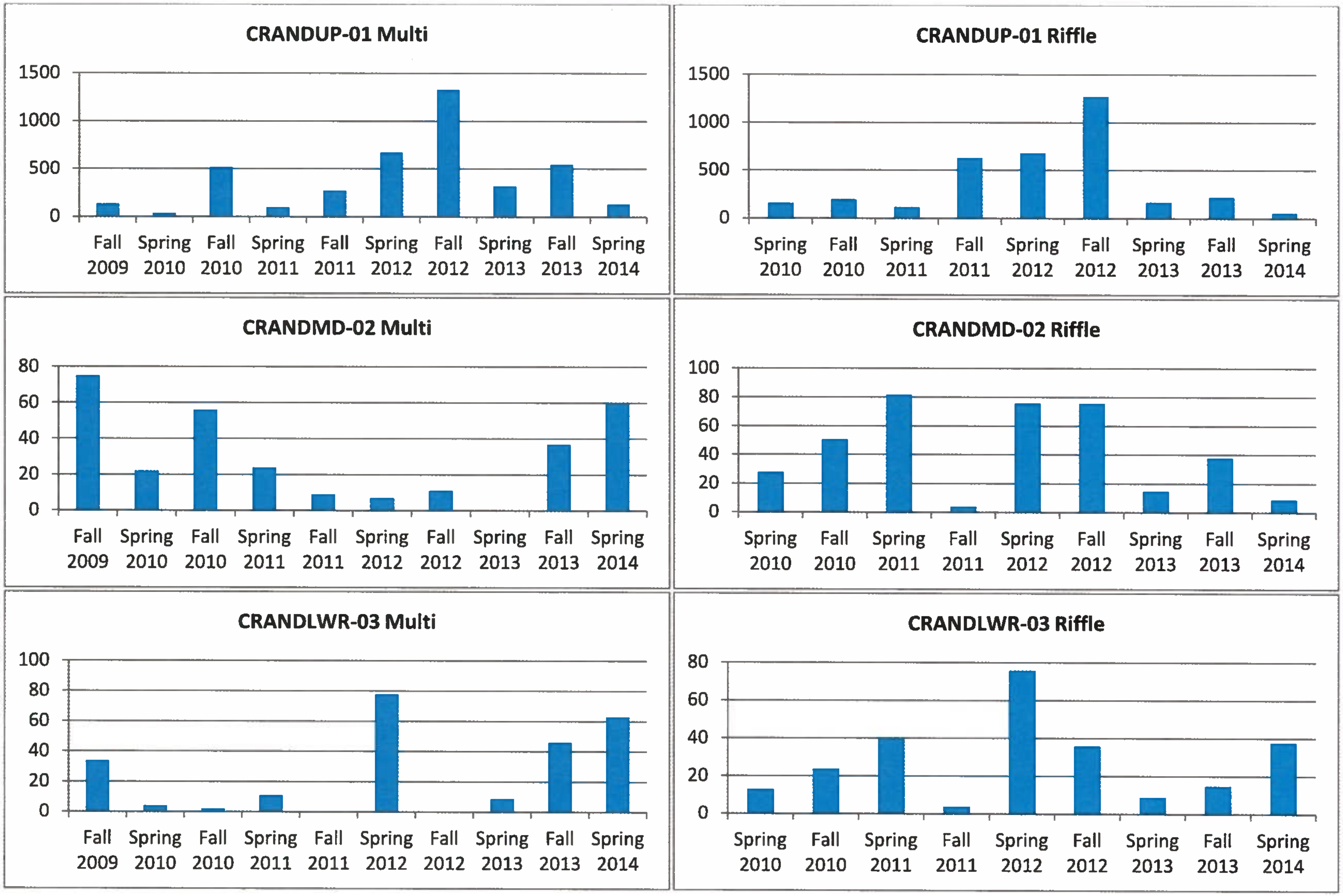
Figures 11c. Number of tolerant taxa for each reach and habitat type from 2009-2014



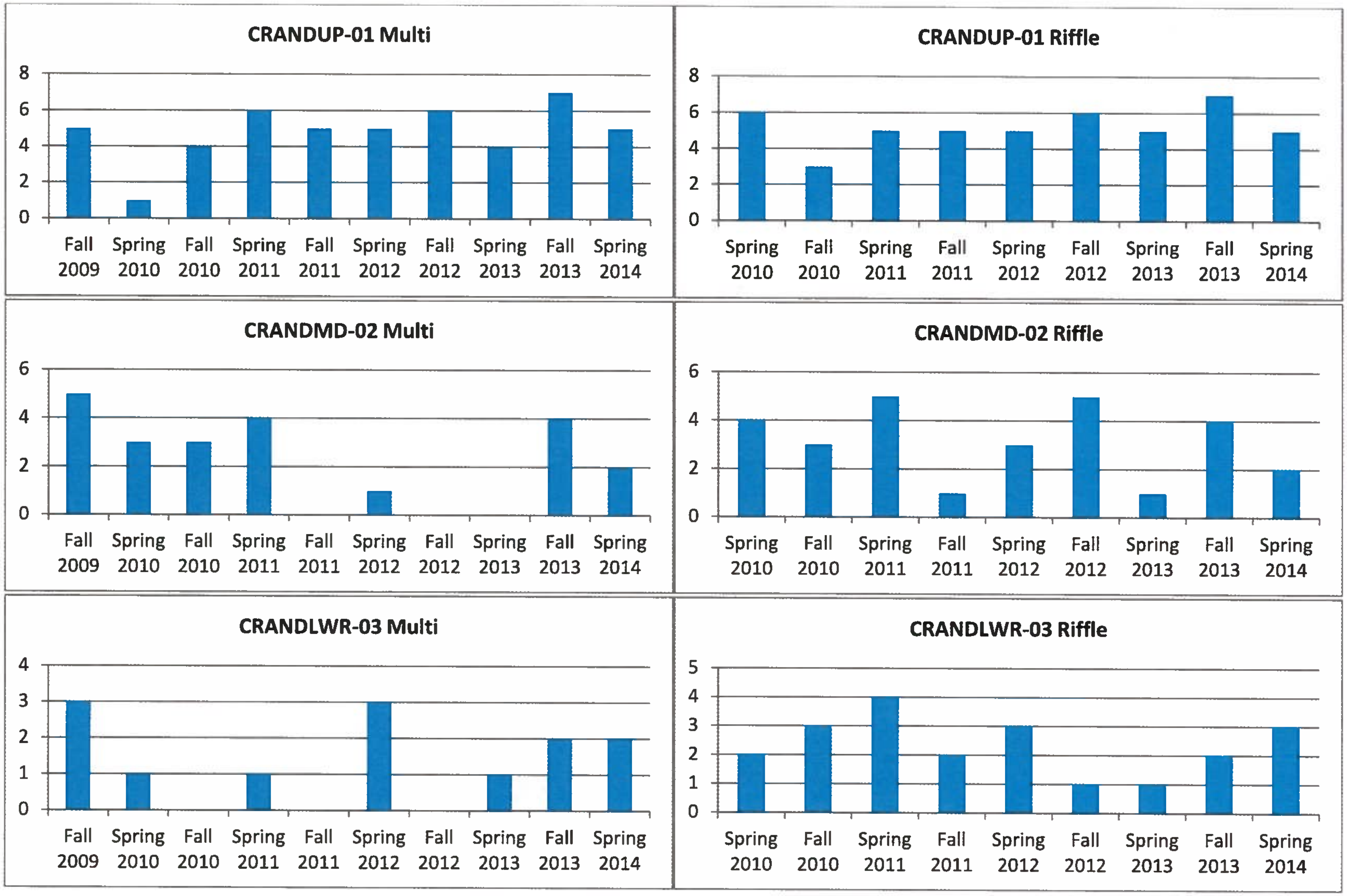
Figures 12c. Percent tolerant organisms for each reach and habitat type from 2009-2014



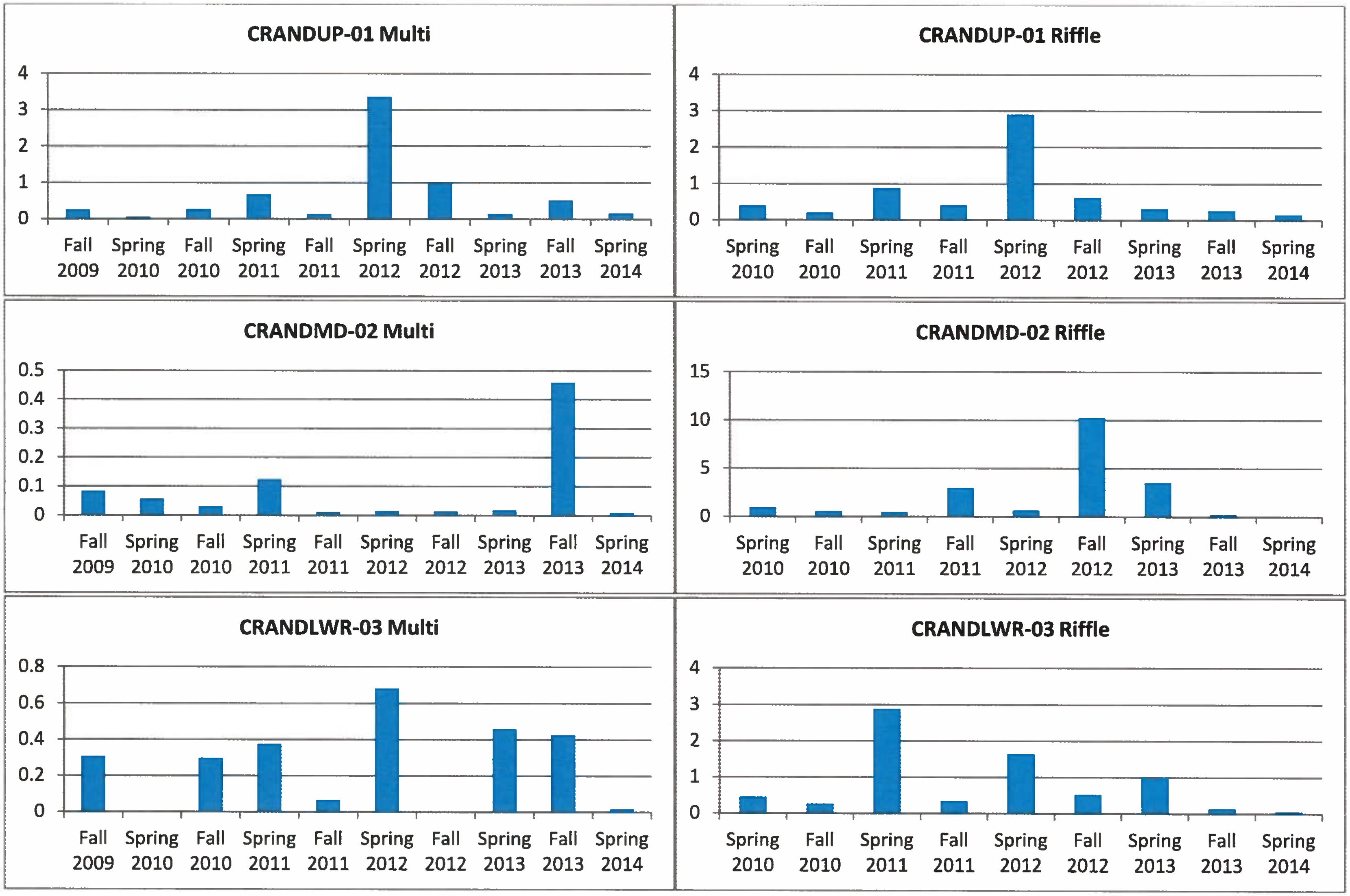
Figures 13c. Number of intolerant taxa for each reach and habitat type from 2009-2014



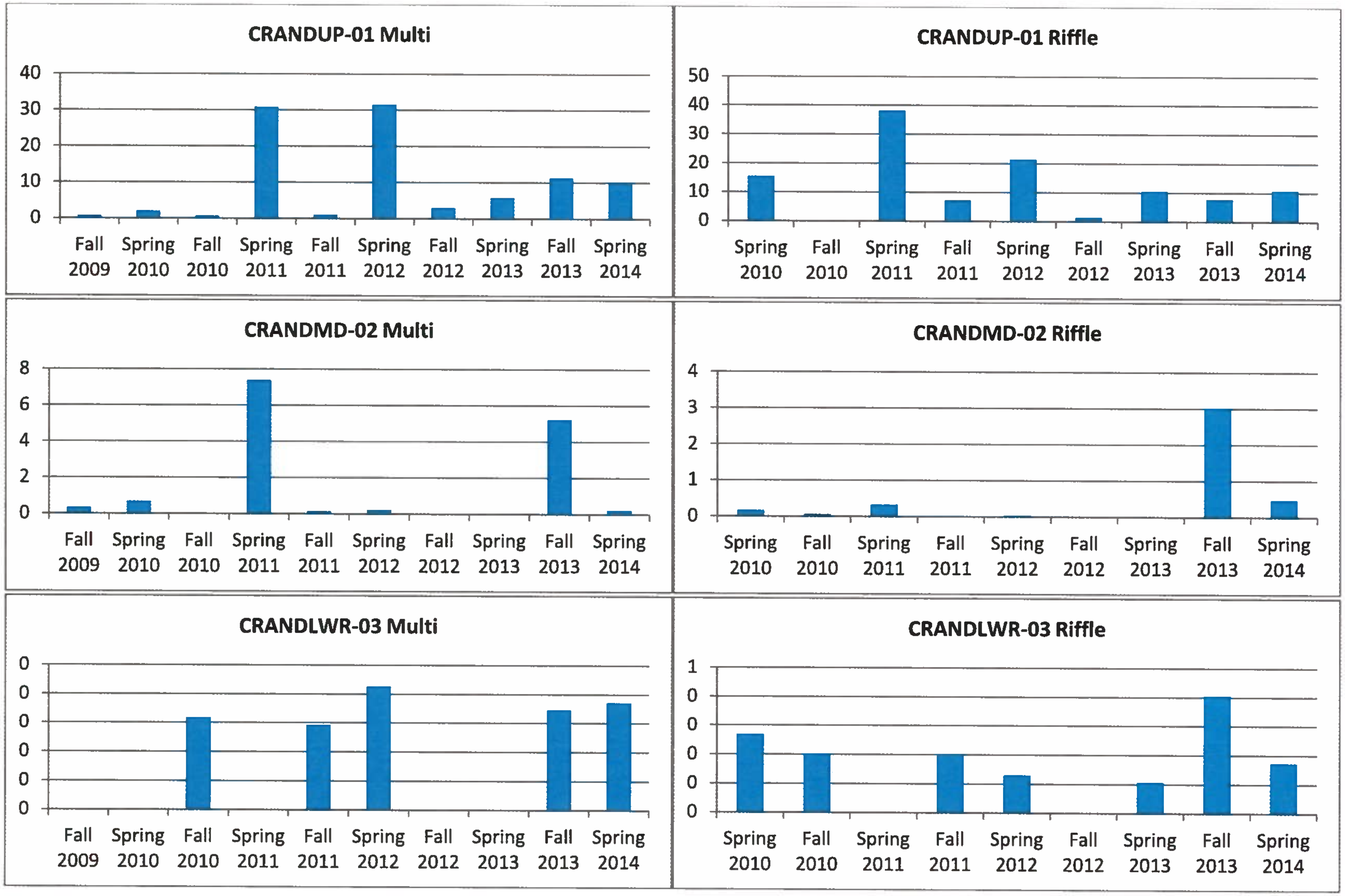
Figures 14c. Percent intolerant organisms for each reach and habitat type from 2009-2014



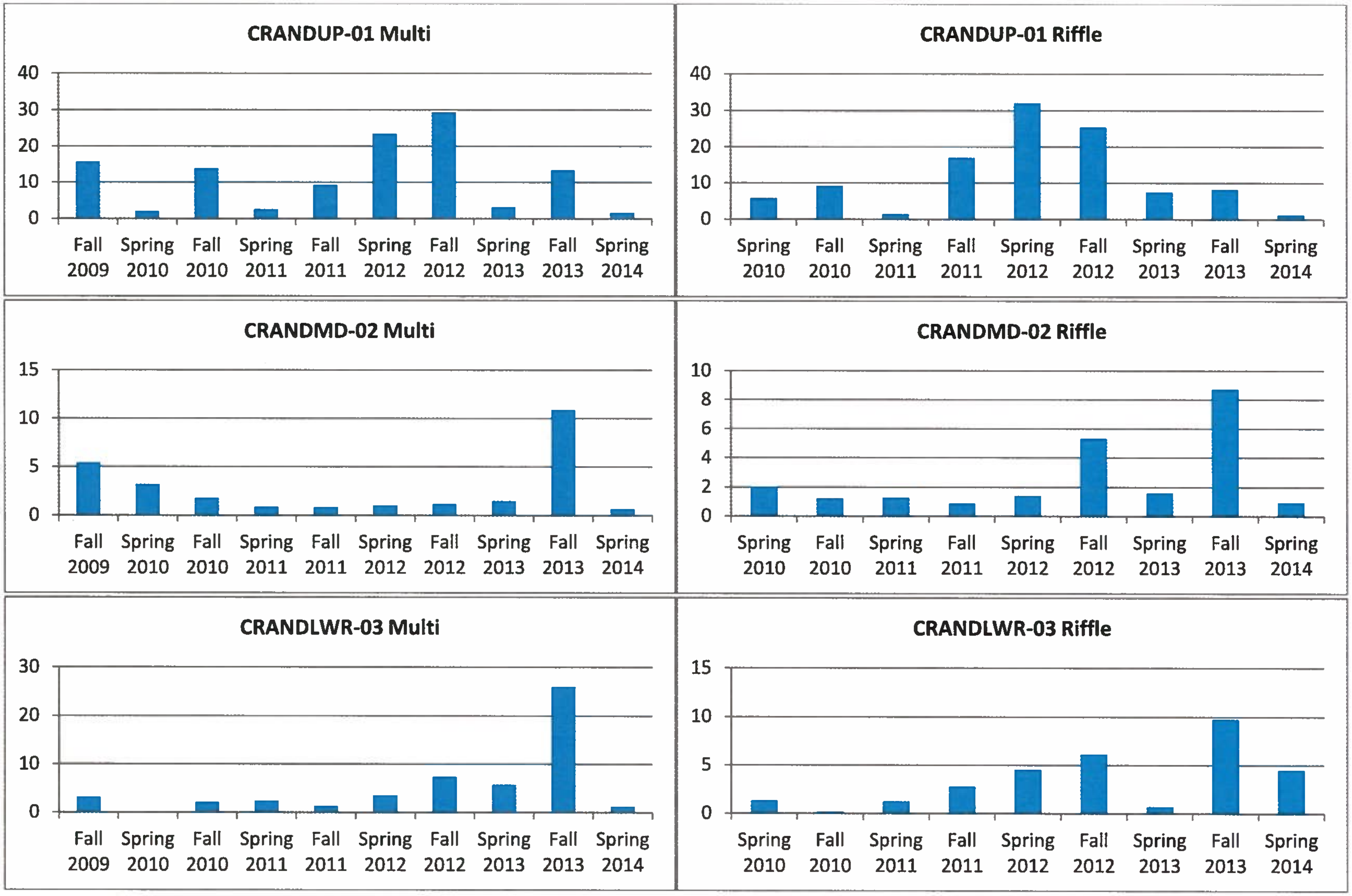
Figures 15c. Ratio of specialist feeders to generalist feeders for each reach and habitat type from 2009-2014



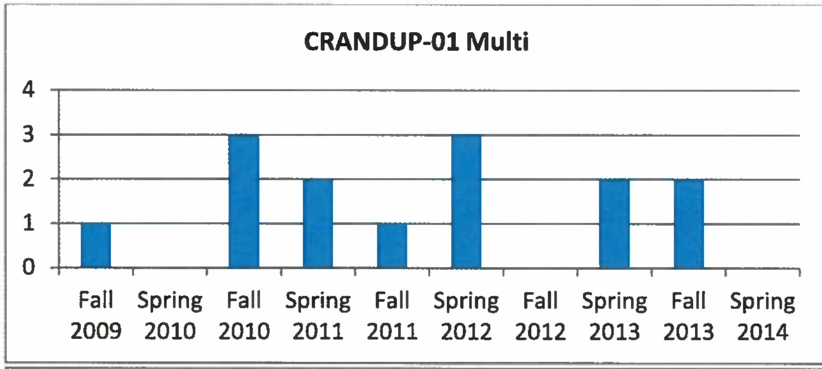
Figures 16c. Percent scrapers for each reach and habitat type from 2009-2014

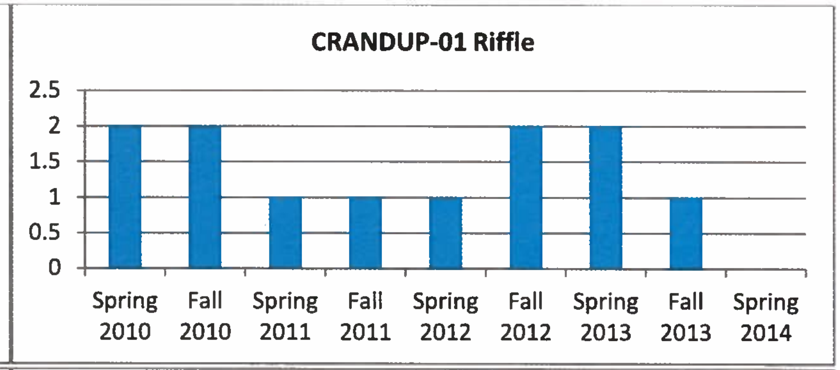


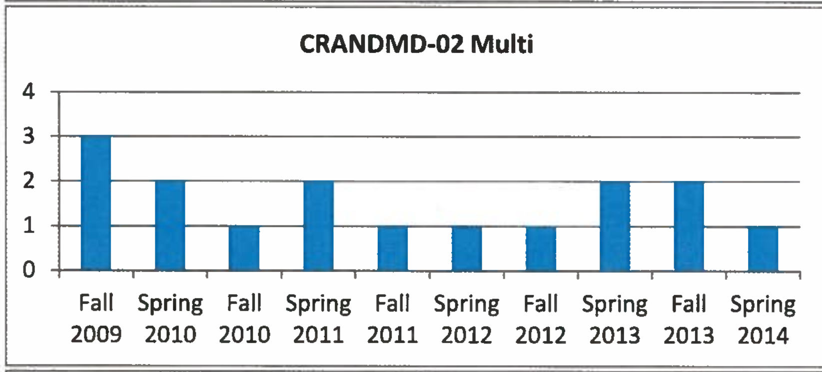
Figures 17c. Percent shredders for each reach and habitat type from 2009-2014

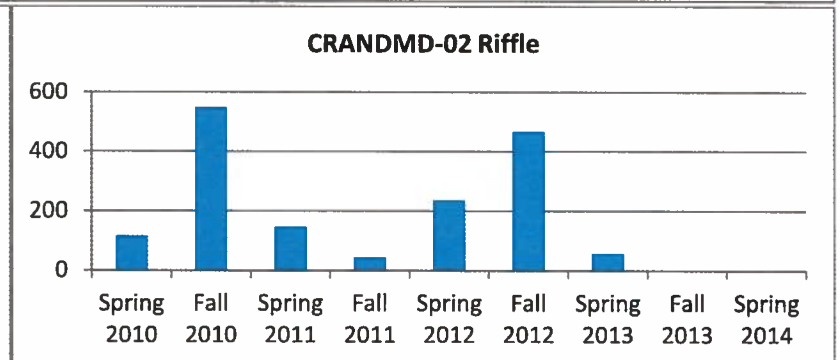


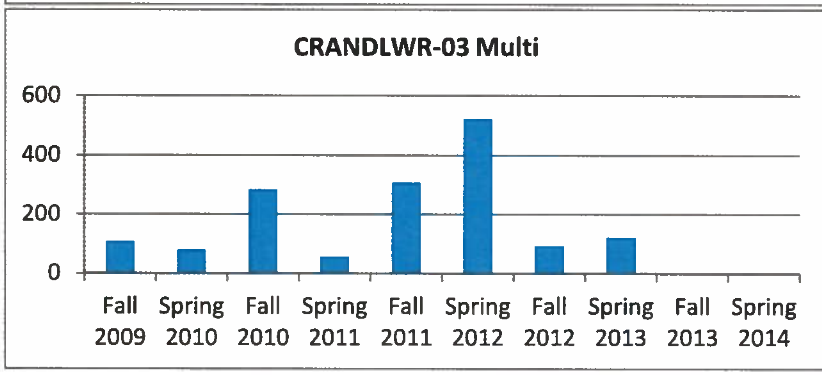
Figures 18c. Number of long-lived taxa for each reach and habitat type from 2009-2014

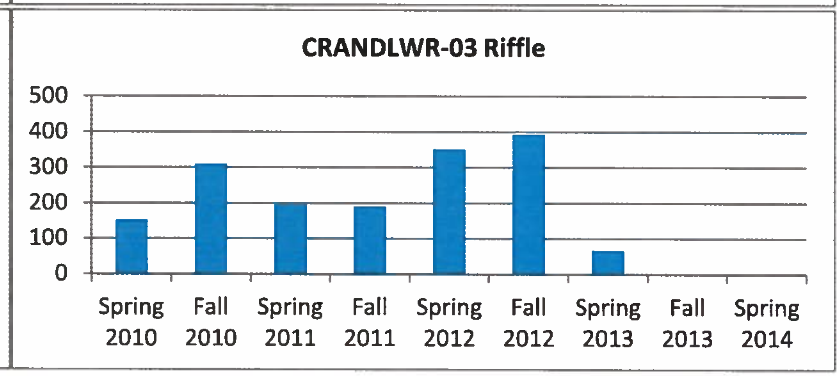




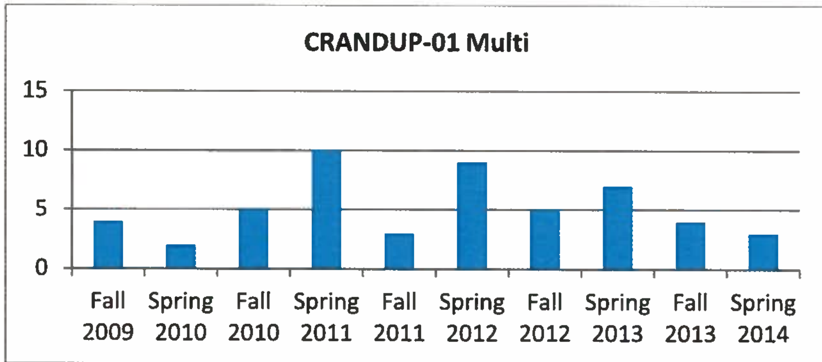


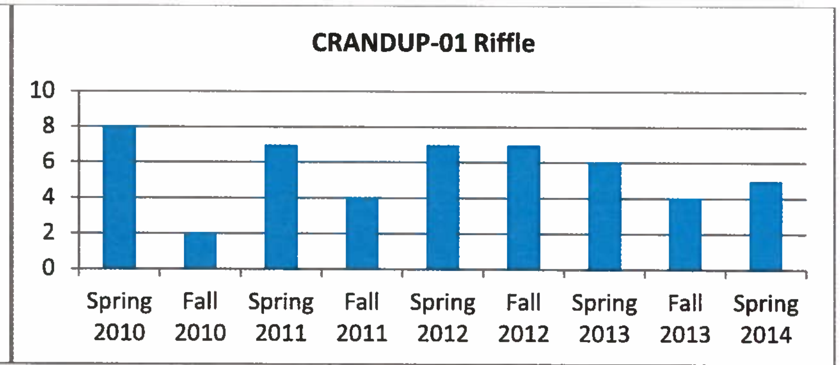


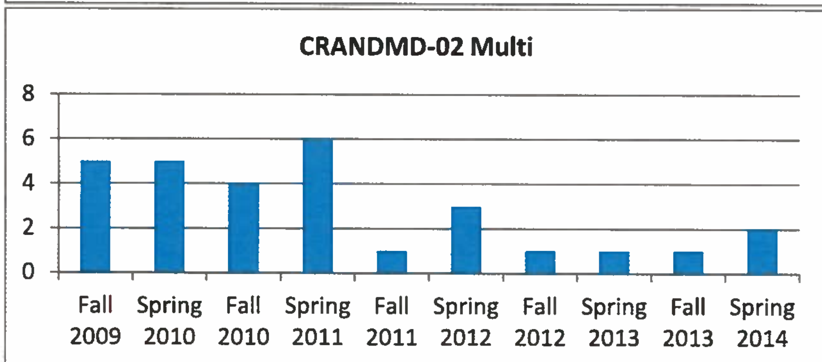


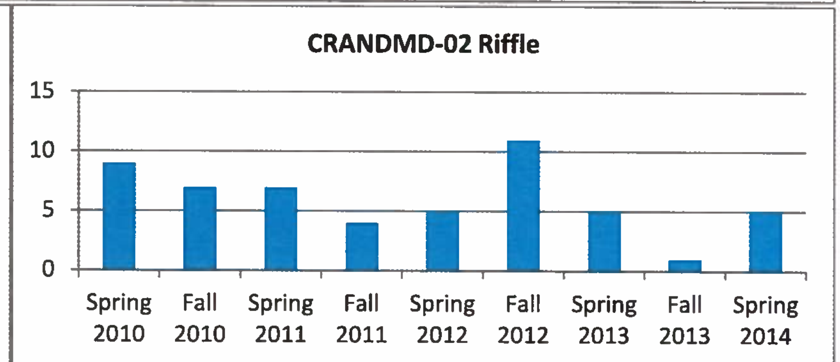


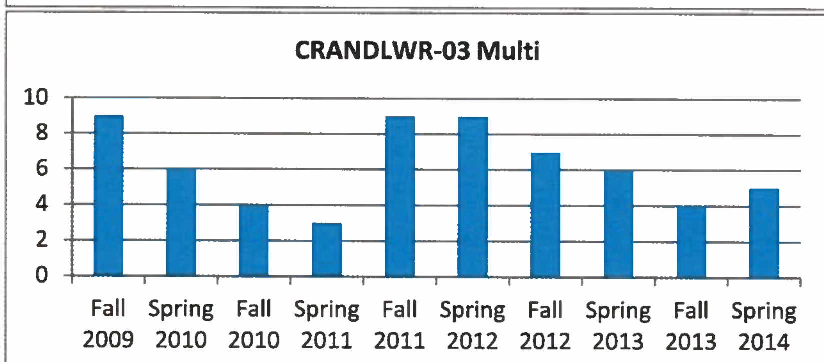
Figures 19c. Number of clinger taxa for each reach and habitat type from 2009-2014

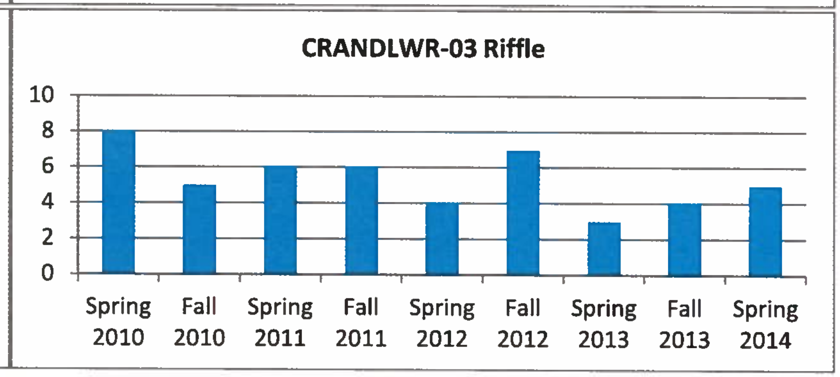




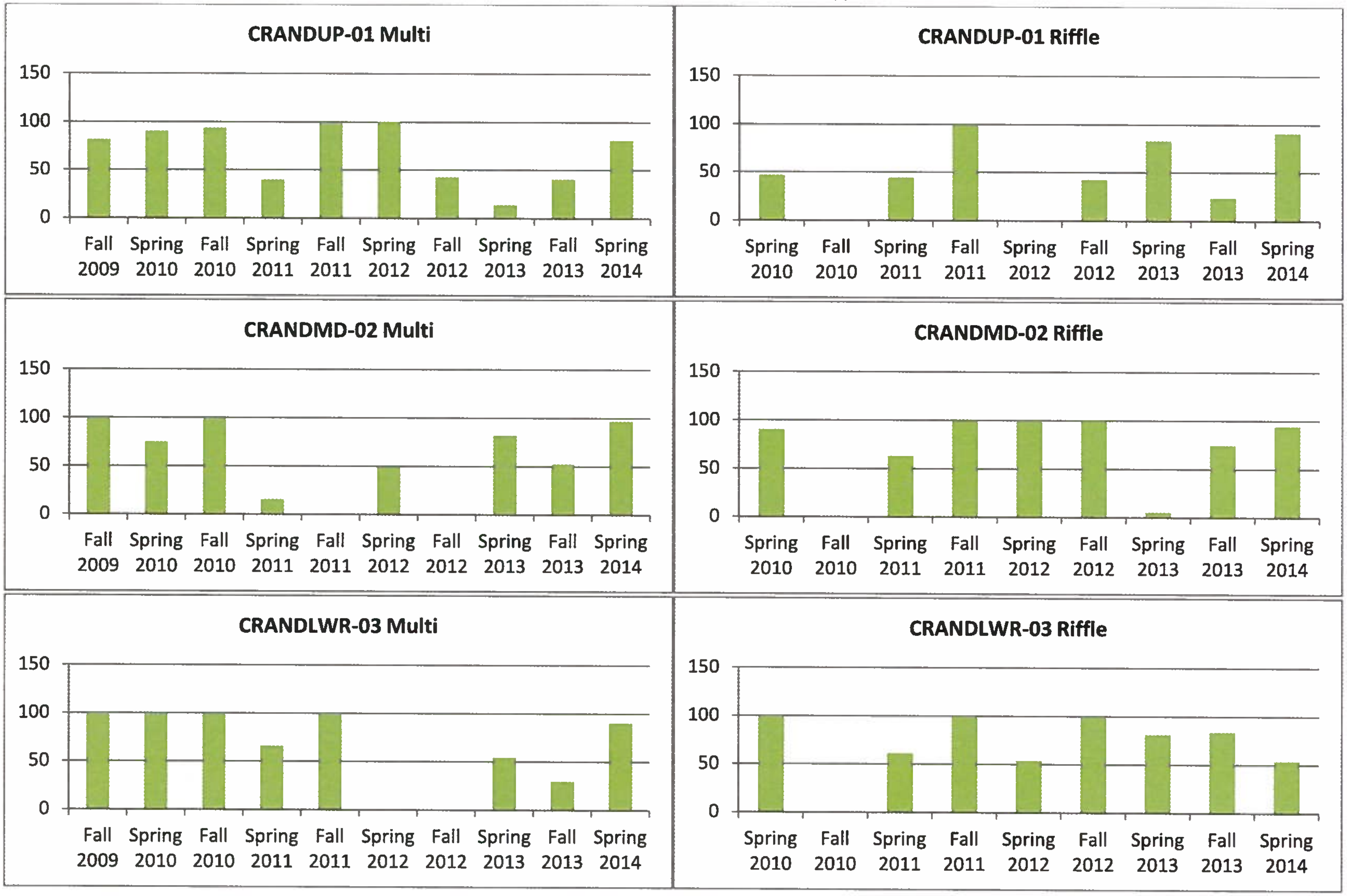




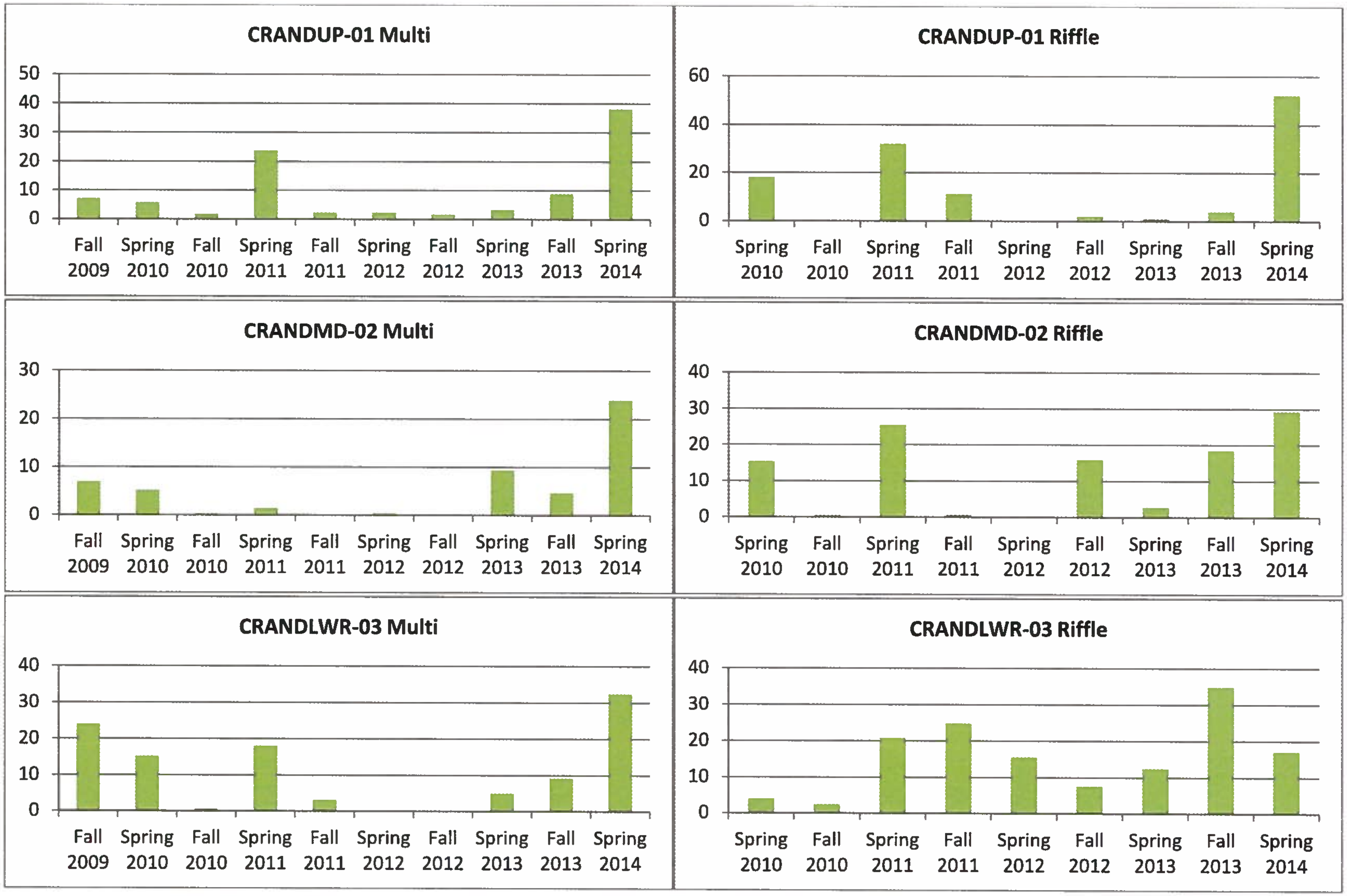




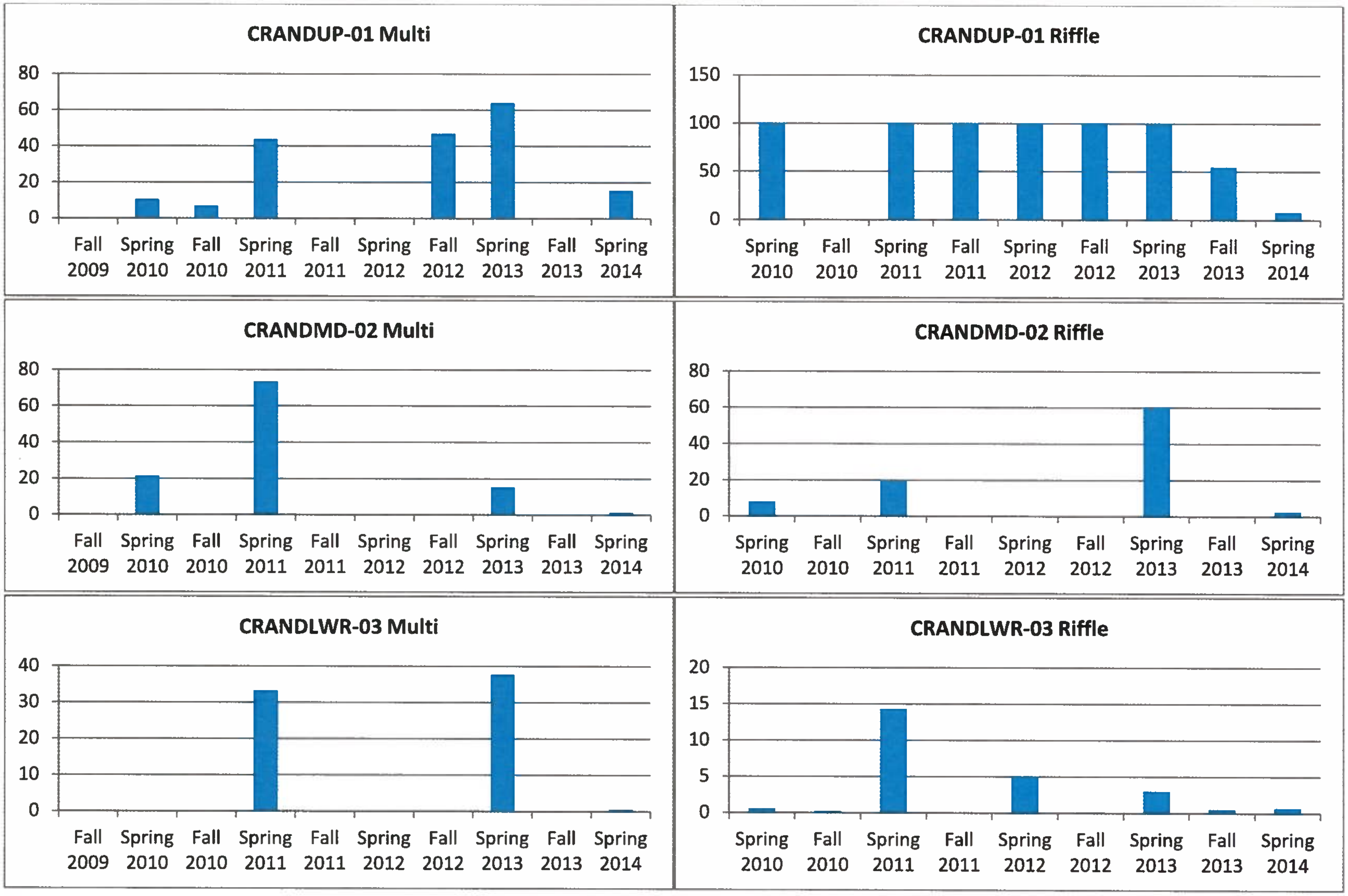
Figures 20c. Percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2009-2014



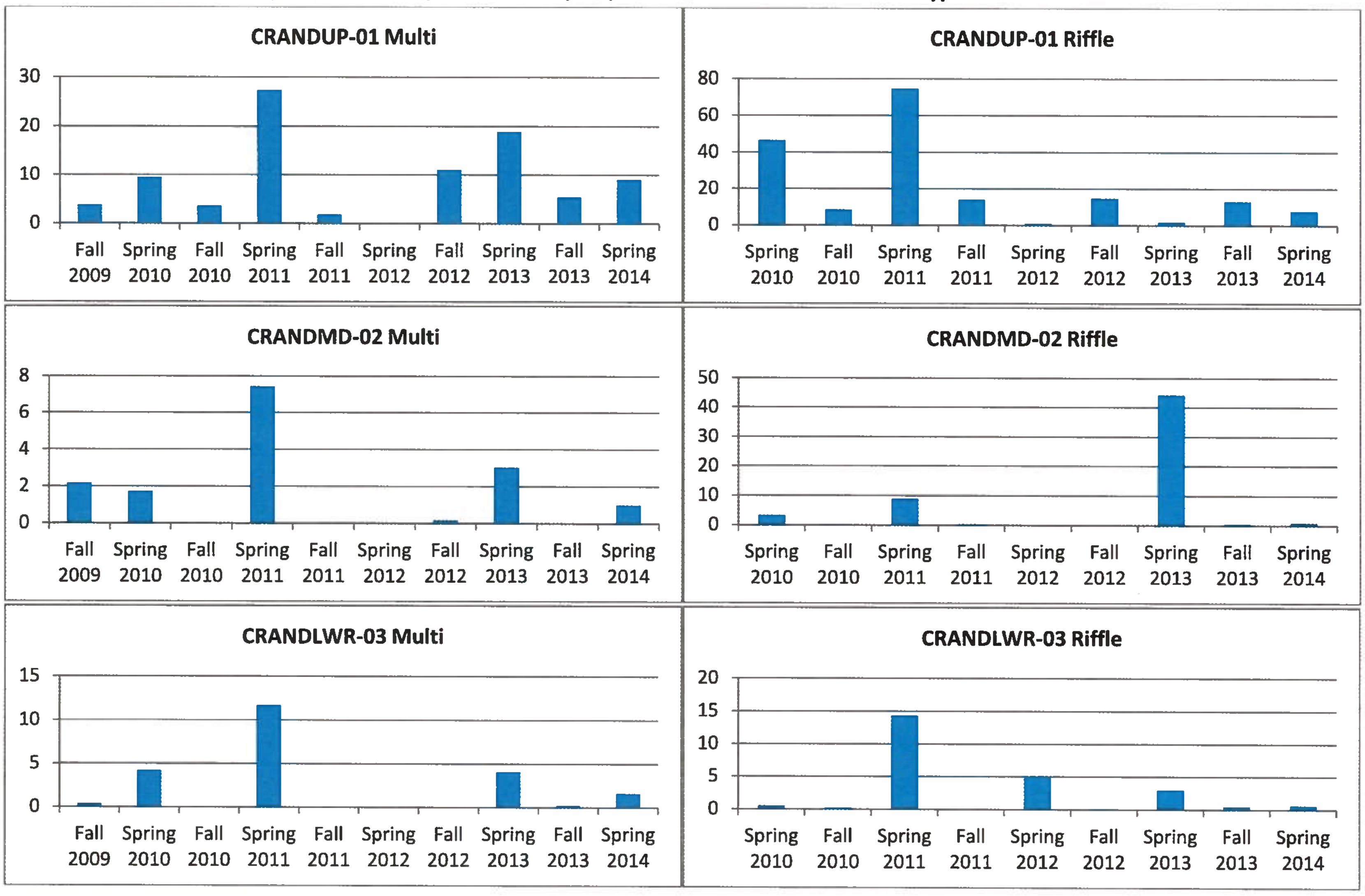
Figures 21c. Percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2014



Figures 22c. Percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2014



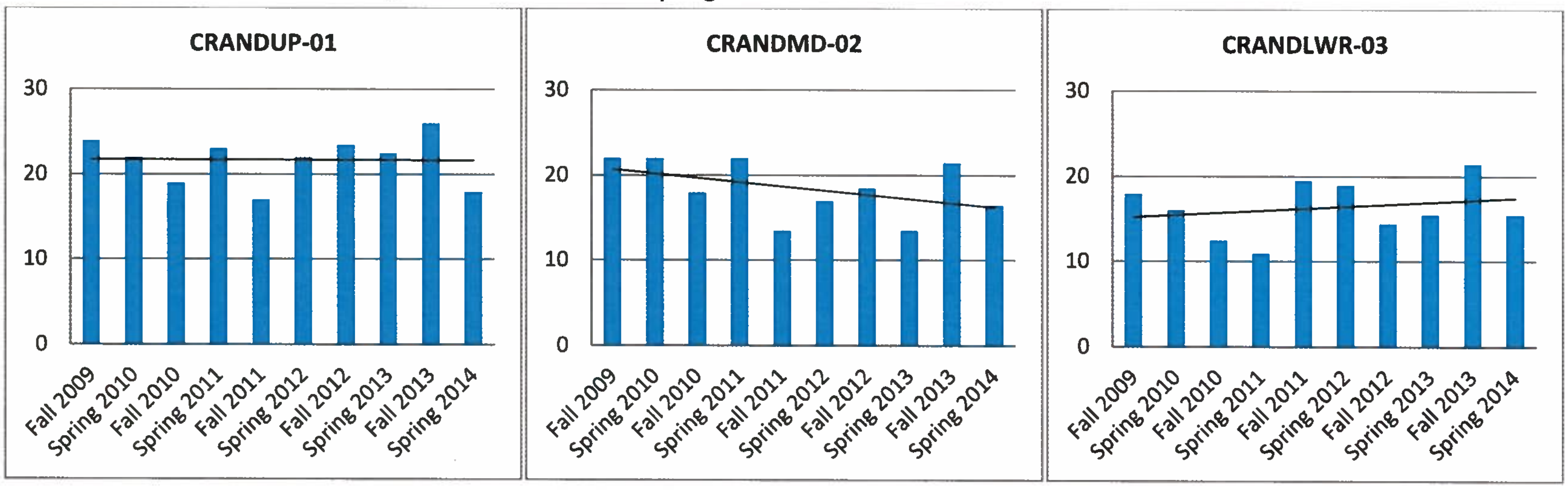
Figures 23c. Percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2014



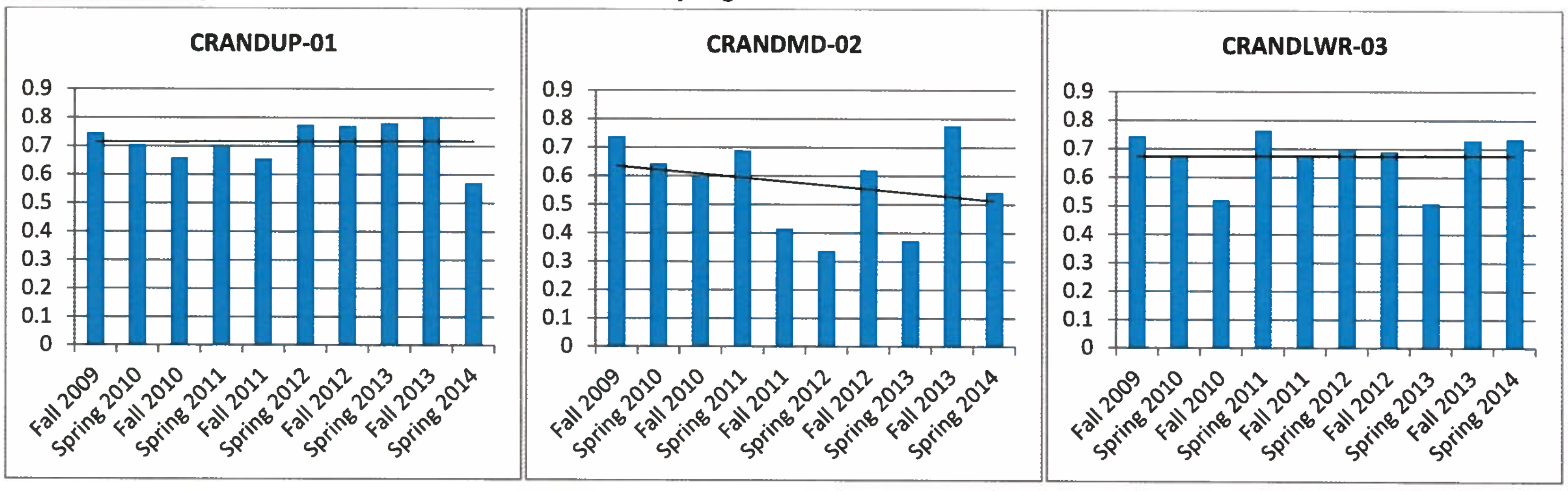
APPENDIX D

MACROINVERTEBRATE FIGURES FALL 2009- SPRING 2014 AVERAGED

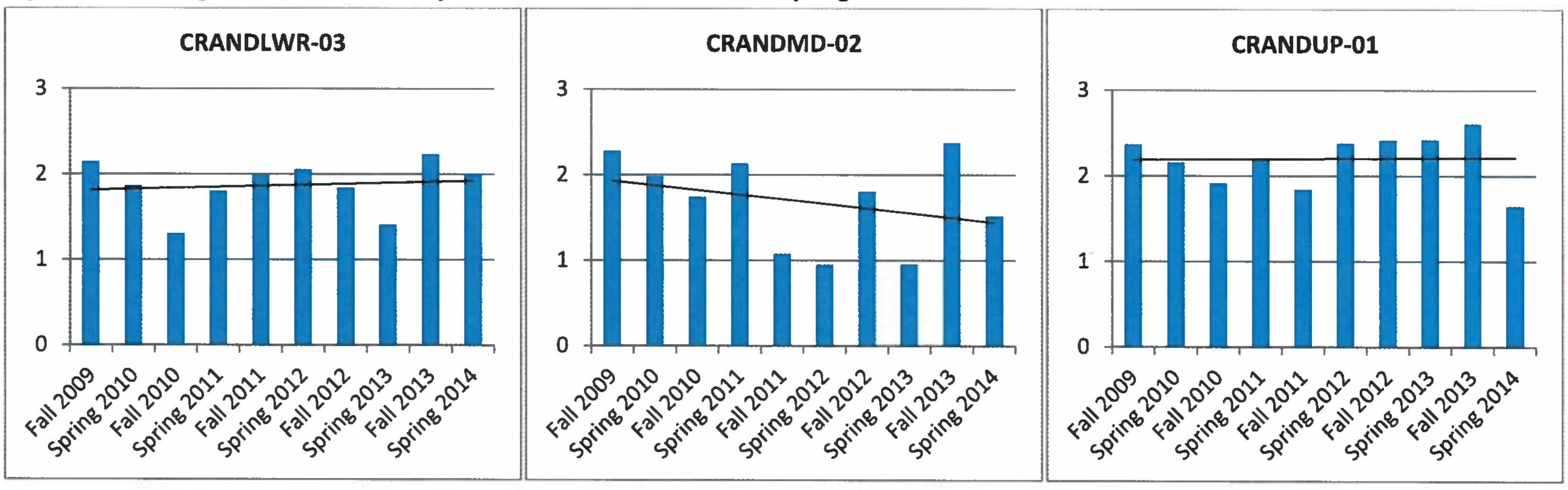
Figures 1d. Average richness in each reach from Fall 2009- Spring 2014



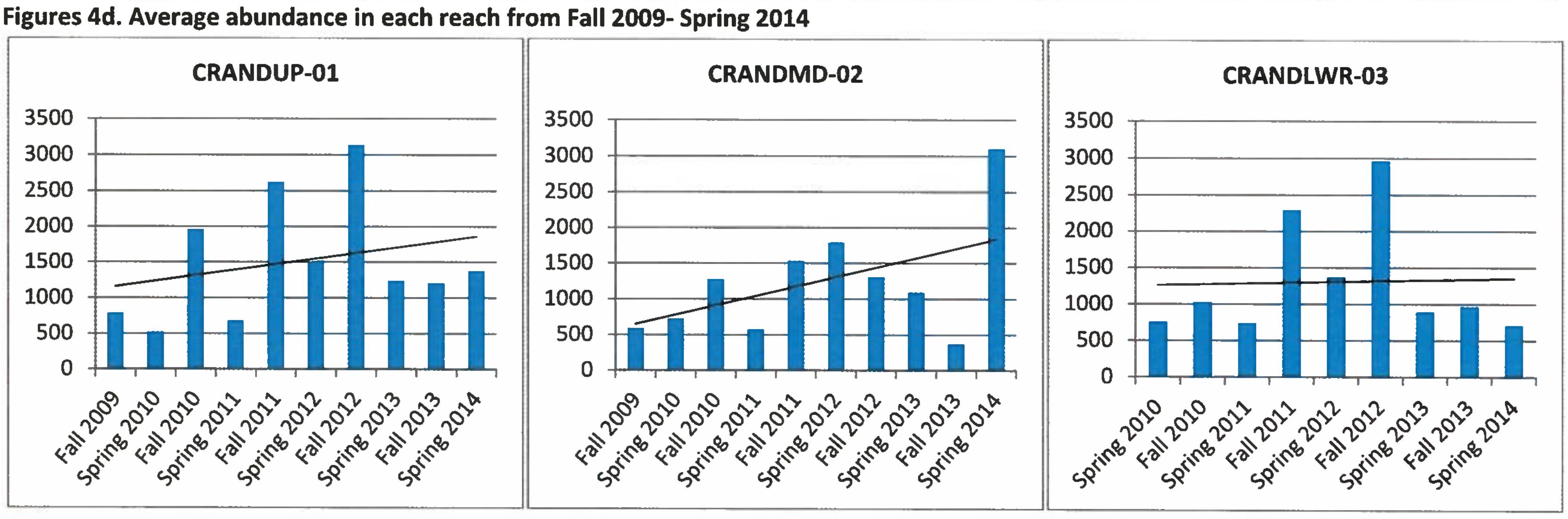
Figures 2d. Average evenness in each reach from Fall 2009- Spring 2014



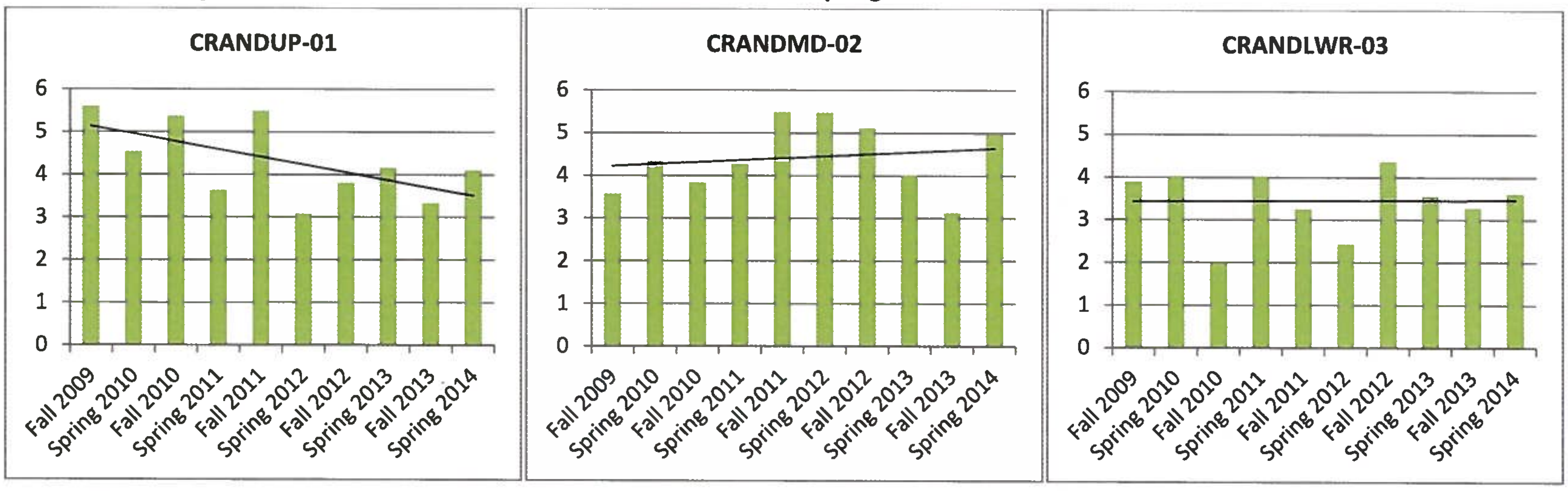
Figures 3d. Average Shannon's Diversity in each reach from Fall 2009- Spring 2014



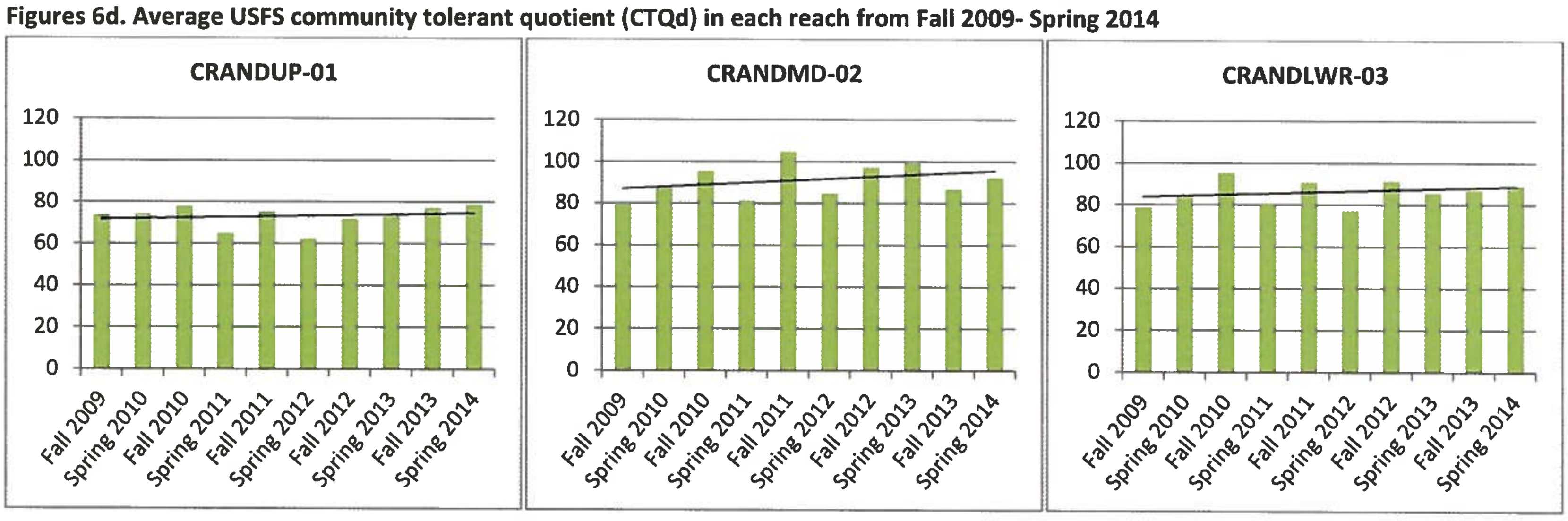
Figures 4d. Average abundance in each reach from Fall 2009- Spring 2014



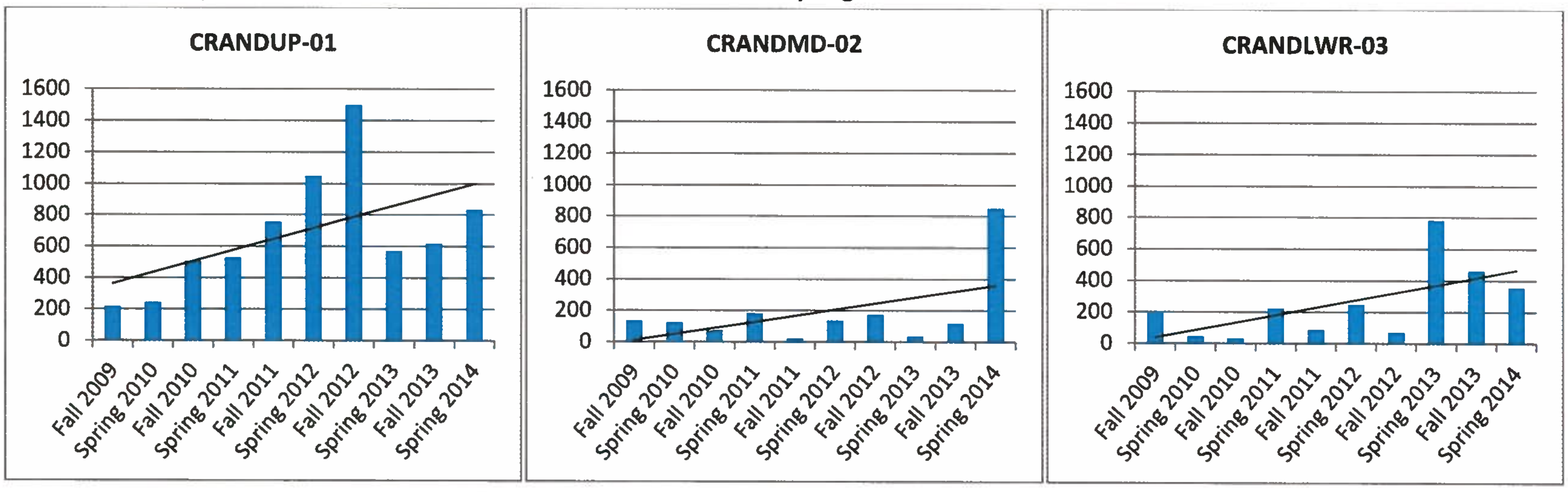
Figures 5d. Average Hilsenhoff Biotic Index in each reach from Fall 2009- Spring 2014



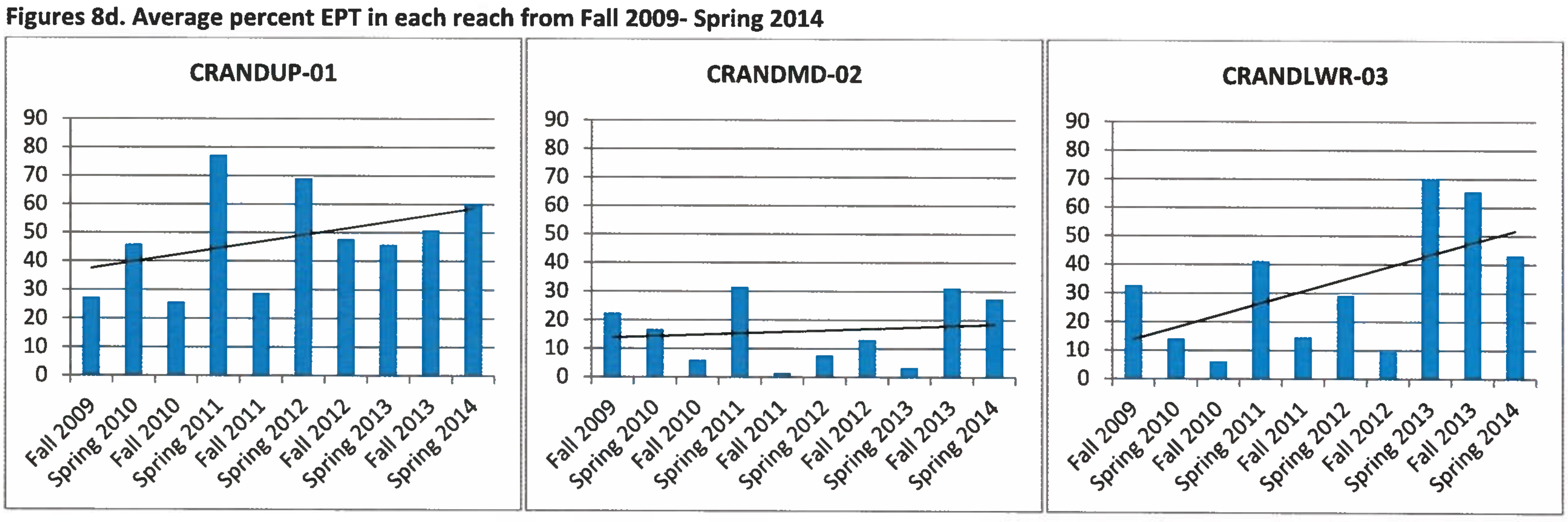
Figures 6d. Average USFS community tolerant quotient (CTQd) in each reach from Fall 2009- Spring 2014



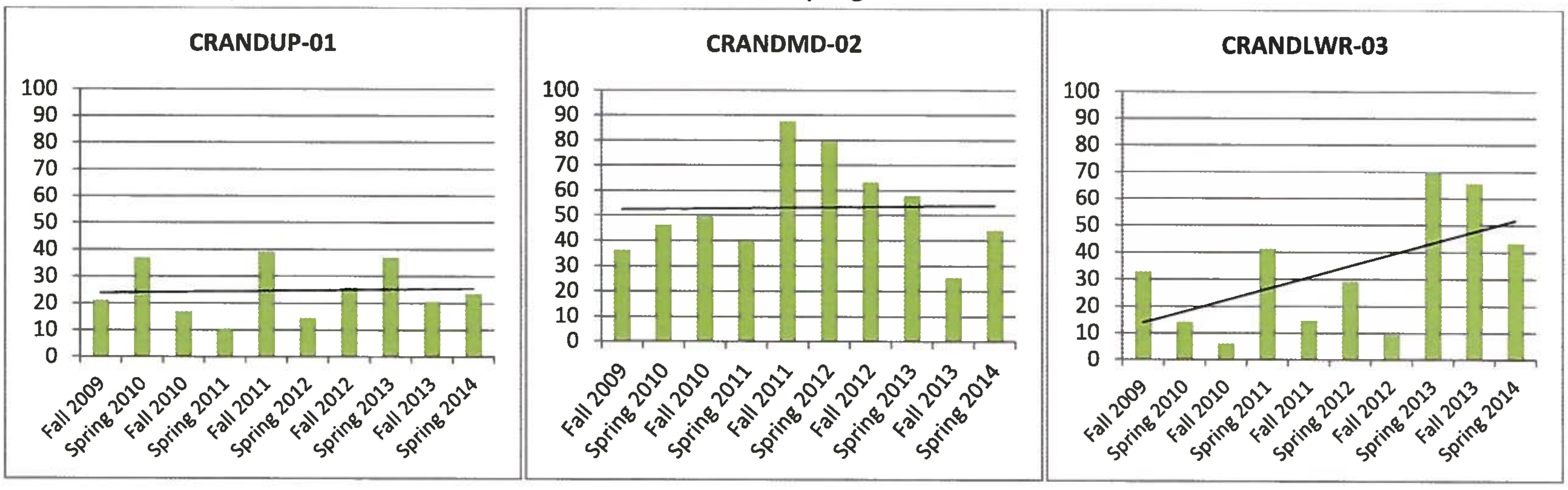
Figures 7d. Average EPT taxa abundance in each reach from Fall 2009- Spring 2014



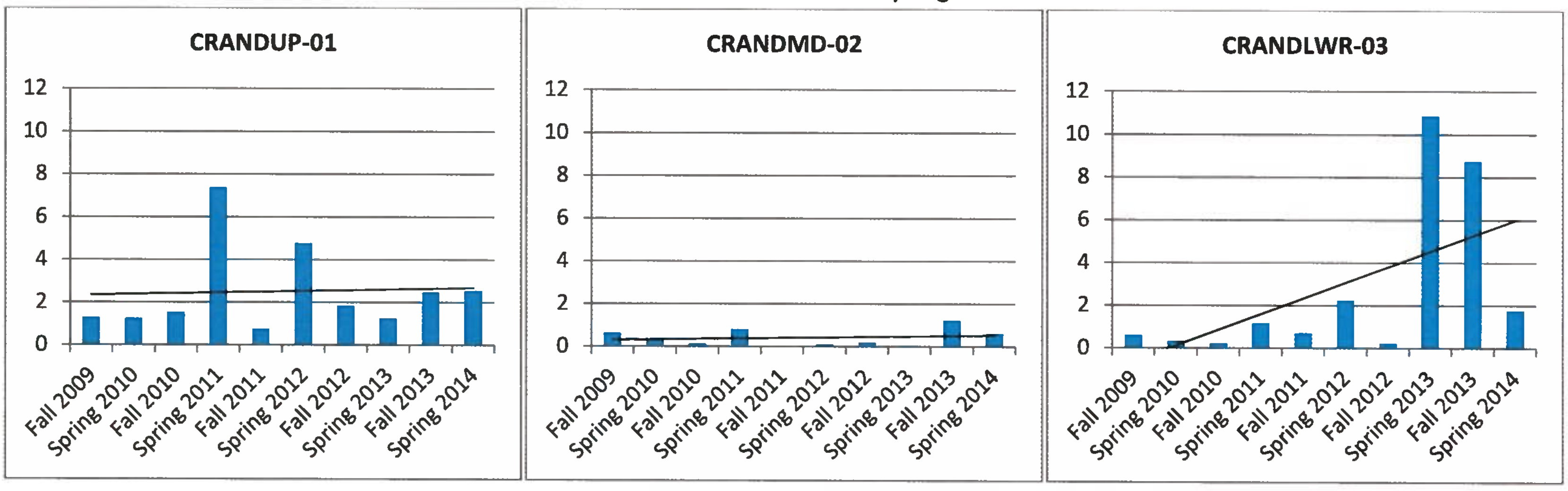
Figures 8d. Average percent EPT in each reach from Fall 2009- Spring 2014



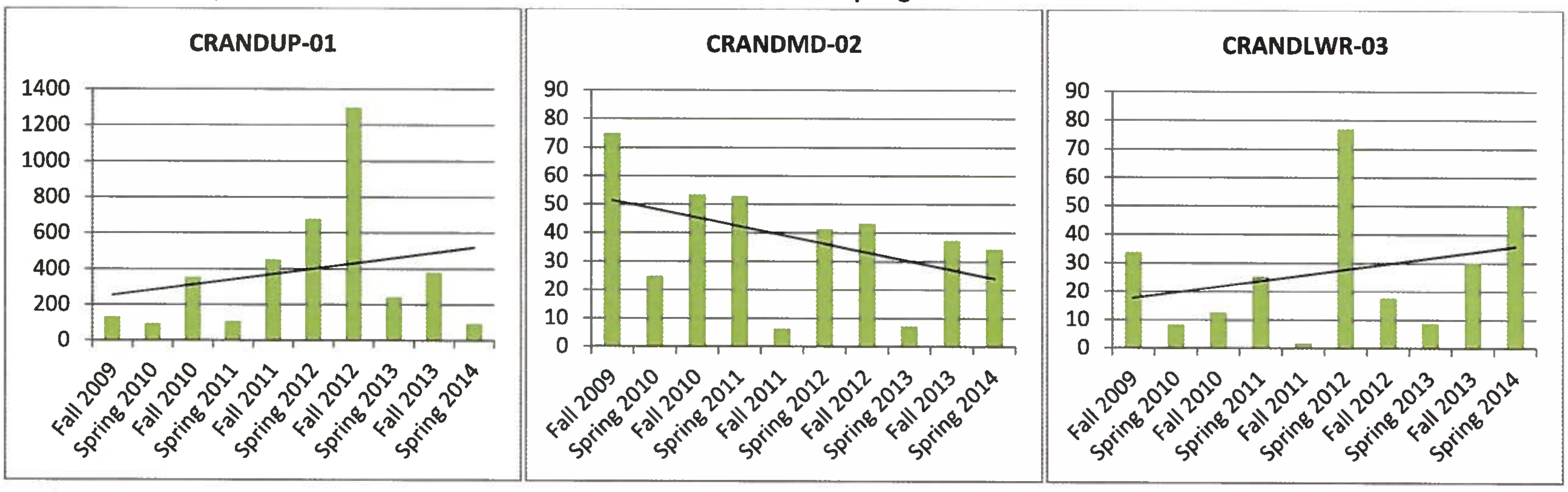
Figures 9d. Average percent Chironomids in each reach from Fall 2009- Spring 2014



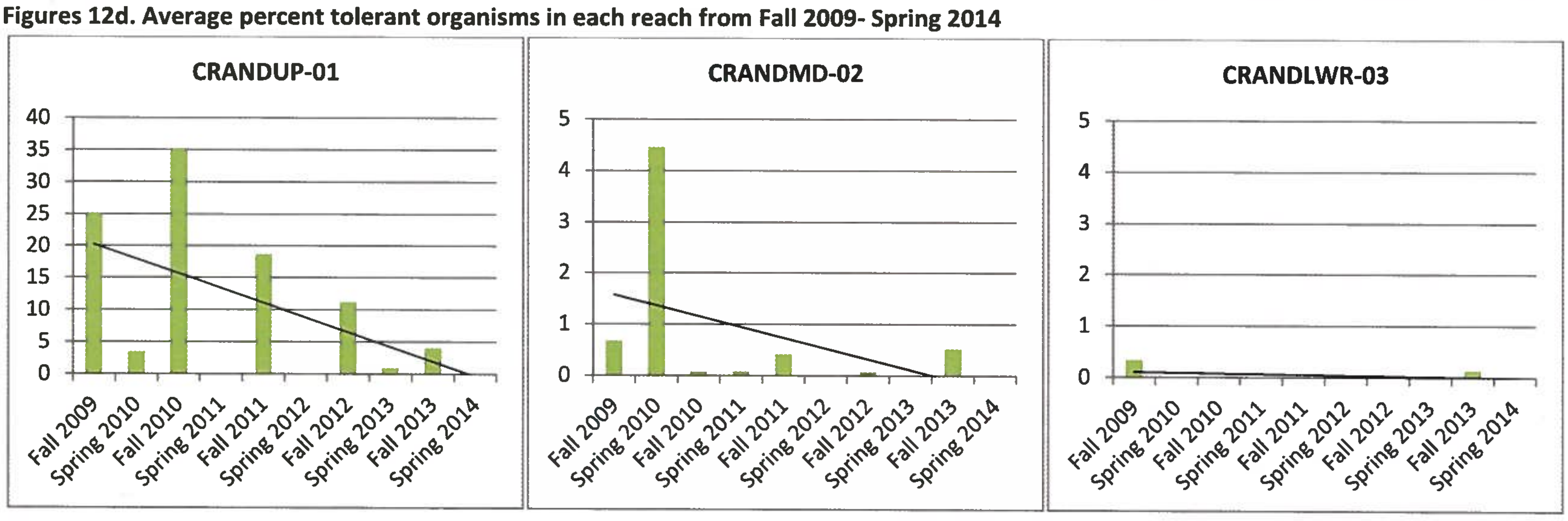
Figures 10d. Average ratio of EPT to Chironomids in each reach from Fall 2009- Spring 2014



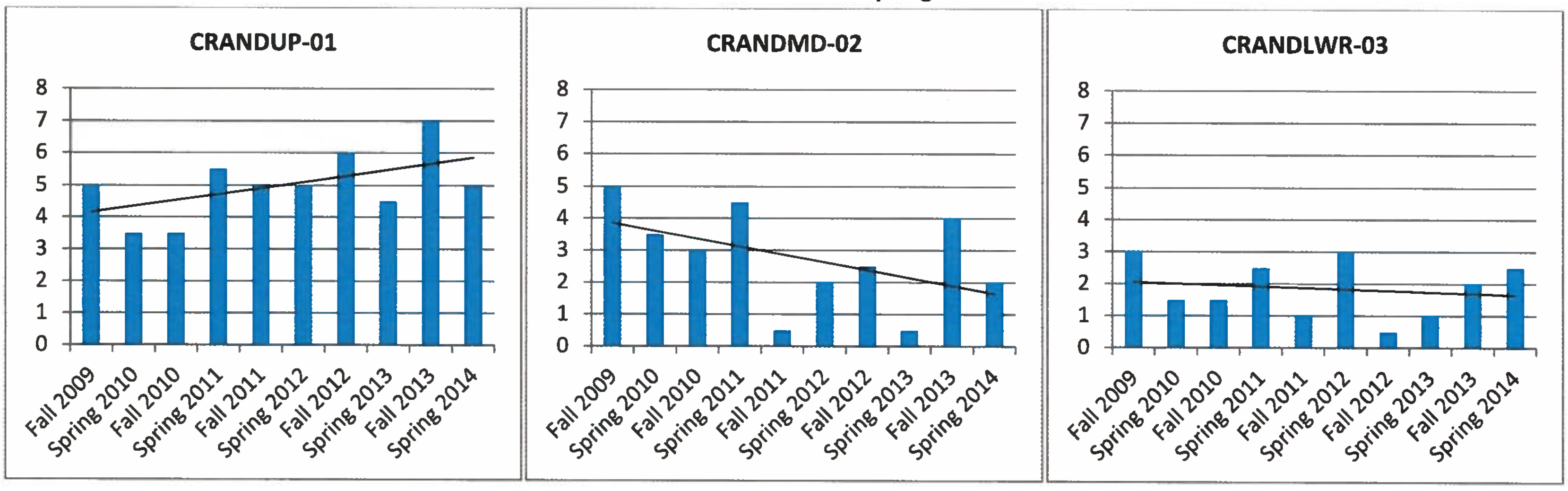
Figures 11d. Average number of tolerant taxa in each reach from Fall 2009- Spring 2014



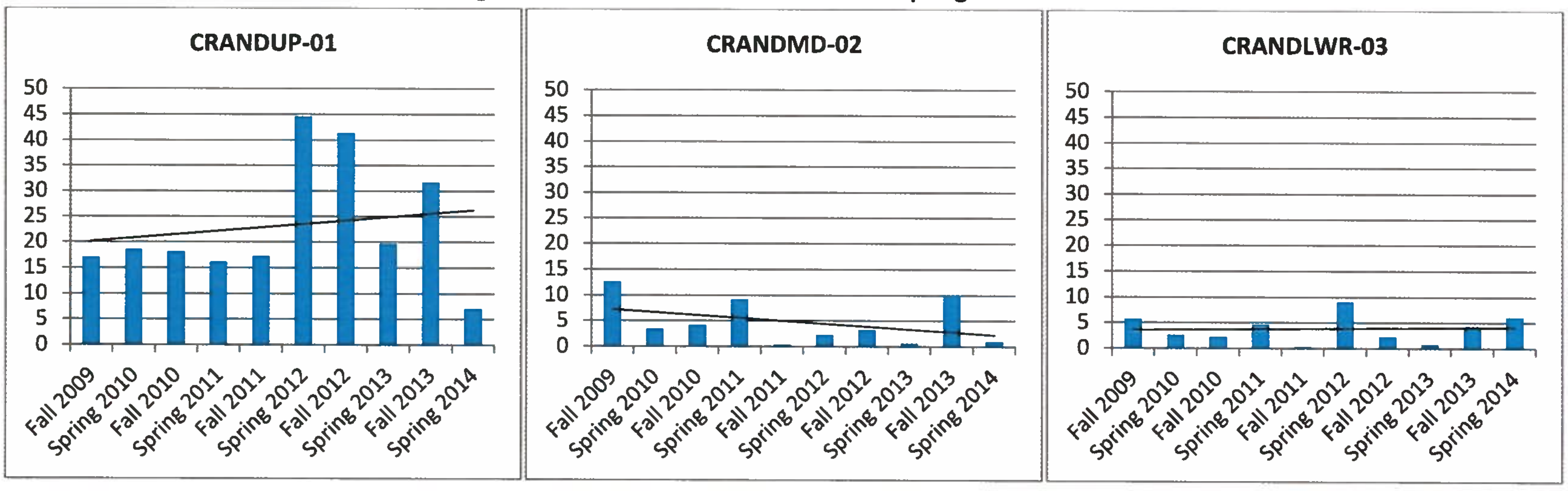
Figures 12d. Average percent tolerant organisms in each reach from Fall 2009- Spring 2014



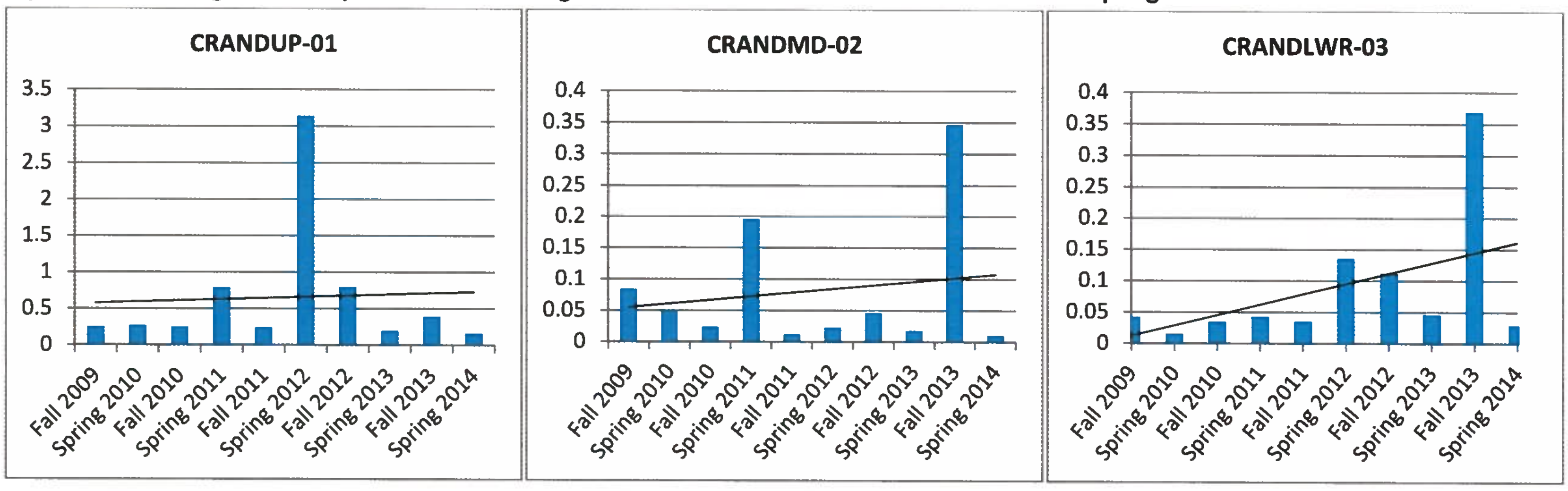
Figures 13d. Average number of intolerant taxa in each reach from Fall 2009- Spring 2014



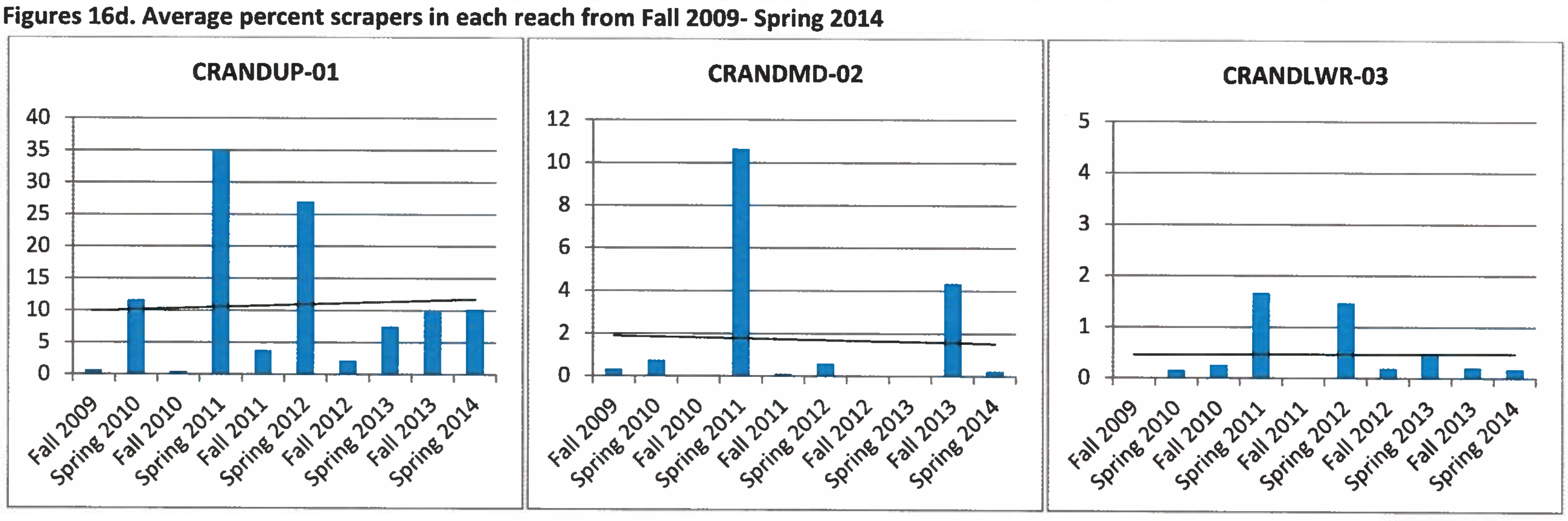
Figures 14d. Average percent intolerant organisms in each reach from Fall 2009- Spring 2014



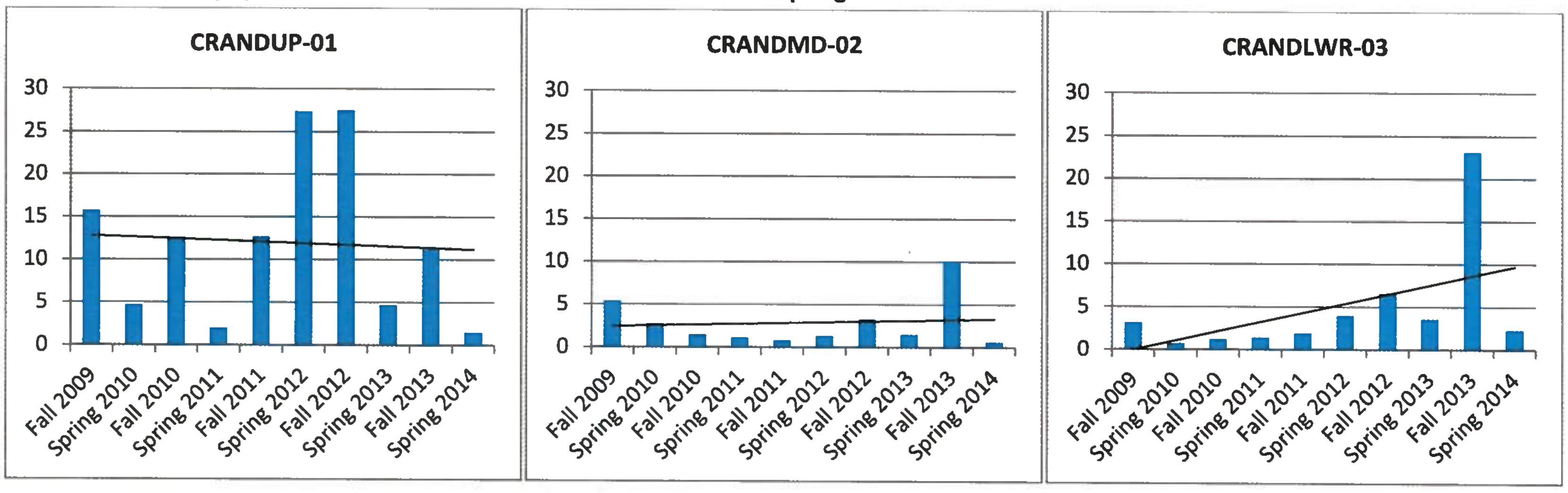
Figures 15d. Average ratio of specialist feeders to generalist feeders in each reach from Fall 2009- Spring 2014



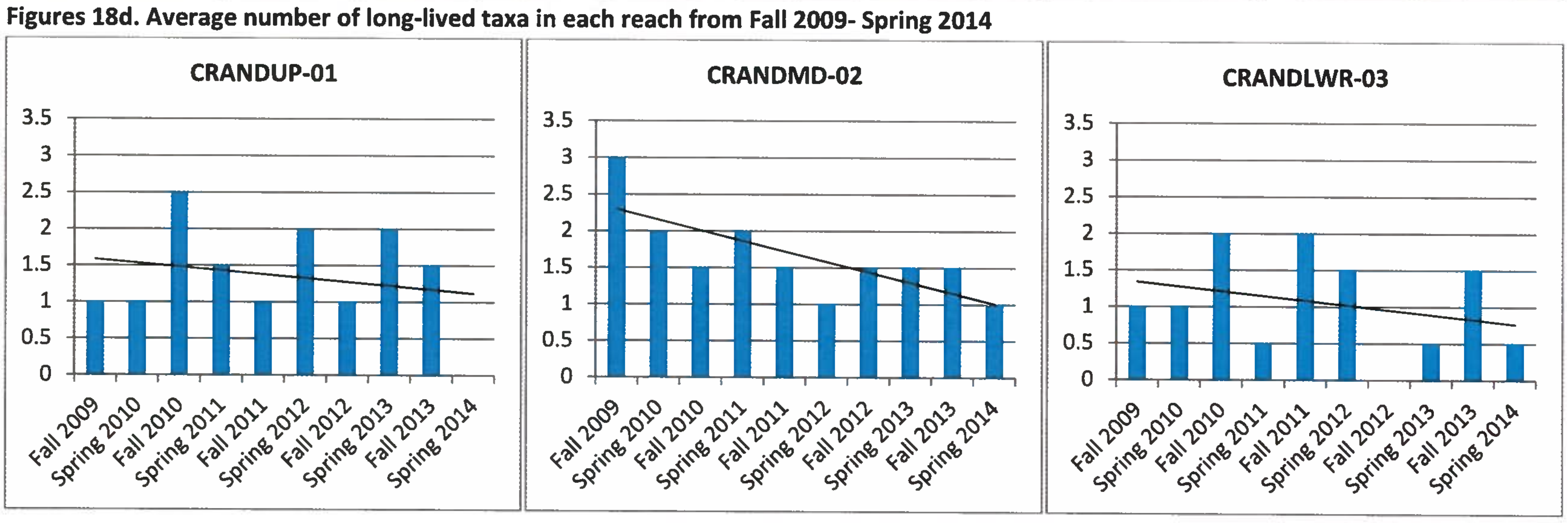
Figures 16d. Average percent scrapers in each reach from Fall 2009- Spring 2014



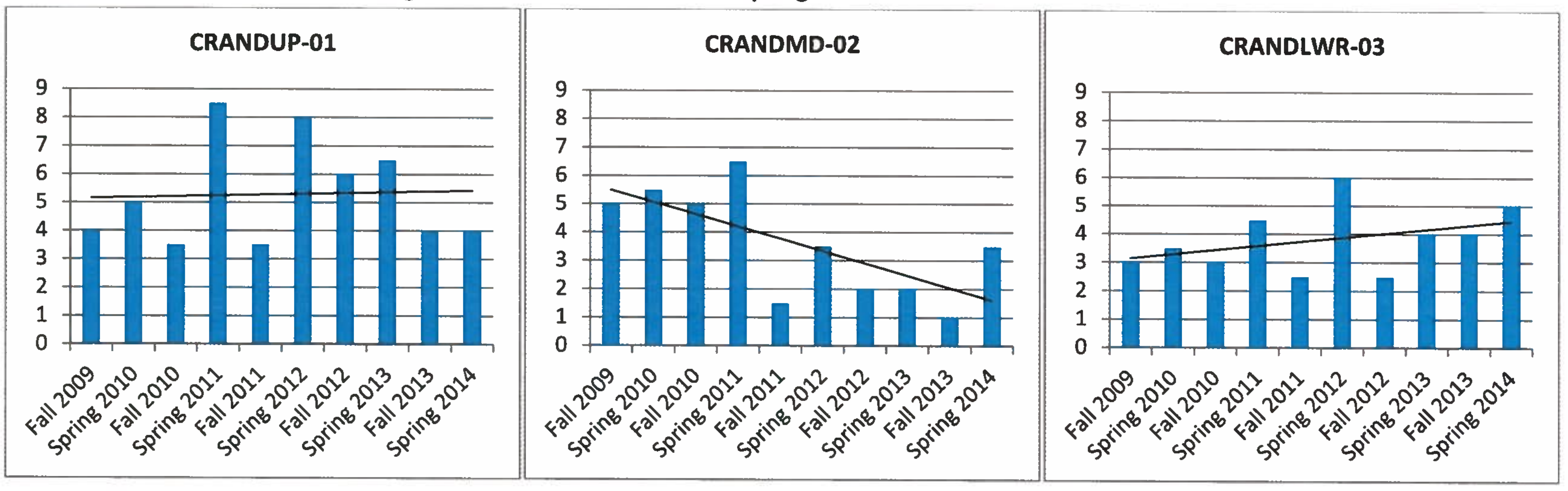
Figures 17d. Average percent shredders in each reach from Fall 2009- Spring 2014



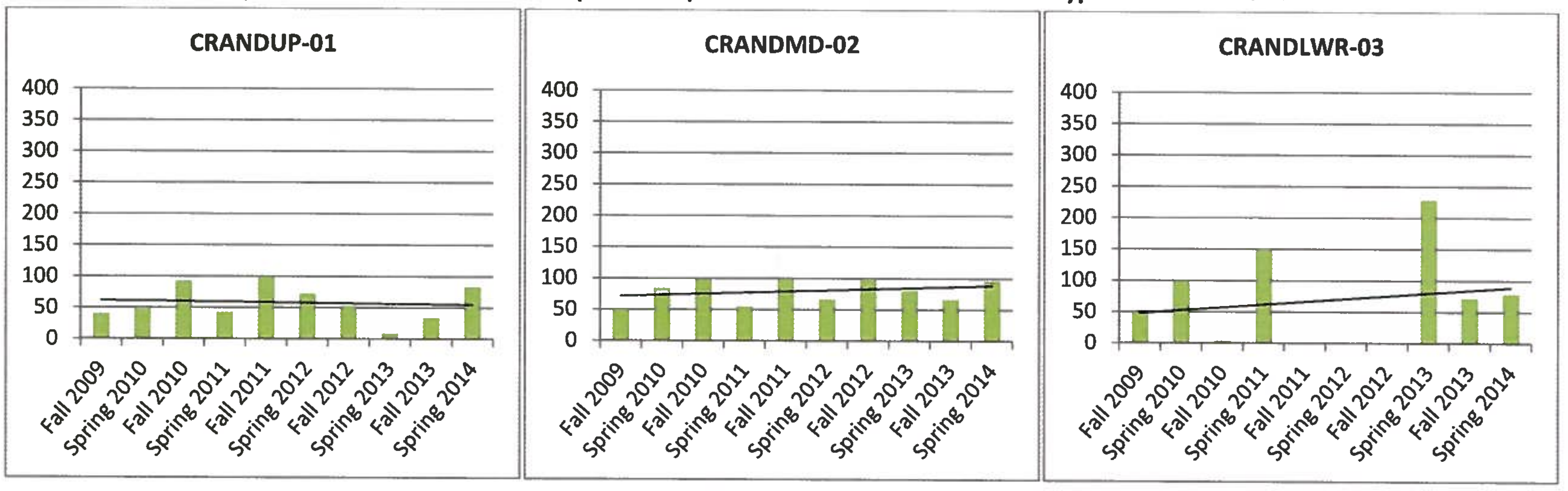
Figures 18d. Average number of long-lived taxa in each reach from Fall 2009- Spring 2014



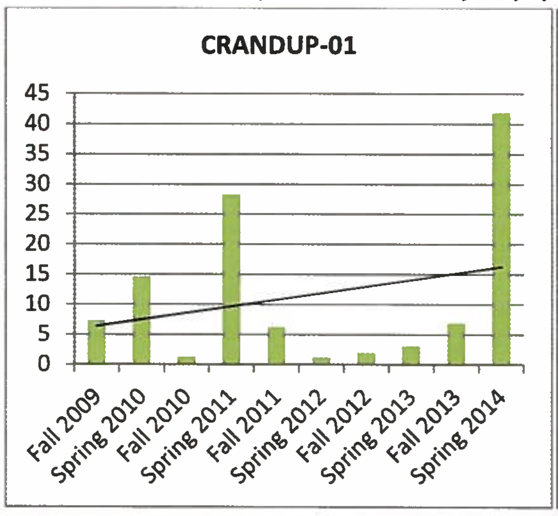
Figures 19d. Average number of clinger taxa reach from Fall 2009- Spring 2014

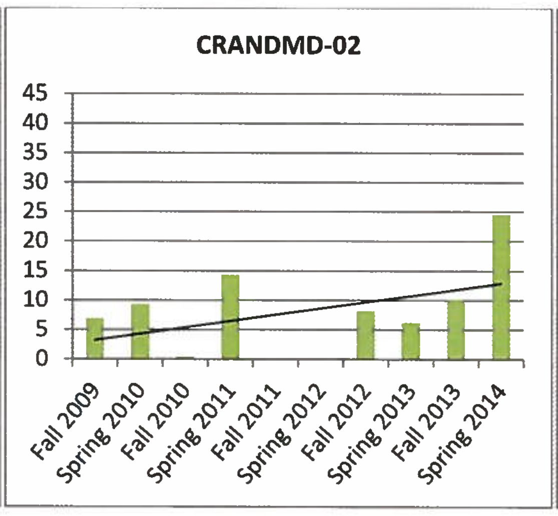


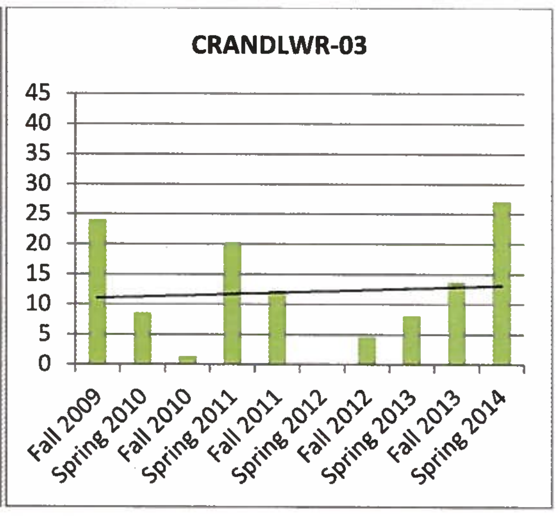
Figures 20d. Average percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2009-2014



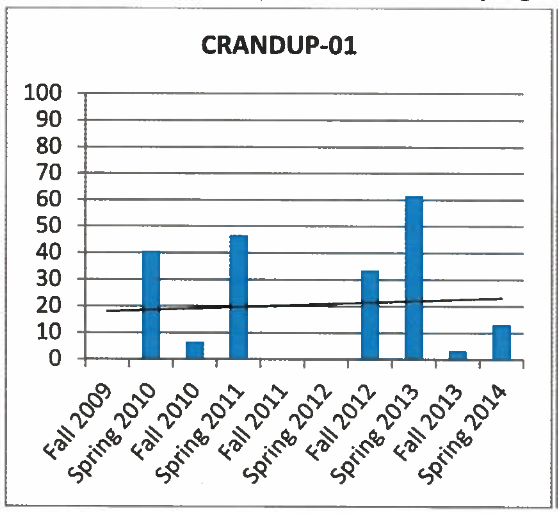
Figures 21d. Average percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2014

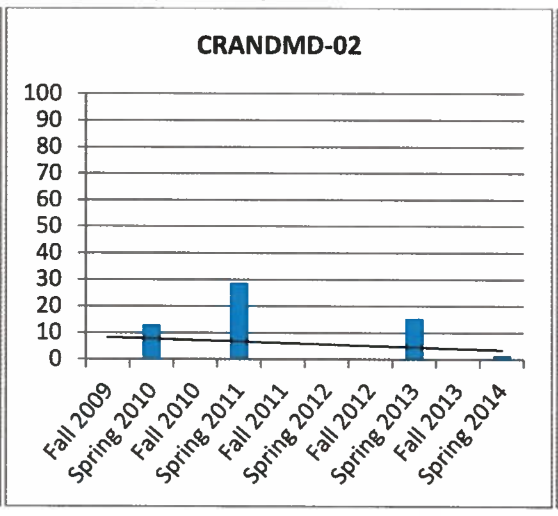


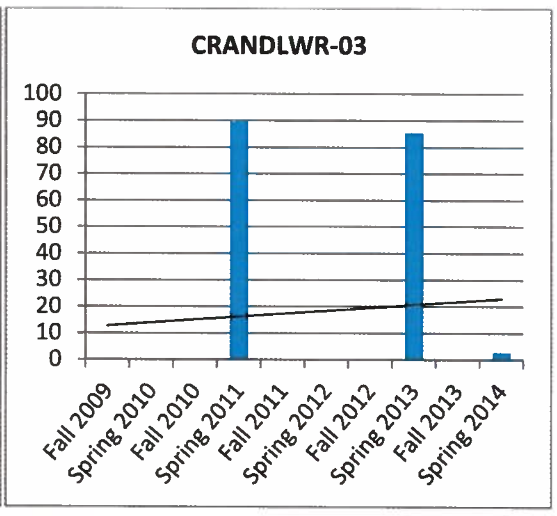




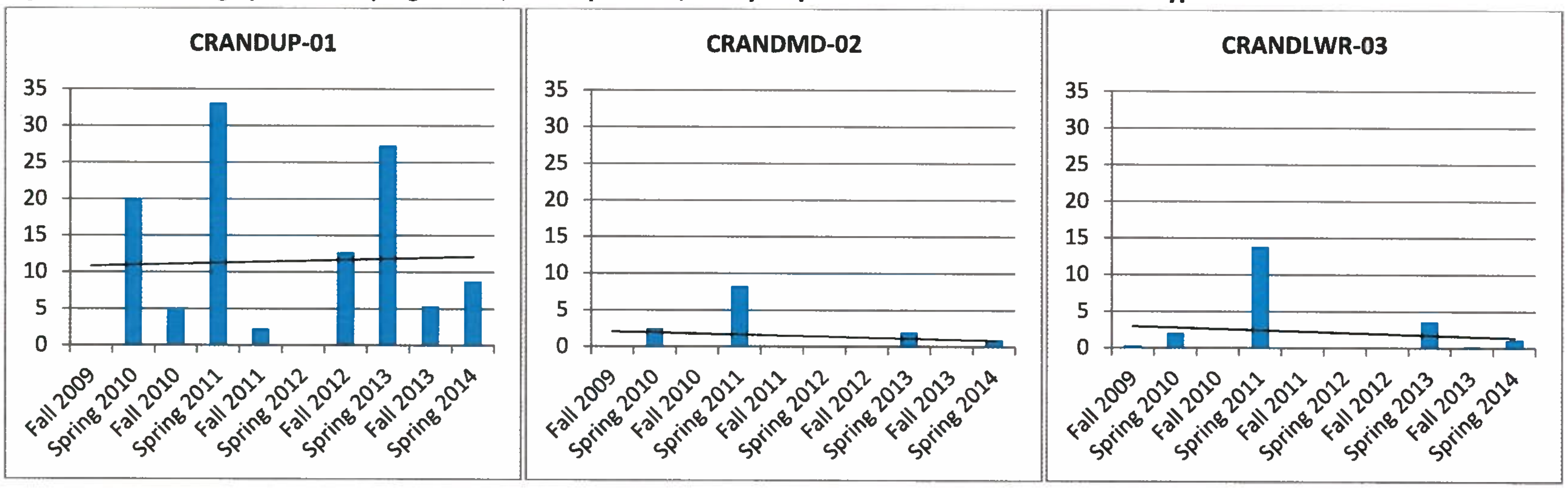
Figures 22d. Average percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2014







Figures 23d. Average percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2014



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 11th and 12th, 2014. The count is the total number of individuals found, identified, and retained for future reference.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Samples	Count
Annelida	Clitellata						5	177
Arthropoda	Arachnida	Trombidiformes					3	58
			Arrenuridae		Arrenurus		1	6
			Hygrobatidae				2	4
			Lebertiidae		Lebertia		6	203
			Sperchonidae				1	3
					Sperchon		3	41
			Torrenticolidae		Testudacarus		1	2
	Insecta	Coleoptera	Dryopidae		Helichus		1	2
			Elmidae				1	4
					Narpus	concolor	5	74
		Diptera	Ceratopogonidae				2	13
				Ceratopogoninae	Probezzia		4	89
			Chironomidae				4	196
				Chironominae			5	56
				Orthocladiinae			6	3518
				Tanypodinae			3	27
			Dixidae		Dixa		1	5
			Empididae				1	12
					Neoplasta		5	127
				Hemerodromiinae			1	8
					Chelifera		4	88
			Pelecorhynchidae		Glutops		1	1
			Psychodidae		Pericoma		1	2
			Simuliidae				2	23
				Simuliinae	Simulium		5	1395
			Stratiomyidae		Caloparyphus		2	43
					Stratiomys		1	6
			Tipulidae				2	4
					Dicranota		4	11
					Hexatoma		1	1
				Limoniinae	Antocha	monticola	1	2
					Limnophila		1	1
				Tipulinae	Tipula		2	10
		Ephemeroptera	Ameletidae		Ameletus		1	2
			Baetidae		Baetis		6	3138
					Diphetor	hageni	5	170
			Ephemerellidae				2	5
					Drunella		2	4
					Drunella	grandis	1	1
			Heptageniidae				2	99
					Cinygmula		6	197
					Epeorus		3	12
			Leptophlebiidae				2	13
					Paraleptophlebia		2	6
		Plecoptera					1	6
			Chloroperlidae		Sweltsa		1	6
				Chloroperlinae	Suwallia		1	2
			Nemouridae				2	36
					Zapada		1	8
					Zapada		1	7
				Amphinemurinae			2	10
			Perlodidae				1	5
					Megarcys	signata	1	3
				Isoperlinae	Isoperla		6	79

Phylum	Class	Order	Family	SubFamily	Genus	Species	Samples	Count
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche		1	1
				Hydropsychinae	Hydropsyche		2	40
			Limnephilidae				2	17
				Limnephilinae	Hesperophylax		4	33
			Rhyacophilidae		Rhyacophila		5	72
					Rhyacophila	angelita group	4	49
					Rhyacophila	rotunda group	1	2
					Rhyacophila	vofixa group	2	54
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		6	265
Nemata							2	19
Platyhelminthes	Turbellaria						4	37
Total:	Taxa:	66	Genera:	48	Families:	34		10617

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 12, 2014 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, 87.5% was identified and retained. A total of 806 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152958. OTU= Operational Taxonomic Unit

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	32
Arthropoda	Arachnida	Trombidiformes					Adult	5
			Hygrobatidae				Adult	2
			Lebertiidae		Lebertia		Adult	65
			Sperchonidae		Sperchon		Adult	22
			Torrenticolidae		Testudacarus		Adult	2
	Insecta	Coleoptera	Dryopidae		Helichus		Adult	2
			Elmidae		Narpus	concolor	Larvae	2
		Diptera	Ceratopogonidae				Larvae	7
				Ceratopogoninae	Probezzia		Larvae	30
			Chironomidae				Pupae	32
				Chironominae			Larvae	32
				Orthocladiinae			Larvae	467
				Tanypodinae			Larvae	10
			Dixidae		Dixa		Larvae	5
			Empididae		Neoplasta		Larvae	15
				Hemerodromiinae	Chelifera		Larvae	47
			Psychodidae		Pericoma		Larvae	2
			Simuliidae	Simuliinae	Simulium		Larvae	35
			Stratiomyidae		Caloparyphus		Larvae	2
			Tipulidae				Larvae	2
				Tipulinae	Tipula		Larvae	2
		Ephemeroptera	Ameletidae		Ameletus		Larvae	2
			Baetidae		Baetis		Larvae	783
					Diphetor	hageni	Larvae	27
			Ephemerellidae				Larvae	2
					Drunella		Larvae	2
			Heptageniidae				Larvae	55
					Cinygmula		Larvae	146
					Epeorus		Larvae	2
			Leptophlebiidae		Paraleptophlebia		Larvae	5
		Plecoptera	Chloroperlidae	Chloroperlinae	Suwallia		Larvae	2
			Nemouridae				Larvae	22
					Zapada		Larvae	7
			Perlodidae	Isoperlinae	Isoperla		Larvae	12
		Trichoptera	Rhyacophilidae		Rhyacophila		Larvae	42
					Rhyacophila	rotunda gr	Larvae	2
					Rhyacophila	vofixa gro	Larvae	32
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	57
Platyhelminthes	Turbellaria						Adult	17
Total:	OTU Taxa:	40	Genera:	25	Families:	24		2037

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 12, 2014 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 528 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152959. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	1
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	7
			Sperchonidae				Adult	3
	Insecta	Diptera	Ceratopogonidae				Larvae	5
			Chironomidae				Pupae	23
				Chironominae			Larvae	9
				Orthocladiinae			Larvae	78
			Empididae	Hemerodromiinae			Larvae	8
					Chelifera		Larvae	11
			Pelecorhynchidae		Glutops		Larvae	1
			Simuliidae				Larvae	20
			Tipulidae				Larvae	1
					Dicranota		Larvae	3
					Hexatoma		Larvae	1
		Ephemeroptera	Baetidae		Baetis		Larvae	374
			Ephemerellidae				Larvae	3
					Drunella	grandis	Larvae	1
			Heptageniidae				Larvae	45
					Cinygmula		Larvae	34
			Leptophlebiidae				Larvae	1
		Plecoptera	Nemouridae		Zapada		Larvae	8
			Perlodidae				Larvae	5
					Megarcys	signata	Larvae	3
				Isoperlinae	Isoperla		Larvae	5
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche		Larvae	1
					Rhyacophila		Larvae	14
					Rhyacophila	vofixa group	Larvae	22
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	12
Platyhelmint	Turbellaria						Adult	12
Total:	OTU Taxa:	29	Genera:	14	Families:	16		711

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, 2014 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, 37.5% was identified and retained. A total of 920 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 15152960. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	29
Arthropoda	Arachnida	Trombidiformes					Adult	29
			Arrenuridae		Arrenurus		Adult	6
			Lebertiidae		Lebertia		Adult	104
	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	60
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	54
			Chironomidae				Pupae	110
				Chironominae			Larvae	8
				Orthocladiinae			Larvae	2189
				Tanypodinae			Larvae	12
			Empididae				Larvae	12
					Neoplasta		Larvae	70
				Hemerodromiinae	Chelifera		Larvae	29
			Simuliidae	Simuliinae	Simulium		Larvae	1154
			Stratiomyidae		Caloparyphus		Larvae	41
					Stratiomys		Larvae	6
			Tipulidae		Dicranota		Larvae	6
		Ephemeroptera	Baetidae		Baetis		Larvae	1288
					Diphetor	hageni	Larvae	23
			Heptageniidae		Cinygmula		Larvae	12
					Epeorus		Larvae	6
			Leptophlebiidae				Larvae	12
		Plecoptera					Larvae	6
			Chloroperlidae		Sweltsa		Larvae	6
			Perlodidae	Isoperlinae	Isoperla		Larvae	6
		Trichoptera	Limnephilidae				Larvae	12
				Limnephilinae	Hesperophylax		Larvae	23
			Rhyacophilidae		Rhyacophila		Larvae	6
					Rhyacophila	angelita group	Larvae	31
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	23
Nemata							Adult	6
Platyhelminthes	Turbellaria						Adult	6
Total:	OTU Taxa:	32	Genera:	19	Families:	17		5385

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, 2014 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 614 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152961. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	47
Arthropoda	Arachnida	Trombidiformes	Hygrobatidae				Adult	1
			Lebertiidae		Lebertia		Adult	7
	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	7
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	3
			Chironomidae				Pupae	31
				Chironominae			Larvae	4
				Orthocladiinae			Larvae	382
				Tanypodinae			Larvae	5
			Empididae		Neoplasta		Larvae	8
				Hemerodromiinae	Chelifera		Larvae	1
			Simuliidae	Simuliinae	Simulium		Larvae	54
			Tipulidae		Dicranota		Larvae	1
		Ephemeroptera	Baetidae		Baetis		Larvae	245
					Diphetor	hageni	Larvae	5
			Ephemerellidae		Drunella		Larvae	1
			Heptageniidae		Cinygmula		Larvae	3
					Epeorus		Larvae	4
		Plecoptera	Perlodidae	Isoperlinae	Isoperla		Larvae	3
		Trichoptera	Limnephilidae				Larvae	5
				Limnephilinae	Hesperophylax		Larvae	3
			Rhyacophilidae		Rhyacophila		Larvae	4
					Rhyacophila	angelita group	Larvae	1
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	1
Platyhelmint	Turbellaria						Adult	1
Total:	OTU Taxa:	**25**	Genera:	**16**	Families:	**15**		**827**

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, 2014 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 494 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152962. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes					Adult	24
			Lebertiidae		Lebertia		Adult	11
			Sperchonidae		Sperchon		Adult	9
	Insecta	Coleoptera	Elmidae				Larvae	4
					Narpus	concolor	Larvae	2
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	2
			Chironomidae	Chironominae			Larvae	2
				Orthocladiinae			Larvae	339
			Empididae		Neoplasta		Larvae	30
			Simuliidae	Simuliinae	Simulium		Larvae	122
			Tipulidae	Limoniinae	Antocha	monticola	Larvae	2
		Ephemeroptera	Baetidae		Baetis		Larvae	350
					Diphetor	hageni	Larvae	35
			Heptageniidae		Cinygmula		Larvae	2
		Plecoptera	Nemouridae	Amphinemurinae			Larvae	9
			Perlodidae	Isoperlinae	Isoperla		Larvae	33
		Trichoptera	Hydropsychidae	Hydropsychinae	Hydropsyche		Larvae	35
			Limnephilidae	Limnephilinae	Hesperophylax		Larvae	4
			Rhyacophilidae		Rhyacophila		Larvae	7
	Insecta				Rhyacophila	angelita group	Larvae	15
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	37
Total:	OTU Taxa:	**21**	Genera:	**15**	Families:	**16**		**1074**

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, 2014 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 424 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152963. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	68
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	9
			Sperchonidae		Sperchon		Adult	9
	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	3
		Diptera	Chironomidae	Orthocladiinae			Larvae	62
			Empididae		Neoplasta		Larvae	4
			Simuliidae				Pupae	3
				Simuliinae	Simulium		Larvae	31
			Tipulidae		Dicranota		Larvae	1
				Limoniinae	Limnophila		Larvae	1
				Tipulinae	Tipula		Larvae	8
		Ephemeroptera	Baetidae		Baetis		Larvae	99
					Diphetor	hageni	Larvae	80
			Heptageniidae		Cinygmula		Larvae	1
			Leptophlebiidae		Paraleptophlebia		Larvae	1
		Plecoptera	Nemouridae				Larvae	14
				Amphinemurinae			Larvae	1
			Perlodidae	Isoperlinae	Isoperla		Larvae	20
		Trichoptera	Hydropsychidae	Hydropsychinae	Hydropsyche		Larvae	5
			Limnephilidae	Limnephilinae	Hesperophylax		Larvae	3
			Rhyacophilidae		Rhyacophila	angelita group	Larvae	1
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	134
Nemata							Adult	14
Total:	OTU Taxa:	23	Genera:	17	Families:	16		572

2014

Annual Report

Macro-Invertebrate Study #2

Crandall Canyon Mine Macroinvertebrate Study Fall 2014

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1.0 INTRODUCTION

EIS Environmental & Engineering Consulting (EIS) collected benthic macroinvertebrate samples from Crandall Creek on September 24th and 25th, 2014. The creek is located near Huntington, Utah. From 2009 to 2012, the creek was sampled by JBR Environmental Consultants, Inc. (JBR). Samples were collected from three different reaches of Crandall Creak. These three reaches were located directly upstream of the Crandall Canyon mine (CRANDUP-01), in the middle reach (CRANDMD-02) which is immediately downstream of the mine's discharge location, and a lower reach (CRANDLWR-03) located at the end of the creek before the confluence of Crandall Creek and Huntington Creek. Each reach was 150 meters long.

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

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

1.1 Background

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

In 2009, DOGM required the mine to contract a qualified biologist to sample macroinvertebrates in Crandall Creek twice yearly (Spring and Fall) to monitor water quality and provide reports documenting the survey results. The first seven surveys were completed by JBR (JBR 2012). They included surveys from the Fall of 2009 until the Fall of 2012. EIS has since completed three more surveys starting in the Spring of 2013. This report provides the results of the Fall survey of 2014. The samples were collected September 24th and 25th, 2014. The samples were then shipped to the BugLab in Logan, Utah for processing, as per UDWQ requirements.

2.0 SITE LOCATIONS AND DESCRIPTION

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

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

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

CRANDUP-01 September 25th, 2014 - Upstream

CRANDMD-02 September 24th, 2014 – Upstream

CRANDLWR-03 September 24th, 2014 - 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, C, and D. Some of these graphs include a breakdown of predominant taxonomic groups, graphs of the different diversity and biotic indices, abundances, total taxa richness, EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa richness, individual taxa richness, Tolerant and Intolerant taxa richness, percent richness, Hilsenhoff Biotic Index, different functional feeding group richnesses, and abundances. As mentioned in previous reports, no one metrics can be used to explain the potential influences the mine may have on the creek. Multiple metrics were used as in previous years to compare data from site to site and year to year. Descriptions of why these values are beneficial are below and have been taken directly out of the Bug Labs report (Judson and Miller 2013)

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

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

EPT- A summary of the taxonomic richness and abundance within the insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT). These orders are commonly considered sensitive to pollution (Karr and Chu 1998, as referenced in Judson and Miller 2010).

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

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

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

Clinger taxa- The number of clinger taxa have been found by Karr and Chu (1998, as referenced in Judson and Miller 2010) to respond negatively to human disturbance. These taxa typically cling to the tops of rocks and are thought to be reduced by sedimentation or abundant algal growths.

Long-lived taxa- The number of long-lived taxa was calculated as the number of taxa collected that typically have 2-3 year life cycles. Disturbances and water quality and habitat impairment typically reduces the number of long-lived taxa (Karr and Chu 1998, as referenced in Judson and Miller 2010).

Biotic indices- Biotic indices use the indicator taxa concept. Taxa are assigned water quality tolerance values based on their tolerance to pollution. Scores are typically weighted by taxa relative abundance. In the US, the most commonly used biotic index is the Hilsenhoff Biotic Index (Hilsenhoff 1987 and 1988, as referenced in Judson and Miller 2010). The USFS and BLM throughout the western U.S. have also frequently used the USFS Community Tolerance Quotient.

Hilsenhoff Biotic Index -The Hilsenhoff Biotic Index (HBI) summarizes the overall pollution tolerances of the taxa collected. This index has been used to detect nutrient enrichment, high sediment loads, low dissolved oxygen, and thermal impacts. It is best at detecting organic pollution. Families were assigned an index value from 0 (taxa normally found only in high quality unpolluted water) to 10 (taxa found only in severely polluted waters). Family level values were taken from Hilsenhoff (1987 and 1988, as referenced in Judson and Miller 2010) and a family level HBI was calculated for each sampling location for which there were a sufficient number of individuals and taxa collected to perform the calculations. Sampling locations with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-

10 polluted. Rather than using mean HBI values for a sample, taxon HBI values can also be used to determine the number of pollution intolerant and tolerant taxa occurring at a site. In this report, taxa with HBI values <2 were considered intolerant clean water taxa and taxa with HBI values 2-8 were considered pollution tolerant taxa. The number of tolerant and intolerant taxa and the abundances of tolerant and intolerant taxa were calculated for each sampling location.

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

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

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

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

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

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

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

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

In addition, EIS used the BugLab's data set to calculate several other metrics that JBR also indicated being potentially useful for macroinvertebrate analysis. These are described below.

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

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

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

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

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

4.0 RESULTS & DISCUSSION

The results prepared by the BugLab (Miller 2013) are incorporated into the tables of the following appendices. As with assessment, multiple metrics and datasets should be relied upon to make a finding of whether any impact or nonimpact has occurred between the mine's groundwater discharge and Crandall Creek. Numerous metrics should be used in evaluating what may be happening in the creek. In this study, the natural variability of any of these metrics is not known due to limited number of samples sites, absence of replicates, and partial historical baseline information. Therefore, it is difficult to determine whether there is an impact between sites from analyzing only one metric. This section and its associated appendices will review these metrics within this season's individual sample, spatially among each reach and habitat type, and any temporal changes since 2009. Data is compared from the reference reach (CRANDUP-01) to the other two reaches. Additionally, a comparison between the middle reach directly below the mine (CRANDMD-02) and the lowest reach (CRANDLWR-03) can be made to assess the spatial limit and overall condition. The metrics evaluated include the various measurement types recommended by EPA (Barbour et al 1999). They include tolerance indices (HBI, CTQd), diversity (Shannon's), community composition (% EPT), and functional feeding groups (Percent Scraper/Shredders).

Appendix A of the report includes a summarization of the raw and standardized data for the samples collected in September of 2014. The following Appendices B, C, and D graph the previously mentioned matrices to show a visual comparison. Appendix B begins with a graph showing the distribution of the dominate orders within each reach and sample type (Figure 1b) as well as the numerical values (Table 1b). It is followed by numerous graphs that represent the Fall 2014 sample set and show a visual comparison of potential differences between the habitat types as well as spatial variation (Figures 2b-24b). The graphs of Appendix C include all the data gathered since Fall 2009 for temporal comparison among all the samples. They are differentiated by the multi-habitat and target riffle samples for further comparison (Figures 1c-23c). The graphs in Appendix D also contain data since the Fall of 2009; however the values from both the multi-habitats and riffle habitats sample were combined to obtain an average value assess any potential overall trends throughout the years (Figures 24c-42c).

A total of 67 operational taxonomic units (OTU) were identified in the Fall 2014 sample set. There were 28 families and 35 genera present. Most of the insect orders most commonly found in macroinvertebrate communities were found in each reach, orders Diptera, Ephemeroptera, Plecoptera, and Trichoptera. The common order Coleoptera was found in all samples except those taken from the upper reach. Non-insect invertebrates were also identified in all samples. In the upper reach the dominate order in both the multi-habitat and riffle habitat was Diptera making up 52 and 61 percent of the sample, respectively. In the middle reach, Diptera was also found to be the most dominate order in both the types of habitat, at 71 and 86 percent, respectively. In the lower reach the dominate order in the multi-habitat was also Diptera at 43 percent. In the riffle habitat the dominate order was Ephemeroptera at 63 percent (Figure 1b and Table 1b). A dominance of any single order or taxon greater than 50 percent suggests environmental stress, which the all the reaches exhibited. However, in the lowest reach, the dominate order was Ephemeroptera which is commonly considered to be sensitive to pollution (Karr and Chu 1998).

The orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) are commonly considered sensitive to pollution and fluctuation in their abundance can be an indicator of stream health (Karr & Chu 1999). In the upper reach, the orders EPT made up 41.9 percent of the taxa found in the multi habitat, and 33.4 percent of the riffle habitat (Figure 9b). In the middle reach directly below the mine, EPT percentages were at 10.0 and 9.3 percent of abundance in multi-habitat and riffle samples. In the lower reach, EPT was 24.4 percent in the multi habitat and 79.9 percent in the riffle (Figure 9b).

Although Crandall Creek as a whole continues to provide less than ideal habitat for a macroinvertebrate community, all of the samples contained at least one distinct taxon that is considered to be intolerant to pollution. The upper reach had the highest number of intolerant taxa in both habitat types with 5 distinct taxa in the multi-habitat and 8 in the riffle habitat. The middle reach had 1 distinct intolerant taxon in each type of habitat. The lower reach multi-habitat had 1 distinct intolerant taxa and the riffle had 2 (Figure 14b). The upper multi-habitat had 20 unique taxa and there were 21 distinct taxa in the riffle. The middle reach multi-habitat had 13 distinct taxa and the riffle sample had 7. The richness in the lower reach multi-habitat was 16 and was 11 in the riffle habitat (Figure 2b). The number of distinct taxa appears to be fluctuating within all reaches and both habitat types year to year; more data is likely required to find a real discernible trend. These same results were found when evaluating many of the other metrics.

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

4.1 Comparison of Targeted Riffle and Multi-Habitat Samples

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

The graphs in Appendix B display the differences between the two habitats within this dataset (September 2014). In this season's dataset, many of the metrics indicate that the riffle habitat may have poorer conditions when compared to the multi-habitat. However, similar results were not found in previous sample sets so it cannot be said with any certainty that the riffle habitat is of poorer quality than other habitats. Appendix C graphs each habitat type since Fall of 2009. The richness in the upstream reach was about the same between the two habitats, in the multi-habitat was 20 and in the riffle it was 21. In the middle reach, the multi-habitat sample had 13 distinct taxa and where the riffle had 7. The lower reach had 16 taxa in the multi-habitat and 11 in the riffle samples (Figure 2b). Shannon's Diversity in upper multi-reach habitat was 2.19 and 2.05 in the riffle habitat. In the middle reach the multi-habitat was 1.39 and the riffle habitat it was 0.76. In the lower reach the multi-habitat was 2.01 and the riffle habitat was 1.27 (Figure 3b). The evenness in the lower multi and riffle habitats were 0.73 and 0.67, respectively. In the middle reach the multi-habitat was 0.54 and the riffle was 0.39, and in the lower reach the evenness was 0.72 and 0.53, respectively (Figure 4b).

In this dataset, both habitats had similar abundances of macroinvertebrates, with the exception of the middle reach. The abundance in the upper reach was 2835 in the multi-habitat and 2391 in the riffle. In the middle reach multi-habitat it was 963 and 1659 in the riffle and in the lower reach it was 1115 and 1132, respectively (Figure 5b). The HBI, which a lower value indicates less pollution, was 4.60 in the upper reach multi-habitat and 4.99 in the riffle. It was 4.71 and 5.50 in the middle reach, respectively. In the lowest reach, the HBI was 3.09 in the multi-habitat and 4.16 in the riffle (Figure 6b). The CTQd, which a lower the value indicates higher quality unpolluted water as well, was 79 in the upper reach multi-habitat and 72 in the riffle. In the middle reach these values were 96 in both habitat types. In the lower reach the multi-habitat was

91 and the riffle was 84 (Figure 7b). Appendices A and B have more specific detail on all the values found and metrics graphed for visual comparison. While addressing any trends or spatial differences, both riffle and multi-habitat results were averaged and this value was used.

4.2 Spatial Variation in Macroinvertebrate Community

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

The average richness in the upper reach was found to be 20.5, in the middle reach there were 10 distinct taxa found, and in the lower reach 13.5 (Figure 1d). The average evenness value was 0.70 in the upper reach, 0.47 in the middle reach and 0.63 in the lower reach (Figure 2d). The average Shannon's Diversity in the upper reach was 2.12, in the middle reach it was 1.07, and in the lower reach it was 1.64 (Figure 3d). The average abundance of individuals was 2613 in the upper reach, 1311 in the middle reach and 1123.5 in the lower reach (Figure 4d). The HBI, in which the lower the value indicates less pollution in the stream, was 4.60 in the upper reach, 5.50 in the middle reach and 4.16 in the lower reach (Figure 5d). The CTQd, which a lower value also indicates higher quality unpolluted water, was 75.5 in the upper reach, 96 in the middle reach, and 87.5 in the lower reach (Figure 6d). It appears that the middle and lower reaches may be in a decline when compared to the upper reach. However, these reaches are getting better over time, as the next section will discuss. Appendices C and D has more specific detail on all the values found and metrics graphed for visual comparison.

4.3 Temporal Variation in Macroinvertebrate Community

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

The upper reach, which should not be impacted by the mine's discharge, has great variability within each metric. For example the average richness in Fall 2009 was 24, it was at its lowest in Fall of 2011 with a value of 17, went up to its highest in the Fall of 2013 with a value of 26. In this sample, the average richness between the multi and riffle habitats was 20.5 (Figure 1d). The evenness values were around 0.70 in 2009-2011, increased to around 0.77 from 2012-2013, and now are back to 0.70 with this current sample. Similar variability is present within all the metrics. As with the Spring 2014 results, about a third of the metrics indicate declining conditions, another third indicate fairly stable conditions, and the remaining third indicate increasing conditions.

The middle reach also has this variation occurring throughout the years. The middle reach is increasing in the number of macroinvertebrates found (Figure 4d) and the taxa EPT is showing signs of improvement (Figure 7d). The remaining metrics are highly variable or indicate an overall decline since 2009. As found in Spring 2014, the lower reach generally appears to be getting better in quality over time. While many of the metrics indicate a less than optimal habitat in the lower reach when compared to the upper reach, there are several that prove otherwise. The HBI, Percent EPT, and a few species specific metrics had higher values when compared to the upper reach (Figures 1d-23d). As stated before, the more data acquired the more discernable the trends may be.

5.0 CONCLUSION

The samples for the 2013 Fall Macroinvertebrate Study were collected on September 24th and 25th, 2014 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 variability among all the sampled reaches and generally show reduced habitat quality and less than optimal conditions in all sampled locations. It does appear that the upper and the lower reach are increasing in quality standards or staying fairly stable since 2009. In the middle reach, the overall quality seems to be lower than the other two reaches; however multiple metrics indicate that it is improving compared to earlier years sampled. 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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November 13, 2014

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
152966	CRANDUP-01	9/25/2014	Reachwide	Kick net	0.46	50	650
152967	CRANDUP-01	9/25/2014	Targeted Riffle	Kick net	0.74	37.5	651
152968	CRANDMD-02	9/24/2014	Reachwide	Kick net	0.46	100	443
152969	CRANDMD-02	9/24/2014	Targeted Riffle	Kick net	0.74	50	613
152970	CRANDLWR-03	9/24/2014	Reachwide	Kick net	0.46	100	513
152971	CRANDLWR-03	9/24/2014	Targeted Riffle	Kick net	0.74	81.25	680

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
152966	9/25/2014	CRANDUP-01 Multi	2835	1159	Chironomidae	41.41
152967	9/25/2014	CRANDUP-01 Riffle	2391	799	Chironomidae	45.67
152968	9/24/2014	CRANDMD-02 Multi	963	96	Chironomidae	64.07
152969	9/24/2014	CRANDMD-02 Riffle	1659	155	Chironomidae	80.83
152970	9/24/2014	CRANDLWR-03 Multi	1115	272	Pisidiidae	27.26
152971	9/24/2014	CRANDLWR-03 Riffle	1132	904	Baetidae	63.16
Mean			1682.5	564.2		53.74

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
152966	9/25/2014	CRANDUP-01 Multi	42	28	26	18	2.188424	0.730514
152967	9/25/2014	CRANDUP-01 Riffle	44	29	23	18	2.052547	0.674177
152968	9/24/2014	CRANDMD-02 Multi	29	15	20	4	1.386033	0.540374
152969	9/24/2014	CRANDMD-02 Riffle	31	21	19	4	0.761622	0.391396
152970	9/24/2014	CRANDLWR-03 Multi	38	22	20	8	2.011259	0.725408
152971	9/24/2014	CRANDLWR-03 Riffle	31	21	20	9	1.27419	0.531379
Mean			35.8	22.7	21.3	10.16667	1.612346	0.598875

*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
152966	9/25/2014	CRANDUP-01 Multi	20	8	2.188424	0.730514
152967	9/25/2014	CRANDUP-01 Riffle	21	10	2.052547	0.674177
152968	9/24/2014	CRANDMD-02 Multi	13	3	1.386033	0.540374
152969	9/24/2014	CRANDMD-02 Riffle	7	2	0.761622	0.391396
152970	9/24/2014	CRANDLWR-03 Multi	16	5	2.011259	0.725408
152971	9/24/2014	CRANDLWR-03 Riffle	11	5	1.27419	0.531379
Mean			14.66667	6	1.612346	0.598875

Table 6a. Genera richness by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
152966	9/25/2014	CRANDUP-01 Multi	0	13	6	0	0	0	6	6	1	0	1
152967	9/25/2014	CRANDUP-01 Riffle	0	14	6	0	0	0	7	5	1	0	1
152968	9/24/2014	CRANDMD-02 Multi	1	11	2	0	0	0	1	1	1	0	0
152969	9/24/2014	CRANDMD-02 Riffle	1	5	1	0	0	0	1	2	1	0	0
152970	9/24/2014	CRANDLWR-03 Multi	1	14	3	0	0	0	2	3	1	0	1
152971	9/24/2014	CRANDLWR-03 Riffle	1	9	3	0	0	0	1	5	0	0	0
Mean			0.7	11.0	3.5	0.0	0.0	0.0	3.0	3.7	0.8	0.0	0.5

Table 7a. Total Abundance by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
152966	9/25/2014	CRANDUP-01 Multi	0	1485	570	0	0	0	363	226	52	0	83
152967	9/25/2014	CRANDUP-01 Riffle	0	1466	531	0	0	0	140	128	18	0	18
152968	9/24/2014	CRANDMD-02 Multi	4	687	35	0	0	0	9	52	7	0	0
152969	9/24/2014	CRANDMD-02 Riffle	3	1426	135	0	0	0	7	14	11	0	0
152970	9/24/2014	CRANDLWR-03 Multi	4	480	226	0	0	0	15	30	46	0	304
152971	9/24/2014	CRANDLWR-03 Riffle	2	205	717	0	0	0	15	173	0	0	0
Mean			2	958	369	0	0	0	91.5	103.8	22.2	0.0	67.5

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
152966	9/25/2014	CRANDUP-01 Multi	4.603333	Some organic pollution	79
152967	9/25/2014	CRANDUP-01 Riffle	4.993333	Some organic pollution	72
152968	9/24/2014	CRANDMD-02 Multi	4.713333	Some organic pollution	96
152969	9/24/2014	CRANDMD-02 Riffle	5.5	Some organic pollution	96
152970	9/24/2014	CRANDLWR-03 Multi	3.093333	Potential slight organic pollution	91
152971	9/24/2014	CRANDLWR-03 Riffle	4.16	Potential slight organic pollution	84
Mean			4.510556		86.33

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.

			Intolerant Taxa				Tolerant Taxa			
Sample ID	Collection Date	Station	Richness	Percent	Abundance	Percent	Richness	Percent	Abundance	Percent
152966	9/25/2014	CRANDUP-01 Multi	5	25	585	21	1	5	78	3
152967	9/25/2014	CRANDUP-01 Riffle	8	38	242	10	1	5	106	4
152968	9/24/2014	CRANDMD-02 Multi	1	8	9	1	1	8	7	1
152969	9/24/2014	CRANDMD-02 Riffle	1	14	9	1	0	0	0	0
152970	9/24/2014	CRANDLWR-03 Multi	1	6	15	1	0	0	2	0
152971	9/24/2014	CRANDLWR-03 Riffle	2	18	18	2	0	0	2	0
Mean			3.0	18	146.3	6	0.5	3	32.5	1

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
152966	9/25/2014	CRANDUP-01 Multi	3	11	1	4	3	11	3	11	6	22	11	41
152967	9/25/2014	CRANDUP-01 Riffle	4	16	1	4	2	8	2	8	8	32	8	32
152968	9/24/2014	CRANDMD-02 Multi	0	0	0	0	0	0	0	0	5	24	16	76
152969	9/24/2014	CRANDMD-02 Riffle	0	0	0	0	0	0	0	0	4	18	18	82
152970	9/24/2014	CRANDLWR-03 Multi	2	10	0	0	3	14	3	14	5	24	8	38
152971	9/24/2014	CRANDLWR-03 Riffle	0	0	0	0	2	9	2	9	3	14	15	68
Mean			1.5	6.1	0.3	1.3	1.7	7.1	1.7	7.1	5.2	22.3	12.7	56.2

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
152966	9/25/2014	CRANDUP-01 Multi	302	11	248	9	174	6	1587	56	511	18	13	0
152967	9/25/2014	CRANDUP-01 Riffle	117	5	106	4	108	5	1607	67	427	18	26	1
152968	9/24/2014	CRANDMD-02 Multi	54	6	0	0	2	0	637	66	265	28	5	1
152969	9/24/2014	CRANDMD-02 Riffle	11	1	0	0	0	0	1486	90	159	10	3	0
152970	9/24/2014	CRANDLWR-03 Multi	48	4	0	0	433	39	535	48	100	9	-1	0
152971	9/24/2014	CRANDLWR-03 Riffle	21	2	2	0	230	20	802	71	78	7	-1	0
Mean			92.2	4.7	59.3	2.2	157.8	11.7	1109.0	66.3	256.7	14.8	7.5	0.3

Data summarization

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

Related fields in Excel Output:

[Fixed Count]

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

Richness metrics

Richness is a component and estimate of community structure and stream health based on the number of distinct taxa. Taxa richness normally decreases with decreasing water quality. In some situations organic enrichment can cause an increase in the number of pollution tolerant taxa. Taxa richness was calculated for operational taxonomic units (OTUs) and the number of unique genera, and families. The values for operational taxonomic units may be overestimates of the true taxa richness at a site if individuals were the same taxon as those identified to lower taxonomic levels or they may be underestimates of the true taxa richness if multiple taxa were present within a larger taxonomic grouping but were not identified. All individuals within all samples were generally identified similarly according to Standard Taxonomic Effort (see Appendix 1 or NAMC website), so that comparisons in operational taxonomic richness among samples within this dataset are appropriate, but comparisons to other data sets may not. Comparisons to other datasets should be made at the genera or family level.

Related fields in Excel Output:

[Richness]

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

[# of EPT Taxa]

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

[Shannon's Diversity]

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

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

[Simpson's Diversity]

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

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

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

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

[Evenness]

A measure of the distribution of taxa within a community. Value ranges from 0-1 and approach zero as a single taxa becomes more dominant. The evenness index used in this report was calculated as: [Shannon's Diversity]/ln([Richness]) following Ludwig and Reynolds (1988, equation 8.11, page 93).

Dominance metrics

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

Related fields in Excel Output:

[Dominant Family]

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

[Abundance of Dominant Family]

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

[Dominant Taxa]

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

[Abundance of Dominant Taxa]

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

Tolerance (Biotic) Indices

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

Related fields in Excel Output:

[Hilsenhoff Biotic Index]

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

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 2014

Figure 1b. Percent Predominant Taxonomic Groups Fall 2014 Samples

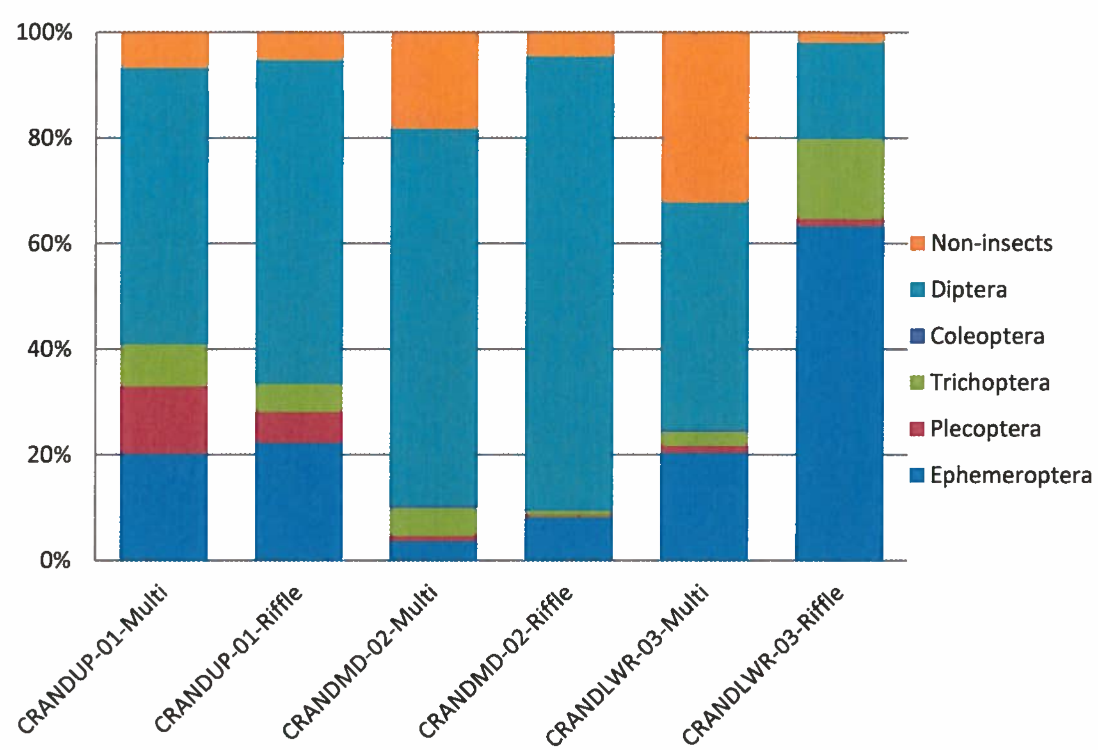


Table 1b. Percent Predominant Taxonomic Groups in the Fall 2014 Samples

	CRANDUP-01-Multi	CRANDUP-01-Riffle	CRANDMD-02-Multi	CRANDMD-02-Riffle	CRANDLWR-03-Multi	CRANDLWR-03-Riffle
Non-insects	7	5	18	5	32	2
Diptera	52	61	71	86	43	18
Coleoptera	0.0	0.0	0.4	0.2	0.4	0.2
Trichoptera	8	5	5	1	3	15
Plecoptera	13	6	1	0	1	1
Ephemeroptera	20	22	4	8	20	63

Figure 2b. Richness

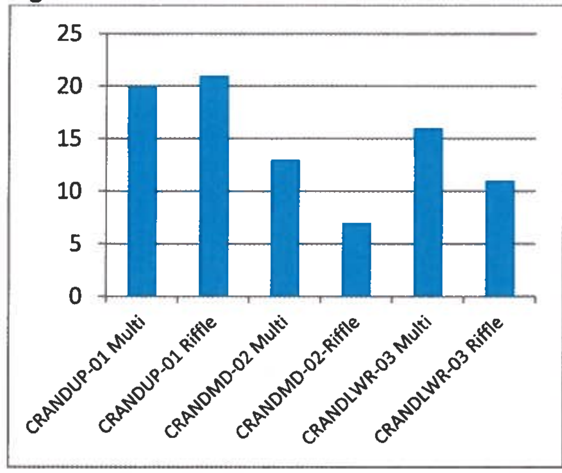


Figure 3b. Shannon's Diversity

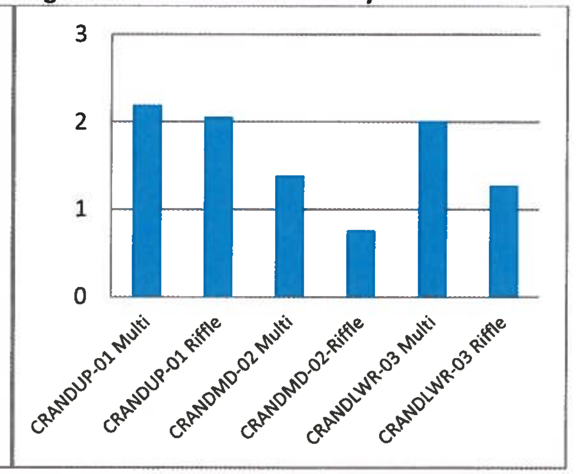


Figure 4b. Evenness

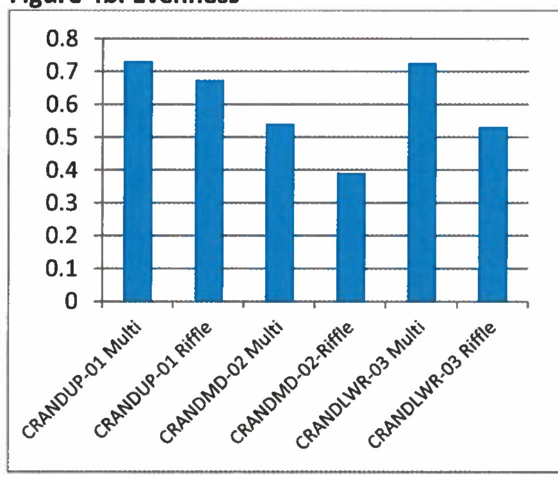


Figure 5b. Abundance

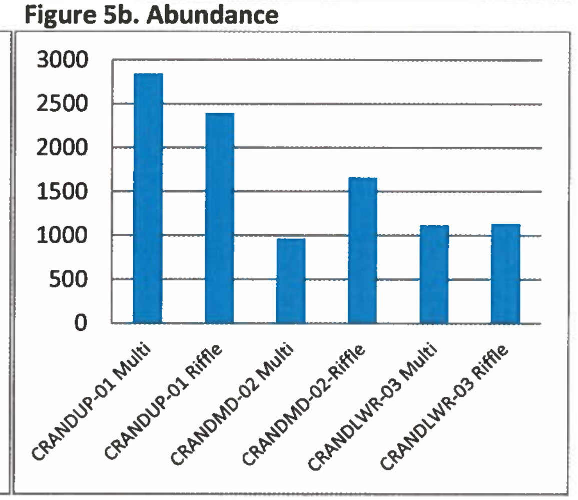


Figure 6b. HBI

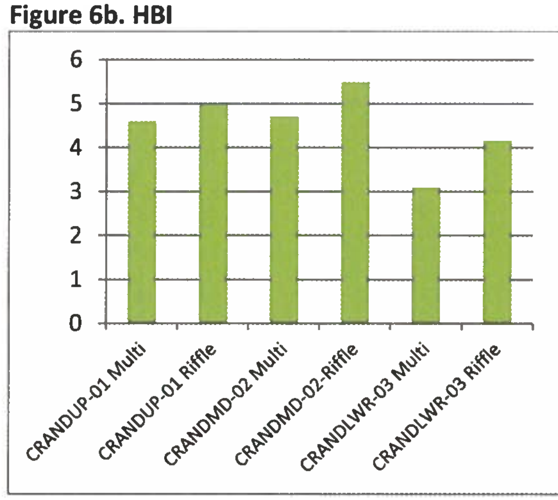


Figure 7b. CTQd

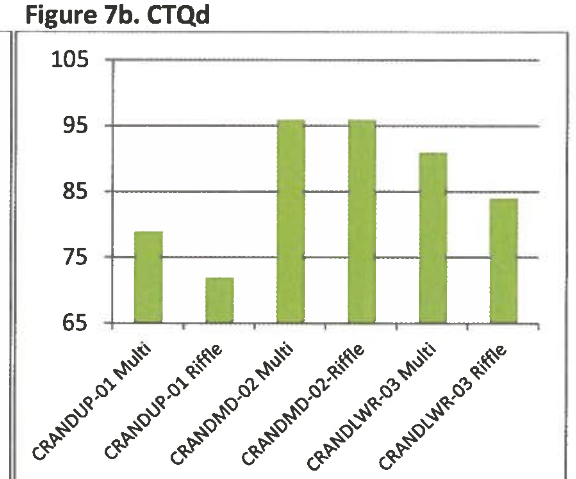


Figure 8b. EPT Taxa Abundance

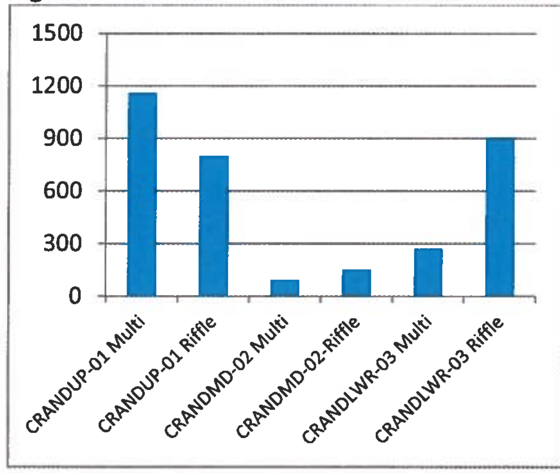


Figure 9b. Percent EPT

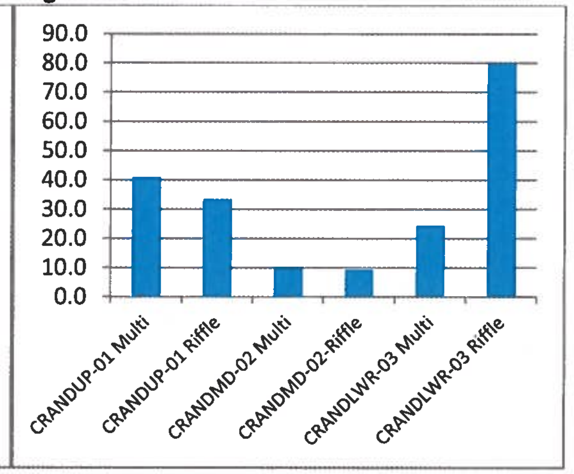


Figure 10b. Percent Chironomids

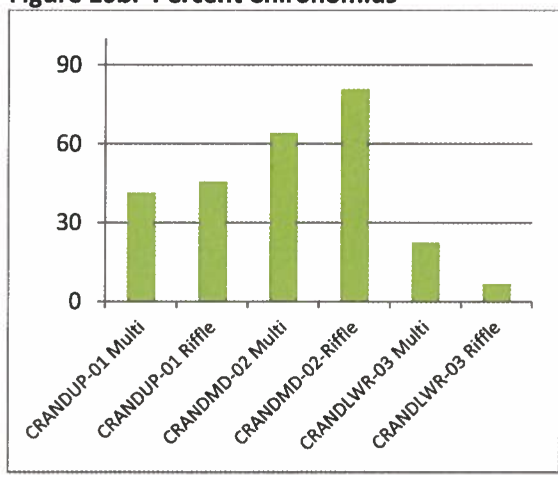


Figure 11b. Ratio of EPT to Chironmonids

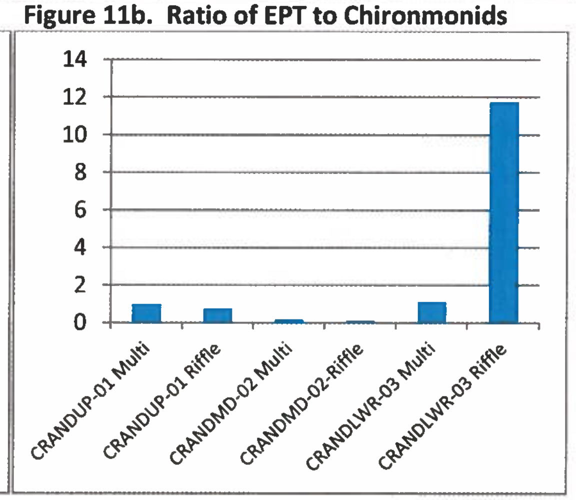


Figure 12b. Number of Tolerant Taxa

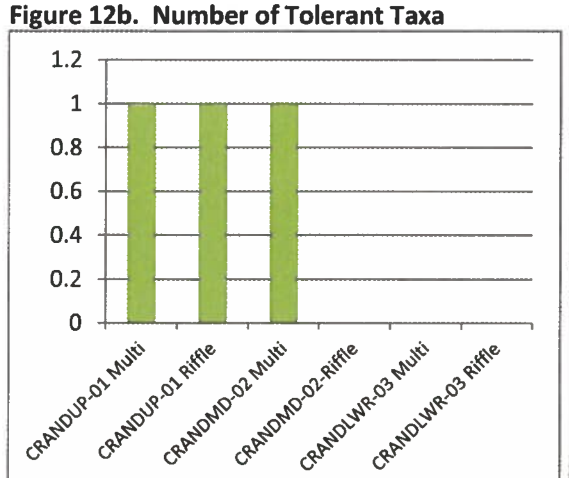


Figure 13b. Percent Tolerant Organisms

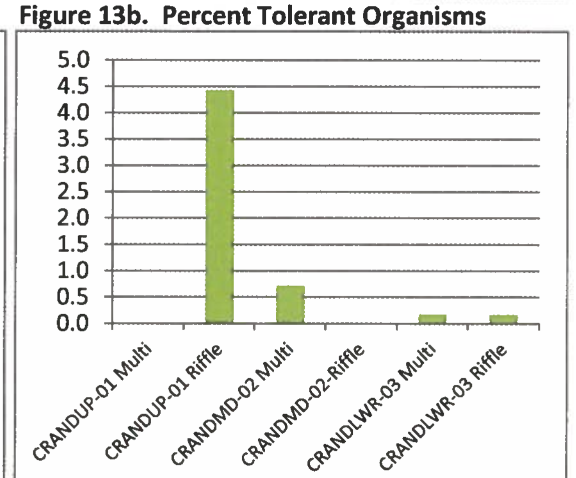


Figure 14b. Number of Intolerant Taxa

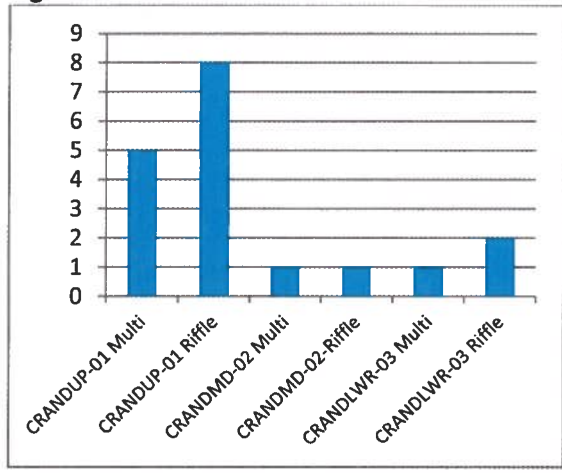


Figure 15b. Percent Intolerant Organisms

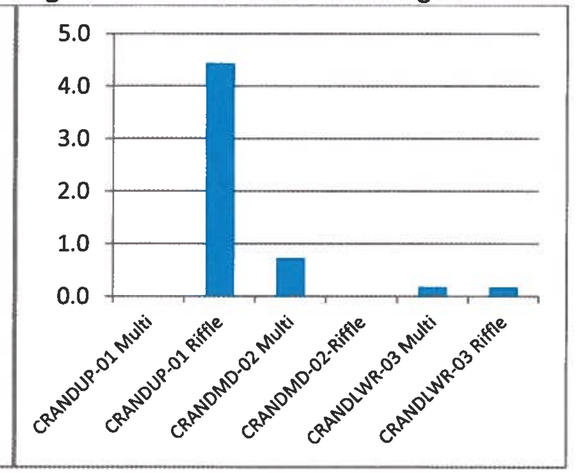


Figure 16b. Specialist Feeders: Generalist Feeders

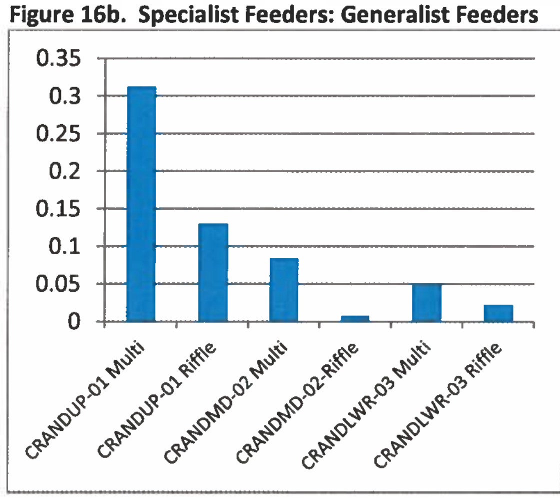


Figure 17b. Percent Shredders

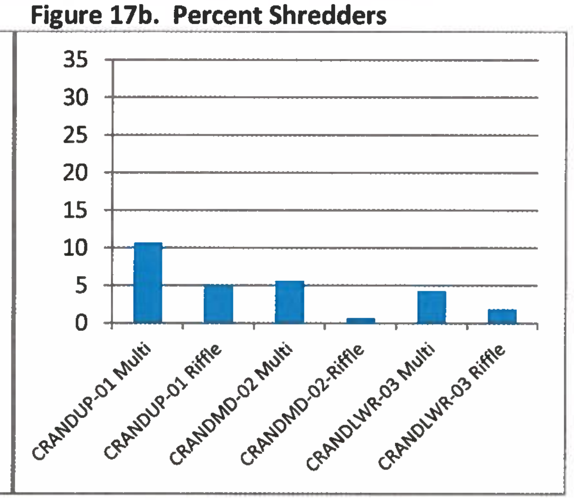


Figure 18b. Percent Scrapers

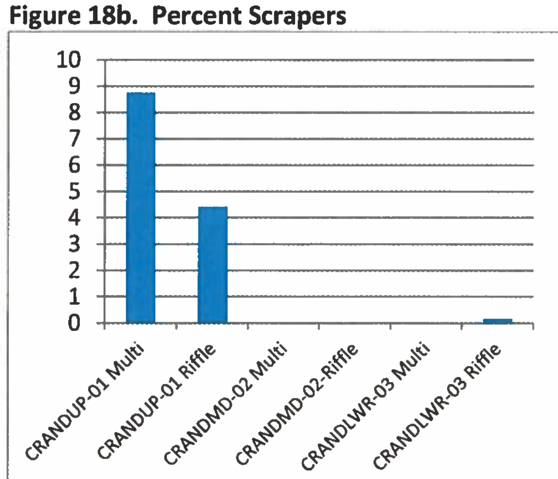


Figure 19b. Number of Long-Lived Taxa

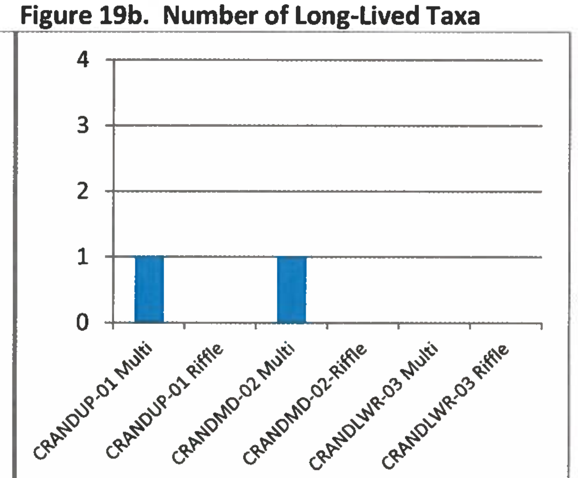


Figure 20b. Number of Clinger Taxa

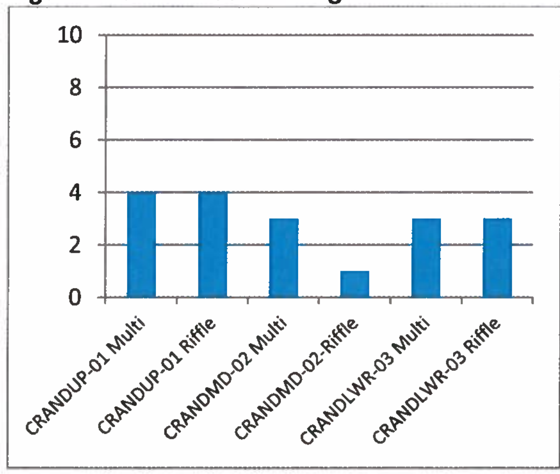


Figure 21b. Baetis:All Ephemetroptera (Percent)

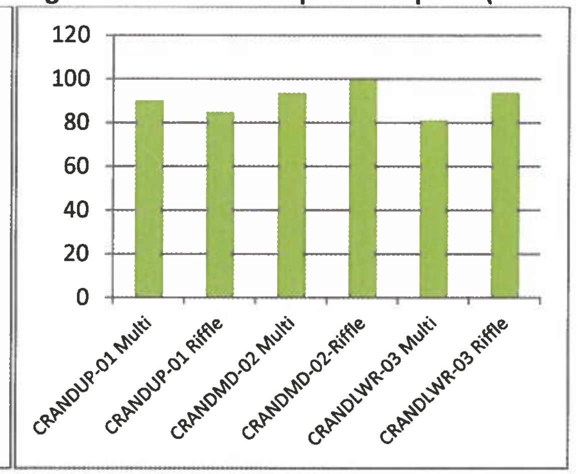


Figure 22b. Baetis, Hydropsychidae & Orthocladiinae (Percent)

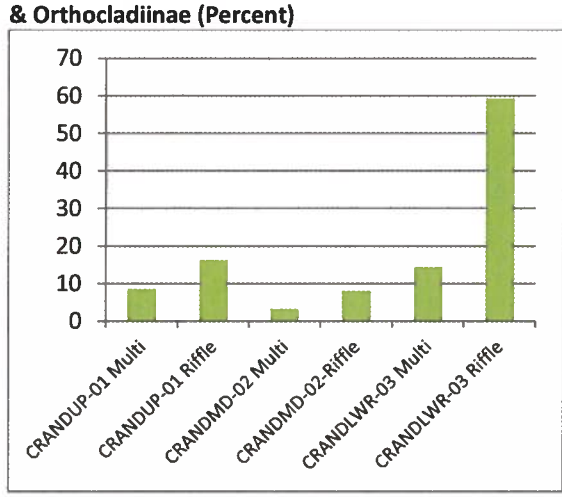


Figure 23b. Heptageniidae: All Ephemeroptera (Percent)

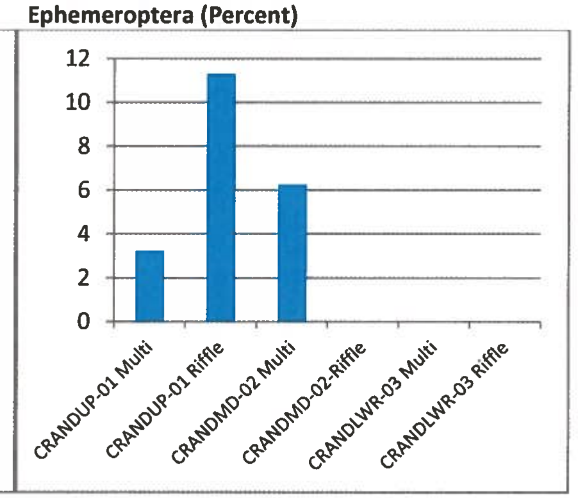
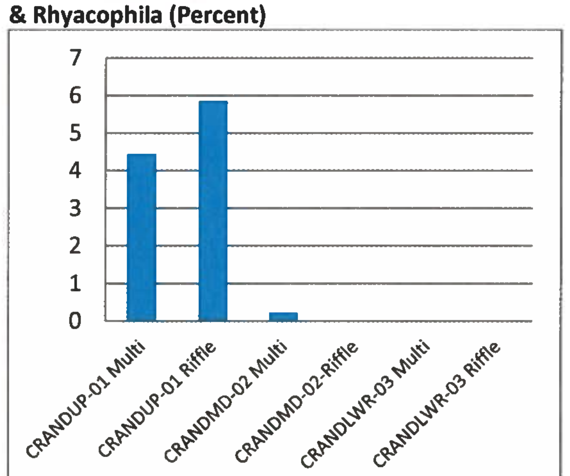


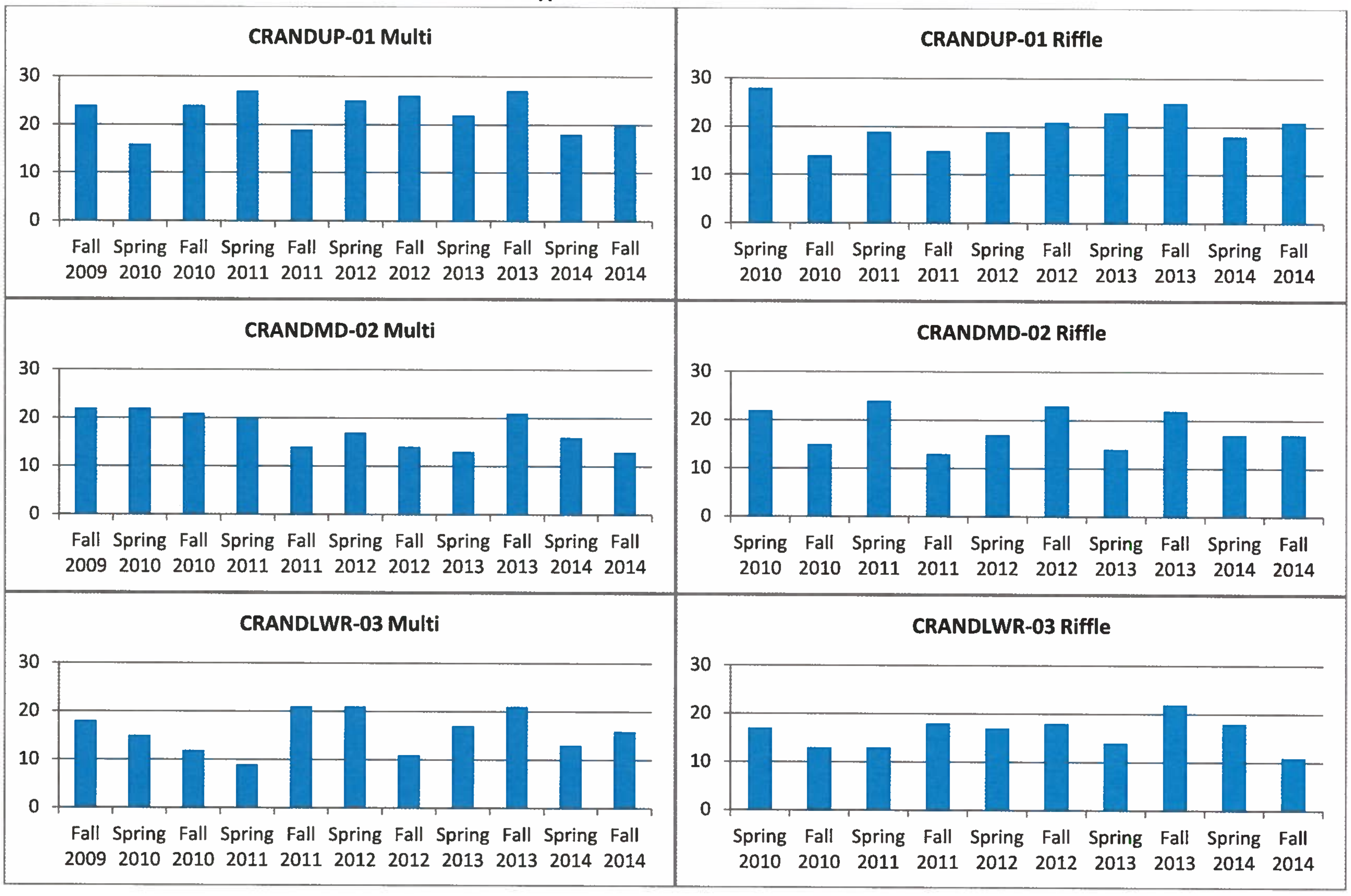
Figure 24b. Heptageniidae, Chloroperlidae & Rhyacophila (Percent)



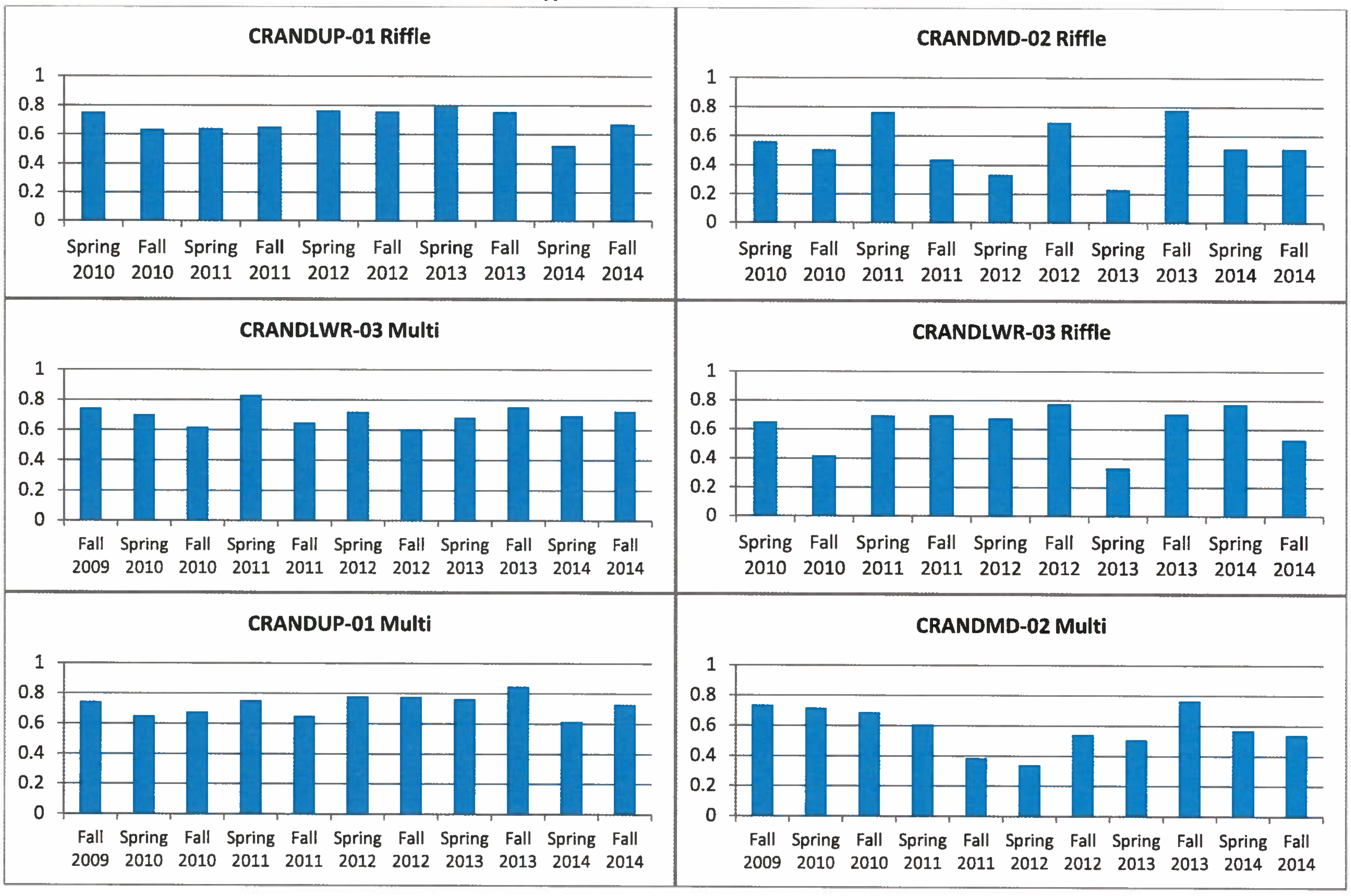
APPENDIX C

MACROINVERTEBRATE FIGURES FALL 2009- FALL 2014

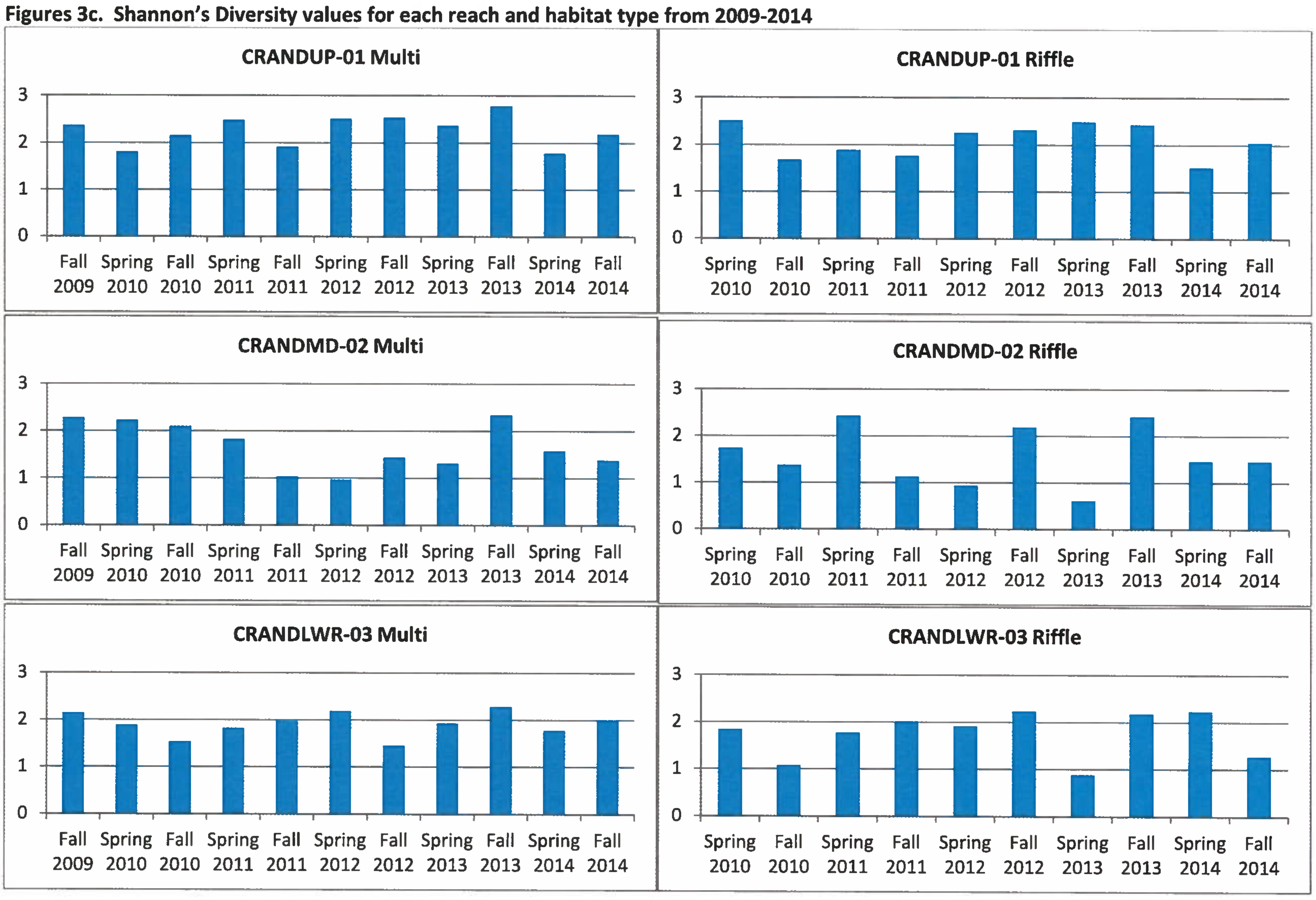
Figures 1c. Richness values for each reach and habitat type from 2009-2014



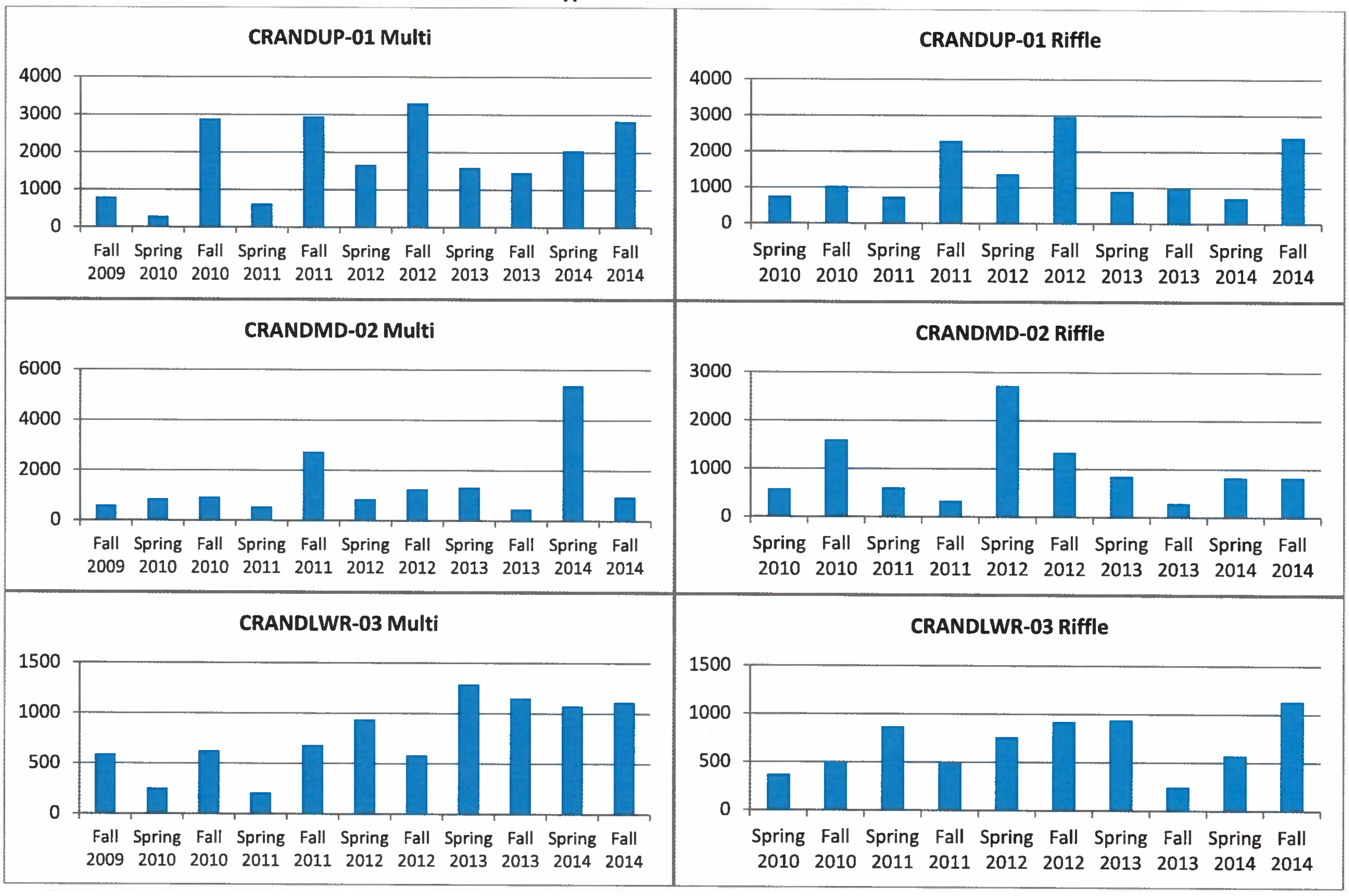
Figures 2c. Evenness values for each reach and habitat type from 2009-2014



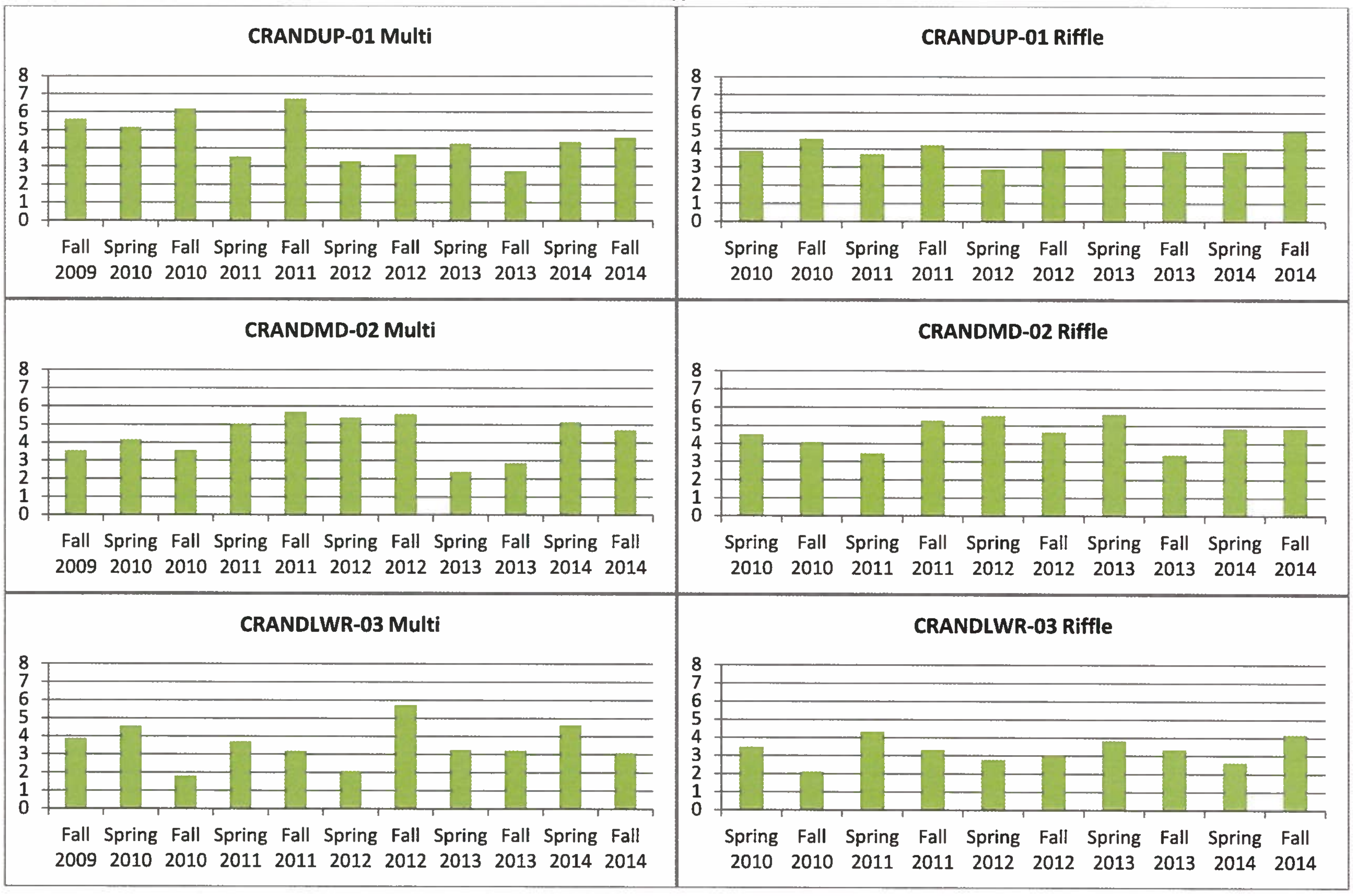
Figures 3c. Shannon's Diversity values for each reach and habitat type from 2009-2014



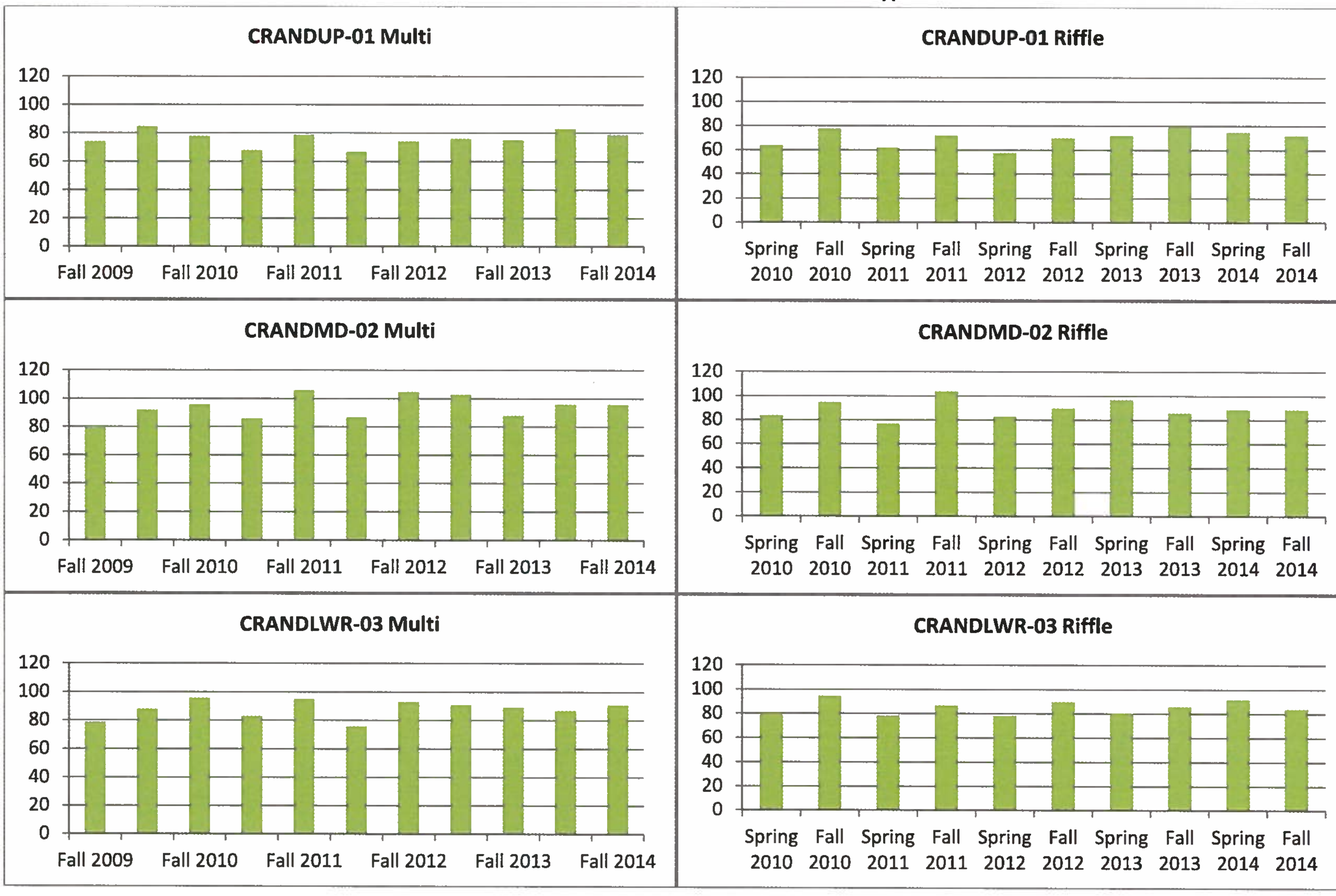
Figures 4c. Abundance values for each reach and habitat type from 2009-2014



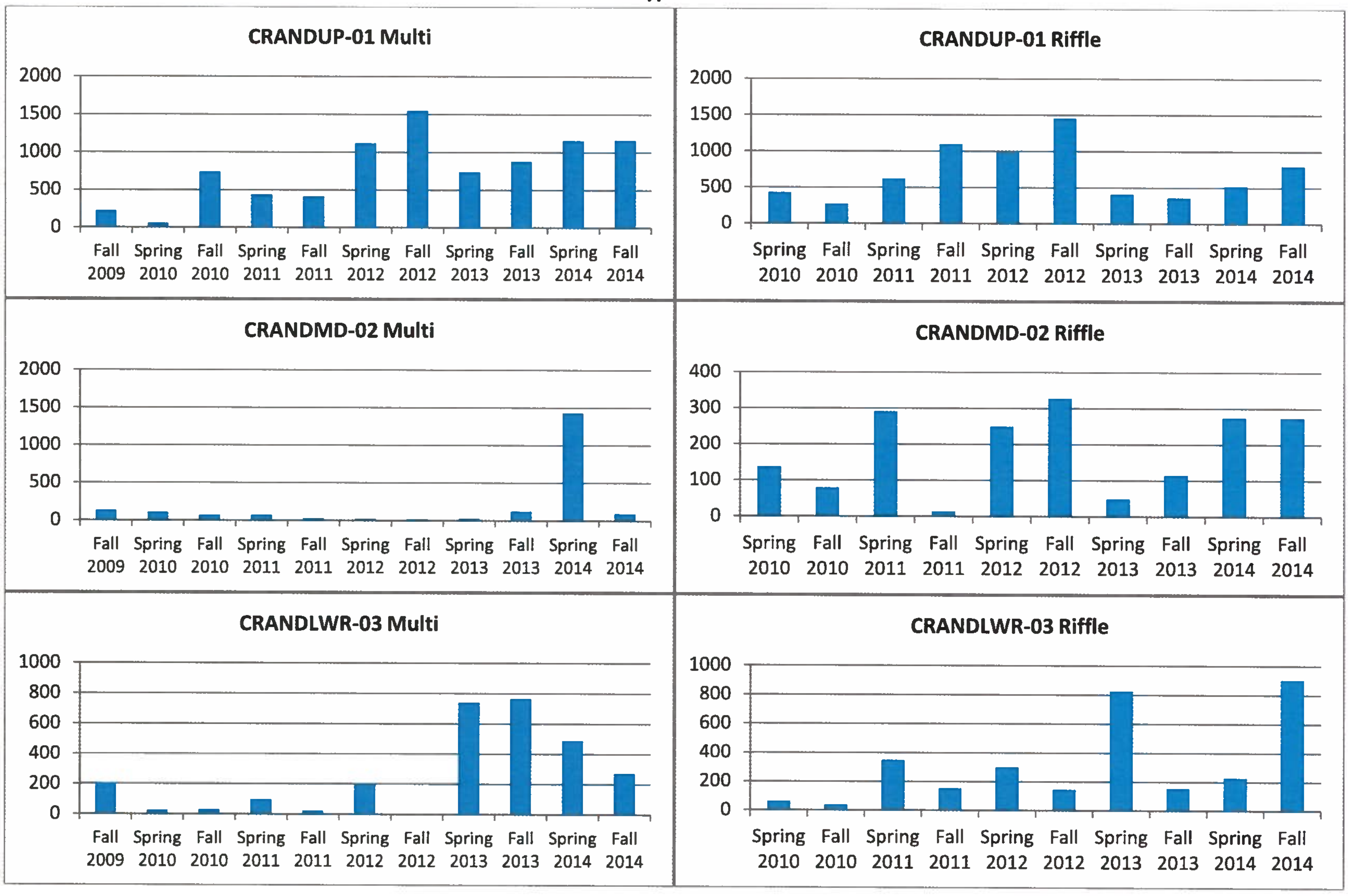
Figures 5c. Hilsenhoff Biotic Index values for each reach and habitat type from 2009-2014



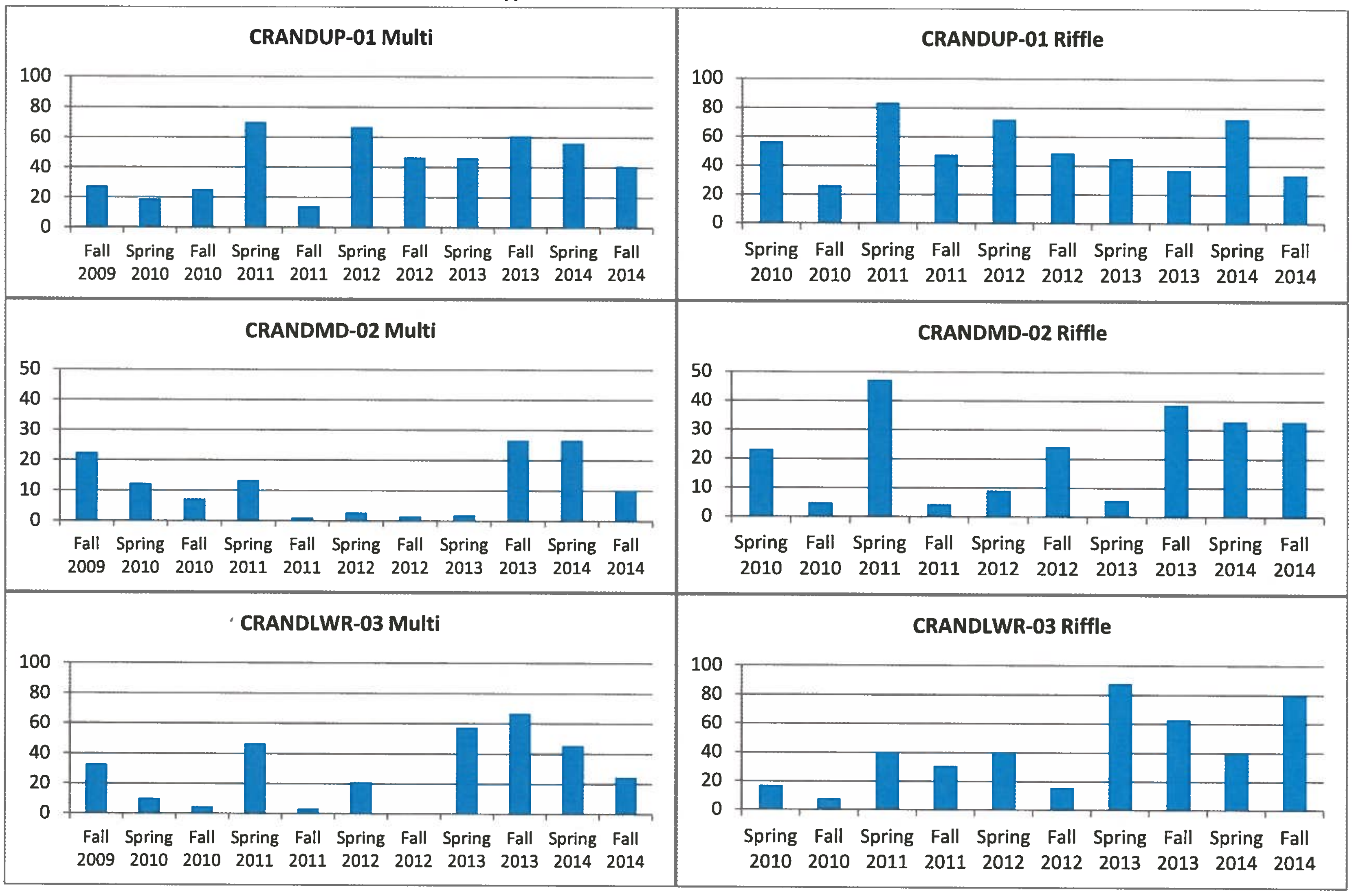
Figures 6c. USFS Community Tolerance Quotient (CTQd) values for each reach and habitat type from 2009-2014



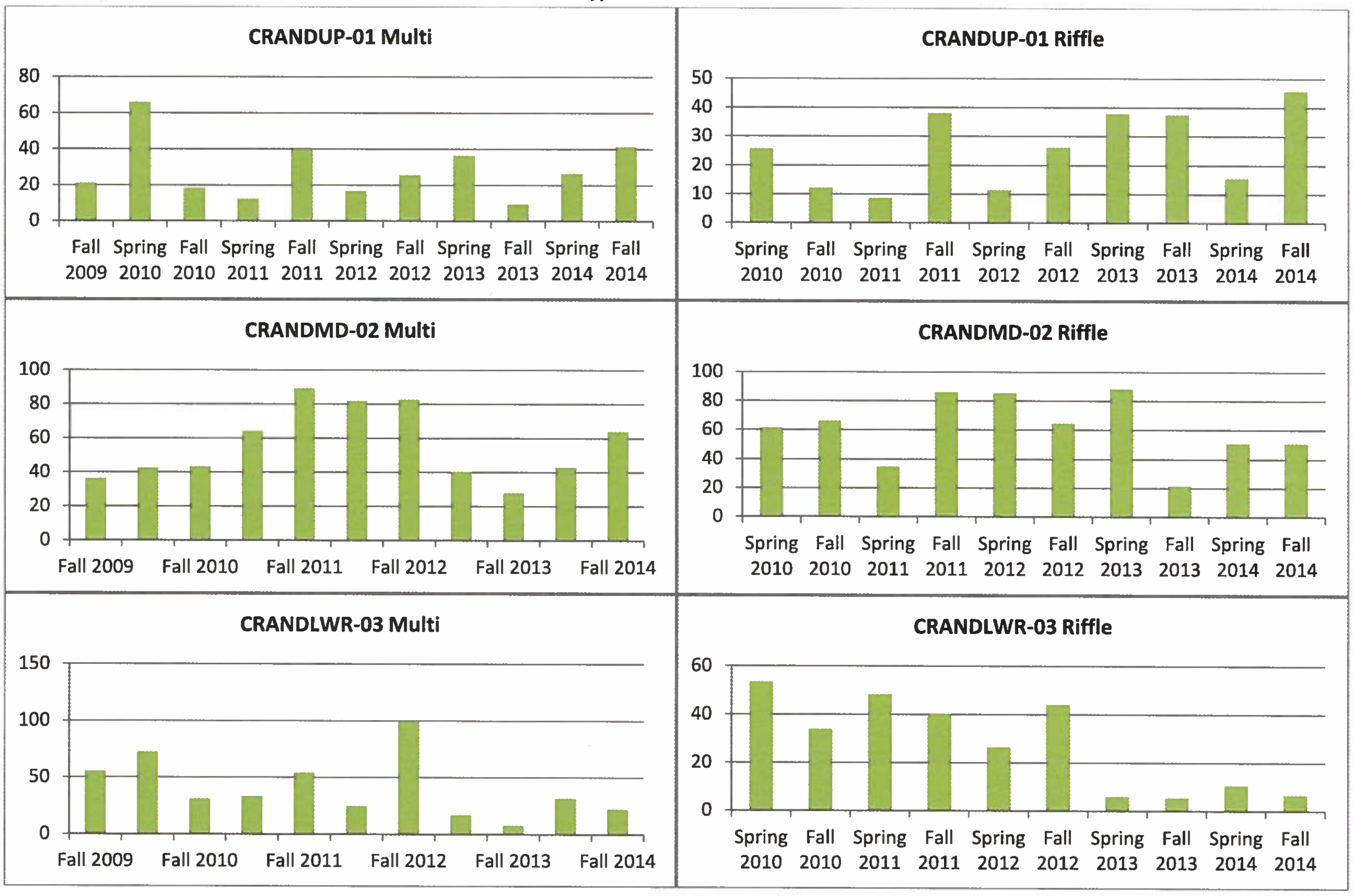
Figures 7c. EPT taxa abundance values for each reach and habitat type from 2009-2014



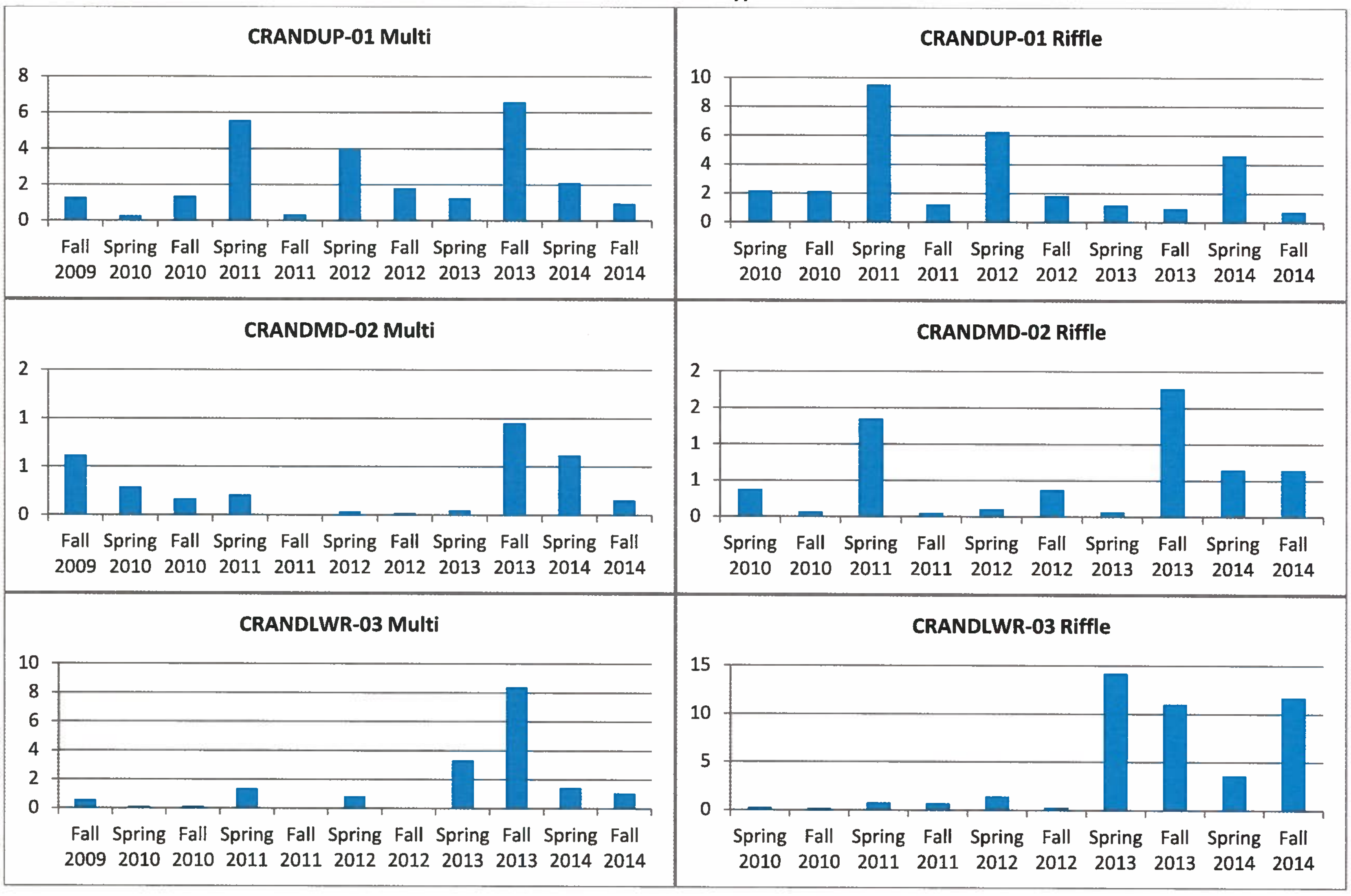
Figures 8c. Percent EPT for each reach and habitat type from 2009-2014



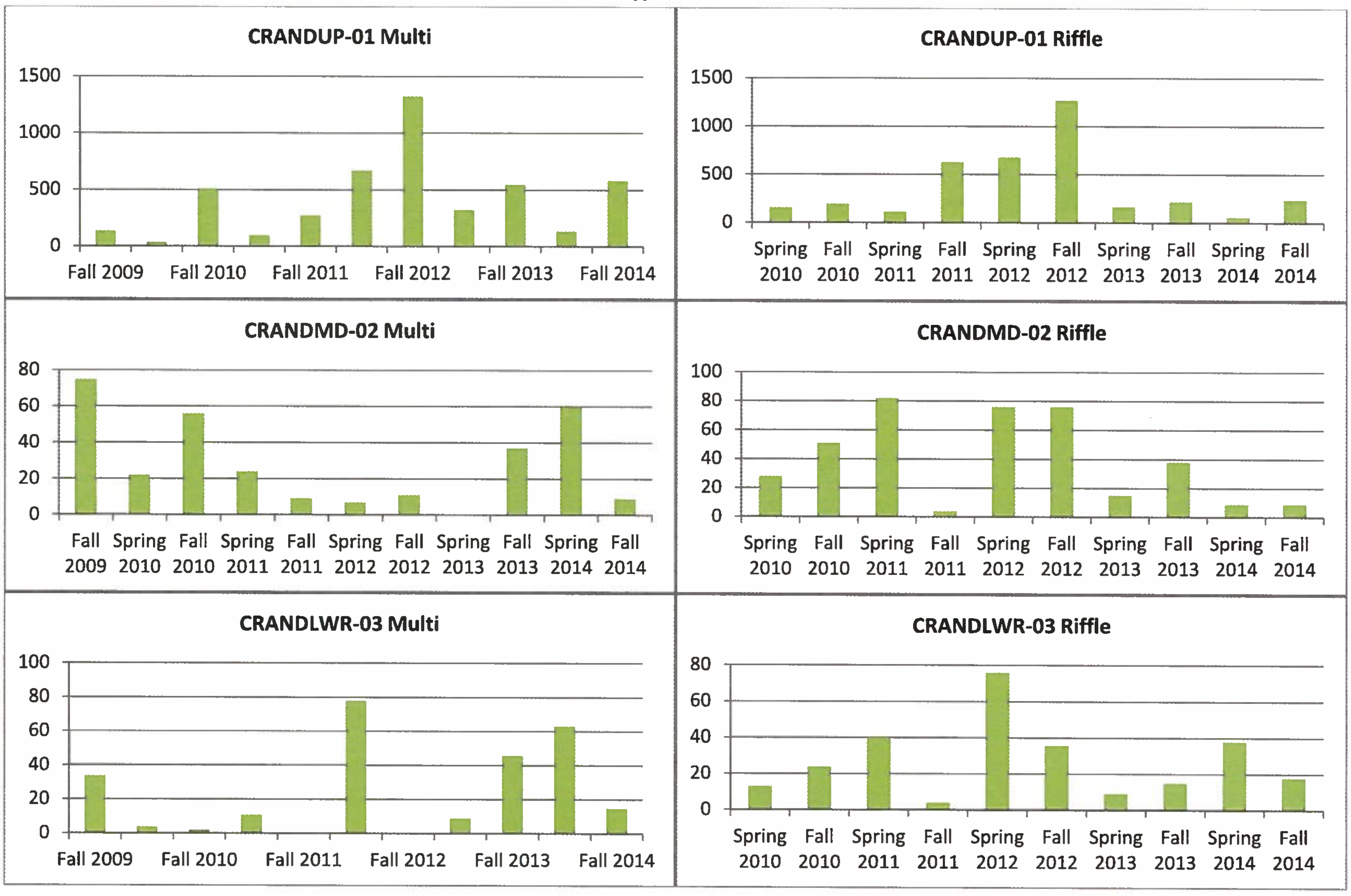
Figures 9c. Percent Chironomids for each reach and habitat type from 2009-2014



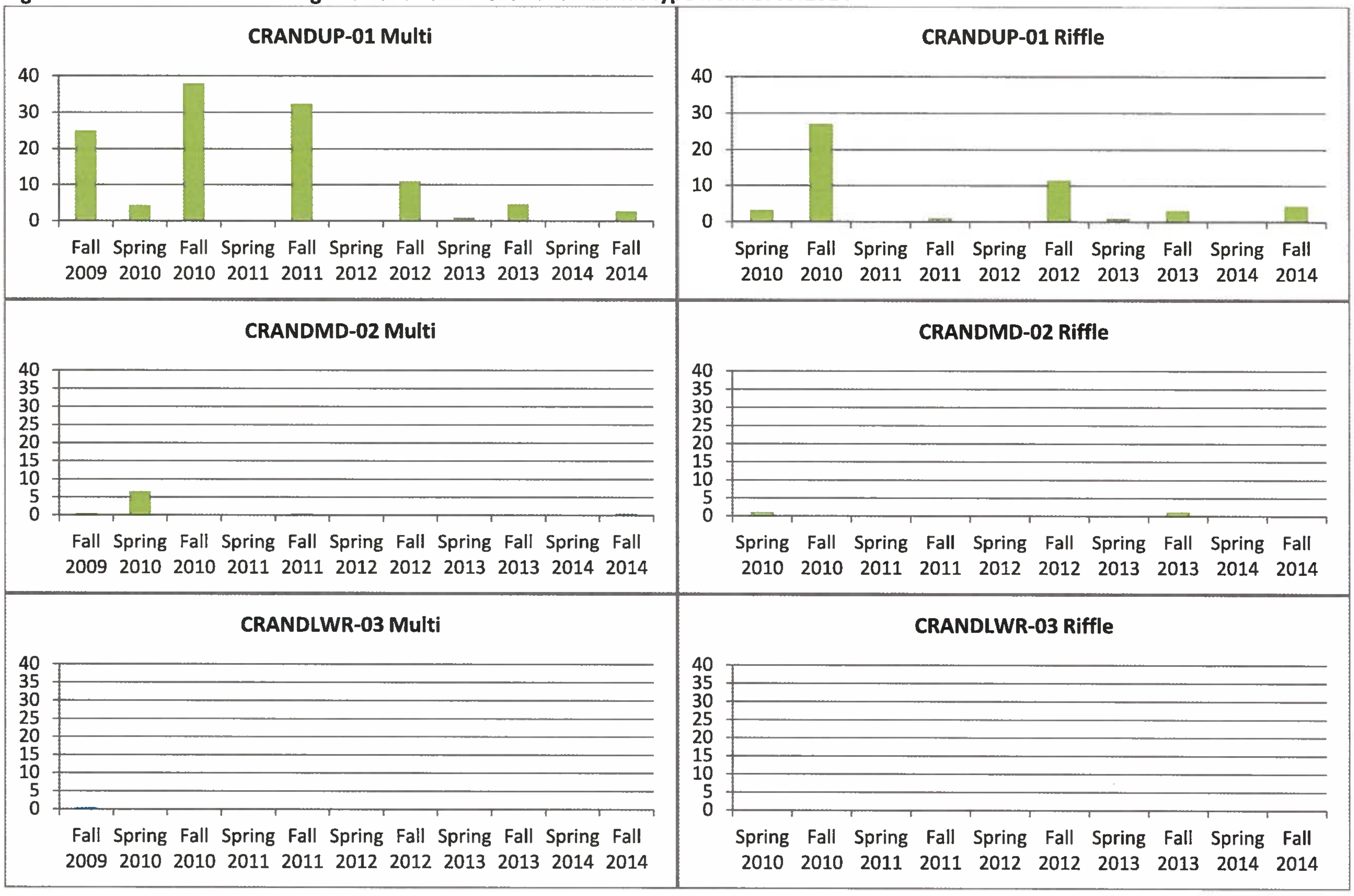
Figures 10c. Ratio of EPT to Chironmoids values for each reach and habitat type from 2009-2014



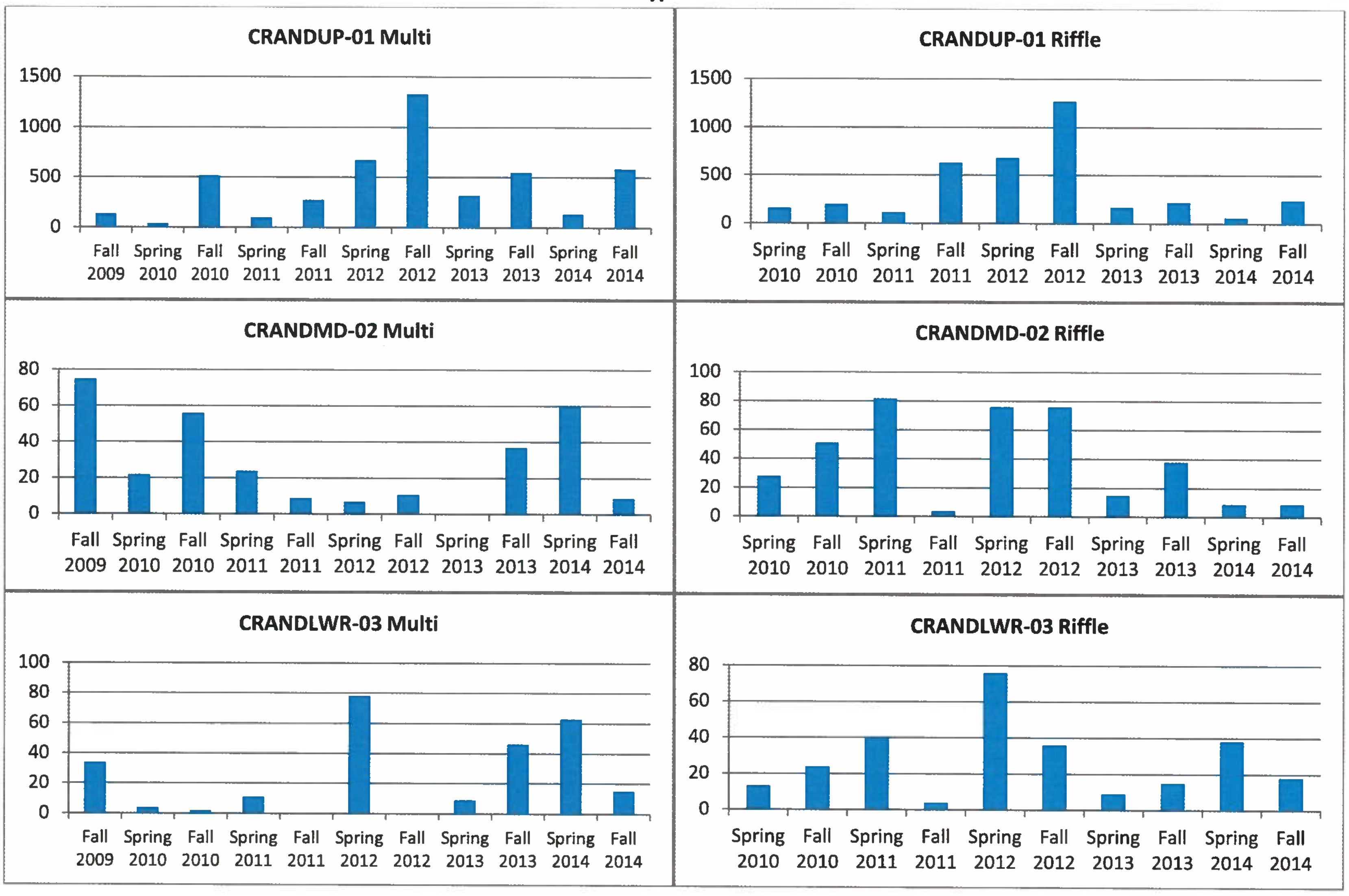
Figures 11c. Number of tolerant taxa for each reach and habitat type from 2009-2014



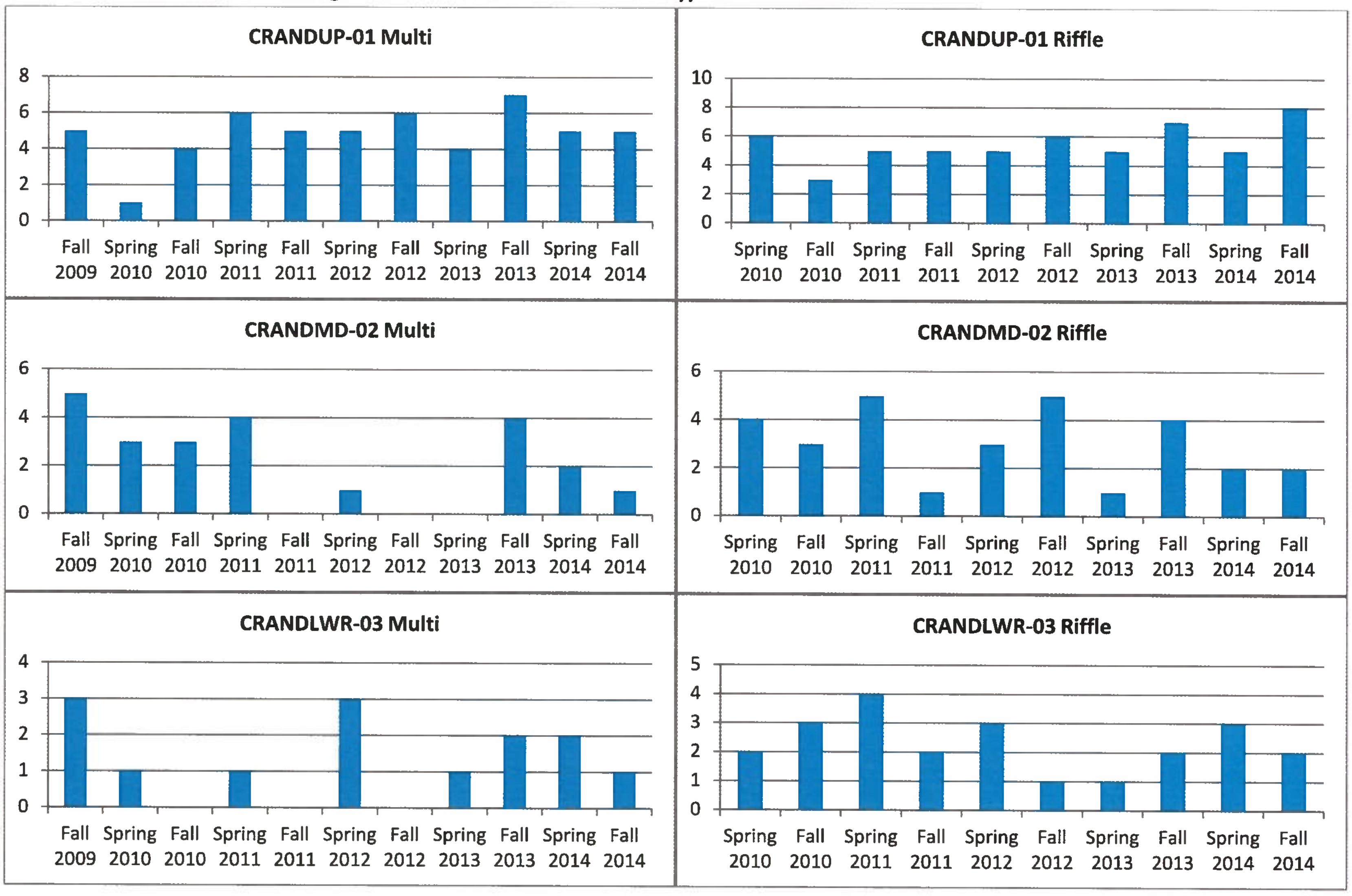
Figures 12c. Percent tolerant organisms for each reach and habitat type from 2009-2014



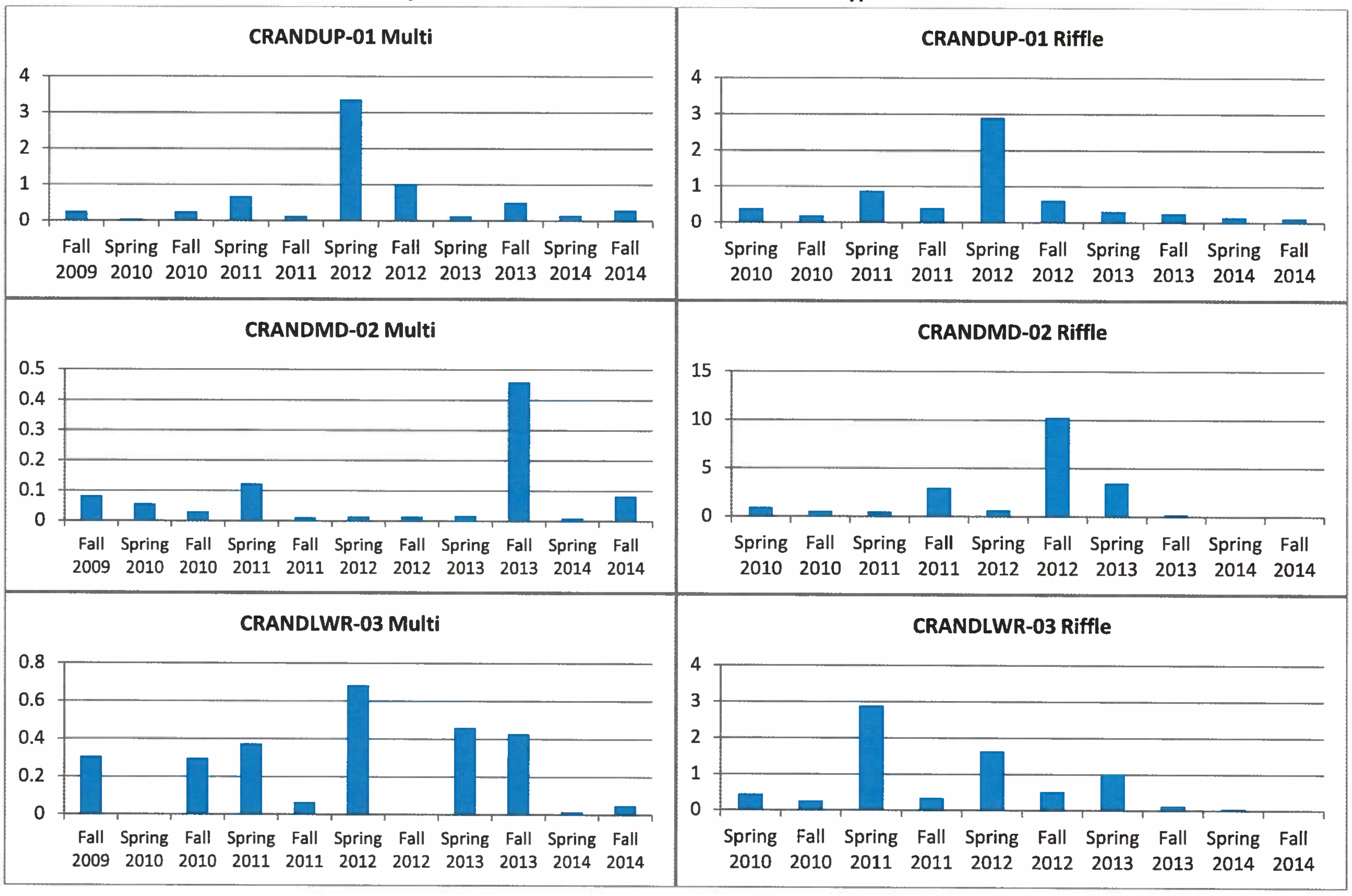
Figures 13c. Number of intolerant taxa for each reach and habitat type from 2009-2014



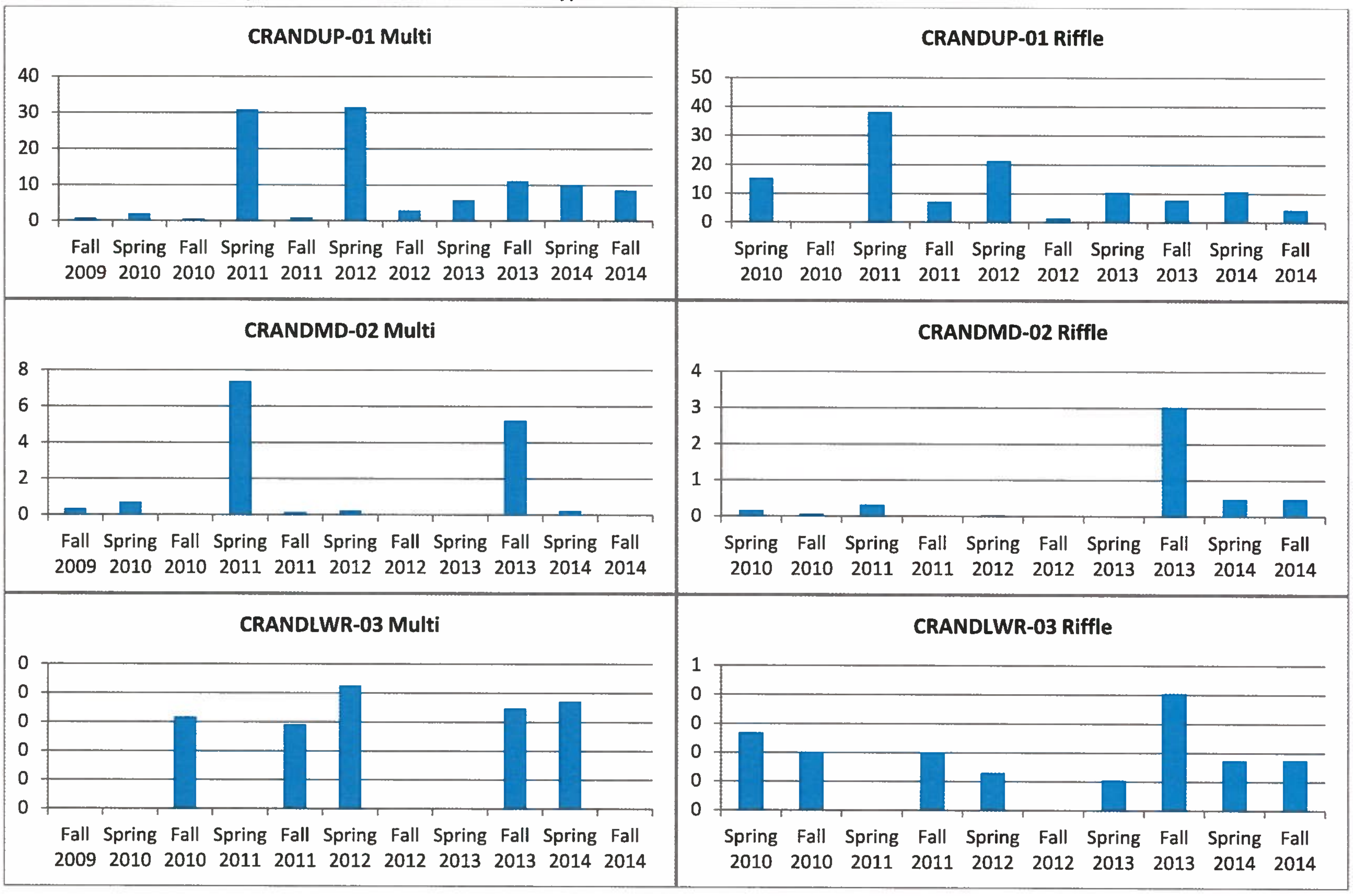
Figures 14c. Percent intolerant organisms for each reach and habitat type from 2009-2014



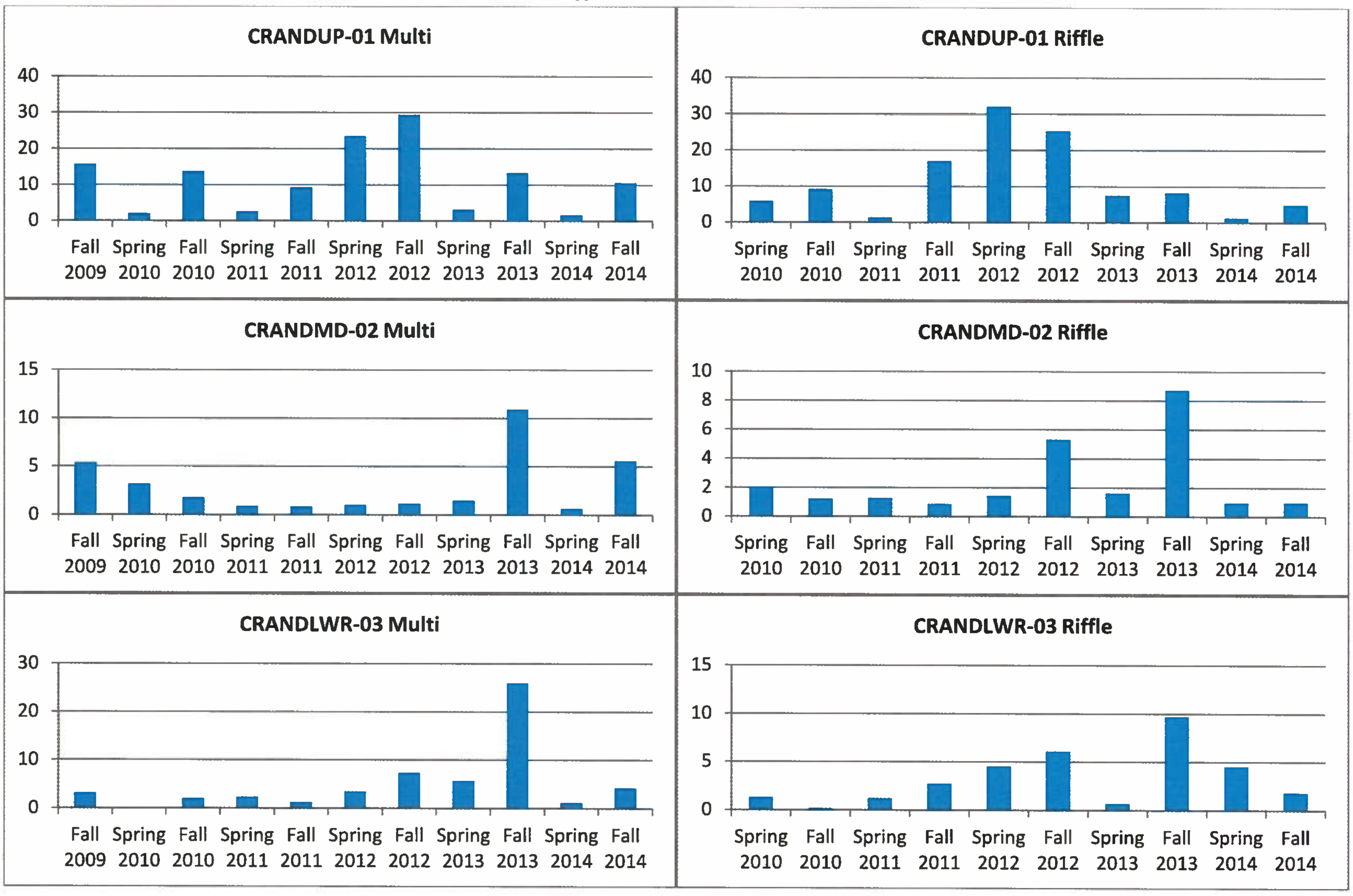
Figures 15c. Ratio of specialist feeders to generalist feeders for each reach and habitat type from 2009-2014



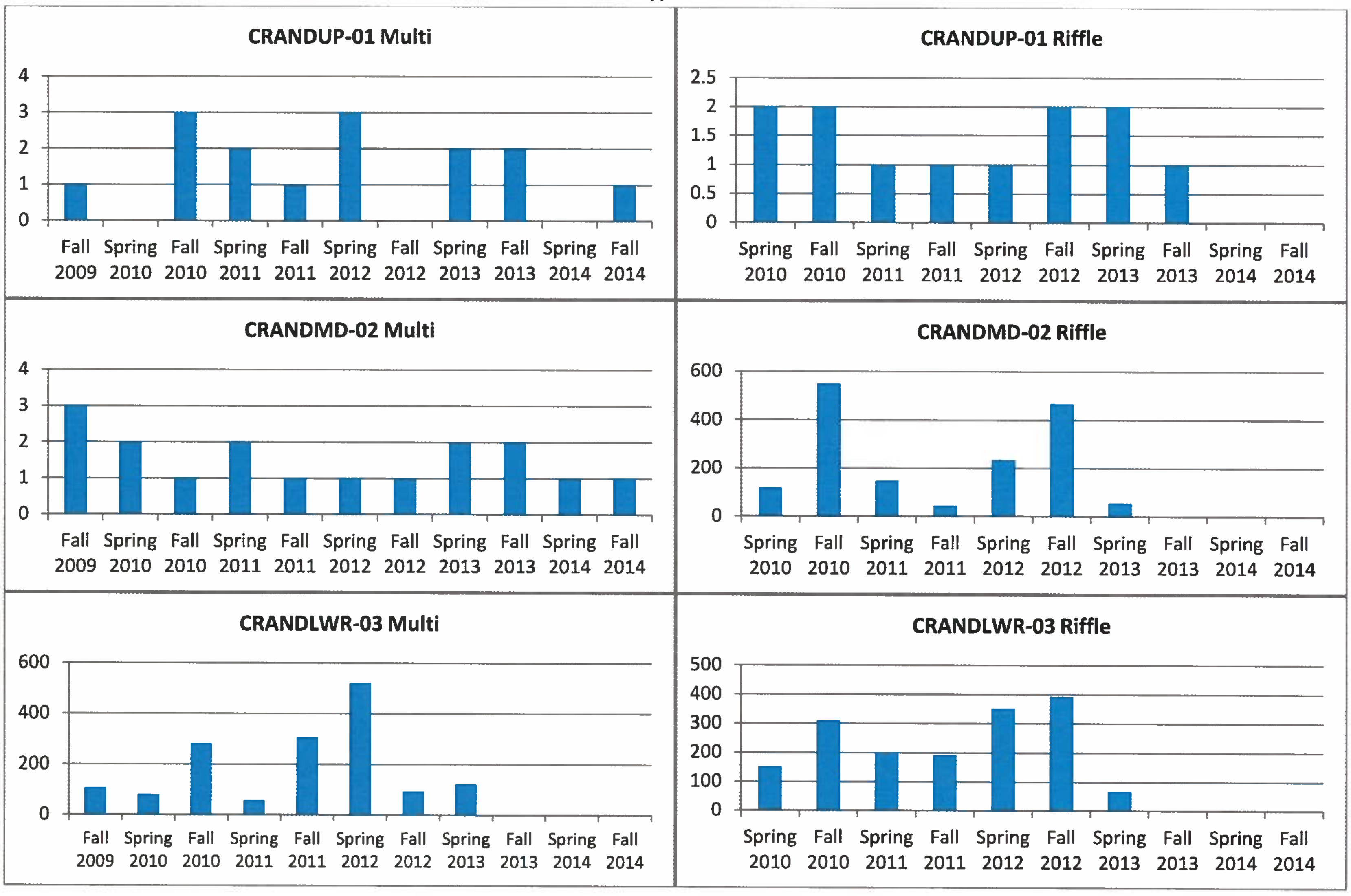
Figures 16c. Percent scrapers for each reach and habitat type from 2009-2014



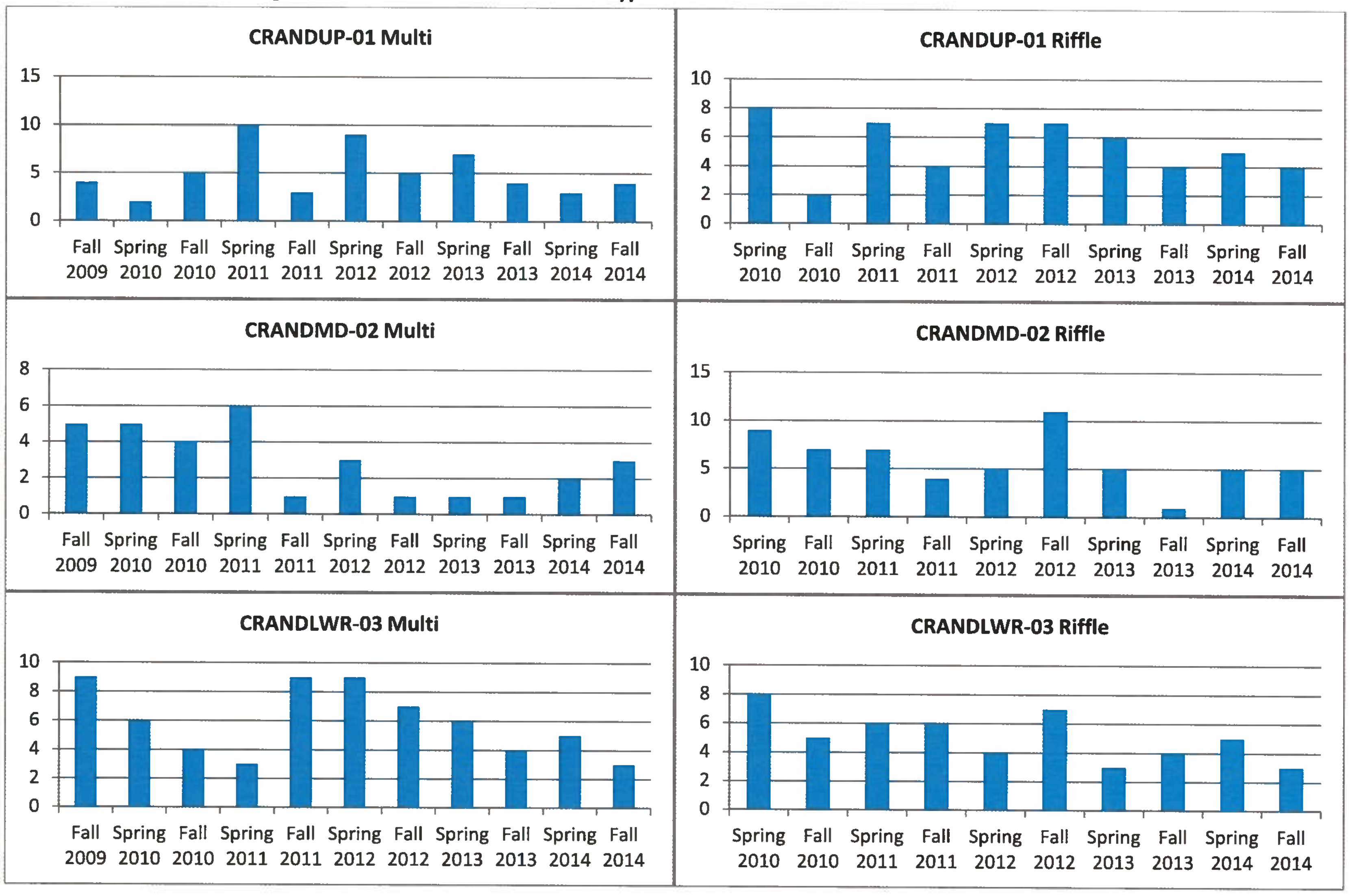
Figures 17c. Percent shredders for each reach and habitat type from 2009-2014



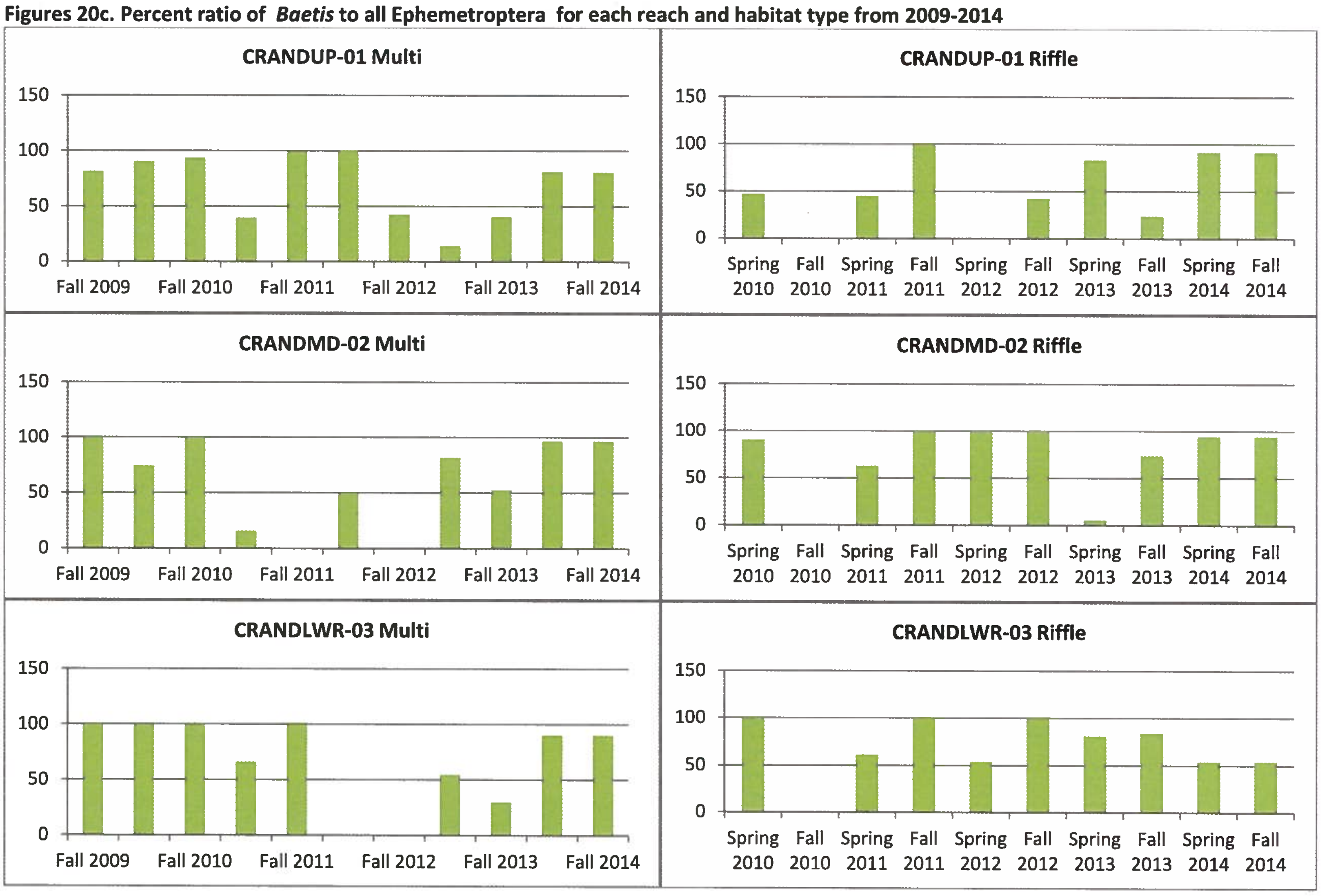
Figures 18c. Number of long-lived taxa for each reach and habitat type from 2009-2014



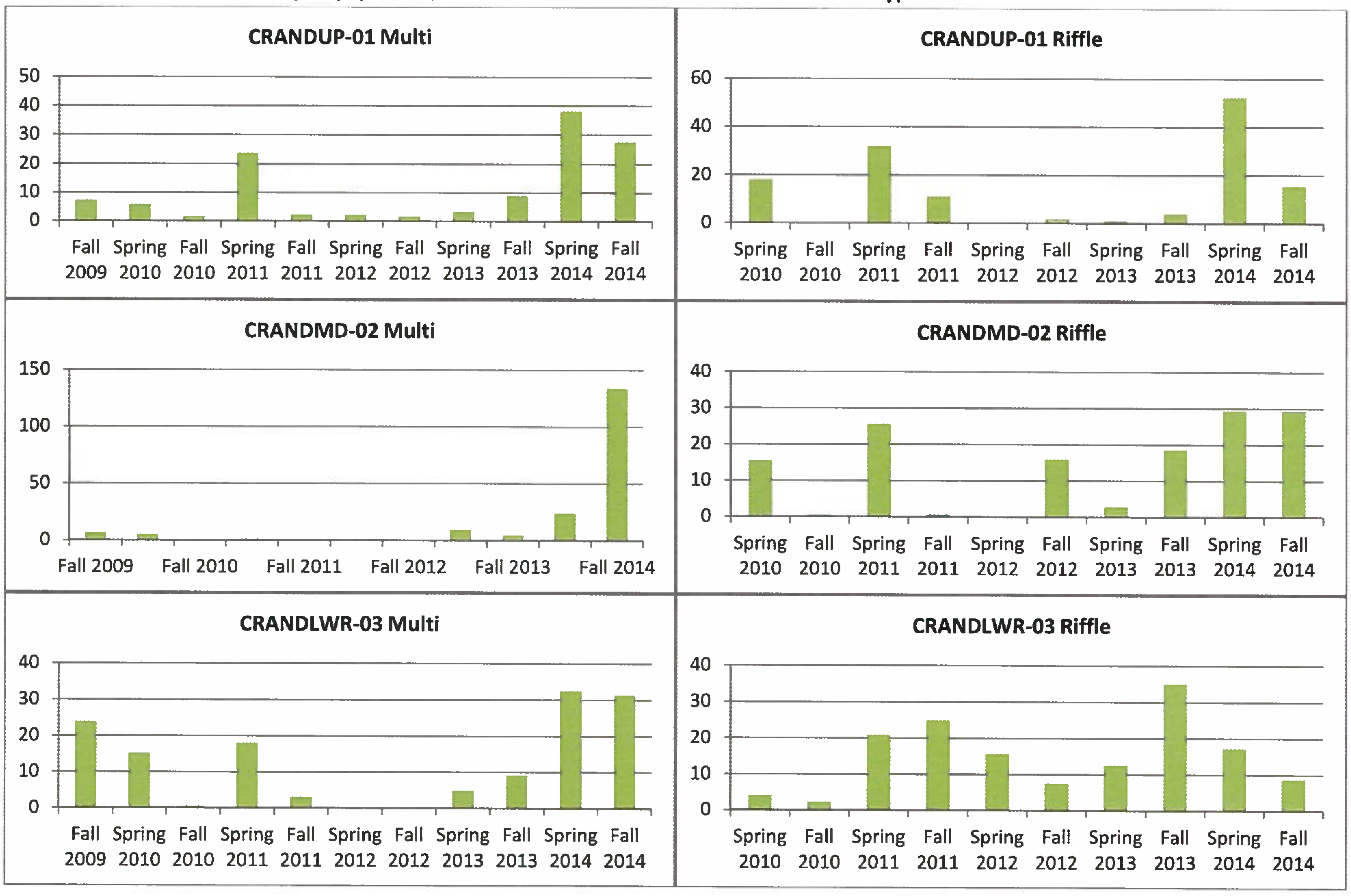
Figures 19c. Number of clinger taxa for each reach and habitat type from 2009-2014



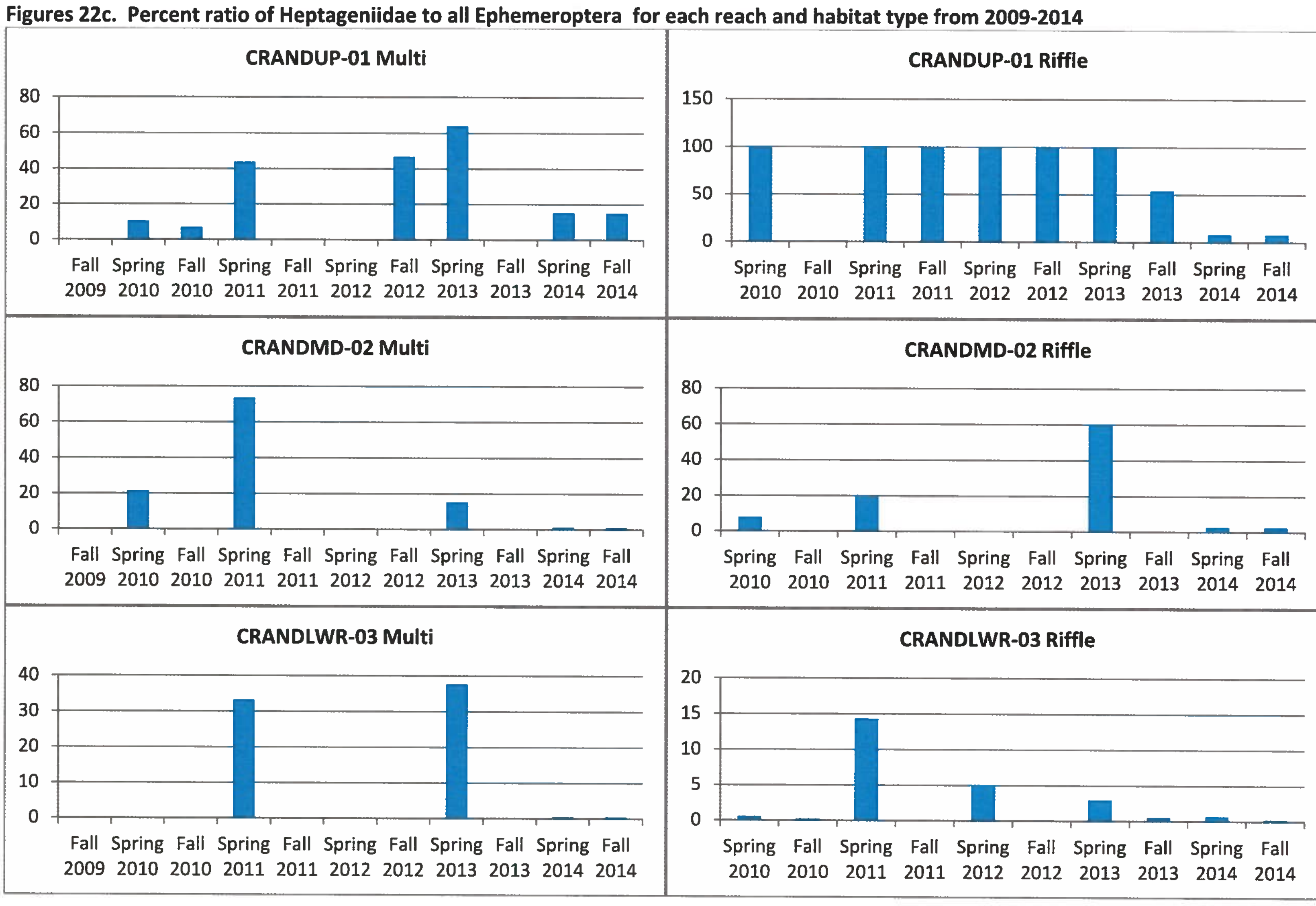
Figures 20c. Percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2009-2014



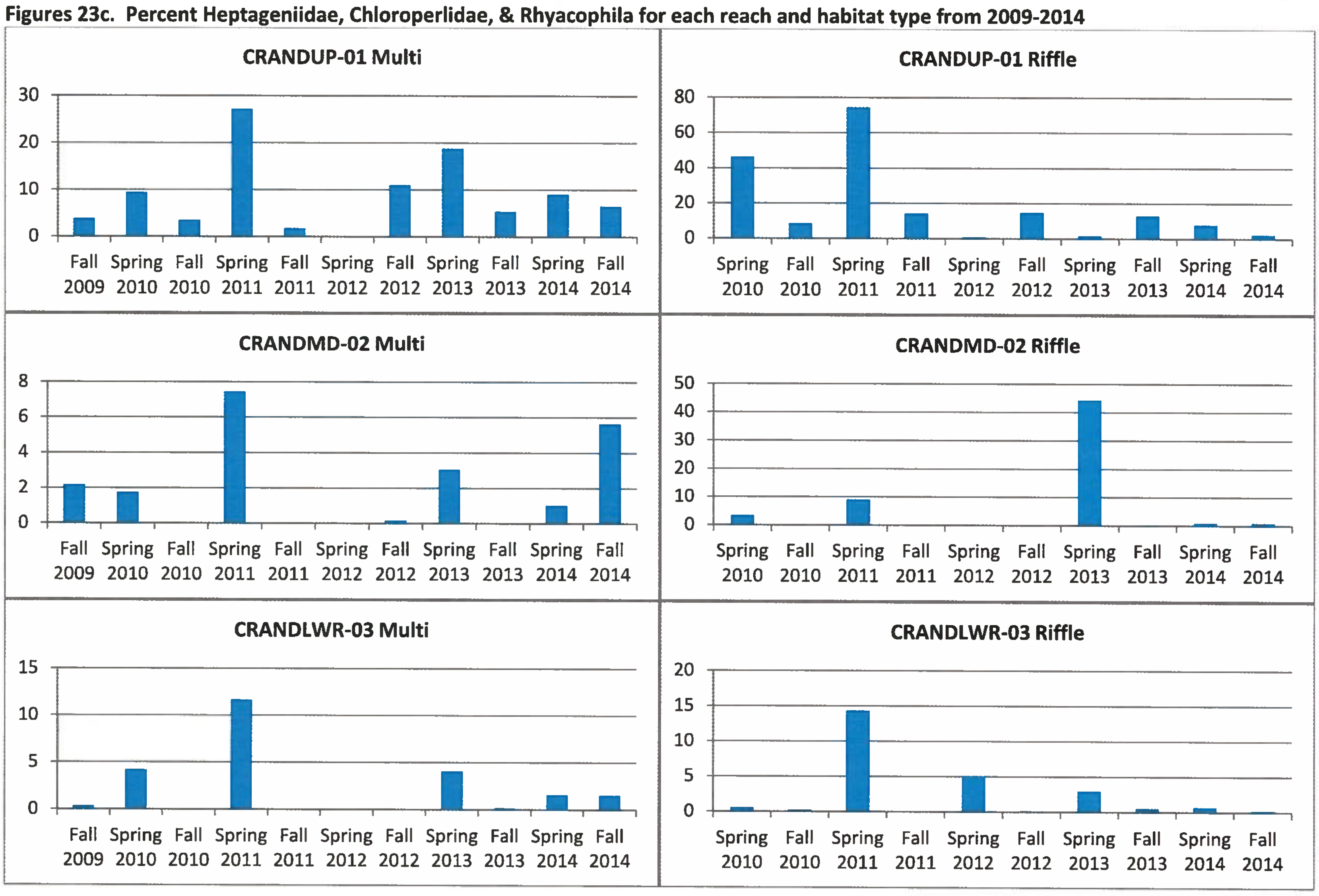
Figures 21c. Percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2014



Figures 22c. Percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2014



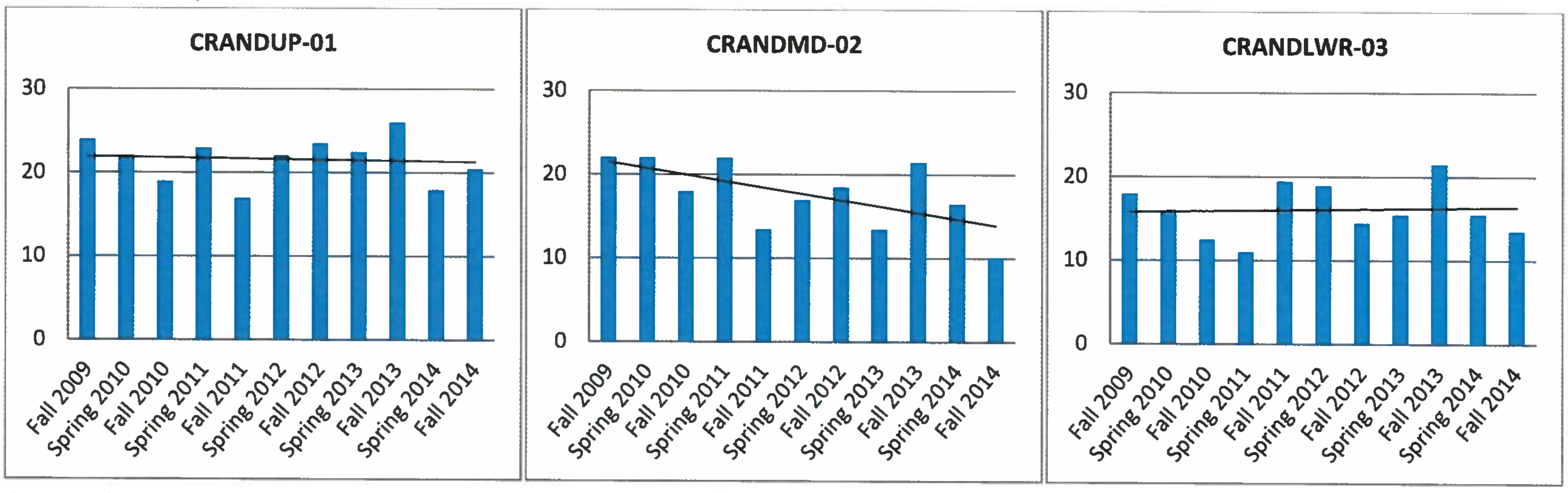
Figures 23c. Percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2014



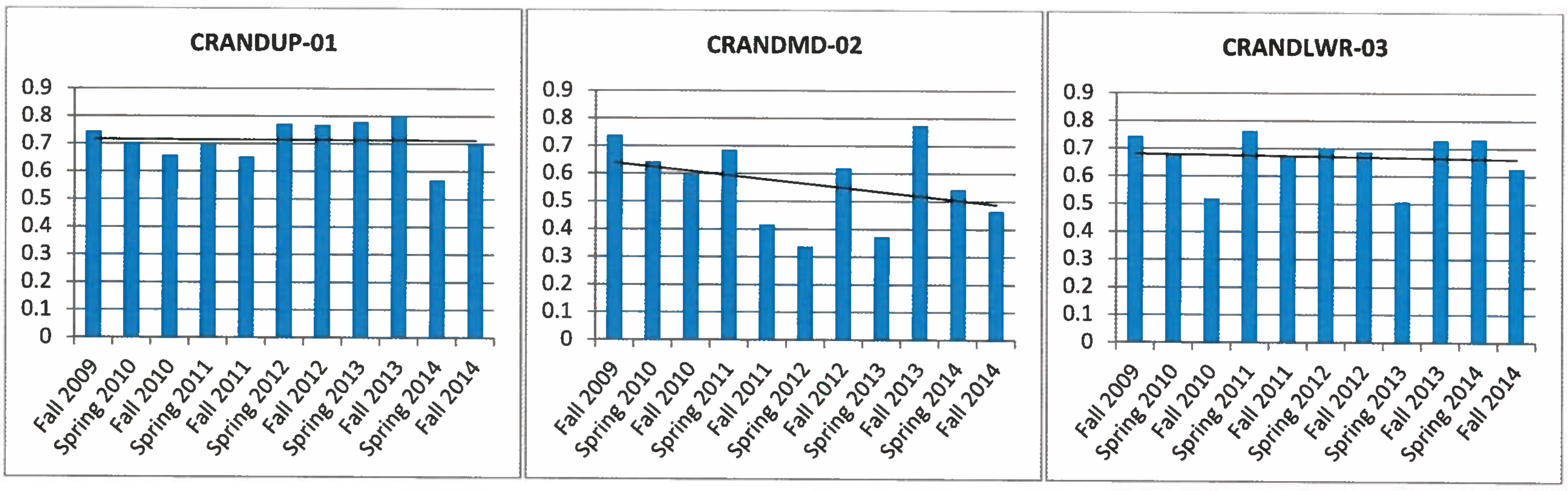
APPENDIX D

MACROINVERTEBRATE FIGURES FALL 2009- FALL 2014 AVERAGED

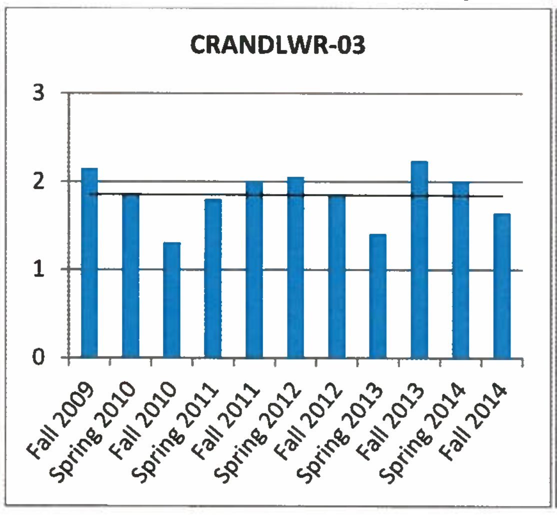
Figures 1d. Average richness in each reach from Fall 2009- Fall 2014

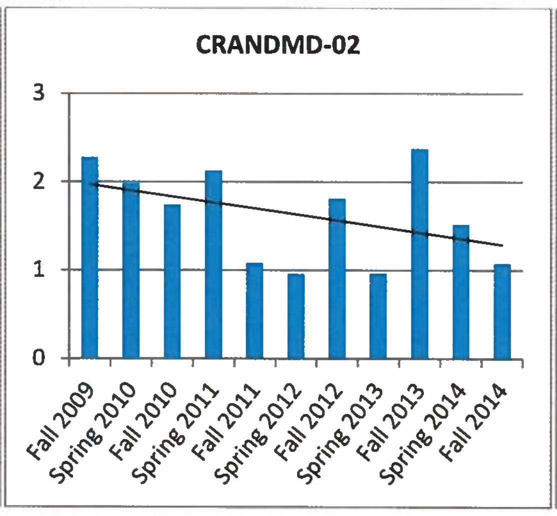


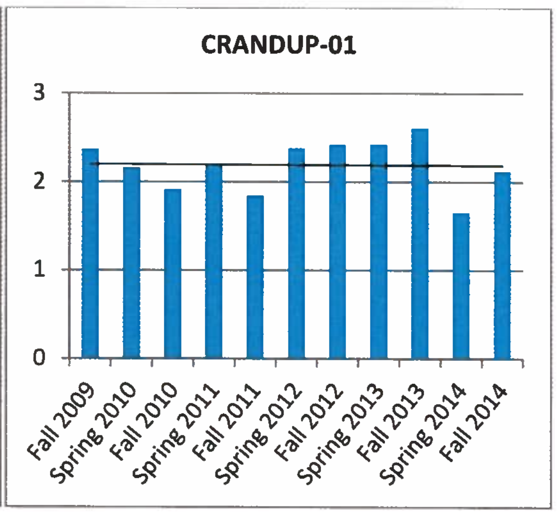
Figures 2d. Average evenness in each reach from Fall 2009- Fall 2014



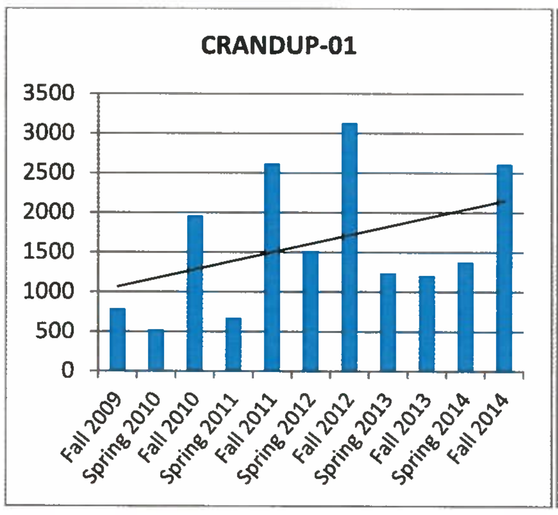
Figures 3d. Average Shannon's Diversity in each reach from Fall 2009- Fall 2014

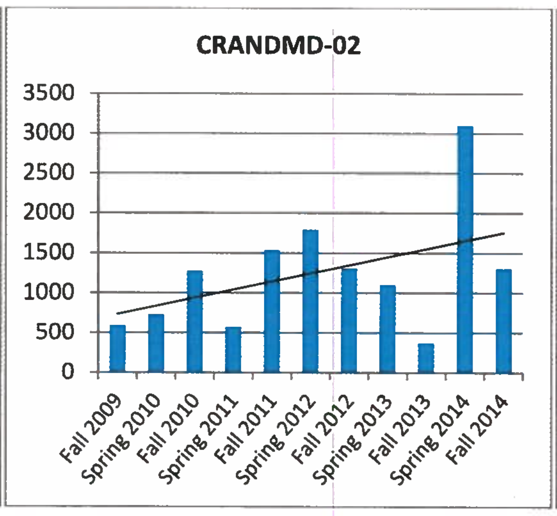


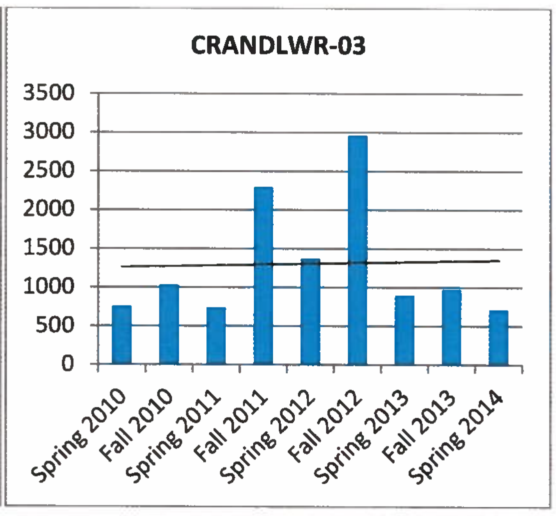




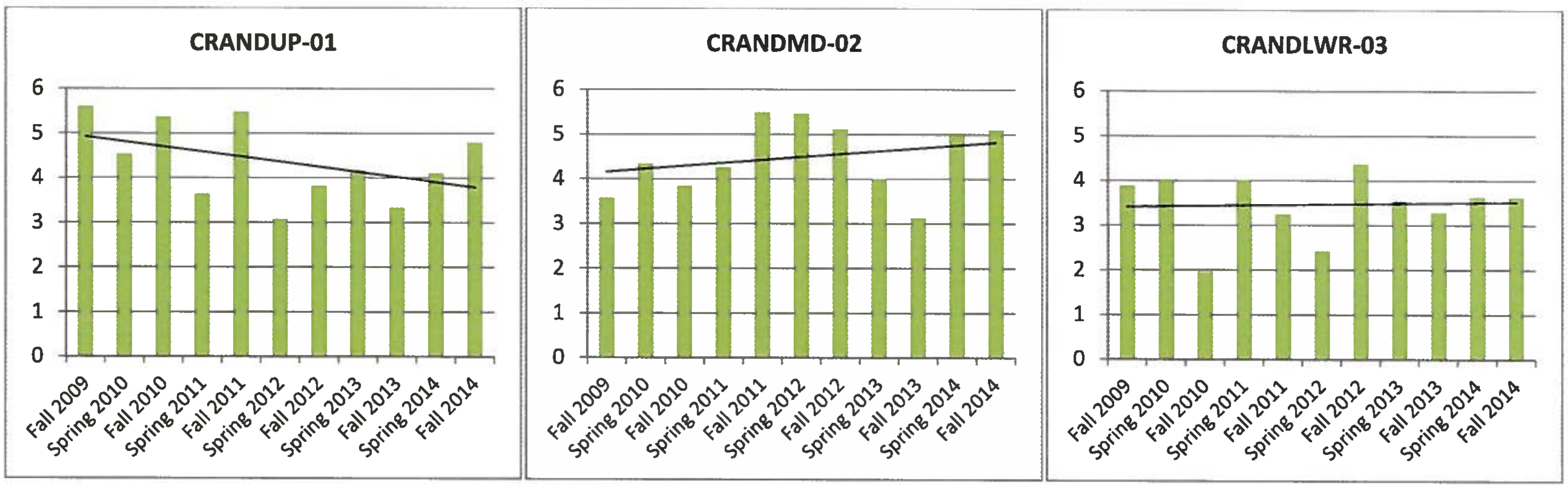
Figures 4d. Average abundance in each reach from Fall 2009- Fall 2014



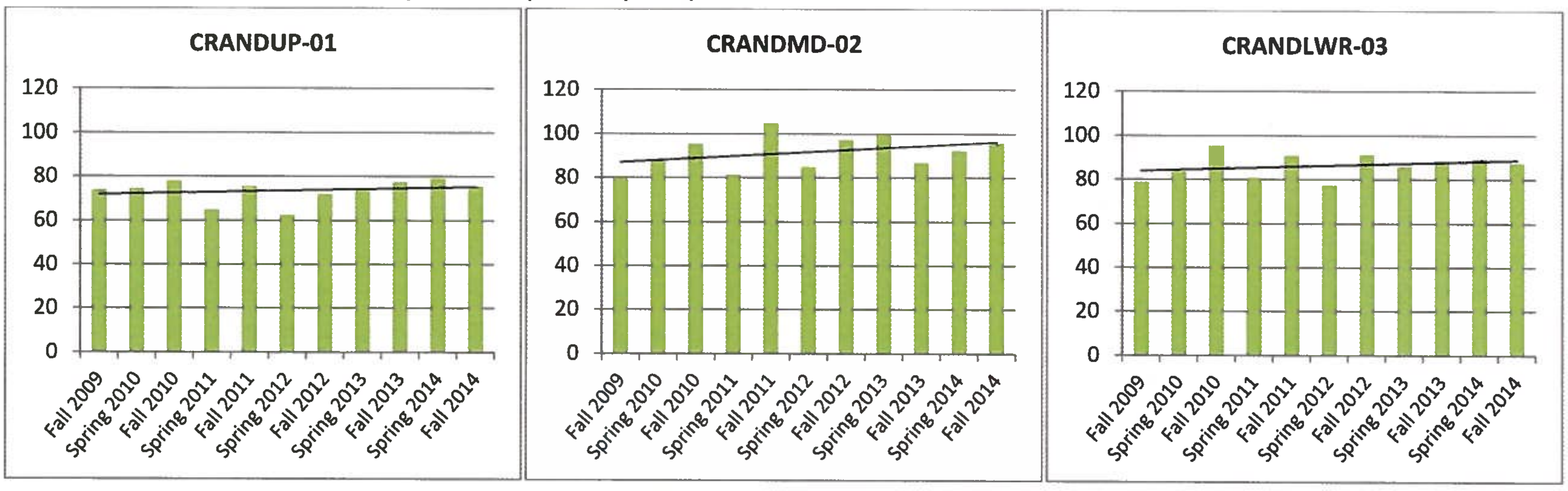




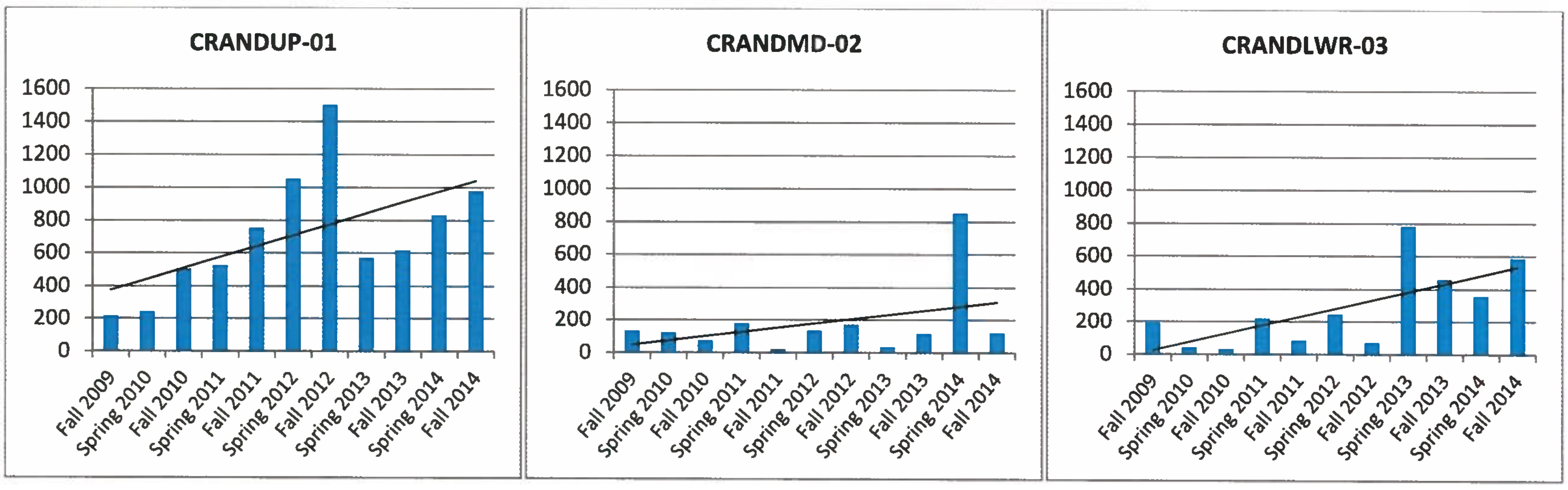
Figures 5d. Average Hilsenhoff Biotic Index in each reach from Fall 2009- Fall 2014



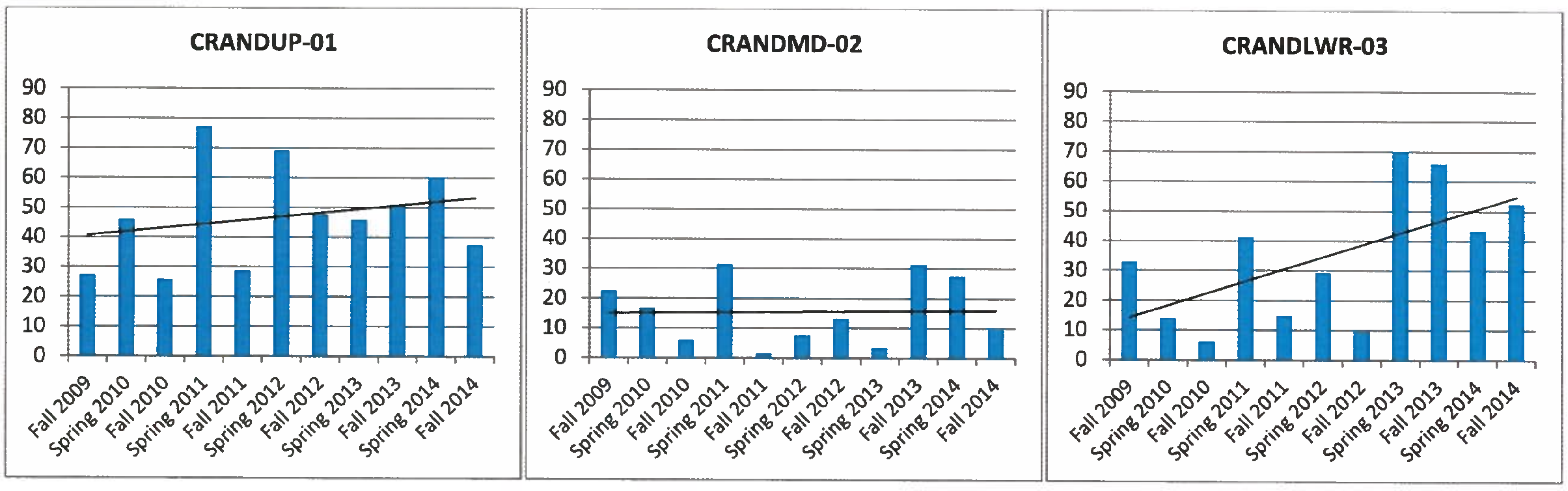
Figures 6d. Average USFS community tolerant quotient (CTQd) in each reach from Fall 2009- Fall 2014



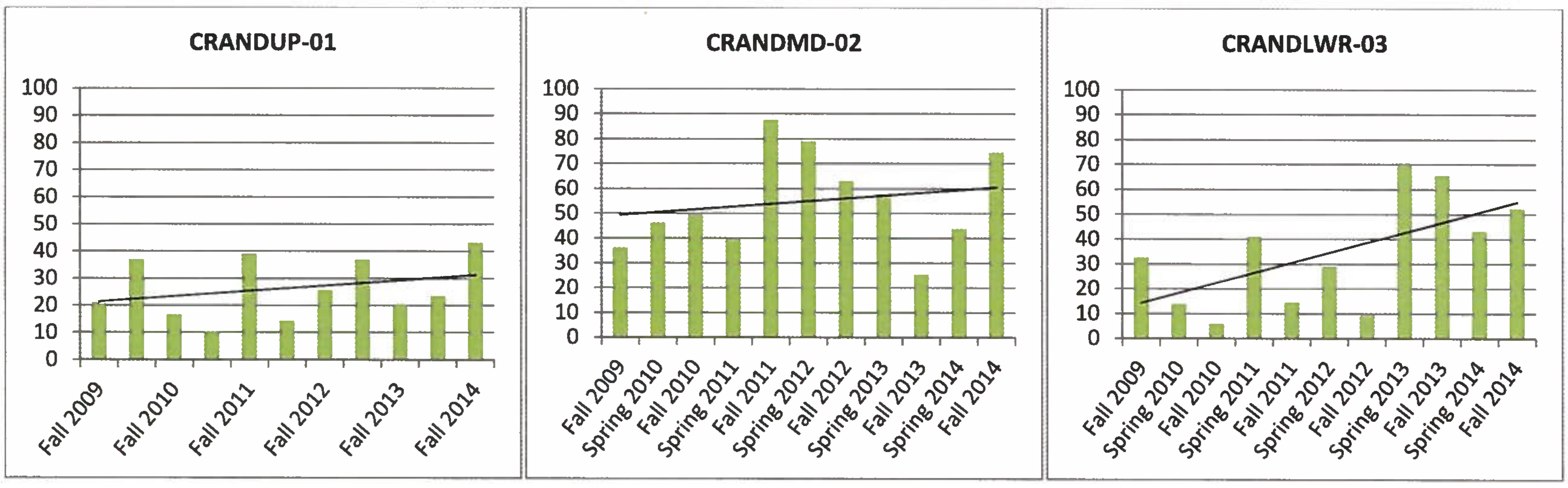
Figures 7d. Average EPT taxa abundance in each reach from Fall 2009- Fall 2014



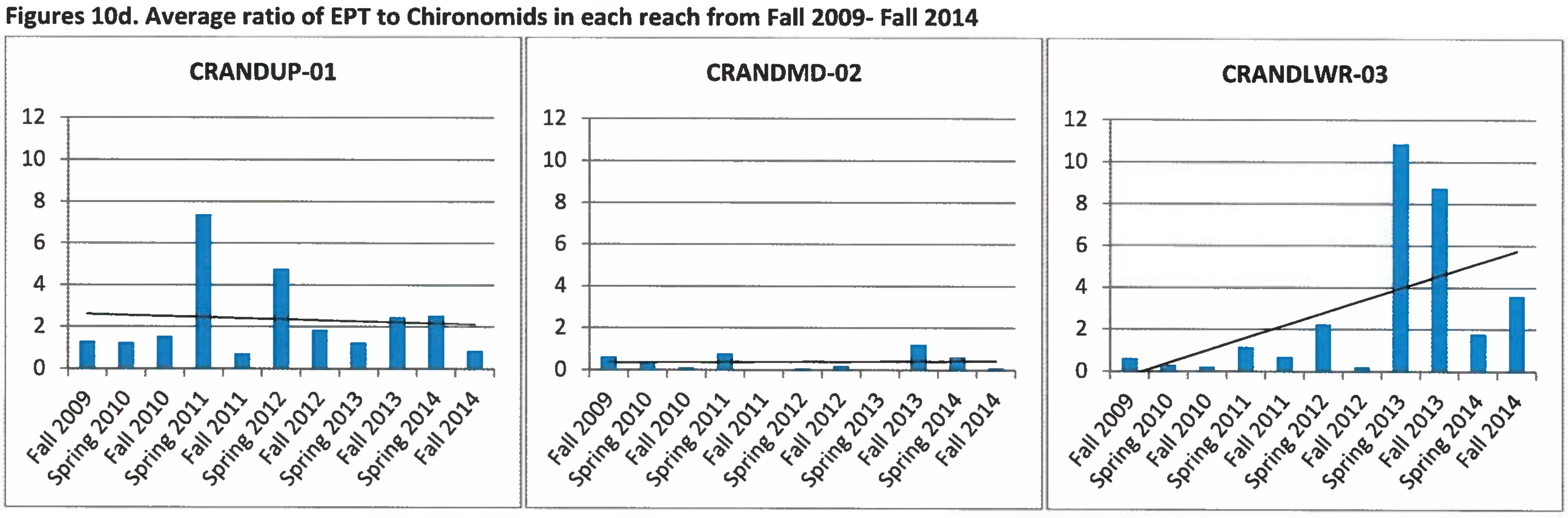
Figures 8d. Average percent EPT in each reach from Fall 2009- Fall 2014



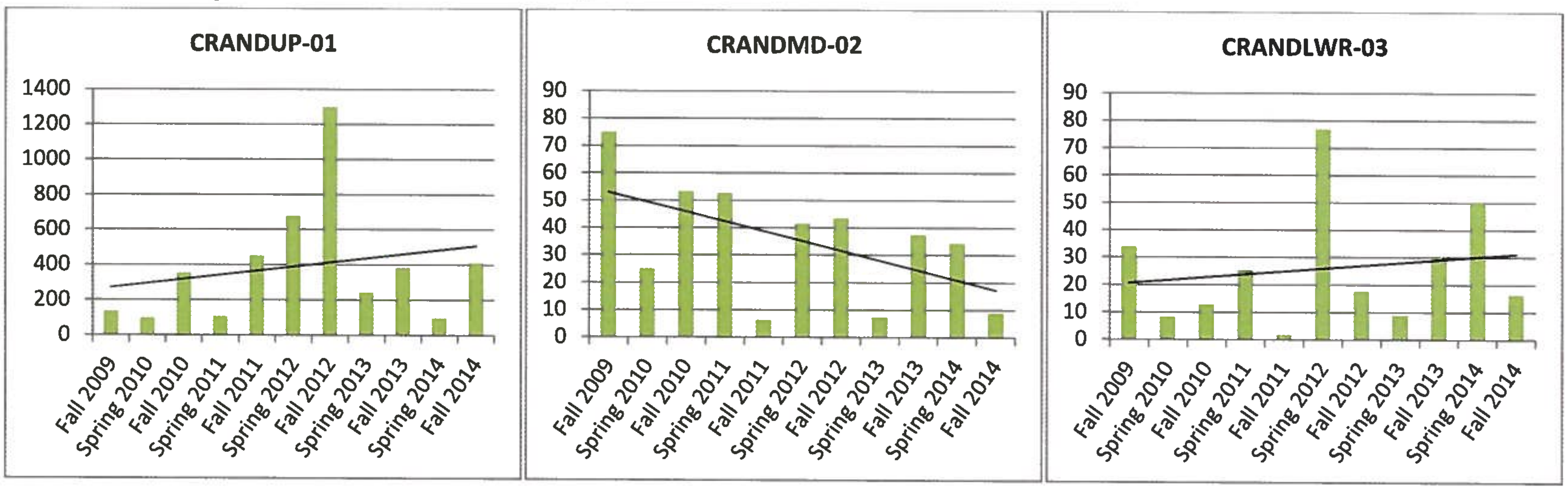
Figures 9d. Average percent Chironomids in each reach from Fall 2009- Fall 2014



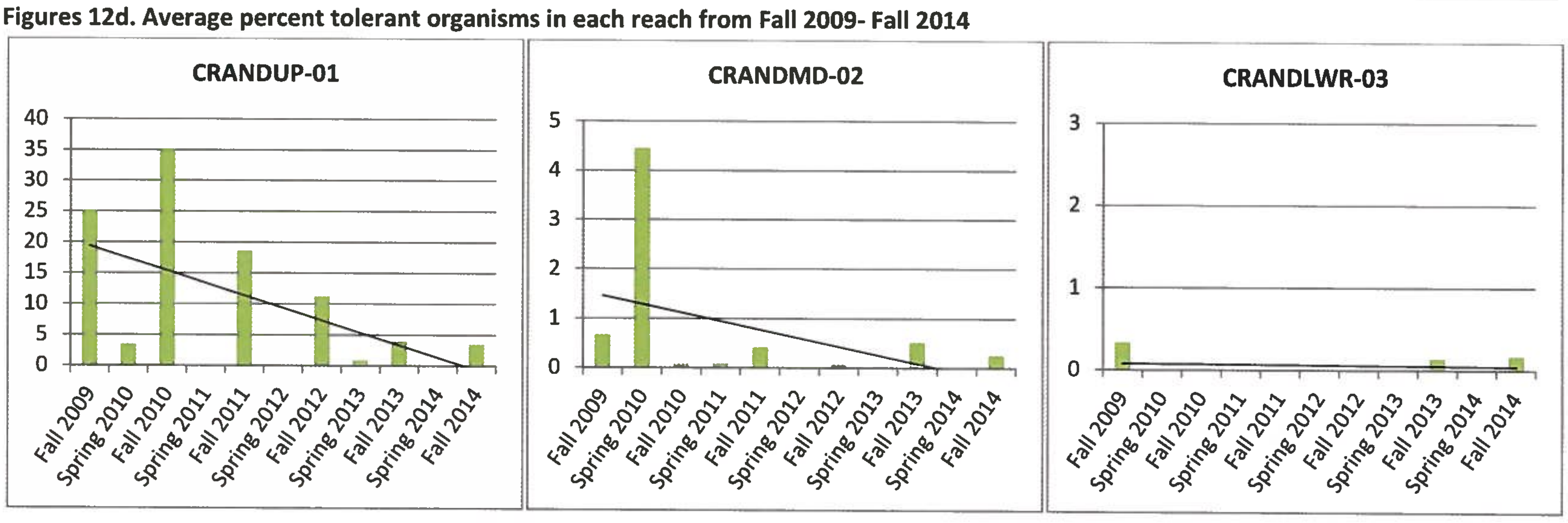
Figures 10d. Average ratio of EPT to Chironomids in each reach from Fall 2009- Fall 2014



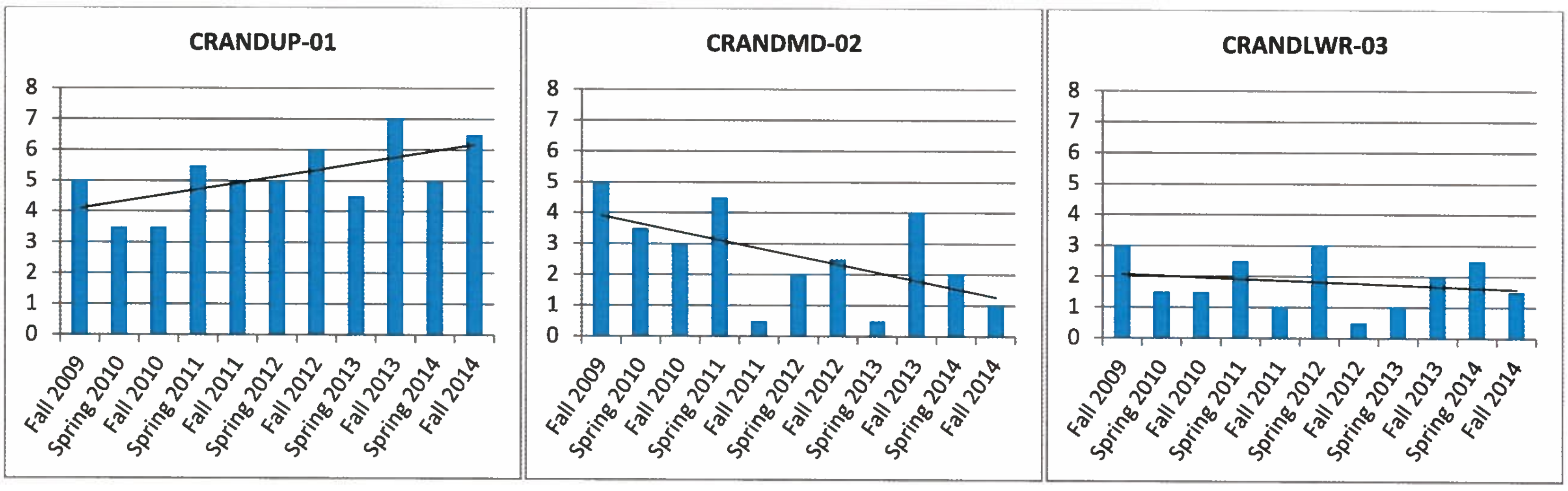
Figures 11d. Average number of tolerant taxa in each reach from Fall 2009- Fall 2014



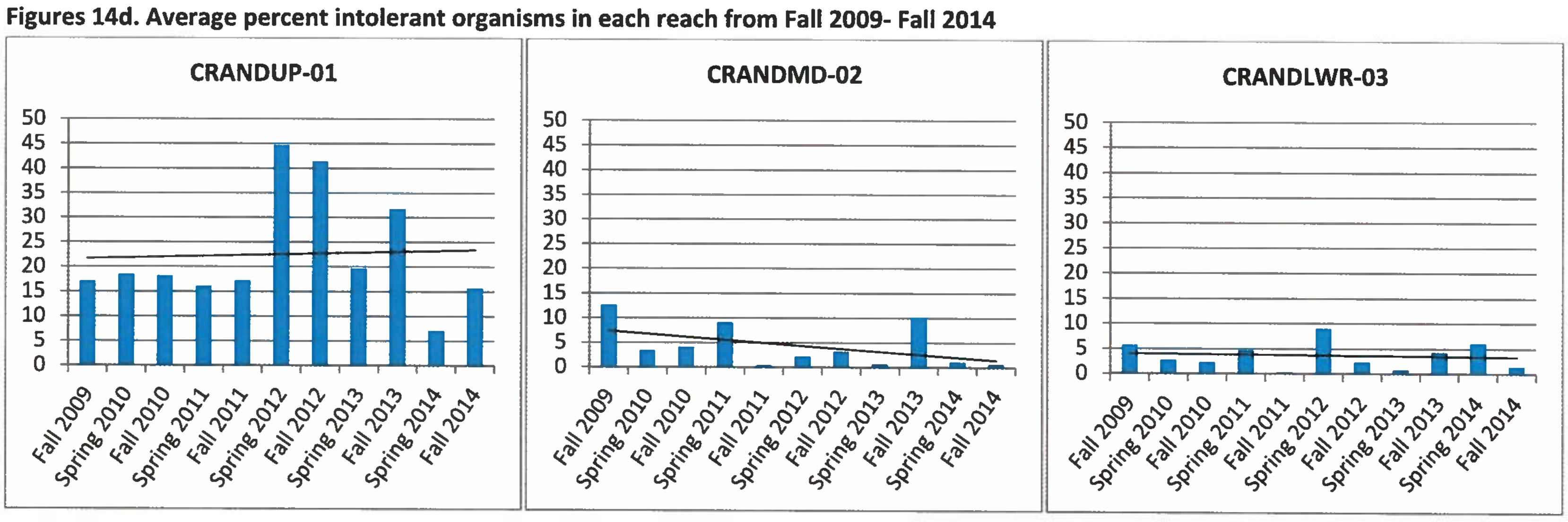
Figures 12d. Average percent tolerant organisms in each reach from Fall 2009- Fall 2014



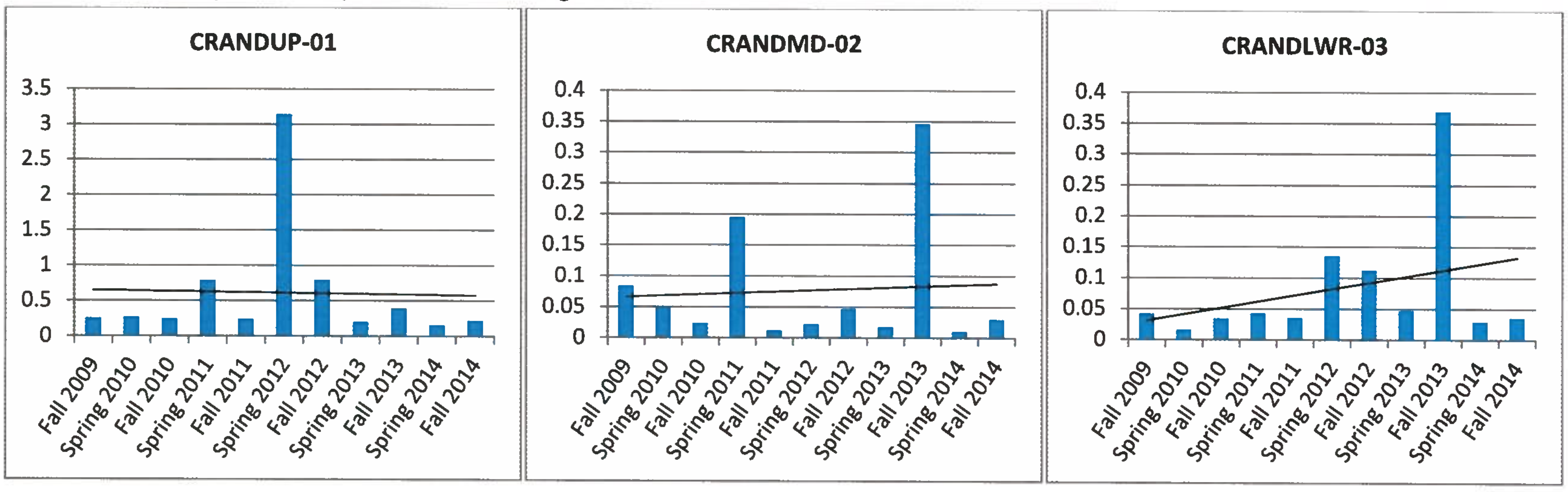
Figures 13d. Average number of intolerant taxa in each reach from Fall 2009- Fall 2014



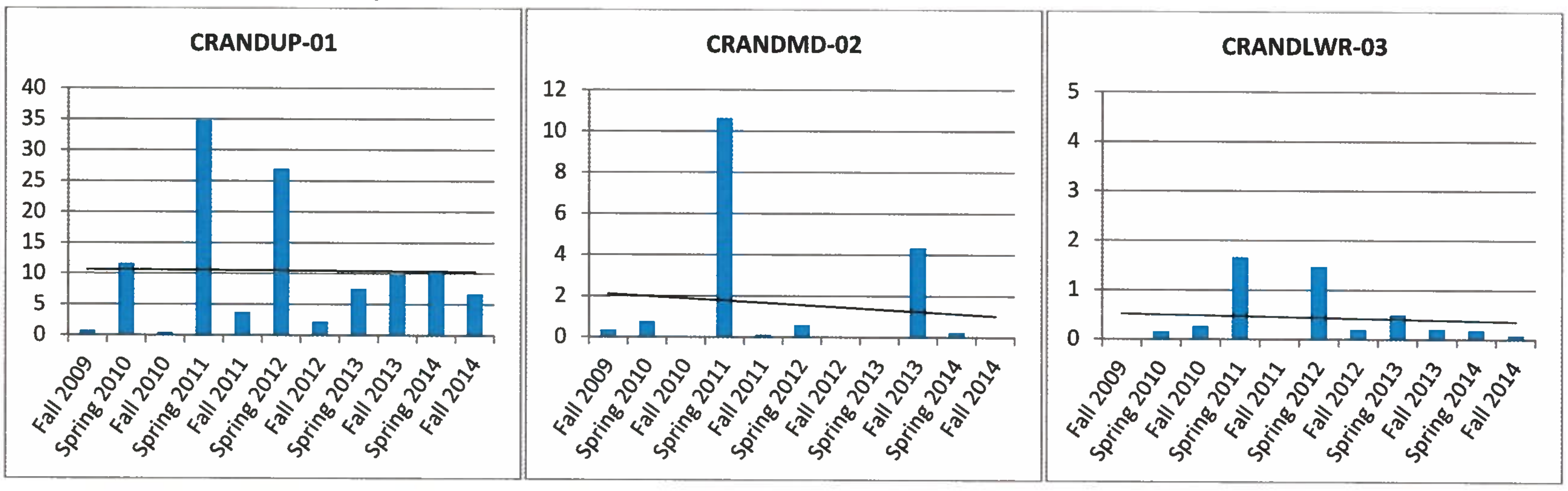
Figures 14d. Average percent intolerant organisms in each reach from Fall 2009- Fall 2014



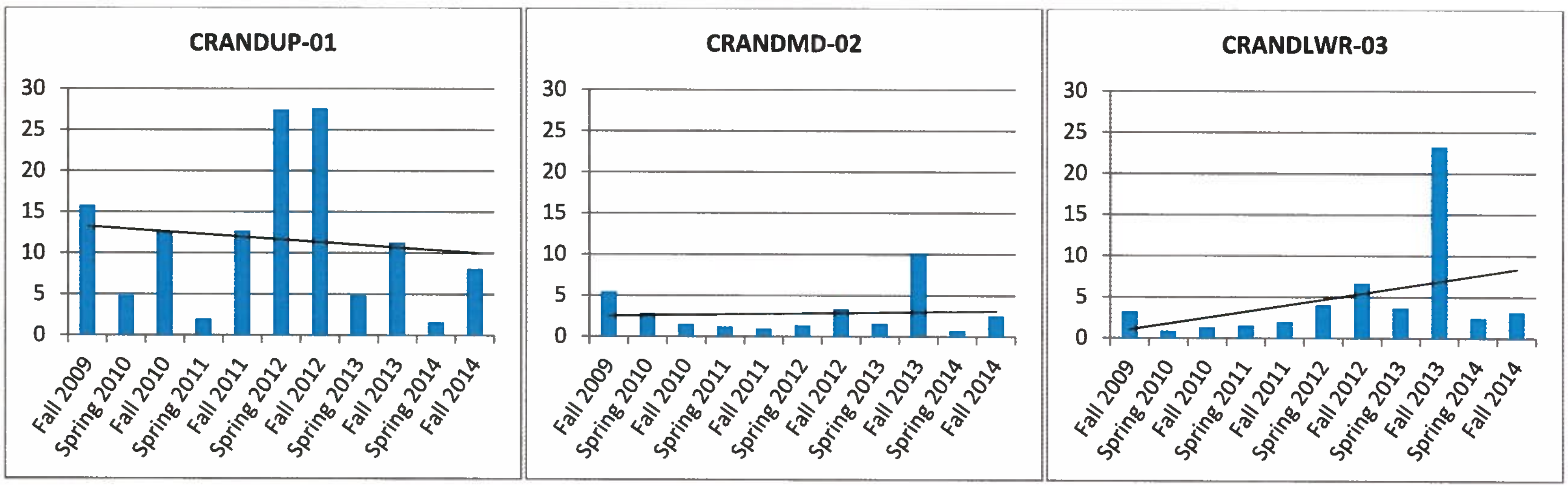
Figures 15d. Average ratio of specialist feeders to generalist feeders in each reach from Fall 2009- Fall 2014



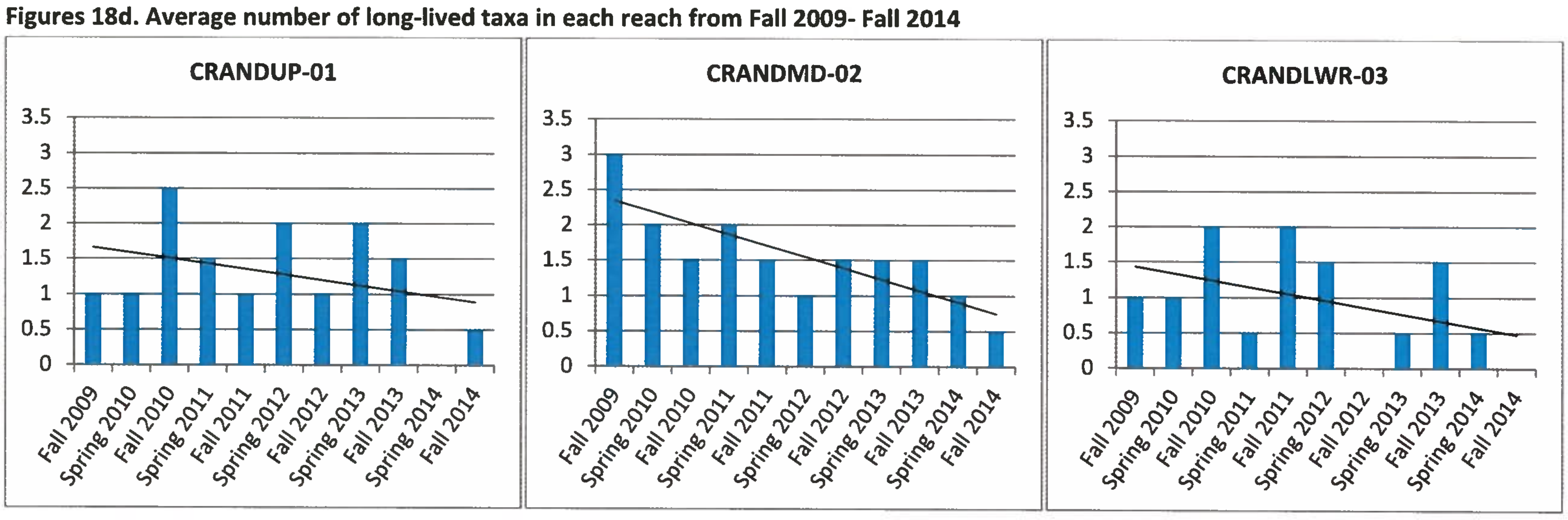
Figures 16d. Average percent scrapers in each reach from Fall 2009- Fall 2014



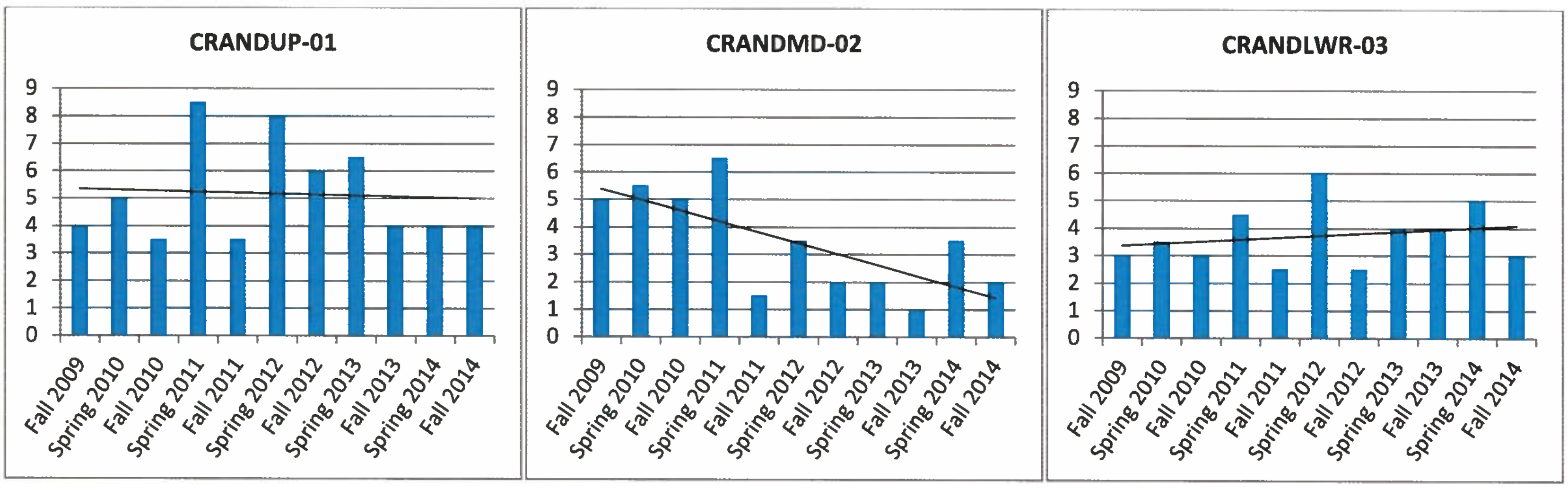
Figures 17d. Average percent shredders in each reach from Fall 2009- Fall 2014



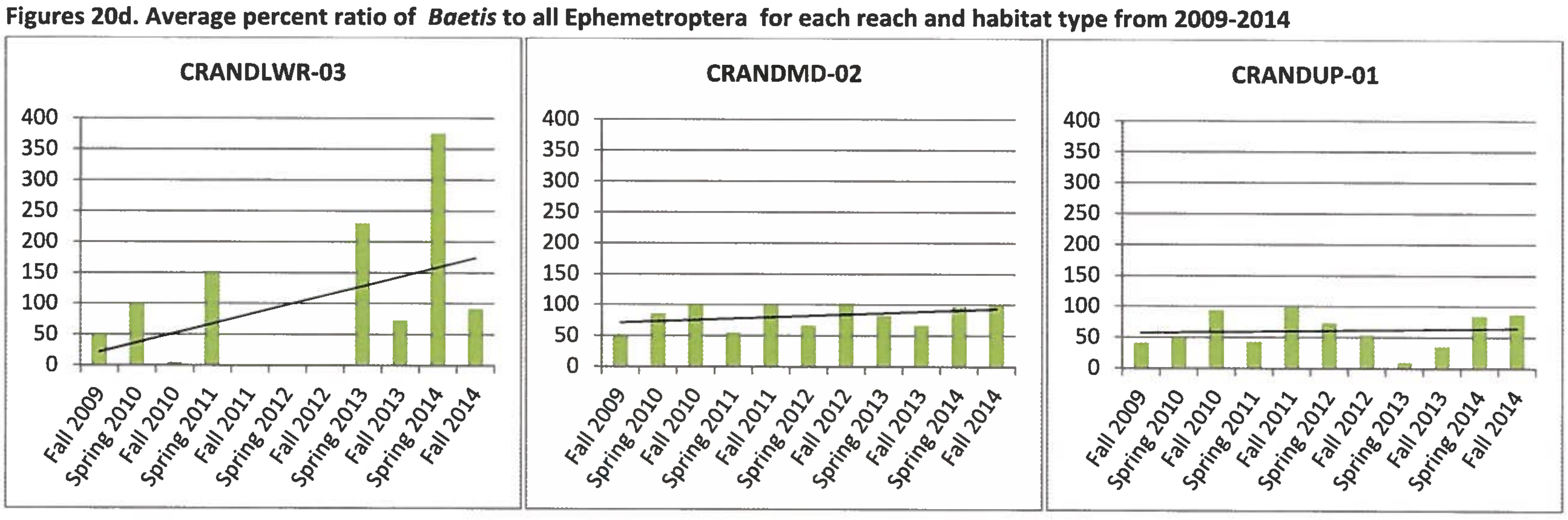
Figures 18d. Average number of long-lived taxa in each reach from Fall 2009- Fall 2014



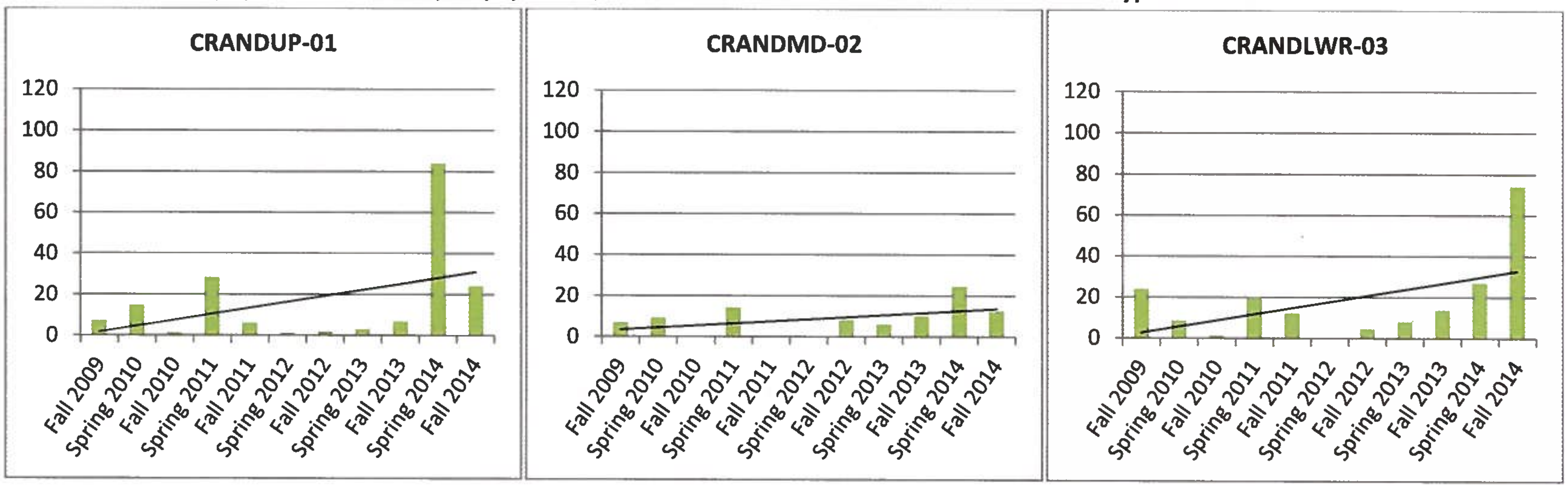
Figures 19d. Average number of clinger taxa reach from Fall 2009- Fall 2014



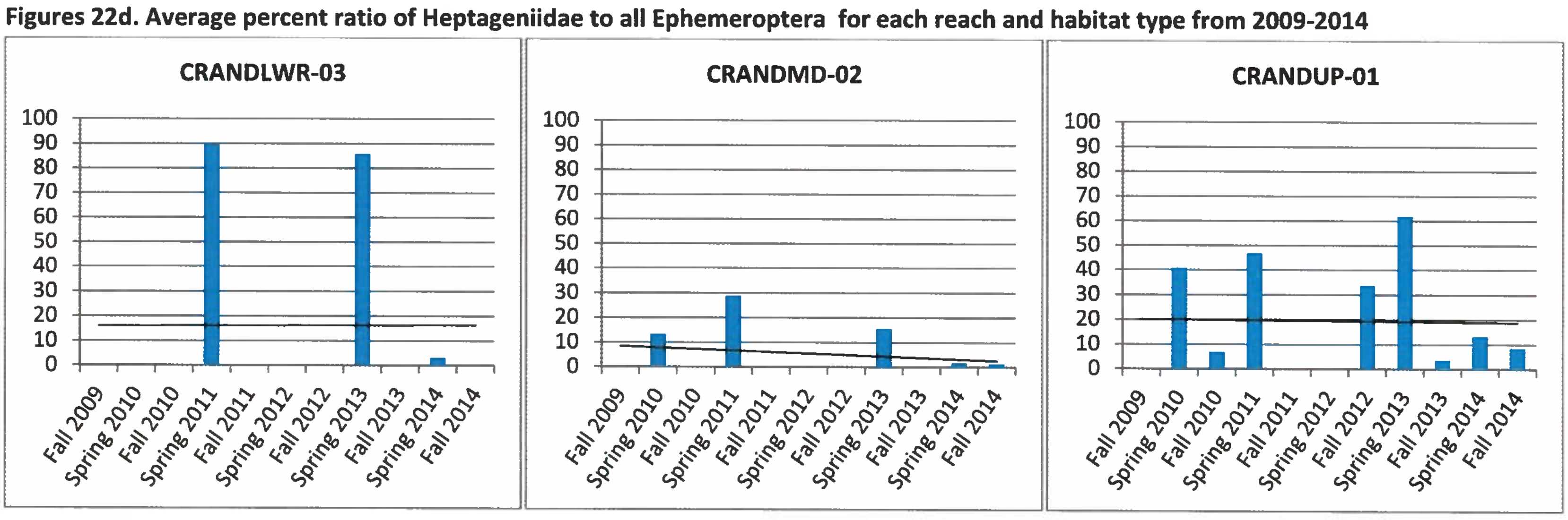
Figures 20d. Average percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2009-2014



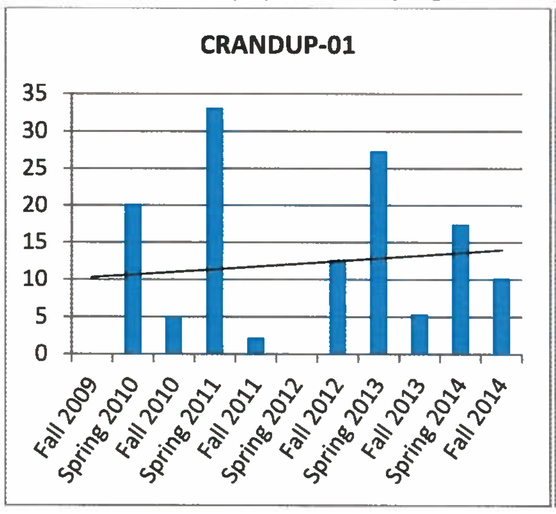
Figures 21d. Average percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2014

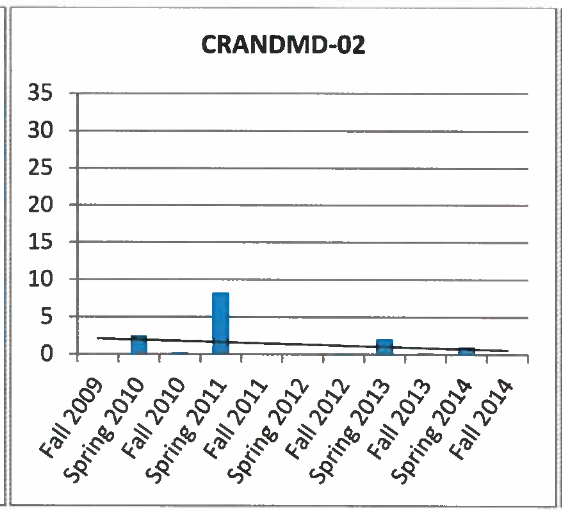


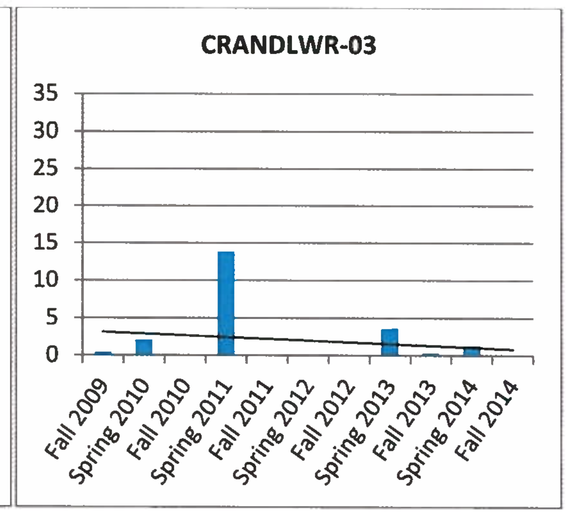
Figures 22d. Average percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2014



Figures 23d. Average percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2014







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 24th and 25th, 2014. The count is the total number of individuals found, identified, and retained for future reference.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Samples	Count
Annelida	Clitellata						5	133
Arthropoda	Arachnida	Trombidiformes					2	31
			Arrenuridae		Arrenurus		2	7
			Hygrobatidae				2	4
			Lebertiidae		Lebertia		5	255
			Sperchonidae				1	9
					Sperchon		4	66
			Torrenticolidae		Testudacarus		2	8
	Entognatha	Collembola					1	4
	Insecta	Coleoptera	Elmidae				1	4
					Narpus	concolor	2	7
			Haliplidae		Brychius		1	2
		Diptera					1	4
			Ceratopogonidae				2	22
				Ceratopogoninae	Probezzia		4	42
			Chironomidae				4	46
				Chironominae			4	348
				Orthocladiinae			6	4030
				Tanypodinae			3	127
			Empididae				1	17
					Neoplasta		4	167
				Hemerodromiinae			4	176
					Chelifera		3	53
			Muscidae				3	14
			Psychodidae		Pericoma		5	194
			Simuliidae				3	134
				Simuliinae	Simulium		4	190
			Stratiomyidae		Caloparyphus		1	4
			Tipulidae				4	32
					Dicranota		3	75
					Hexatoma		1	4
				Limoniinae	Antocha	monticola	2	9
					Limnophila		1	2
				Tipulinae	Tipula		3	58
		Ephemeroptera	Ameletidae		Ameletus		1	17
			Baetidae				1	28
					Baetis		6	1635
					Diphetor	hageni	3	82
			Ephemerellidae				2	40
			Heptageniidae				2	276
					Cinygmula		2	60
					Epeorus		1	2
			Leptophlebiidae				1	57
					Paraleptophlebia		2	15
		Plecoptera					1	18
			Capniidae	Capniinae			2	90
			Nemouridae		Malenka		1	9
					Zapada		1	126
					Zapada		1	18
					Zapada	cinctipes	1	36
				Amphinemurinae	Amphinemura		1	7
			Perlodidae				2	135
					Megarcys	signata	2	13
				Isoperlinae	Isoperla		5	88
				Perlodinae	Skwala	americana	1	9

Phylum	Class	Order	Family	SubFamily	Genus	Species	Samples	Count
		Trichoptera	Hydropsychidae				3	94
				Arctopsychinae	Parapsyche		1	26
					Parapsyche	elsis	1	4
				Hydropsychinae	Hydropsyche		2	93
			Limnephilidae				6	176
				Limnephilinae	Hesperophylax		3	11
			Rhyacophilidae		Rhyacophila		3	13
					Rhyacophila	rotunda group	1	17
					Rhyacophila	vofixa group	2	189
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		3	405
Nemata							1	7
Platyhelminthes	Turbellaria						1	22
Total:	Taxa:	**67**	Genera:	**35**	Families:	**28**		**10095**

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 25th, 2014 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, 50% was identified and retained. A total of 650 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152966.
OTU= Operational Taxonomic Unit

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	52
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	22
			Sperchonidae				Adult	9
			Torrenticolidae		Testudacarus		Adult	4
	Insecta	Diptera					Pupae	4
			Ceratopogonidae				Larvae	17
				Ceratopogoninae	Probezzia		Larvae	17
			Chironomidae				Pupae	17
				Chironominae			Larvae	135
				Orthocladiinae			Larvae	961
				Tanypodinae			Larvae	61
			Empididae	Hemerodromiinae			Larvae	104
			Psychodidae		Pericoma		Larvae	78
			Simuliidae				Larvae	48
			Tipulidae				Larvae	4
					Hexatoma		Larvae	4
				Tipulinae	Tipula		Larvae	33
		Ephemeroptera	Ameletidae		Ameletus		Larvae	17
			Baetidae		Baetis		Larvae	243
			Ephemerellidae				Larvae	22
			Heptageniidae				Larvae	222
					Cinygmula		Larvae	9
			Leptophlebiidae				Larvae	57
		Plecoptera	Capniidae	Capniinae			Larvae	83
			Nemouridae		Malenka		Larvae	9
					Zapada		Larvae	126
			Perlodidae				Larvae	130
					Megarcys	signata	Larvae	7
				Isoperlinae	Isoperla		Larvae	9
		Trichoptera	Hydropsychidae				Larvae	13
				Arctopsychinae	Parapsyche		Larvae	26
					Parapsyche	elsis	Larvae	4
			Limnephilidae				Larvae	57
			Rhyacophilidae		Rhyacophila		Larvae	9
					Rhyacophila	vofixa gro	Larvae	117
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	83
Platyhelminthes	Turbellaria						Adult	22
Total:	OTU Taxa:	**37**	Genera:	**16**	Families:	**21**		**2835**

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 25th, 2014 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, 37.5% was identified and retained. A total of 651 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152967. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	18
Arthropoda	Arachnida	Trombidiformes					Adult	29
			Lebertiidae		Lebertia		Adult	43
			Sperchonidae		Sperchon		Adult	7
			Torrenticolidae		Testudacarus		Pupae	11
	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	126
			Chironomidae				Larvae	922
				Chironominae			Larvae	34
				Orthocladiinae			Larvae	23
				Tanypodinae			Larvae	1
			Empididae		Neoplasta		Larvae	106
				Hemerodromiinae			Larvae	79
					Chelifera		Larvae	4
			Muscidae				Larvae	4
			Psychodidae		Pericoma		Larvae	16
			Simuliidae	Simuliinae	Simulium		Larvae	390
			Tipulidae				Larvae	18
					Dicranota		Larvae	54
				Tipulinae	Tipula		Larvae	52
		Ephemeroptera	Baetidae		Baetis		Larvae	14
					Diphetor	hageni	Larvae	18
			Ephemerellidae				Larvae	7
			Heptageniidae				Larvae	7
					Cinygmula		Larvae	45
			Leptophlebiidae		Paraleptophlebia		Larvae	11
		Plecoptera					Larvae	25
			Capniidae	Capniinae			Larvae	4
			Nemouridae		Zapada		Adult	18
					Zapada	cinctipes	Adult	7
				Amphinemurinae	Amphinemura		Larvae	4
			Perlodidae	Isoperlinae	Isoperla		Larvae	14
				Perlodinae	Skwala	americana	Larvae	36
		Trichoptera	Hydropsychidae				Larvae	9
			Limnephilidae				Larvae	18
				Limnephilinae	Hesperophylax		Larvae	71
			Rhyacophilidae		Rhyacophila	rotunda group	Adult	4
					Rhyacophila	vofixa group	Larvae	105
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Larvae	17
Nemata							Larvae	22
Total:	OTU Taxa:	39	Genera:	21	Families:	21		2393

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 24th, 2014 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 443 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152968. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	7
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		Arrenurus		Adult	2
			Hygrobatidae				Adult	146
			Lebertiidae		Lebertia		Adult	17
			Sperchonidae		Sperchon		Larvae	4
	Insecta	Coleoptera	Elmidae		Narpus	concolor	Pupae	2
		Diptera	Chironomidae				Larvae	43
				Chironominae			Larvae	539
				Orthocladiinae			Larvae	33
				Tanypodinae			Larvae	11
			Empididae		Neoplasta		Larvae	7
				Hemerodromiinae			Larvae	2
			Muscidae				Larvae	2
			Psychodidae		Pericoma		Larvae	33
			Simuliidae	Simuliinae	Simulium		Larvae	2
			Stratiomyidae		Caloparyphus		Larvae	9
			Tipulidae				Larvae	50
		Ephemeroptera	Baetidae		Baetis		Pupae	2
			Heptageniidae		Epeorus		Larvae	4
		Plecoptera	Perlodidae	Isoperlinae	Isoperla		Adult	4
		Trichoptera	Limnephilidae				Larvae	2
							Larvae	41
Total:	OTU Taxa:	**21**	Genera:	**11**	Families:	**16**		**962**

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 24th, 2014 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, 50% was identified and retained. A total of 613 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152969. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	11
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	41
			Sperchonidae		Sperchon		Adult	24
	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	3
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	1341
			Chironomidae	Orthocladiinae			Larvae	27
			Empididae		Neoplasta		Larvae	1
				Hemerodromiinae	Chelifera		Larvae	135
			Muscidae				Larvae	11
		Ephemeroptera	Baetidae		Baetis		Larvae	3
		Plecoptera	Perlodidae		Megarcys	signata	Larvae	8
		Trichoptera	Limnephilidae				Larvae	7
			Rhyacophilidae		Rhyacophila		Larvae	49
Total:	OTU Taxa:	13	Genera:	9	Families:	11		1661

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 24th, 2015 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 513 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 15270. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	46
Arthropoda	Arachnida	Trombidiformes					Adult	2
			Arrenuridae		Arrenurus		Adult	4
	Entognath:	Collembola					Larvae	4
	Insecta	Coleoptera	Elmidae				Larvae	4
		Diptera	Ceratopogonidae				Pupae	15
				Ceratopogoninae	Probezzia		Larvae	43
			Chironomidae				Larvae	191
				Chironominae			Larvae	17
				Orthocladiinae			Larvae	2
			Empididae				Larvae	59
				Hemerodromiinae			Pupae	26
			Psychodidae		Pericoma		Larvae	30
			Simuliidae				Larvae	22
							Larvae	2
				Simuliinae	Simulium		Larvae	48
			Tipulidae				Larvae	9
					Dicranota		Larvae	28
				Limoniinae	Antocha	monticola	Larvae	161
				Tipulinae	Tipula		Larvae	4
		Ephemeroptera	Baetidae				Larvae	11
					Baetis		Larvae	13
					Diphetor	hageni	Larvae	11
		Plecoptera	Perlodidae				Larvae	7
				Isoperlinae	Isoperla		Adult	304
		Trichoptera	Hydropsychidae	Hydropsychinae	Hydropsyche		Larvae	37
			Limnephilidae				Larvae	2
				Limnephilinae	Hesperophylax		Adult	2
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Larvae	9
Total:	OTU Taxa:	28	Genera:	13	Families:	13		1113

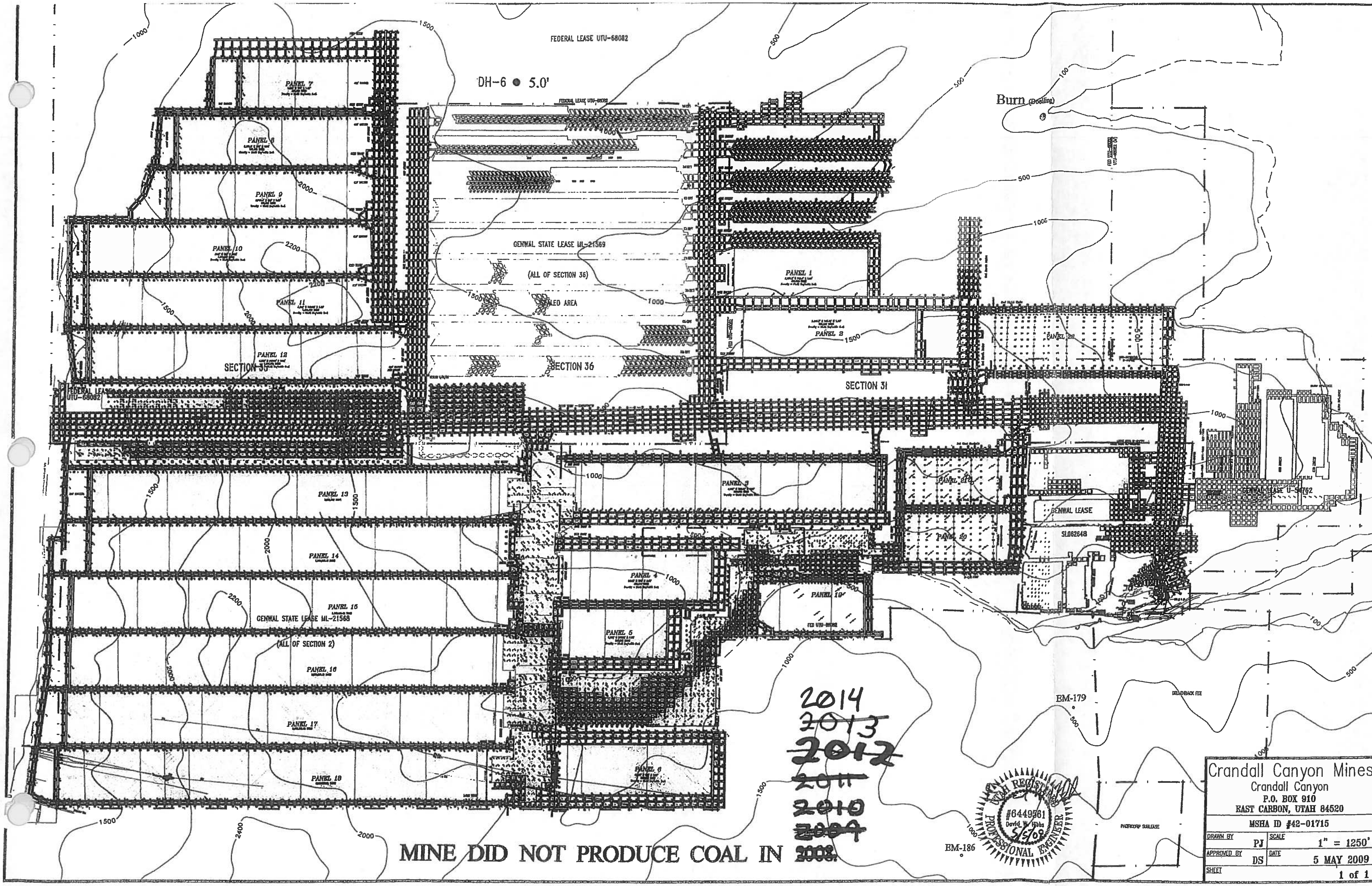
The following taxonomic list and densities are of the aquatic invertebrates identified and retained at Utah State University's BugLab. The sample was collected September 24th, 2014 at the station CRANDLWR-03, Crandall Creek, Lower, Emery County, Utah. The sample was collected from the targeted riffle habitat using a Kick Net. The total area sampled was 0.74 square meters. Of the collected sample, 81.25% was identified and retained. A total of 680 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 152971.
OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes	Hygrobatidae				Adult	2
			Lebertiidae		Lebertia		Adult	3
			Sperchonidae		Sperchon		Adult	17
	Insecta	Coleoptera	Haliplidae		Brychius		Adult	2
		Diptera	Chironomidae	Orthocladiinae			Larvae	77
			Empididae		Neoplasta		Larvae	3
				Hemerodromiinae	Chelifera		Larvae	2
			Psychodidae		Pericoma		Pupae	2
			Simuliidae				Larvae	78
				Simuliinae	Simulium		Larvae	7
			Tipulidae		Dicranota		Larvae	23
				Limoniinae	Antocha	monticola	Larvae	2
				Limoniinae	Limnophila		Larvae	674
		Ephemeroptera	Baetidae		Baetis		Larvae	2
					Diphetor	hageni	Larvae	15
			Leptophlebiidae		Paraleptophlebia		Larvae	70
		Plecoptera	Perlodidae	Isoperlinae	Isoperla		Larvae	80
		Trichoptera	Hydropsychidae				Larvae	20
				Hydropsychinae	Hydropsyche		Larvae	1
			Limnephilidae				Larvae	2
				Limnephilinae	Hesperophylax		Larvae	42
			Rhyacophilidae		Rhyacophila		Larvae	12
Total:	OTU Taxa:	22	Genera:	17	Families:	15		1136

2014

Annual Report

Mine Map


FEDERAL LEASE UTU-68082
DH-6 ● 5.0'
Burn (Coaling)
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 13
PANEL 14
PANEL 15
GENWAL STATE LEASE ML-21568
(ALL OF SECTION 2)
PANEL 16
PANEL 17
PANEL 18
PANEL 3
PANEL 4
PANEL 5
PANEL 6
PANEL 19
PANEL 20
GENWAL LEASE
SL062648
GENWAL LEASE U-54762
BM-179
BM-186
MINE DID NOT PRODUCE COAL IN ~~2008~~ ~~2009~~ ~~2010~~ ~~2011~~ ~~2012~~ ~~2013~~ 2014
UTAH REGISTERED PROFESSIONAL ENGINEER
#6449561
David W. Hibbs
5/5/09
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