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 15, 2017

Attn: Daron Haddock
Permit Supervisor

Re: Crandall Canyon Mines C/15/032
C17-001 2016 Annual Report

Dear Mr. Haddock

Attached you will find the completed Annual Report for Crandall Canyon Mine, 2016.

If you have any questions, please feel free to contact me directly, at 435-888-4000.

Sincerely,

Karin Madsen
Engineering Tech
UtahAmerican Energy, Inc.

APPLICATION FOR PERMIT PROCESSING

Permit Change ☐	New Permit ☐	Renewal ☐	Transfer ☐	Exploration ☐	Bond Release ☐	Permit Number: 015/032
Title of Proposal: C17-001 2016 Annual Report						Mine: Crandall Canyon
						Permittee: Genwal Resources, Inc.

Description, include reason for application and timing required to implement:

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

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

X Attach complete digital copy of the application.

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

/ Karin Madsen / Engineering Tech / 3-14-17
Signed - Name - Position - Date

Subscribed and sworn to before me this 14th day of March, 2017.

Linda Kerns
Notary Public

My Commission Expires: March 27, 2017
Attest: STATE OF Utah
COUNTY OF Carbon

LINDA KERNS
NOTARY PUBLIC • STATE of UTAH
COMMISSION # 663615
COMM. EXP. 03/27/2017

Received by Oil, Gas & Mining

ASSIGNED TRACKING NUMBER

Application for Permit Processing
Detailed Schedule of Changes to the MRP

C17-001 2016 Annual Report	Permit Number: 015/032
	Mine: Crandall Canyon
	Permittee: Genwal Resources Inc.

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

			DESCRIPTION OF MAP, TEXT, OR MATERIALS TO BE CHANGED
☐ ADD	☐ REPLACE	☐ REMOVE	2016 Annual Report
☐ ADD	☐ REPLACE	☐ REMOVE	
☐ ADD	☐ REPLACE	☐ REMOVE	
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☐ ADD	☐ REPLACE	☐ REMOVE	

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

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	5-13-2018
Operator Name	Genwal Resources, Inc.	Phone Number	+1 (435) 888-4000
Mailing Address	PO Box 910	Email	kmadsen@coalsource.com
City	East Carbon		
State	UT	Zip Code	84520

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

OPERATOR COMMENTS

The annual impoundment inspection reports are included for both the Burma Evaporation Basin and the Crandall Canyon Mine Site's primary sediment pond. No evidence of instability, structural weaknesses of visible hazards were observed for either of the impoundments. David Hibbs (State of Utah Professional Engineer #6449561) stamped and signed both of the impoundment reports.

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 2015 reports are due to the Division.
Reports: Submit surveys in annual report.
Citation: MRP, Volume A Text, Chapter 3, page 3-17.

Operator Comments

Macro-invertebrate Study was completed by EIS for the Spring and Fall of 2015. Results are included within the 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

Subsidence Monitoring was completed by Ware Surveying. Results are located within the Annual Report.

Reviewer Comments ☐ Met Requirements ☐ Did Not Meet Requirements

Title: Burma Pond Information/Sampling
Objective: Provide report of accumulated depth of sludge in the Burma Evaporatio Pond. Grab samples to obtained every five years or when 7.5" of solid waste has been deposited. Grab Samples to be analyzed for all RCRA metals.
Frequency: Annually
Status: Ongoing
Reports: Include in Annual Report
Citation: Appendix 7-66. Pg. 7

Operator Comments

Sampling was completed by Mt. Nebo Scientific, and the report and sample data is included.

Reviewer Comments ☐ Met Requirements ☐ Did Not Meet Requirements

FUTURE COMMITMENTS AND CONDITIONS

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

Title: RECLAMATION OF CULVERT
Objective: To reclaim part of the culverted section of the stream which provided habitat to the cutthroat trout population. And enhancement of the stream below the mine discharge point due to the impact on the stream habitat and aquatic wildlife that occurred because of the iron-laden water discharge.
Frequency: Once during reclamation.
Status: To be done during reclamation.
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	☒	☐	☐	☒
		☐	☐	☐	☐
		☐	☐	☐	☐
		☐	☐	☐	☐

Reviewer Comments ☐ Met Requirements ☐ Did Not Meet Requirements

Subsidence Table Included.

UtahAmerican Energy, Inc.

Crandall Canyon Mine - Subsidence Survey

10/6/2016

YEAR			2004	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	2015-2016 (FEET)
A	413190.85	2080628.41	10440.47	10439.53	10439.43	10439.47	10439.48	10439.41	10439.43	10439.45	10439.44	10439.45	10439.48	-0.03
B	413095.74	2080610.92	10426.40	10425.43	10425.40	10425.41	10425.38	10425.41	10425.40	10425.37	10425.40	10425.47	10425.51	-0.04
C	412995.22	2080594.07	10412.27	10411.20	10411.23	10411.23	10411.16	10411.18	10411.17	10411.20	10411.16	10411.24	10411.31	-0.07
D	412897.30	2080578.76	10400.21	10399.21	10399.25	10399.18	10399.23	10399.24	10399.21	10399.27	10399.23	10399.27	10399.32	-0.05
E	412795.72	2080563.91	10385.11	10384.15	10384.18	10384.13	10384.16	10384.17	10384.18	10384.15	10384.14	10384.20	10384.25	-0.05
J	412296.72	2080487.65	10323.47	10323.29	10323.20	10323.15	10323.26	10323.18	10323.19	10323.22	10323.22	10323.26	10323.29	-0.03
N	411898.88	2080428.44	10313.15	10313.15	10313.13	10313.16	10313.16	10313.16	10313.10	10313.17	10313.15	10313.16	10313.21	-0.05
O	411798.12	2080415.52	10316.56	10316.49	10316.50	10316.56	10316.52	10316.56	10316.57	10316.55	10316.53	10316.52	10316.52	0.00
P	411700.03	2080403.24	10321.64	10321.65	10321.65	10321.69	10321.66	10321.65	10321.64	10321.63	10321.65	10321.64	10321.62	0.02
Q	411599.74	2080390.76	10326.61	---	---	---	---	10326.53	10326.53	10326.56	10326.55	10326.52	10326.48	0.04
R	411550.40	2080383.83	10330.17	---	---	---	---	10330.15	10330.08	10330.11	10330.09	10330.07	10330.05	0.02
S	411501.07	2080376.56	10333.65	---	---	---	---	10333.51	10333.57	10333.54	10333.52	10333.59	10333.56	0.03
T	411399.27	2080366.35	10342.83	---	---	---	---	10342.74	10342.75	10342.77	10342.74	10342.78	10342.77	0.01
U	411299.82	2080354.19	10349.80	---	---	---	---	10349.68	10349.64	10349.69	10349.68	10349.67	10349.66	0.01
V	411247.57	2080350.11	10353.81	---	---	---	---	10353.84	10353.77	10353.80	10353.81	10353.74	10353.70	0.04
W	411198.08	2080343.54	10358.03	---	---	---	---	10357.94	10357.98	10357.93	10357.96	10357.96	10357.92	0.04
X	411147.67	2080337.97	10360.97	---	---	---	---	10360.78	10360.89	10360.83	10360.81	10360.84	10360.78	0.06
Y	411097.90	2080332.61	10365.90	---	---	---	---	10365.78	10365.84	10365.85	10365.85	10365.77	10365.75	0.02
Z	411044.53	2080331.80	10371.01	---	---	---	---	10370.93	10371.01	10370.98	10370.99	10370.99	10370.95	0.04
AA	410994.37	2080331.13	10376.37	---	---	---	---	10376.27	10376.36	10376.34	10376.30	10376.35	10376.34	0.01
EE	410741.97	2080325.86	10430.72	---	---	---	---	10430.86	10430.97	10430.91	10430.94	10430.95	10430.96	-0.01
GG	410619.62	2080334.65	10435.38	---	---	---	---	10435.09	10435.41	10435.40	10435.43	10435.39	10435.38	0.01
HH	410508.23	2080321.51	10435.17	---	---	---	---	10435.63	10435.11	10435.18	10435.15	10435.16	10435.15	0.01
II	410458.36	2080312.15	10433.84	---	---	---	---	10434.29	10433.84	10433.88	10433.82	10433.61	10433.65	-0.04
JJ	410409.35	2080302.79	10433.25	---	---	---	---	10433.73	10433.20	10433.23	10433.20	10433.08	10433.12	-0.05
KK	410359.98	2080292.88	10432.40	---	---	---	---	10432.87	10432.42	10432.40	10432.43	10432.22	10432.29	-0.07
LL	410265.30	2080265.04	10428.65	---	---	---	---	10428.57	10428.47	10428.49	10428.46	10428.55	10428.54	0.01
NN	409769.08	2080125.54	10347.00	---	---	---	---	10346.66	10346.71	10346.68	10346.70	10346.75	10346.69	0.06
OO	409498.68	2080210.27	10284.52	---	---	---	---	10284.27	10284.26	10284.29	10284.25	10284.17	10284.20	-0.03
PP	409291.54	2080286.75	10262.98	---	---	---	---	10263.41	10263.41	10263.38	10263.39	10263.17	10263.22	-0.05

WARE SURVEYING & ENGINEERING

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

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

1344 North 1000 West
Price, Utah 84501

UtahAmerican Energy, Inc.

Crandall Canyon Mine

East Mountain Reclaimed Slide Area

10/6/2016

YEAR			2012	2013	2014	2015	2016	
STATION	NORTHING (FEET)	EASTING (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION (FEET)	ELEVATION DIFFERENCE
Benchmark	413145.90	2079155.88	9986.04	9986.04	9986.04	9986.04	9986.04	0.00
1	413105.83	2079216.62	9987.03	9987.03	9987.06	9987.05	9987.10	-0.05
2	413079.15	2079242.82	9985.59	9985.45	9985.47	9985.51	9985.50	0.01
3	413068.96	2079262.42	9982.58	9982.37	9981.89	9981.81	9981.85	-0.04
4	413056.95	2079275.88	9980.12	9979.90	9979.56	9979.57	9979.70	-0.13
5	413035.54	2079293.43	9979.24	9979.32	9979.33	9979.35	9979.42	-0.07
6	413009.81	2079312.22	9977.00	9976.78	9976.80	9976.83	9976.87	-0.04
7	413011.56	2079280.20	9967.21	9966.96	9966.95	9967.37	9967.19	0.18
8	413027.60	2079264.79	9963.57	9963.59	9963.59	9963.84	9963.80	0.04
9	413034.15	2079256.20	9964.10	9964.16	9964.10	9964.33	9964.27	0.06
10	413040.75	2079245.24	9963.48	9963.28	9963.28	9963.66	9963.59	0.07
11	413044.33	2079234.13	9966.05	9965.95	9965.88	9966.29	9966.22	0.07
12	413048.37	2079223.30	9963.67	9963.62	9963.63	9963.66	9963.60	0.06
13	413025.61	2079233.40	9954.87	9954.98	9954.97	9955.11	9955.09	0.02
14	413020.64	2079240.46	9955.37	9955.31	9955.29	9955.31	9955.33	-0.02
15	413009.89	2079253.75	9955.08	9955.03	9955.00	9955.06	9955.01	0.05
16	412997.97	2079264.46	9957.58	9957.45	9957.46	9957.48	9957.51	-0.03
17	412994.73	2079233.22	9945.34	9945.34	9945.35	9945.33	9945.28	0.05
18	413001.96	2079217.74	9940.01	9939.88	9939.91	9939.86	9939.91	-0.05
19	412986.19	2079204.91	9928.78	9928.58	9928.57	9928.59	9928.63	-0.04
20	412960.88	2079205.24	9917.01	9916.98	9916.95	9917.00	9916.97	0.03

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Phone: 435-820-4335

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UtahAmerican Energy Inc. 10/6/2016

CRANDALL AERIAL TARGETS

	Local / mine coordinates (feet)		
Station	**Northing**	**Easting**	**Ground Elevation**
S-27	422,261.66	2,076,294.63	8,846.01
AERIAL 16-93	416,060.62	2,076,215.54	9,174.54
AERIAL 2-95	411,165.18	2,076,298.98	8,964.92
AERIAL 1-95	408,103.30	2,075,765.12	8,909.12
CRANDALL FORK	411,293.85	2,088,689.43	8,344.51
HORSE CANYON	423,076.32	2,092,353.56	8,198.00
30B	410,740.51	2,082,158.98	10,094.65
192	405,598.68	2,081,701.43	10,463.84
AERIAL 25	415,349.71	2,082,422.54	10,573.30
AERIAL 14	418,827.57	2,082,692.59	10,392.12
AERIAL 22	414,406.24	2,087,330.02	9,655.95
AERIAL 1-93	405,514.11	2,087,806.19	9,985.17
AERIAL 21	414,640.46	2,091,260.21	9,761.65
AERIAL 6-63 B	417,471.94	2,086,720.84	9,685.65
AERIAL 16A	421,635.48	2,097,717.31	7,593.84
AERIAL 07	416,517.40	2,097,586.34	7,460.70
MILLFORK AERIAL	405,295.80	2,093,777.04	9,885.30
S-4	410,723.03	2,101,380.86	7,317.80
NEW YARD NAIL	410,605.67	2,094,432.73	7,874.70

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IMPOUNDMENT INSPECTION AND CERTIFIED REPORT		Page 1 of

Permit Number	Permit Number: 015/032	Report Date	12-8-16
Mine Name	Crandall Canyon Mine		
Company Name	UtahAmerican Energy, Inc.		
Impoundment Identification	Impoundment Name	Lower Sediment Pond	
	Impoundment Number	None	
	UPDES Permit Number	UT0024368	
	MSHA ID Number	None for the Pond	

IMPOUNDMENT INSPECTION

Inspection Date	12-8-16
Inspected By	Karin Madsen
Reason for Inspection (Annual, Quarterly or Other Periodic Inspection, Critical Installation, or Completion of Construction)	4th Quarter

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

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

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 when surveyed was approximately 7766'.

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

Principle	7780.81'
Emergency	7781.81'

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

Pond has approximately 2' of ice and snow on top. Ice level is well below the high water markers.

Sediment levels were surveyed in November, 2016.

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

No observable problems exist at the inlets or outlets.

Vegetation surrounding the pond is good.

Sediment level was approximately 7766 when surveyed.

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: _____ Date: 12-8-16

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT		Page 3 of

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

Two 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:

6449561 DAVID W. HIBBS 12/8/16 STATE OF UTAH

[PE Cert. Stamp]

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.

By: David Hibbs President
(Full Name and Title)

Signature: [signature] Date: 12/8/16

P.E. Number & State: 6449561 Utah

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT			Page 1 of
Permit Number	ACT/015/032	Report Date	12-8-16
Mine Name	Crandall Canyon Mine		
Company Name	UtahAmerican Energy, Inc.		
Impoundment Identification	Impoundment Name	Burma Evaporative Pond	
	Impoundment Number	None	
	UPDES Permit Number	UT0024368	
	MSHA ID Number	42-01715	

IMPOUNDMENT INSPECTION

Inspection Date	12-5-16
Inspected By	Karin Madsen
Reason for Inspection (Annual, Quarterly or Other Periodic Inspection, Critical Installation, or Completion of Construction)	4th Quarter

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

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

Required for an impoundment which functions as a SEDIMENTATION POND.

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

Sediment Elevations:

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

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

Approximate sediment level is 6516.1

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

Sediment level surveys were completed in November, 2016. Total accumulated sediment level is an estimate, and can not accurately be measured without being totally evaporated. At time of survey, there was a small amount of water on top of the pond, but it was beginning to freeze.

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: _____ **Date:** 12-8-16

IMPOUNDMENT INSPECTION AND CERTIFIED REPORT		Page 3 of

CERTIFIED REPORT

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

COMMENTS AND OTHER INFORMATION

NONE

Certification Statement:

[PE Cert. Stamp]

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.

By: David Hibbs
(Full Name and Title)

Signature: Date: 12/8/16

P.E. Number & State: 6449561 Utah

Crandall Canyon Mine Macroinvertebrate Study Spring 2016

January 2017

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1.0 INTRODUCTION

EIS Environmental & Engineering Consulting (EIS) collected benthic macroinvertebrate samples from Crandall Creek on June 16th and 17th, 2016. The creek is located near Huntington, Utah. From 2009 to 2012, the creek was sampled by JBR Environmental Consultants, Inc. (JBR). Samples were collected from three different reaches of Crandall Creak. These three reaches were located directly upstream of the Crandall Canyon mine (CRANDUP-01), in the middle reach (CRANDMD-02) which is immediately downstream of the mine's discharge location, and a lower reach (CRANDLWR-03) located at the end of the creek before the confluence of Crandall Creek and Huntington Creek. Each reach was 150 meters long.

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

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

1.1 Background

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

In 2009, DOGM required the mine to contract a qualified biologist to sample macroinvertebrates in Crandall Creek twice yearly (Spring and Fall) to monitor water quality and provide reports

documenting the survey results. The first seven surveys were completed by JBR (JBR 2012). They included surveys from the Fall of 2009 until the Fall of 2012. EIS has since completed two surveys a year (Spring and Fall) starting in the Spring of 2013. This report provides the results of the Spring survey of 2016. The samples were collected June 16th and 17th, 2016. 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 17th, 2016 - Upstream

CRANDMD-02 June 17th, 2016– Upstream

CRANDLWR-03 June 16th, 2016 - 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 Courtwright 2016) 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 2016) are incorporated into the tables of the following appendices. As with assessment, multiple metrics and datasets should be relied upon to make a finding of whether any impact or nonimpact has occurred between the mine's groundwater discharge and Crandall Creek. Numerous metrics should be used in evaluating what may be happening in the creek. In this study, the natural variability of any of these metrics is not known due to limited number of samples sites, absence of replicates, and partial historical baseline information. Therefore, it is difficult to determine whether there is an impact between sites from analyzing only one metric. This section and its associated appendices will review these metrics within this season's individual sample, spatially among each reach and habitat type, and any temporal changes since 2009. In the appendices, a blue colored graph is used when an increase in values indicate a more desirable habitat. A green colored graph is used when the lower the number, or a decline, specifies a healthier steam. Data is compared from the reference reach (CRANDUP-01) to the other two reaches. Additionally, a comparison between the middle reach directly below the mine (CRANDMD-02) and the lowest reach (CRANDLWR-03) can be made to assess the spatial limit and overall condition. The metrics evaluated include the various measurement types recommended by EPA (Barbour et al 1999). They include tolerance indices (HBI, CTQd), diversity (Shannon's), community composition (% EPT), and functional feeding groups (Percent Scraper/Shredders).

Appendix A of the report includes a summarization of the raw and standardized data for the samples collected in June 2016. The following Appendices (B-D) graph the previously mentioned matrices to show a visual comparison. Appendix B begins with a graph showing the distribution of the dominate orders within each reach and sample type (Figure 1b) as well as the numerical values (Table 1b). It is followed by numerous graphs that represent the Spring 2016 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 53 operational taxonomic units (OTU) were identified in the Spring 2016 sample set. There were 25 families and 34 genera present. Most of the insect orders most commonly found

in macroinvertebrate communities were found in each reach, orders Diptera, Ephemeroptera, and Trichoptera. The common order Plecoptera was found in all samples except for the riffles in the middle reach. Coleoptera was found in all samples except for the multi-habitat in the upper reach. Non-insect invertebrates were also identified in all samples.

The dominate order in all samples was found to be Diptera. In the upper reach the dominate order in both the multi-habitat and riffle habitat made up 72 and 81 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 78 percent in the multi-habitat and 88 percent in the riffle. In the lower reach the dominate macroinvertebrate order in the multi-habitat was 22 percent and 52 percent in the riffle habitat (Figure 1b and Table 1b). A dominance of any single order or taxon greater than 50 percent suggests environmental stress, which the all the reaches exhibited except the lower multi-habitat sample. A large percentage of the sample was found to be non-insects, at 57 percent of the overall composition.

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 23.20 percent of the taxa found in the multi habitat, and 17.3 percent of the riffle habitat (Figure 9b). In the middle reach directly below the mine, EPT percentages were at 16.7 and 8.7 percent of abundance in multi-habitat and riffle samples. In the lower reach, EPT was 20.5 percent in the multi habitat and 39.0 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 1 in the riffle habitat. The middle reach had 4 distinct intolerant taxa in the multi-habitat and 1 in the riffle habitat. The lower reach multi-habitat had 1 distinct intolerant taxa and the riffle had 3 (Figure 14b). The upper multi-habitat had 18 unique taxa and there were 11 distinct taxa in the riffle, based off the standardized data. The middle reach multi-habitat had 14 distinct taxa and the riffle sample had 11. The richness in the lower reach multi-habitat was 12 and was 14 in the riffle habitat (Figure 2b). The number of distinct taxa appears to be fluctuating within all reaches and both habitat types year to year; more data is likely required to find a real discernible trend. These same results were found when evaluating many of the other metrics.

As with previous years, the differences in overall habitat among the three reaches likely influence the result of this study. The upper most reach and the lowest reach have similar substrate size compositions, which was largely bedrock overlaid with larger rocks. The lowest reach had a much more cemented substrate. The lack of interstitial spaces results in poorer

habitat conditions for macroinvertebrates (Mize and Deacon 2002). These two reaches were narrower than the middle reach as well as more of a vegetative overstory. It is also important to note the changes in the stream morphology of Crandall Creek when comparing data from previous years. The colonization of beaver and subsequent dams are continuing to change the creek, mainly in the middle reach. The catastrophic impacts to Huntington Creek from major flooding resulting from a major wildfire in 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 (June 2016). Appendix C graphs each habitat type since Fall of 2009. The richness in the multi-habitat upper reach had a higher value than the riffle, at 18 compared to 11, respectively. In the middle reach the multi-habitat also had a slightly higher value than the riffle sample, at 14 distinct taxa compared to 11. However, in the lowest reach the multi-habitat had a richness value of 12 whereas the riffle had a higher value of 14 (Figure 2b). The same pattern was found in the Shannon's Diversity values. In the upper multi-reach habitat the value was 1.84 and 1.38 in the riffle habitat. In the middle reach the multi-habitat was 1.02 and the riffle habitat it was 0.74. In the lower reach the multi-habitat was 1.40 and the riffle habitat was 1.60 (Figure 3b). The evenness in the lower multi and riffle habitats were 0.74 and 0.55, respectively. In the middle reach the multi-habitat was 0.39 and the riffle was 0.31, and in the lower reach the evenness was 0.56 and 0.60, respectively (Figure 4b).

The abundance in the upper reach was 1550 in the multi-habitat and 2805 in the riffle. In the middle reach multi-habitat it was 1407 and 4589 in the riffle and in the lower reach it was 1200 and 541, respectively (Figure 5b). The HBI, which a lower value indicates less pollution, was 4.62 in the upper reach multi-habitat and 5.58 in the riffle. It was 5.28 and 5.59 in the middle reach, respectively. In the lowest reach, the HBI was 1.98 in the multi-habitat and 4.59 in the riffle (Figure 6b). The CTQd, which a lower the value indicates higher quality unpolluted water as well, was 76 in the upper reach multi-habitat and 90 in the riffle. In the middle reach these

values were 85 in the multi-habitat and 90 in the riffle habitat. In the lower reach the multi-habitat was 92 and the riffle was 85 (Figure 7b). Appendices A and B have more specific detail on all the values found and metrics graphed for visual comparison. While addressing any trends or spatial differences, both the riffle and multi-habitat results were averaged and this value was then used (Appendix D).

4.2 Spatial Variation in Macroinvertebrate Community

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

The average richness, or number of distinct taxa, in the upper reach was found to be 14.5, in the middle reach the average was 12.5 and in the lower reach it was 13 (Figure 1d). The average evenness value was 0.59 in the upper reach, 0.35 in the middle reach and 0.58 in the lower reach (Figure 2d). The average Shannon's Diversity in the upper reach was 1.57, in the middle reach it was 0.88, and in the lower reach it was 1.49 (Figure 3d). The average abundance of individuals was 2154.5 in the upper reach, 2996.5 in the middle reach and 870.5 in the lower reach (Figure 4d). The HBI, which the lower the value indicates less pollution in the stream ranging from 0-10, was found to be 5.10 in the upper reach, 5.43 in the middle reach and 3.29 in the lower reach (Figure 5d). The CTQd, which a lower value also indicates higher quality unpolluted water, ranges from 2 to 108. The CTQd was found as 83 in the upper reach, 87.5 in the middle reach, and 88.5 in the lower reach (Figure 6d). Overall, it appears that the quality of water in the middle reach may be in decline when compared to the upper reach. However, the lowest reach appears to be on par when compared to the upper reach. It is also worth mentioning that the upper reach, the reach that should not be affected by the mine, appears to not be in the most favorable condition.

4.3 Temporal Variation in Macroinvertebrate Community

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

The upper reach, which should not be impacted by the mine's discharge, has great variability within each metric. For example the average richness in Fall 2009 was found to be 24, and since it has gone up and down year to year with no real pattern. This sample set produced a richness

value of 14.5. The evenness values were around 0.74 in 2009, dropped down to .65 in Fall 2010, increased to around 0.77 from 2012-2013, and dropped to 0.59 this sample. Similar variability is present within all the metrics.

The middle reach also has this variation occurring throughout the years. The averaged richness value in the Fall 2009 and Spring 2010 sample set was found to be 22. It fluctuated to a low of 13.5 in the Spring of 2013, then back up to 21.5 in the Fall of 2013. Last year it was found to be at 10 distinct taxa. This sample it went up to 12.5. The evenness has also fluctuated throughout the years. In the earlier samples, it was found to be around .60 to .73. It has dropped down to a 0.34 in Spring of 2012, went back up to 0.78 in the Fall of 2013. It has dropped to 0.35 this sample set. Throughout the years, the reach directly below the mine has shown signs of decline.

The lowest reach has shown signs of improved conditions as compared to the middle reach. As with the other two reaches, the numbers have also fluctuated throughout years. In Fall of 2009 the richness was found to be 18, it dropped to 11 in Spring of 2011, went up to 21.5 in the Fall of 2013. There were 13 distinct taxa found this sample. The evenness in 2009 was 0.74, has gone up and down and is currently at 0.58. Refer to Appendix D for further results.

5.0 CONCLUSION

The samples for the 2016 Spring Macroinvertebrate Study were collected on June 16th and 17th, 2016 from each of the three reaches of Crandall Creek. The upper reach is located upstream from the mine and is should not be influenced from ground water discharge from the mine, therefore it is considered as a reference of how conditions should be. The middle and lower reaches are below the mine water discharge. The objective of the survey was to collect macroinvertebrate samples as indicators of water quality in Crandall Creek. The samples collected were sorted and identified to the lowest taxa possible by the BugLab. Abundances of taxa and community composition relationships from the samples are provided to assess the water quality of Crandall Creek.

The survey results show variability among all the sampled reaches and generally show reduced habitat quality and less than optimal conditions in all sampled locations. It does appear that the upper 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. The data for all three reaches fluctuate from year to year and season to season. It is important to note that the substrate and habitat differs greatly between reaches and should be taken into consideration in the results. The changes in stream morphology due to increased beaver dams in the middle reach 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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October 2, 2016

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
154329	CRANDUP-01	6/17/2016	Reachwide	Kick net	0.46	78.25	559
154330	CRANDUP-01	6/17/2016	Targeted Riffle	Kick net	0.74	31.25	631
154331	CRANDMD-02	6/16/2016	Reachwide	Kick net	0.46	87.5	561
154332	CRANDMD-02	6/16/2016	Targeted Riffle	Kick net	0.74	18.75	635
154333	CRANDLWR-03	6/16/2016	Reachwide	Kick net	0.46	100	552
154334	CRANDLWR-03	6/16/2016	Targeted Riffle	Kick net	0.74	100	400

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
154329	6/17/2016	CRANDUP-01 Multi	1570	364	Chironomidae	45.03
154330	6/17/2016	CRANDUP-01 Riffle	2739	474	Chironomidae	58.42
154331	6/16/2016	CRANDMD-02 Multi	1407	235	Chironomidae	74.77
154332	6/16/2016	CRANDMD-02 Riffle	4586	399	Chironomidae	83.45
154333	6/16/2016	CRANDLWR-03 Multi	1200	246	Pisidiidae	55.58
154334	6/16/2016	CRANDLWR-03 Riffle	541	211	Chironomidae	44.73
Mean			2007.2	321.5		60.33

Diversity Indices

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

Sample ID	Collection Date	Station	Total taxa richness	Total genera richness	Total family richness	EPT taxa richness
154329	6/17/2016	CRANDUP-01 Multi	28	24	18	13
154330	6/17/2016	CRANDUP-01 Riffle	23	19	14	10
154331	6/16/2016	CRANDMD-02 Multi	22	19	13	8
154332	6/16/2016	CRANDMD-02 Riffle	18	15	10	4
154333	6/16/2016	CRANDLWR-03 Multi	19	15	15	7
154334	6/16/2016	CRANDLWR-03 Riffle	21	19	14	10
Mean			21.8	18.5	14.0	8.666667

Table 5a. Diversity indicies based on standardized OTU

Sample ID	Collection Date	Station	Total taxa richness	EPT taxa richness	Shannon diversity index	Evenness
154329	6/17/2016	CRANDUP-01 Multi	18	7	1.863184	0.644617
154330	6/17/2016	CRANDUP-01 Riffle	11	3	1.278844	0.533319
154331	6/16/2016	CRANDMD-02 Multi	14	5	1.024843	0.388337
154332	6/16/2016	CRANDMD-02 Riffle	11	3	0.743896	0.310229
154333	6/16/2016	CRANDLWR-03 Multi	12	4	1.392909	0.560548
154334	6/16/2016	CRANDLWR-03 Riffle	14	7	1.578034	0.597954
Mean			13.33333	5	1.313618	0.505834

Table 6a. Genera richness by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
154329	6/17/2016	CRANDUP-01 Multi	0	10	4	0	0	0	5	4	1	0	0
154330	6/17/2016	CRANDUP-01 Riffle	1	8	5	0	0	0	2	3	0	0	0
154331	6/16/2016	CRANDMD-02 Multi	1	8	2	0	0	0	1	5	1	0	1
154332	6/16/2016	CRANDMD-02 Riffle	1	9	2	0	0	0	0	2	1	0	0
154333	6/16/2016	CRANDLWR-03 Multi	1	6	2	0	0	0	2	3	0	0	1
154334	6/16/2016	CRANDLWR-03 Riffle	2	6	4	0	0	0	3	3	1	0	0
Mean			1.0	7.8	3.2	0.0	0.0	0.0	2.2	3.3	0.7	0.0	0.3

Table 7a. Total Abundance by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
154329	6/17/2016	CRANDUP-01 Multi	0	1112	146	0	0	0	74	143	17	0	0
154330	6/17/2016	CRANDUP-01 Riffle	4	2192	399	0	0	0	22	53	0	0	0
154331	6/16/2016	CRANDMD-02 Multi	7	1084	166	0	0	0	10	59	17	0	5
154332	6/16/2016	CRANDMD-02 Riffle	14	3986	292	0	0	0	0	106	108	0	0
154333	6/16/2016	CRANDLWR-03 Multi	2	267	183	0	0	0	50	13	0	0	667
154334	6/16/2016	CRANDLWR-03 Riffle	3	281	154	0	0	0	24	32	32	0	0
Mean			5	1487	223	0	0	0	30.0	67.9	29.1	0.0	112.1

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
154329	6/17/2016	CRANDUP-01 Multi	4.623333	Some organic pollution	76
154330	6/17/2016	CRANDUP-01 Riffle	5.58	Some organic pollution	90
154331	6/16/2016	CRANDMD-02 Multi	5.28	Some organic pollution	85
154332	6/16/2016	CRANDMD-02 Riffle	5.586667	Some organic pollution	90
154333	6/16/2016	CRANDLWR-03 Multi	1.98	No apparent organic pollution	92
154334	6/16/2016	CRANDLWR-03 Riffle	4.59	Some organic pollution	85
Mean			4.606667		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.

Sample ID	Collection Date	Station	Intolerant Taxa Richness	Intolerant Taxa Percent	Intolerant Taxa Abundance	Intolerant Taxa Percent	Tolerant Taxa Richness	Tolerant Taxa Percent	Tolerant Taxa Abundance	Tolerant Taxa Percent
154329	6/17/2016	CRANDUP-01 Multi	5	28	218	14	1	6	0	0
154330	6/17/2016	CRANDUP-01 Riffle	1	9	85	3	0	0	0	0
154331	6/16/2016	CRANDMD-02 Multi	4	29	42	3	0	0	0	0
154332	6/16/2016	CRANDMD-02 Riffle	1	9	106	2	0	0	0	0
154333	6/16/2016	CRANDLWR-03 Multi	1	8	54	5	0	0	0	0
154334	6/16/2016	CRANDLWR-03 Riffle	3	21	39	7	0	0	0	0
Mean			2.5	17	90.7	6	0.2	1	0.0	0

Functional Feeding Groups

Table 10a. Taxa richness by functional feeding groups

Sample ID	Collection Date	Station	Shredders		Scrapers		Collector-filterers		Collector-gatherers		Predators		Unknown	
			Richness	Percent	Richness	Percent	Richness	Percent	Richness	Percent	Richness	Percent	Richness	Percent
154329	6/17/2016	CRANDUP-01 Multi	2	11	2	11	1	6	1	6	7	39	5	28
154330	6/17/2016	CRANDUP-01 Riffle	1	9	1	9	1	9	1	9	4	36	3	27
154331	6/16/2016	CRANDMD-02 Multi	1	7	1	7	1	7	1	7	6	43	4	29
154332	6/16/2016	CRANDMD-02 Riffle	0	0	0	0	1	9	1	9	5	45	4	36
154333	6/16/2016	CRANDLWR-03 Multi	0	0	1	8	3	25	3	25	3	25	2	17
154334	6/16/2016	CRANDLWR-03 Riffle	0	0	2	14	2	14	2	14	5	36	3	21
Mean			0.7	4.6	1.2	8.3	1.5	11.7	1.5	11.7	5.0	37.4	3.5	26.3

Table 11a. Taxa abundance by functional feeding group

Sample ID	Collection Date	Station	Shredders		Scrapers		Collector-filterers		Collector-gatherers		Predators		Unknown	
			Abundance	Percent	Abundance	Percent	Abundance	Percent	Abundance	Percent	Abundance	Percent	Abundance	Percent
154329	6/17/2016	CRANDUP-01 Multi	64	4	19	1	341	22	859	55	288	18	0	0
154330	6/17/2016	CRANDUP-01 Riffle	39	1	48	2	458	17	1946	71	249	9	0	0
154331	6/16/2016	CRANDMD-02 Multi	37	3	2	0	17	1	1236	88	107	8	8	1
154332	6/16/2016	CRANDMD-02 Riffle	0	0	0	0	29	1	4227	92	315	7	15	0
154333	6/16/2016	CRANDLWR-03 Multi	46	4	2	0	689	57	387	32	76	6	0	0
154334	6/16/2016	CRANDLWR-03 Riffle	16	3	4	1	19	4	432	80	69	13	1	0
Mean			33.7	2.5	12.5	0.7	258.8	16.9	1514.5	69.6	184.0	10.2	4.0	0.2

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 2016

Figure 1b. Percent Predominant Taxonomic Groups Spring 2016 Samples

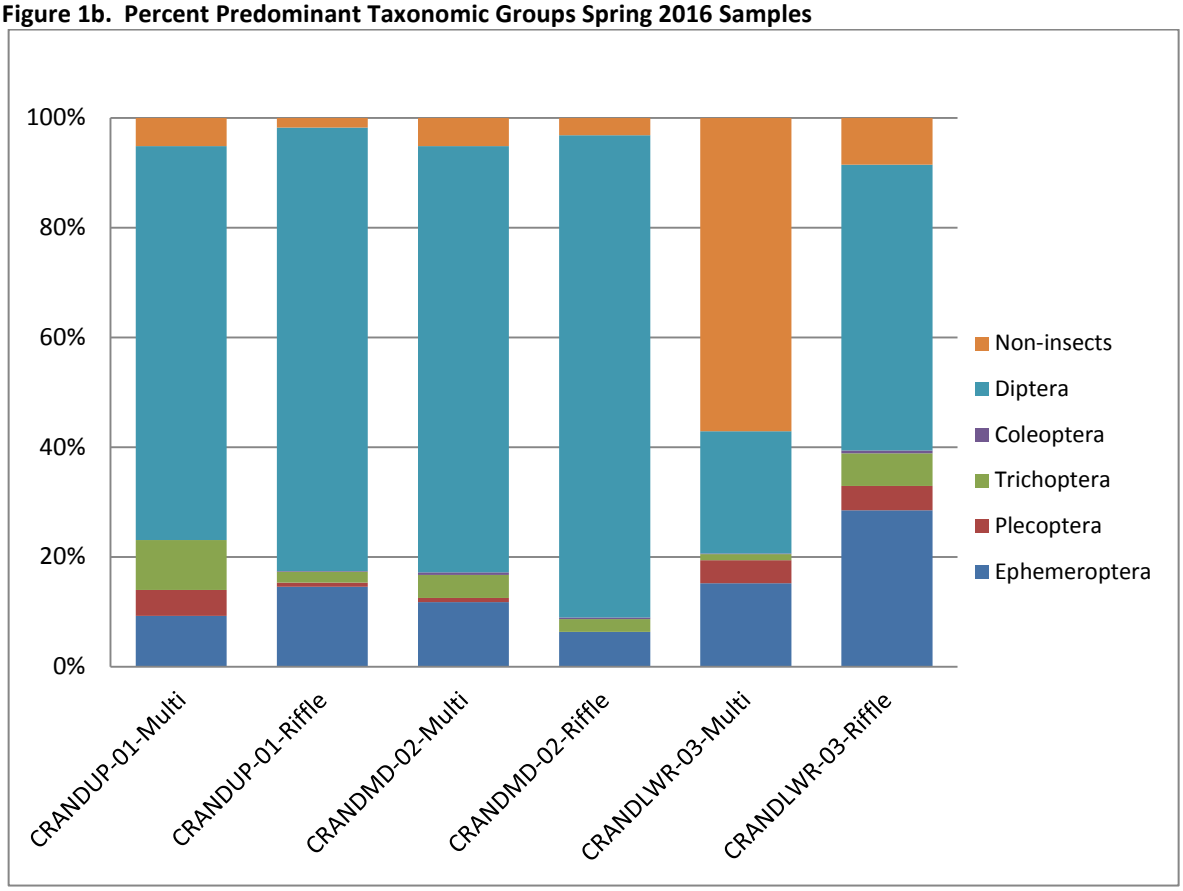


Table 1b. Percent Predominant Taxonomic Groups in the Spring 2016 Samples

	CRANDUP-01-Multi	CRANDUP-01-Riffle	CRANDMD-02-Multi	CRANDMD-02-Riffle	CRANDLWR-03-Multi	CRANDLWR-03-Riffle
Non-insects	5	2	5	3	57	9
Diptera	72	81	78	88	22	52
Coleoptera	0.0	0.1	0.5	0.3	0.2	0.6
Trichoptera	9	2	4	2	1	6
Plecoptera	5	1	1	0	4	4
Ephemeroptera	9	15	12	6	15	28

Figure 2b. Richness

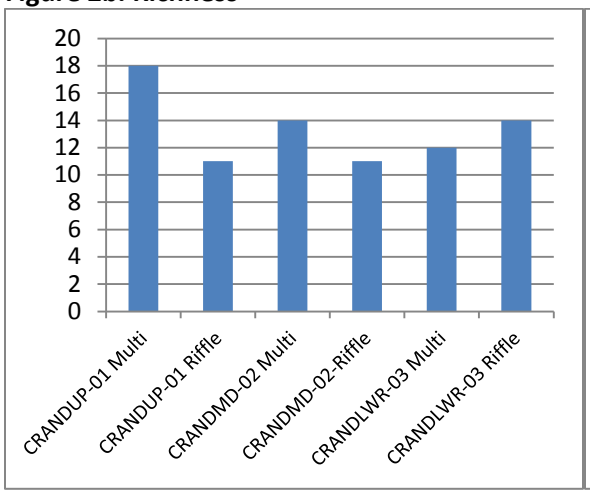


Figure 3b. Shannon's Diversity

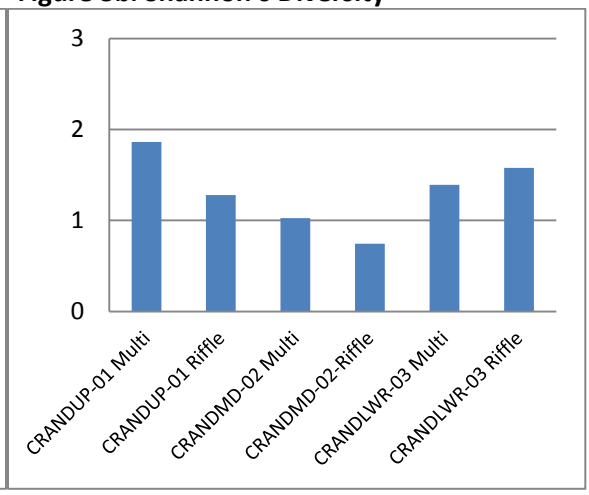


Figure 4b. Evenness

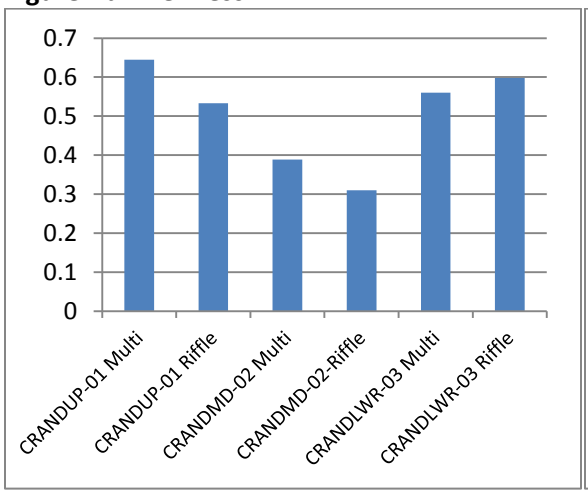


Figure 5b. Abundance

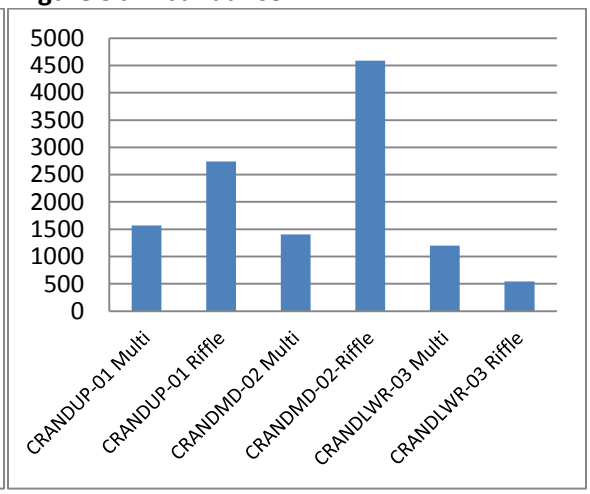


Figure 6b. HBI

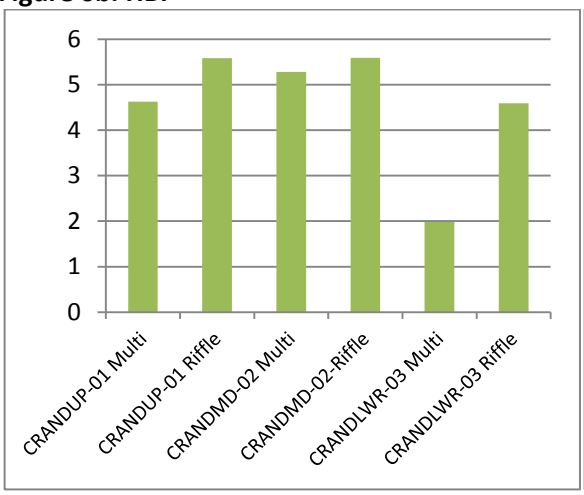
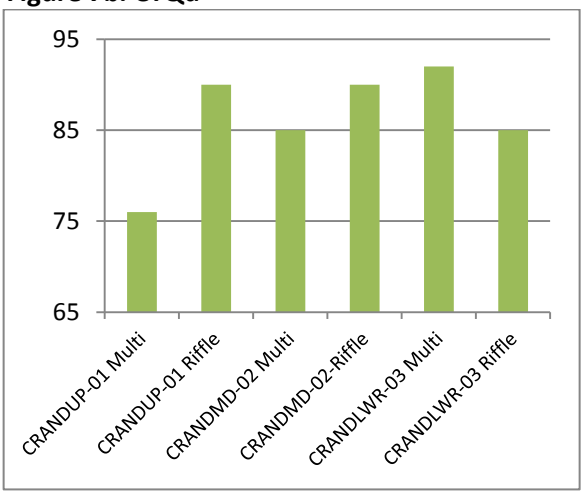


Figure 7b. CTQd



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

Figure 8b. EPT Taxa Abundance

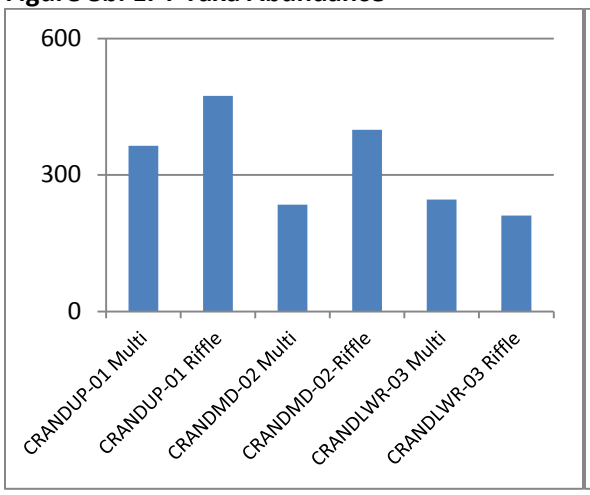


Figure 9b. Percent EPT

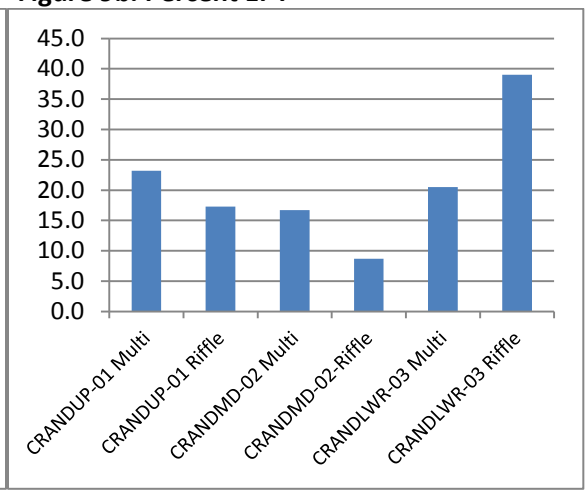


Figure 10b. Percent Chironomids

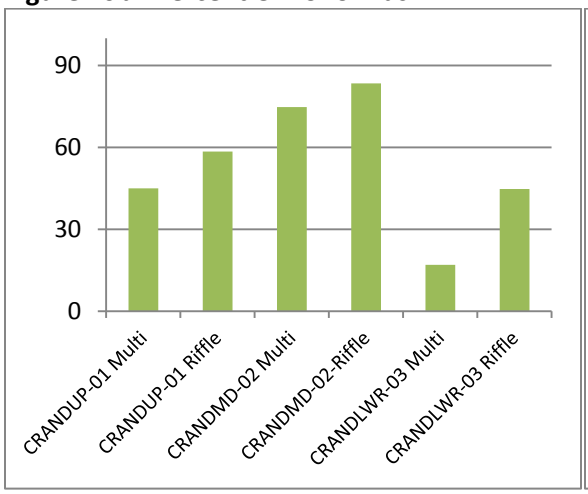


Figure 11b. Ratio of EPT to Chironmonids

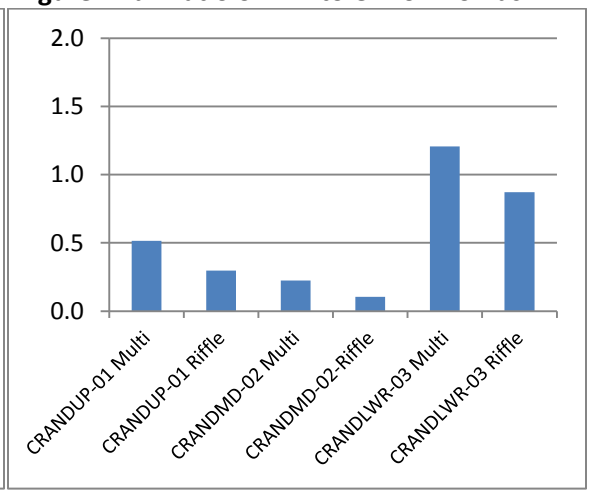


Figure 12b. Number of Tolerant Taxa

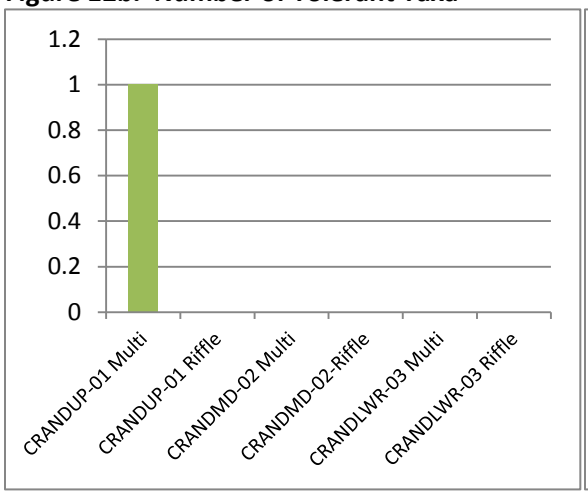


Figure 13b. Percent Tolerant Organisms

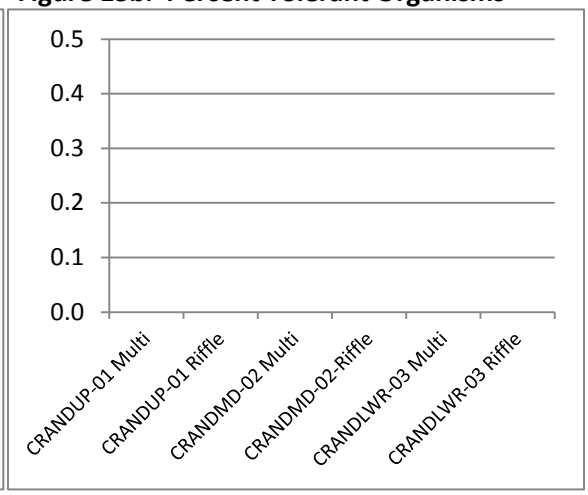


Figure 14b. Number of Intolerant Taxa

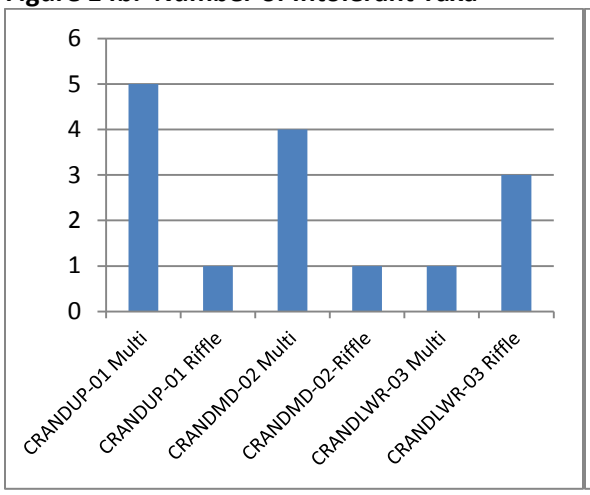


Figure 15b. Percent Intolerant Organisms

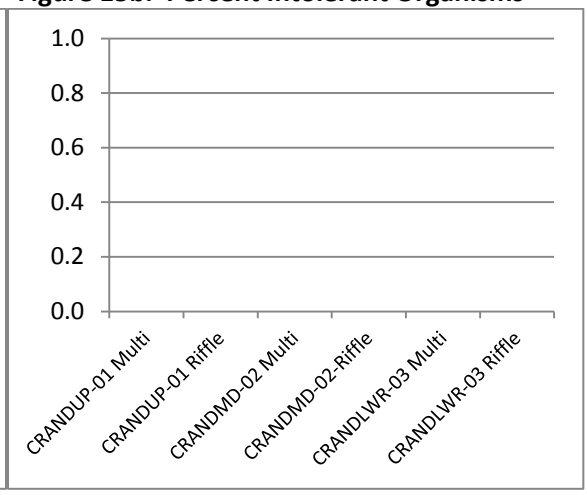


Figure 16b. Specialist Feeders: Generalist Feeders

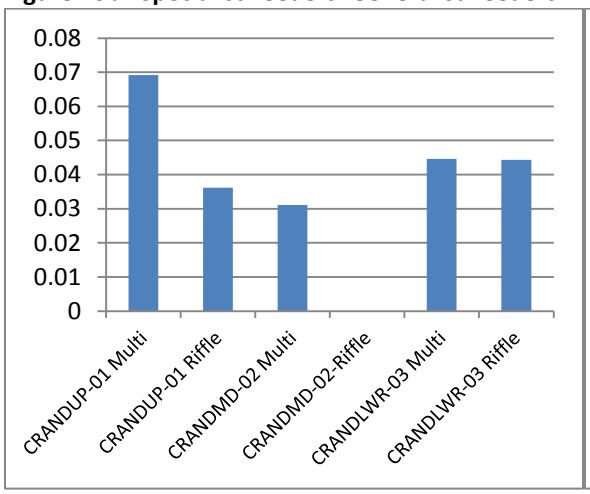


Figure 17b. Percent Shredders

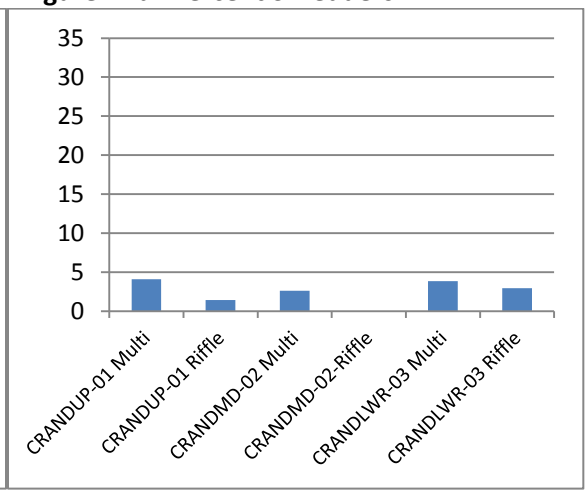


Figure 18b. Percent Scrapers

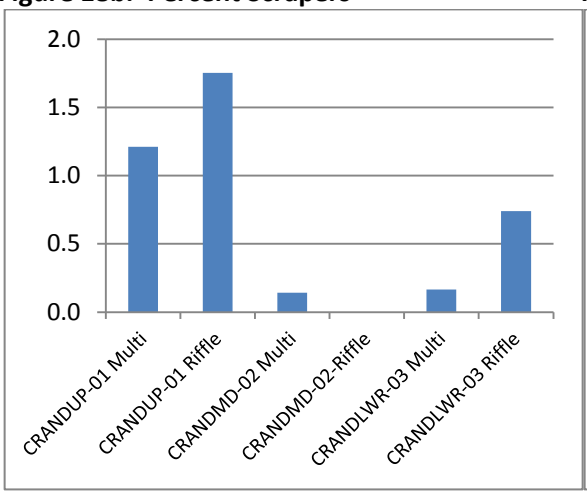


Figure 19b. Number of Long-Lived Taxa

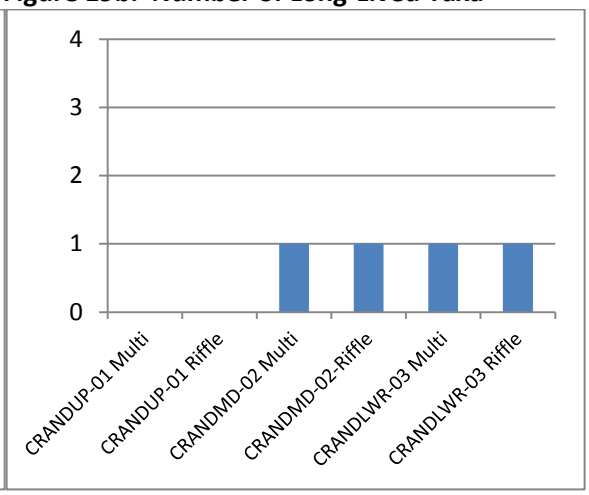


Figure 20b. Number of Clinger Taxa

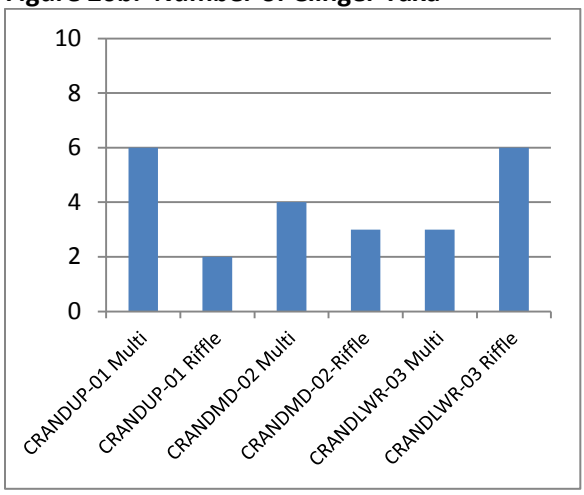


Figure 21b. Baetis:All Ephemetroptera (Percent)

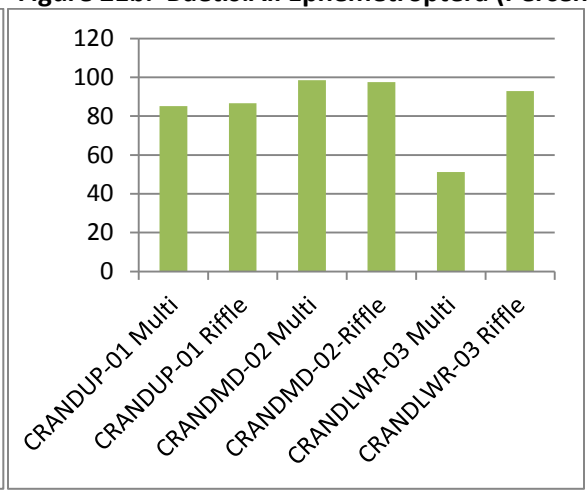


Figure 22b. Baetis, Hydropsychidae & Orthocladiinae (Percent)

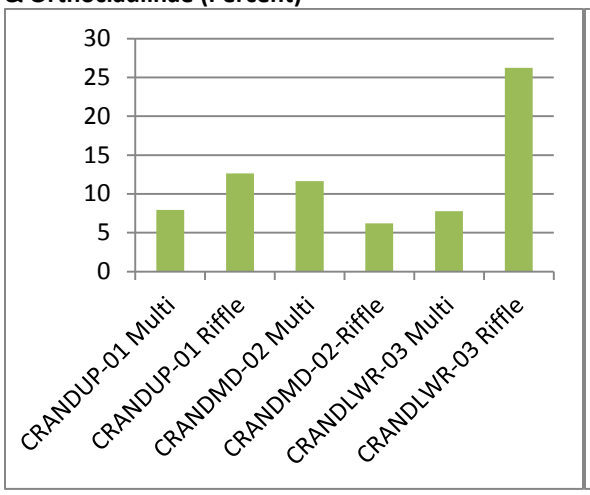


Figure 23b. Heptageniidae: All Ephemeroptera (Percent)

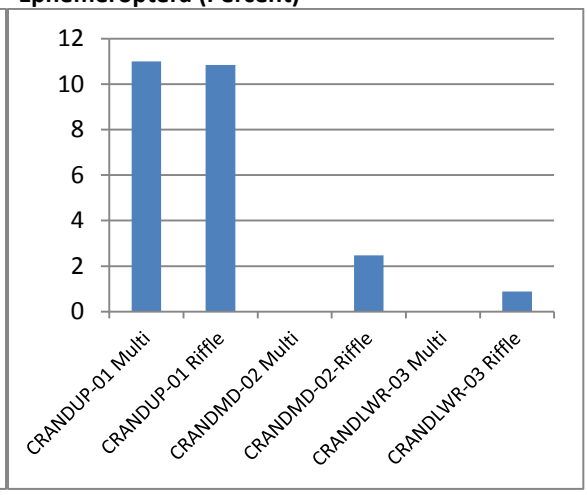
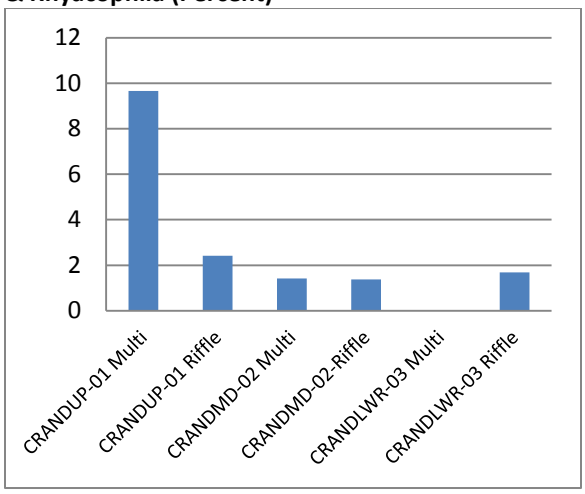


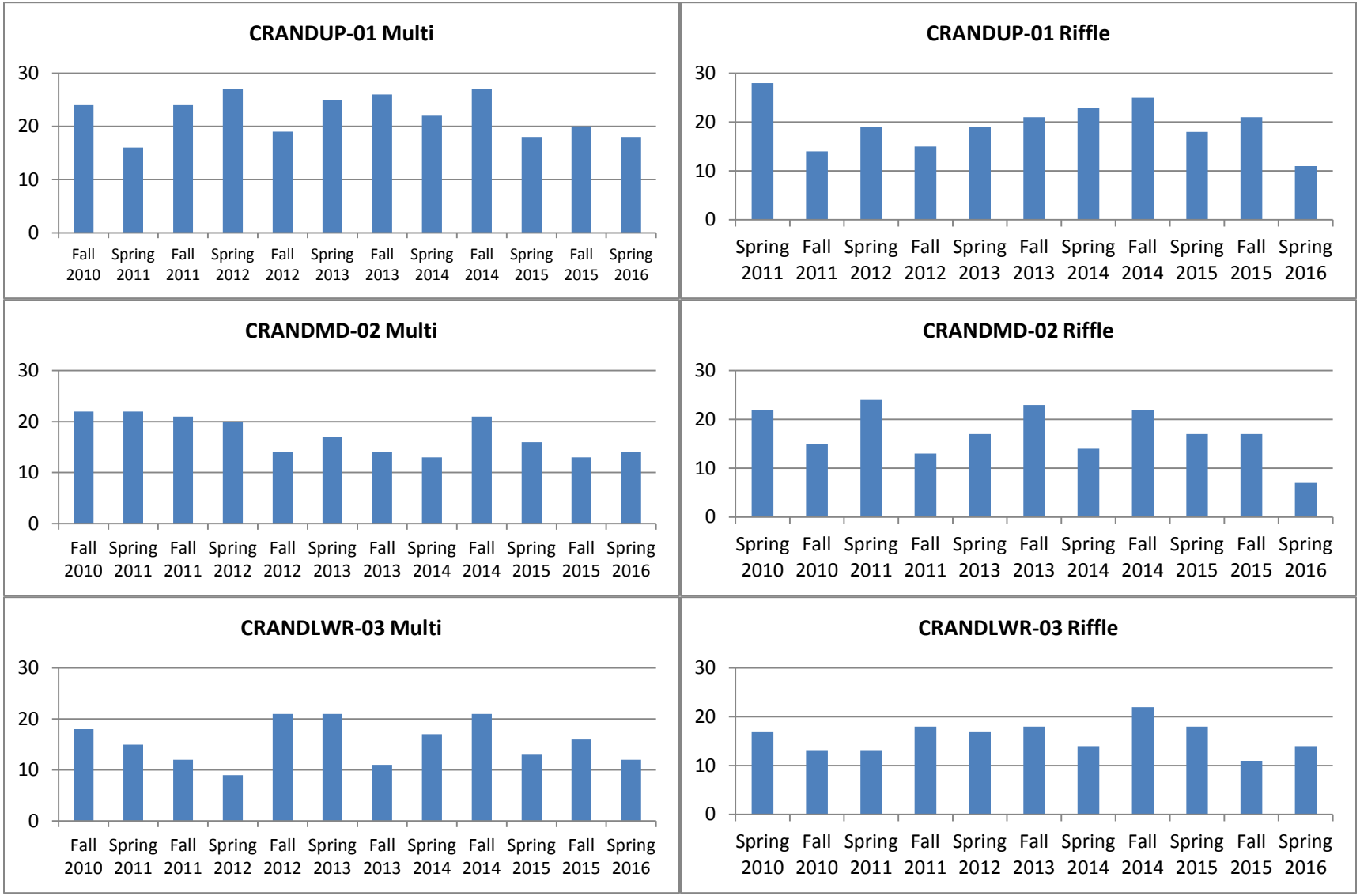
Figure 24b. Heptageniidae, Chloroperlidae & Rhyacophila (Percent)



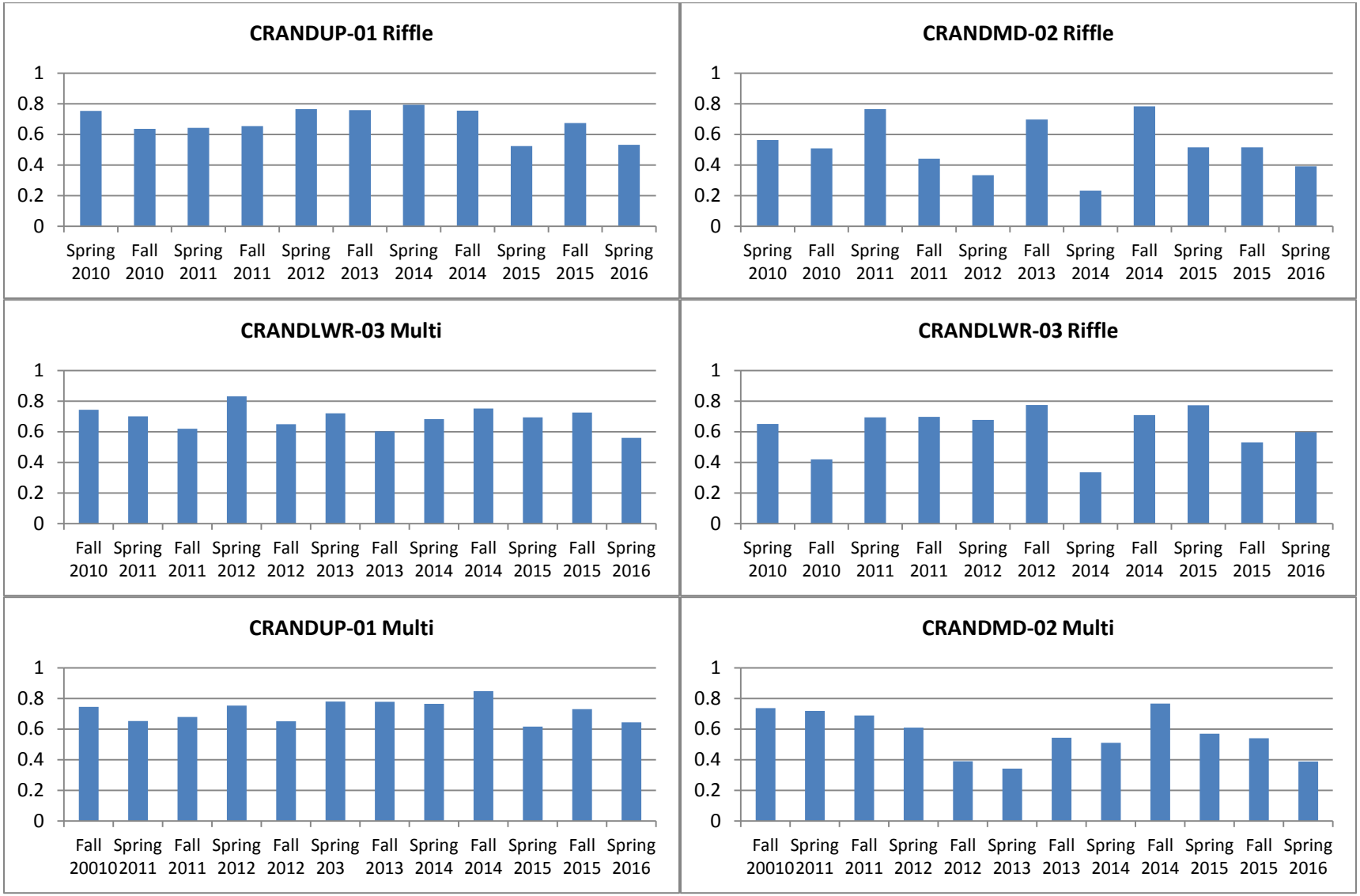
APPENDIX C

MACROINVERTEBRATE FIGURES FALL 2009- SPRING 2016

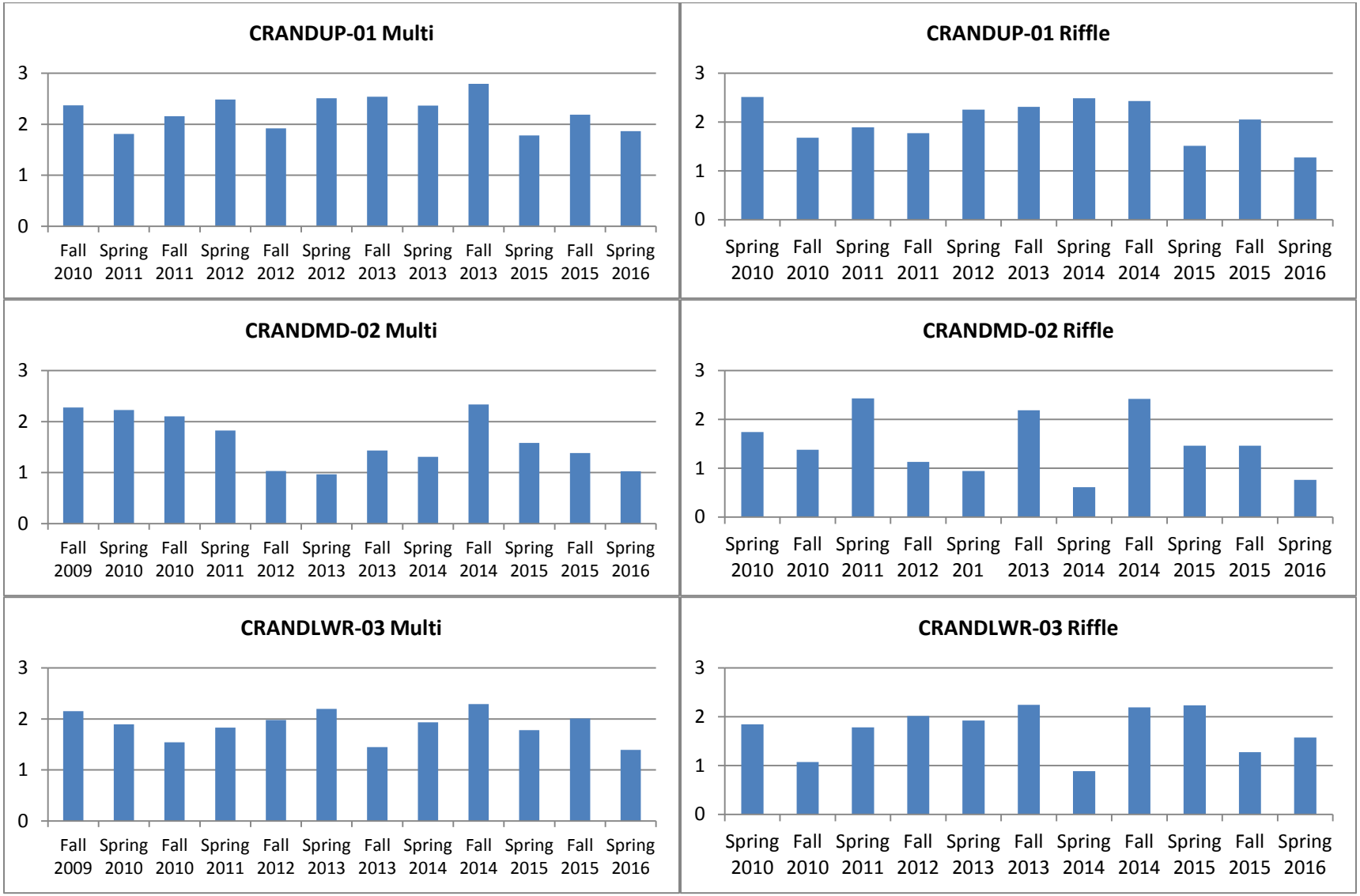
Figures 1c. Richness values for each reach and habitat type from 2010-2016



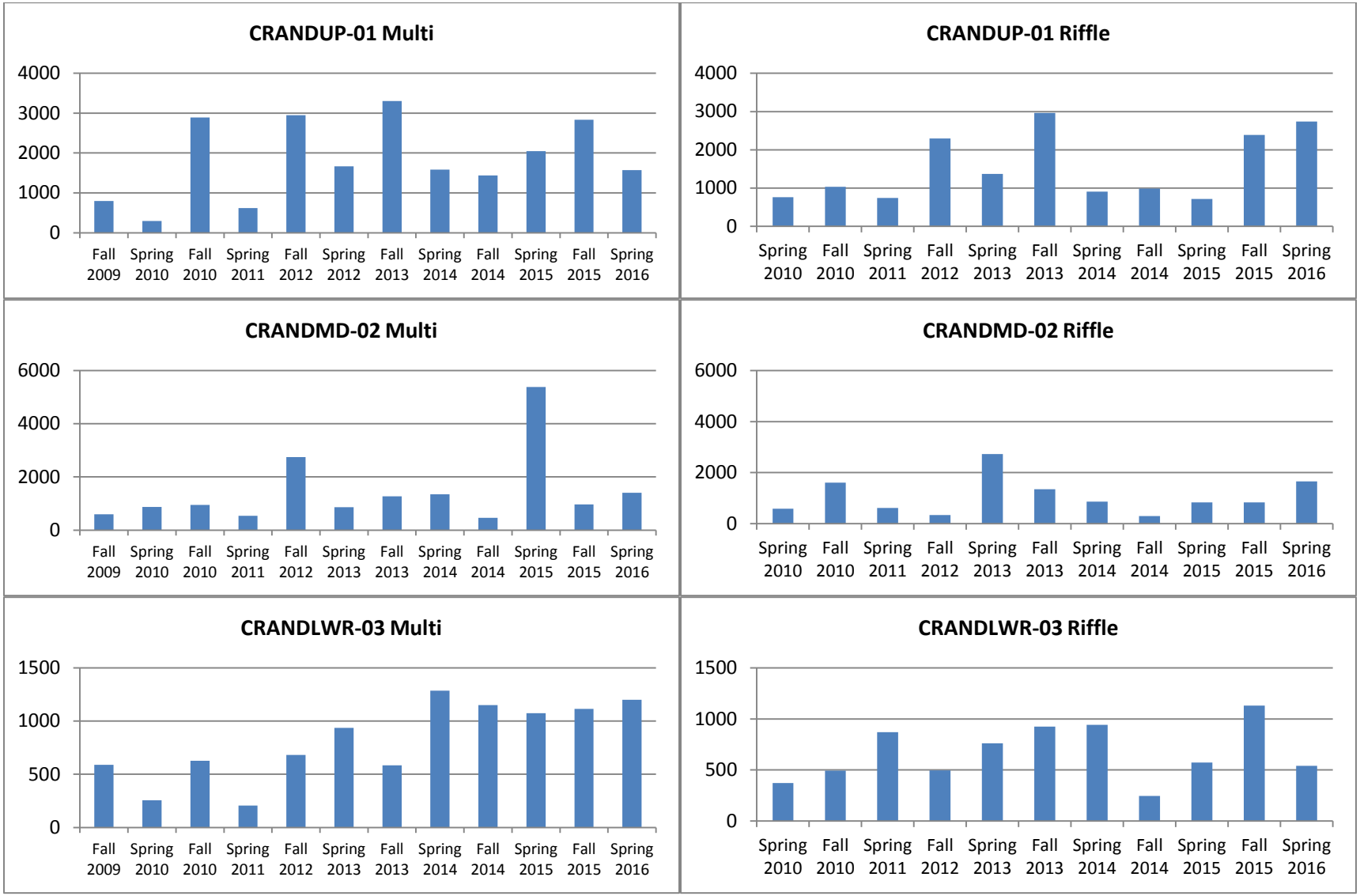
Figures 2c. Evenness values for each reach and habitat type from 2010-2016



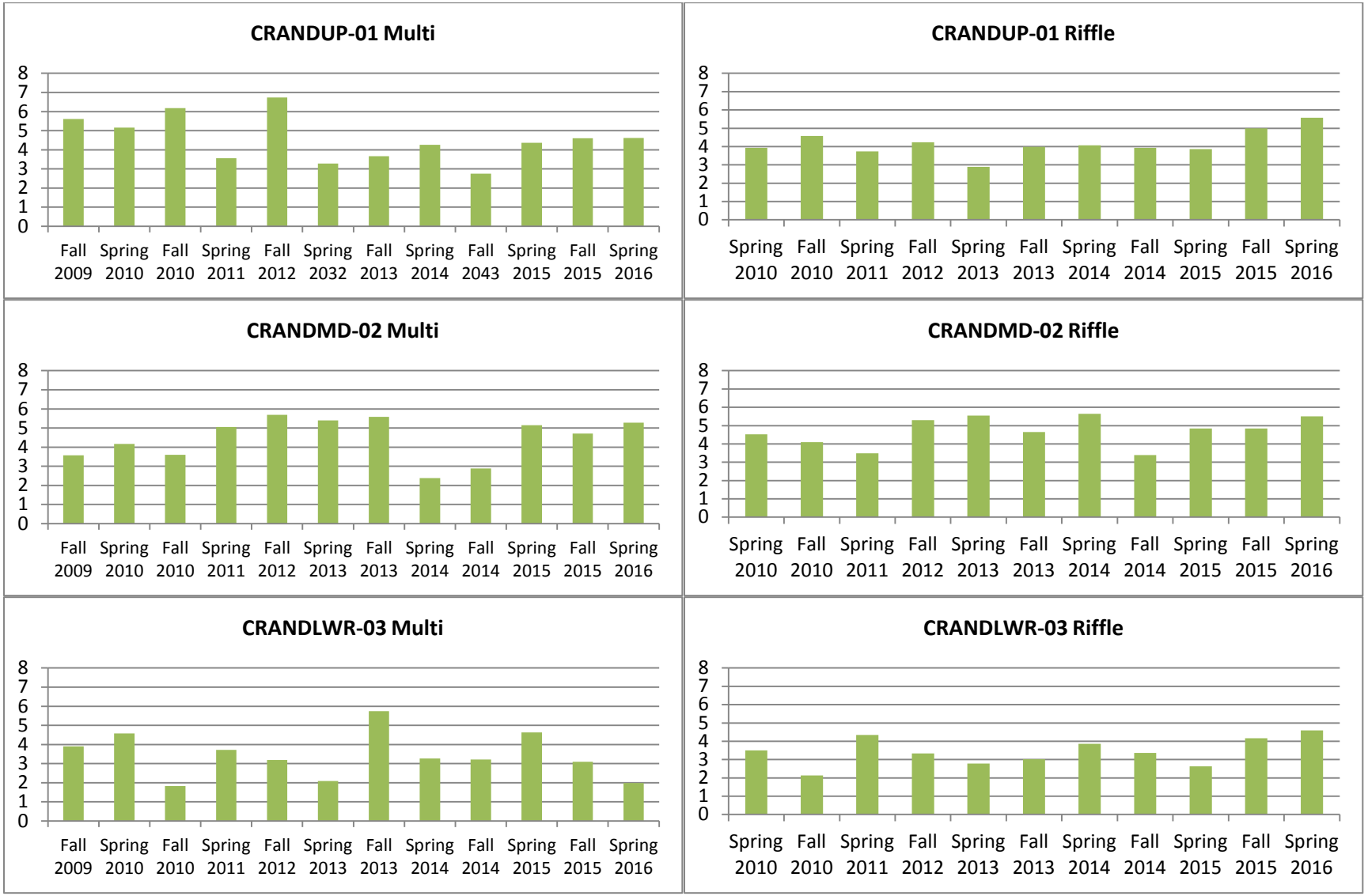
Figures 3c. Shannon's Diversity values for each reach and habitat type from 2010-2016



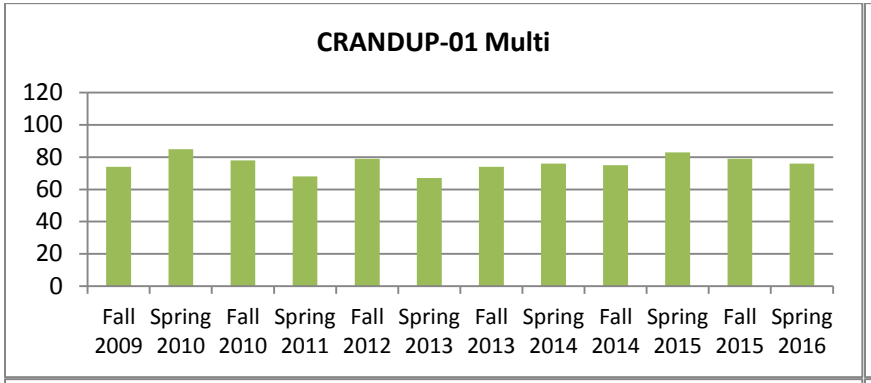
Figures 4c. Abundance values for each reach and habitat type from 2010-2016

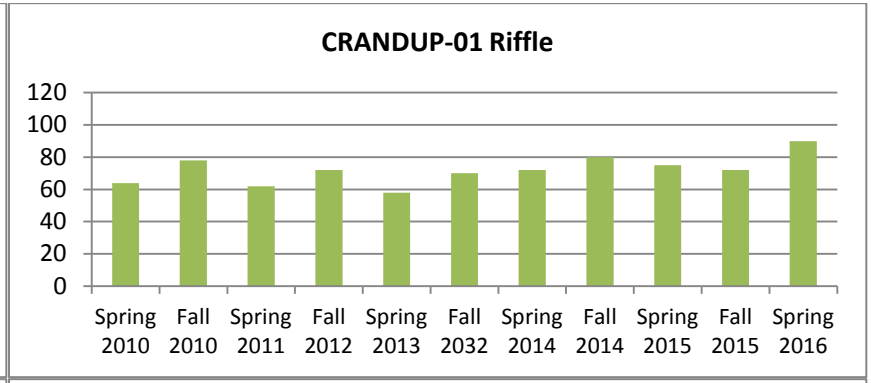


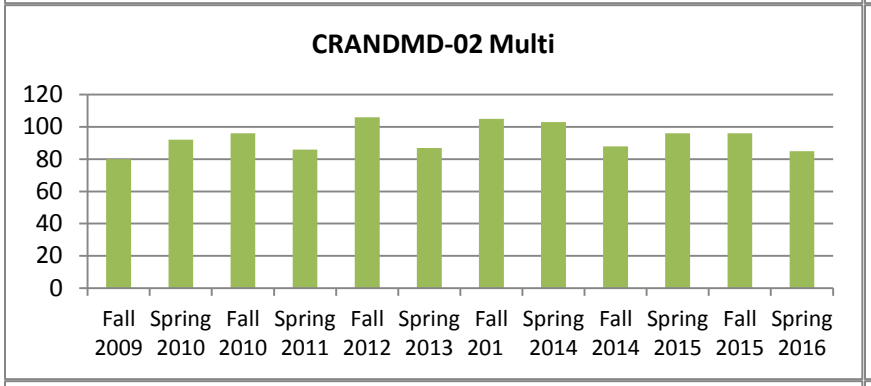
Figures 5c. Hilsenhoff Biotic Index values for each reach and habitat type from 2010-2016

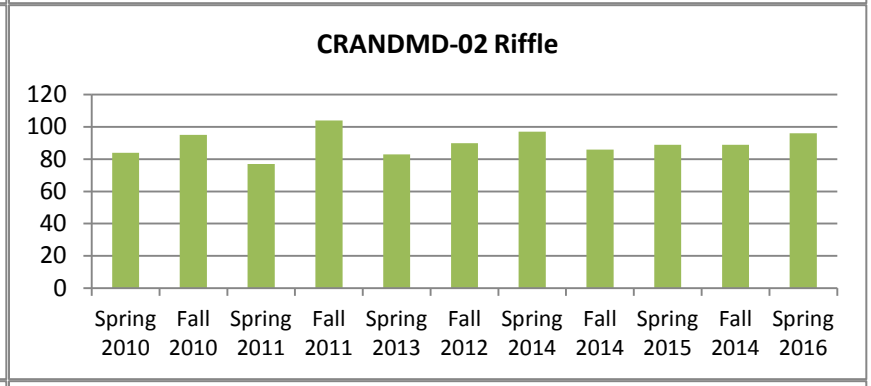


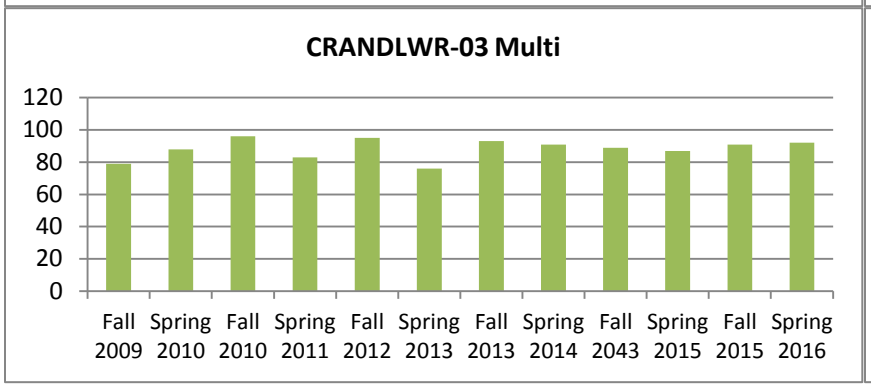
Figures 6c. USFS Community Tolerance Quotient (CTQd) values for each reach and habitat type from 2010-2016

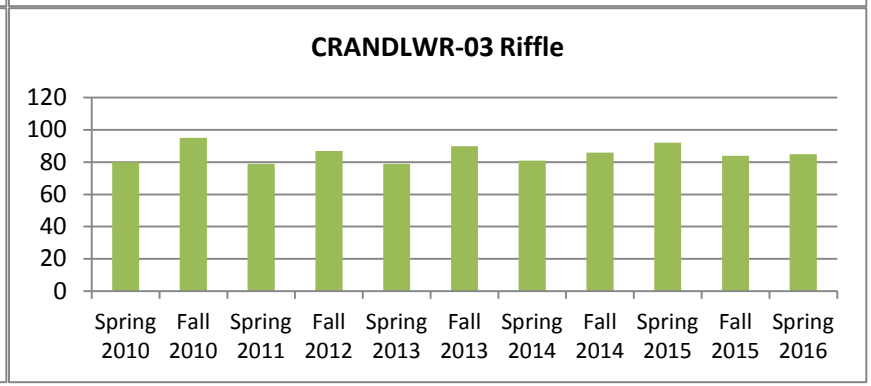




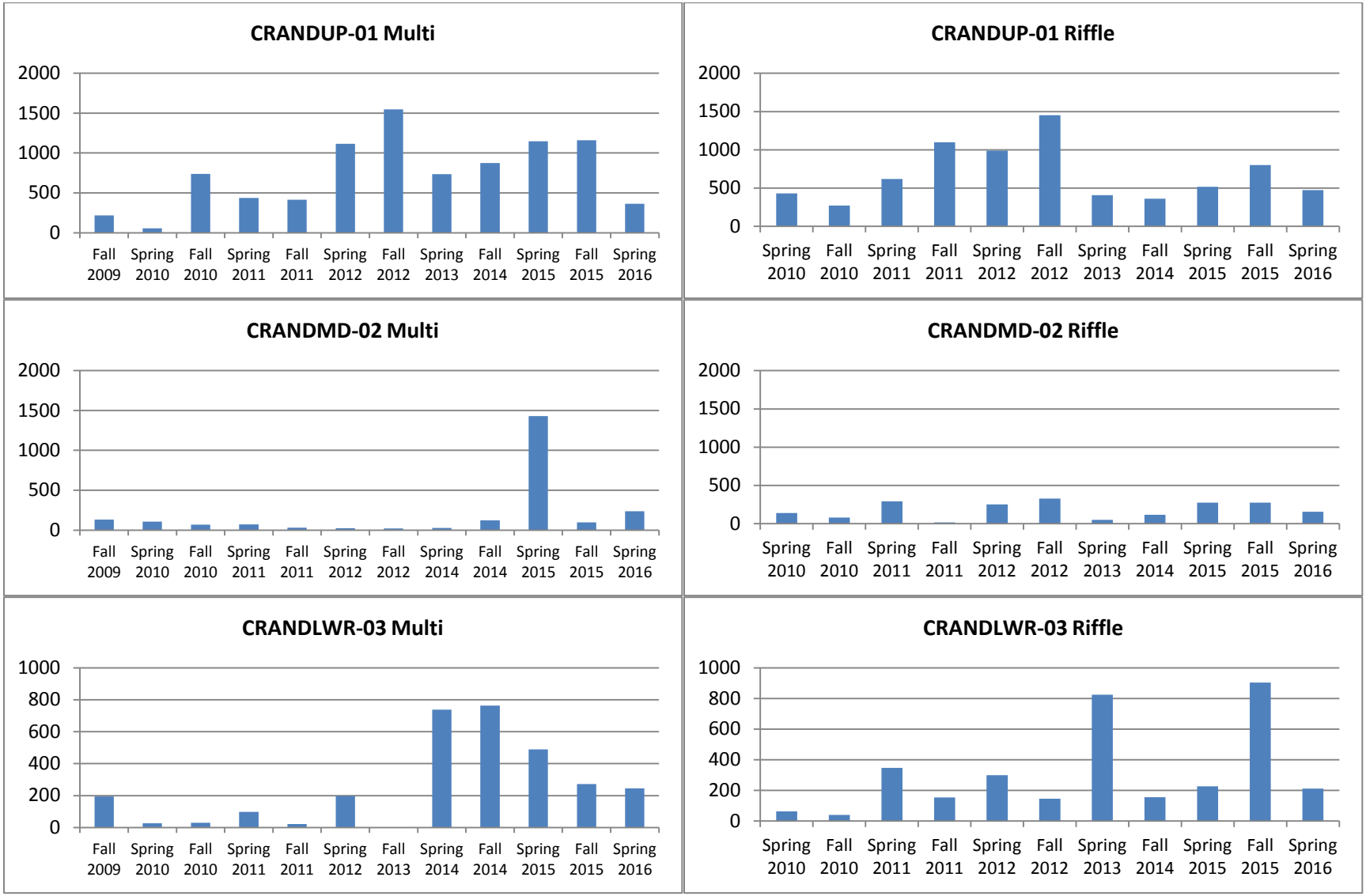




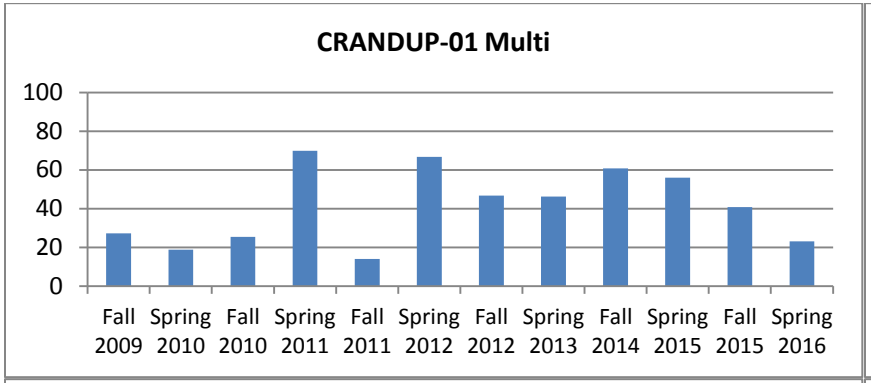


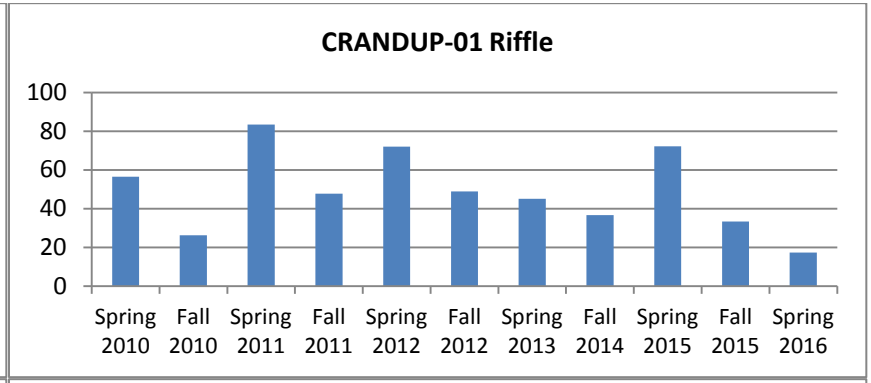


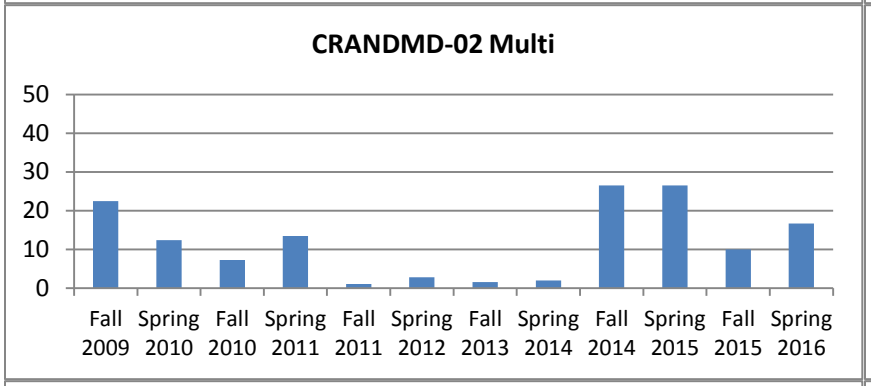
Figures 7c. EPT taxa abundance values for each reach and habitat type from 2010-2016

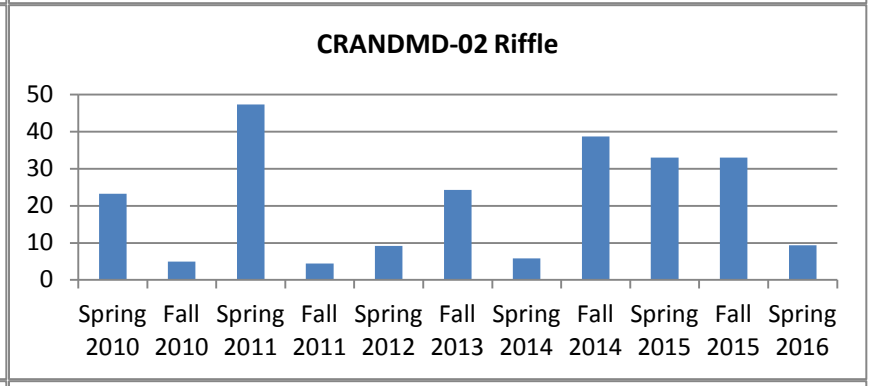


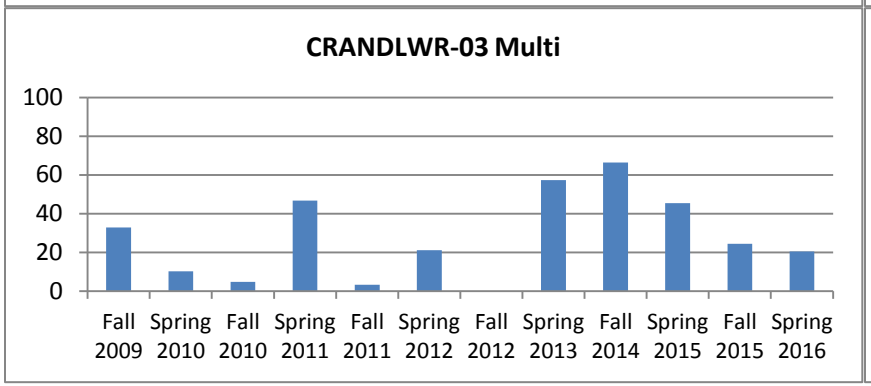
Figures 8c. Percent EPT for each reach and habitat type from 2010-2016

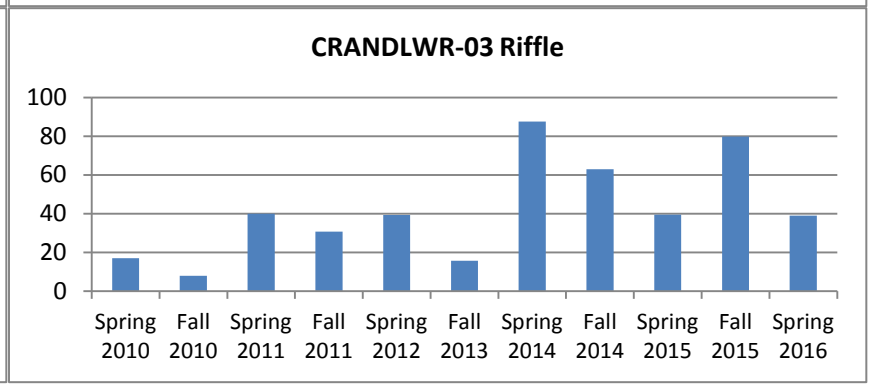




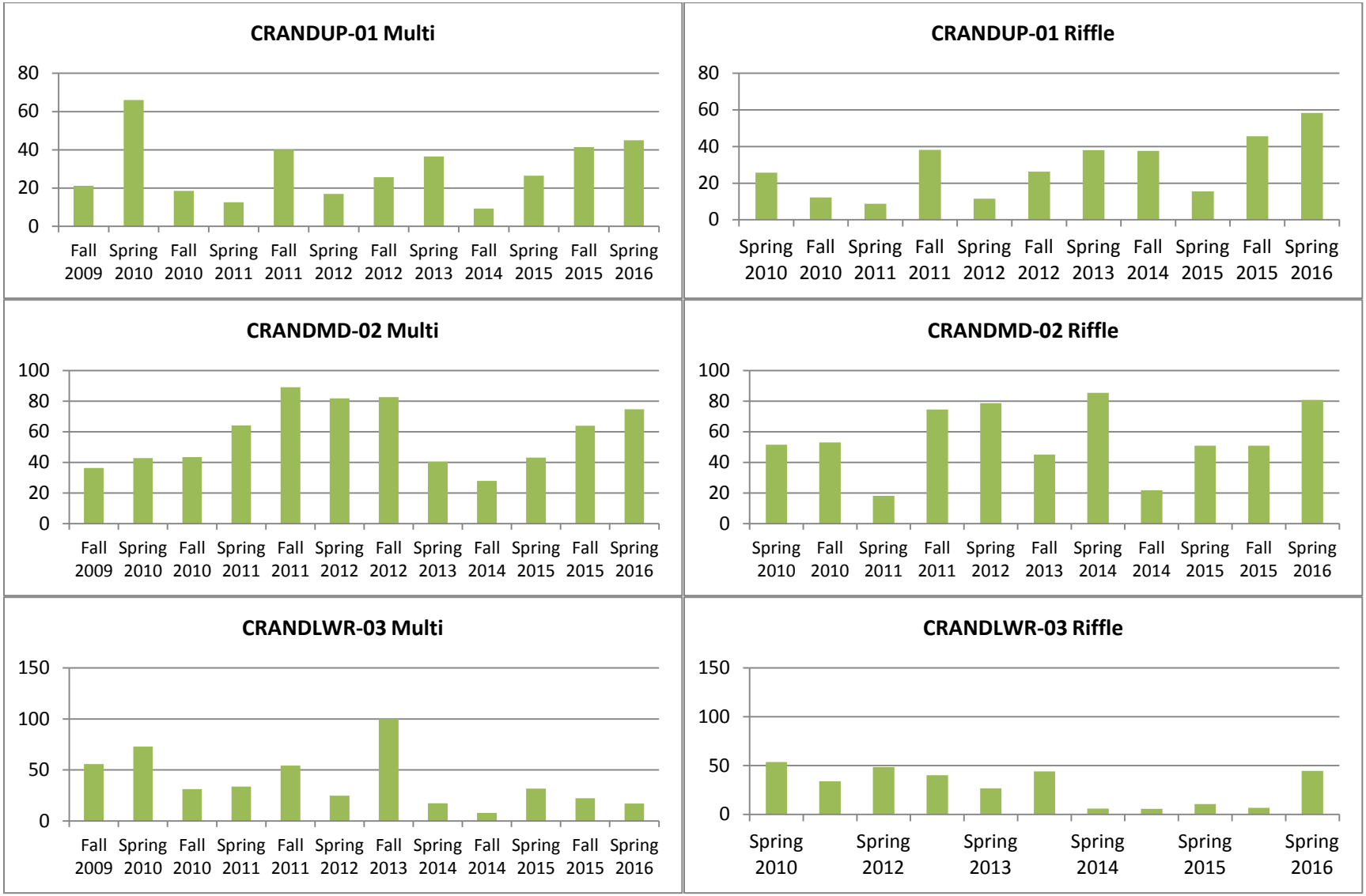




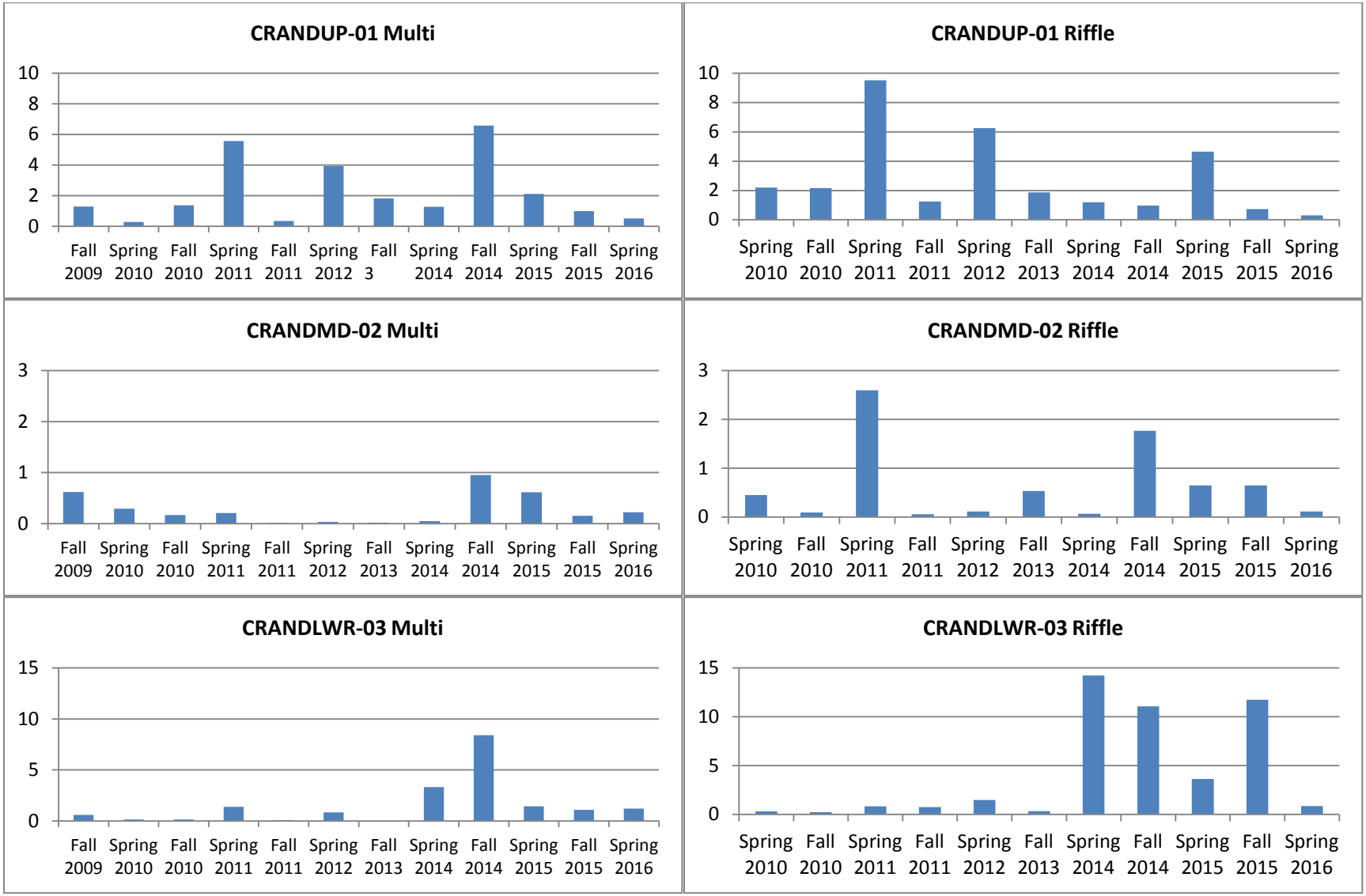




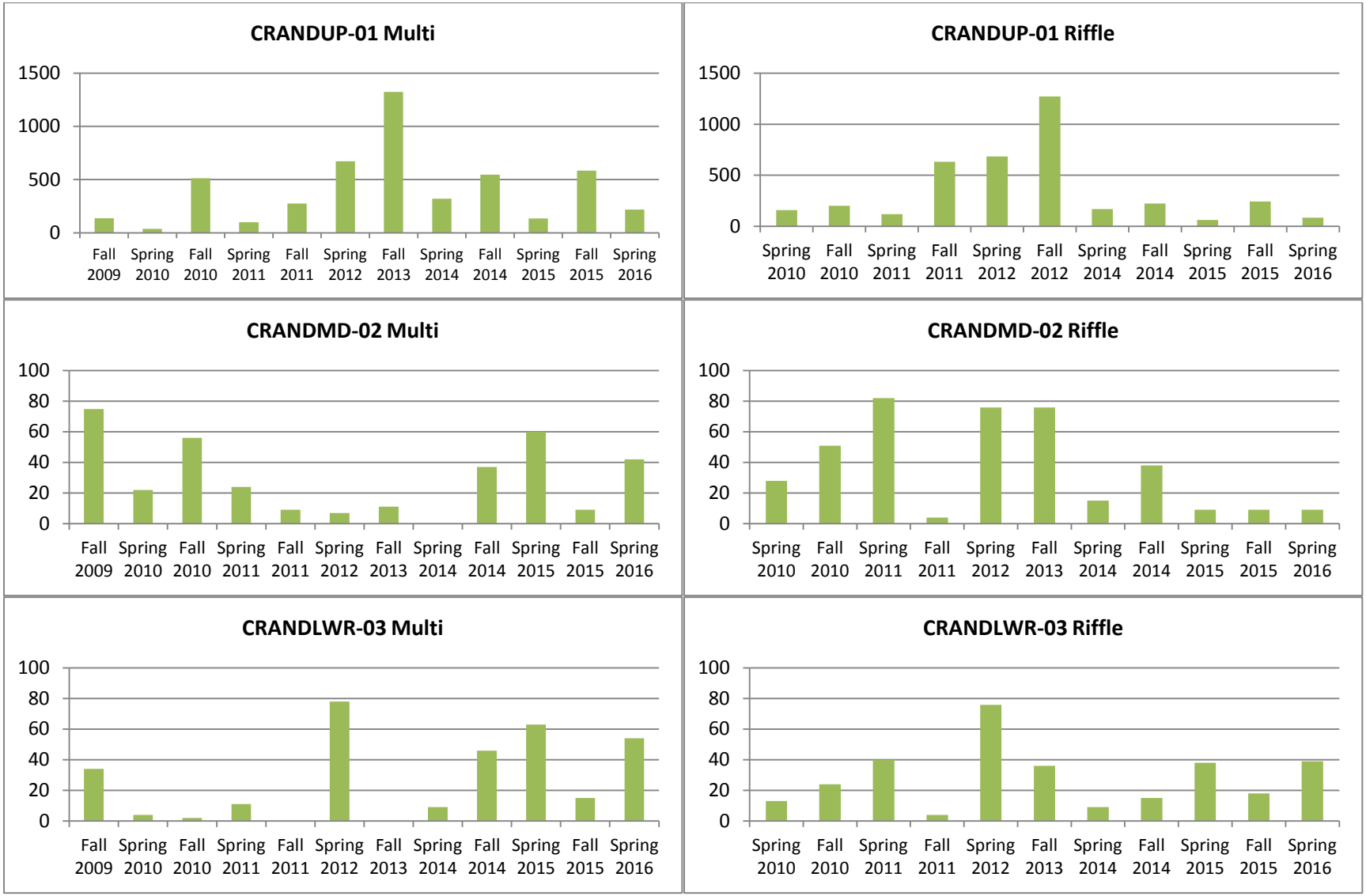
Figures 9c. Percent Chironomids for each reach and habitat type from 2010-2016



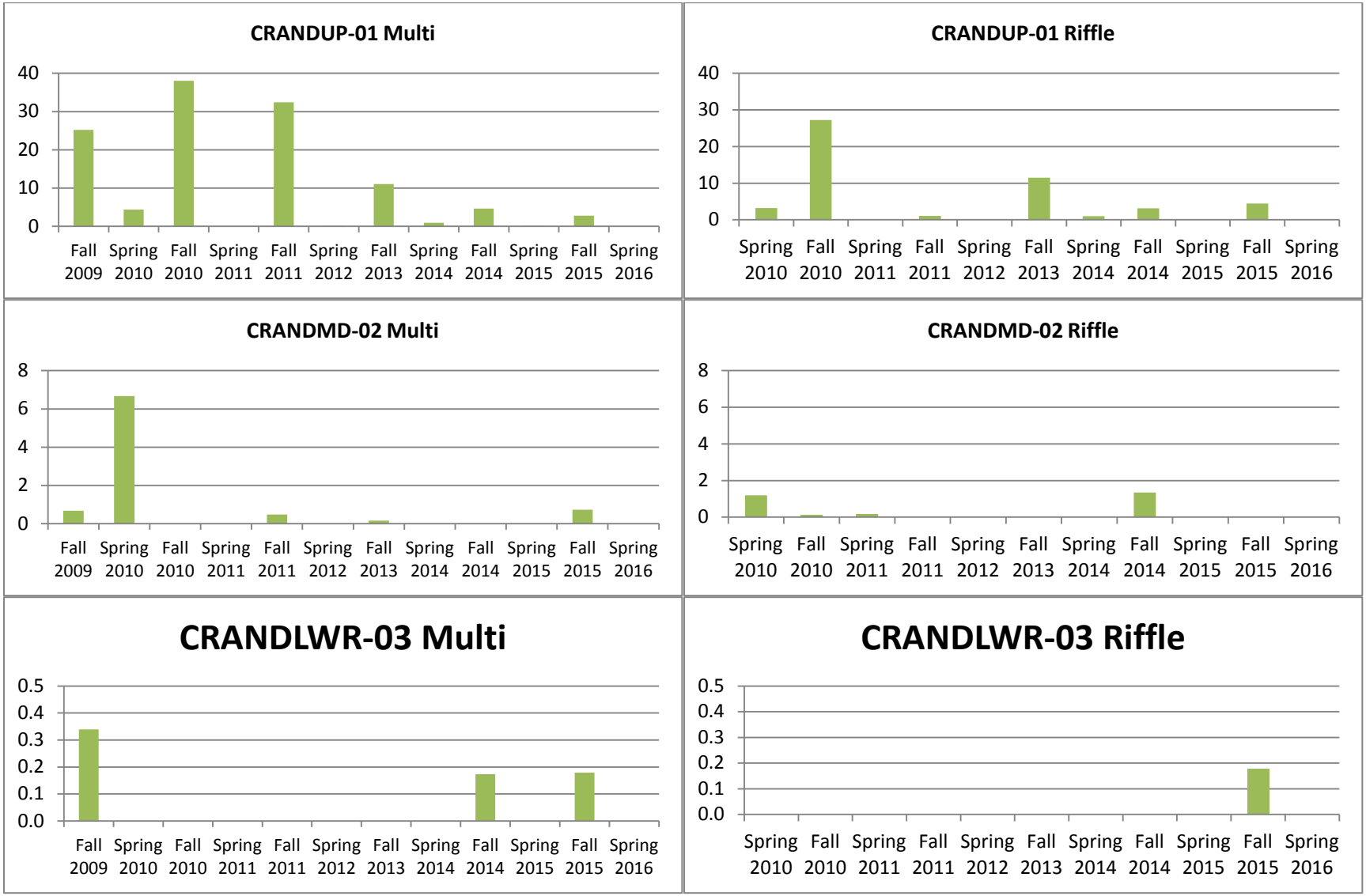
Figures 10c. Ratio of EPT to Chironmoids values for each reach and habitat type from 20010-2016



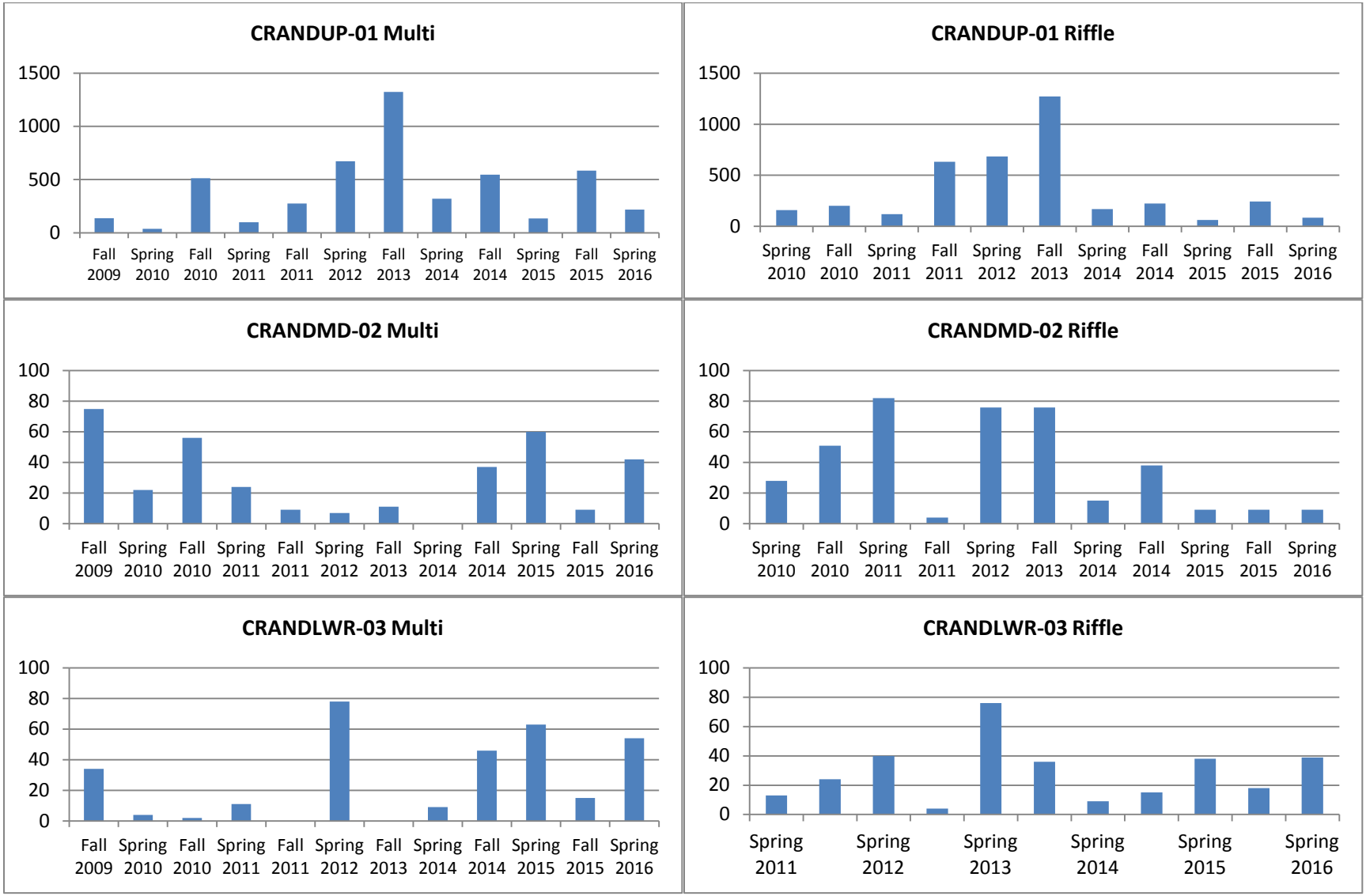
Figures 11c. Number of tolerant taxa for each reach and habitat type from 2010-2016



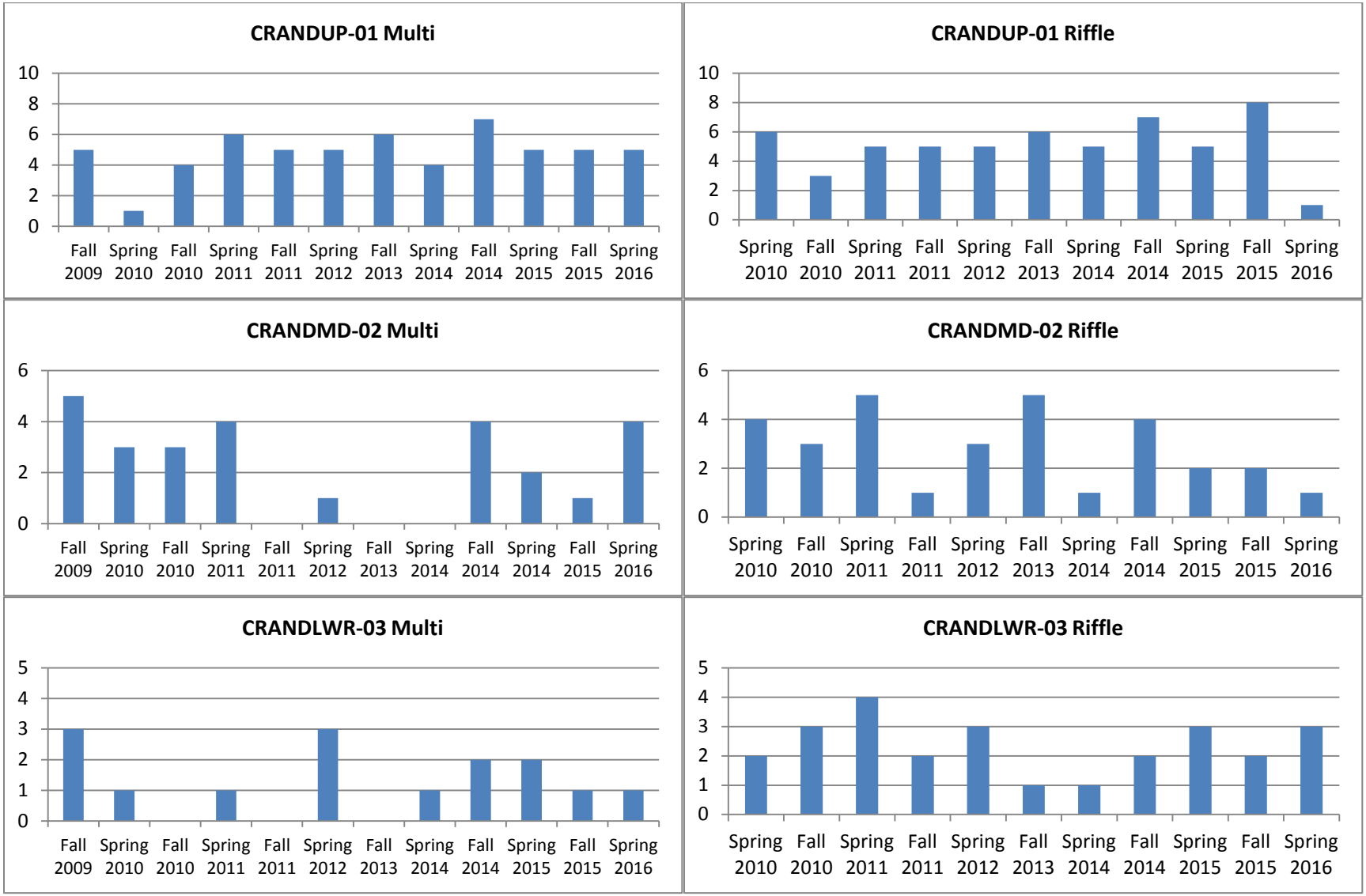
Figures 12c. Percent tolerant organisms for each reach and habitat type from 2010-2016



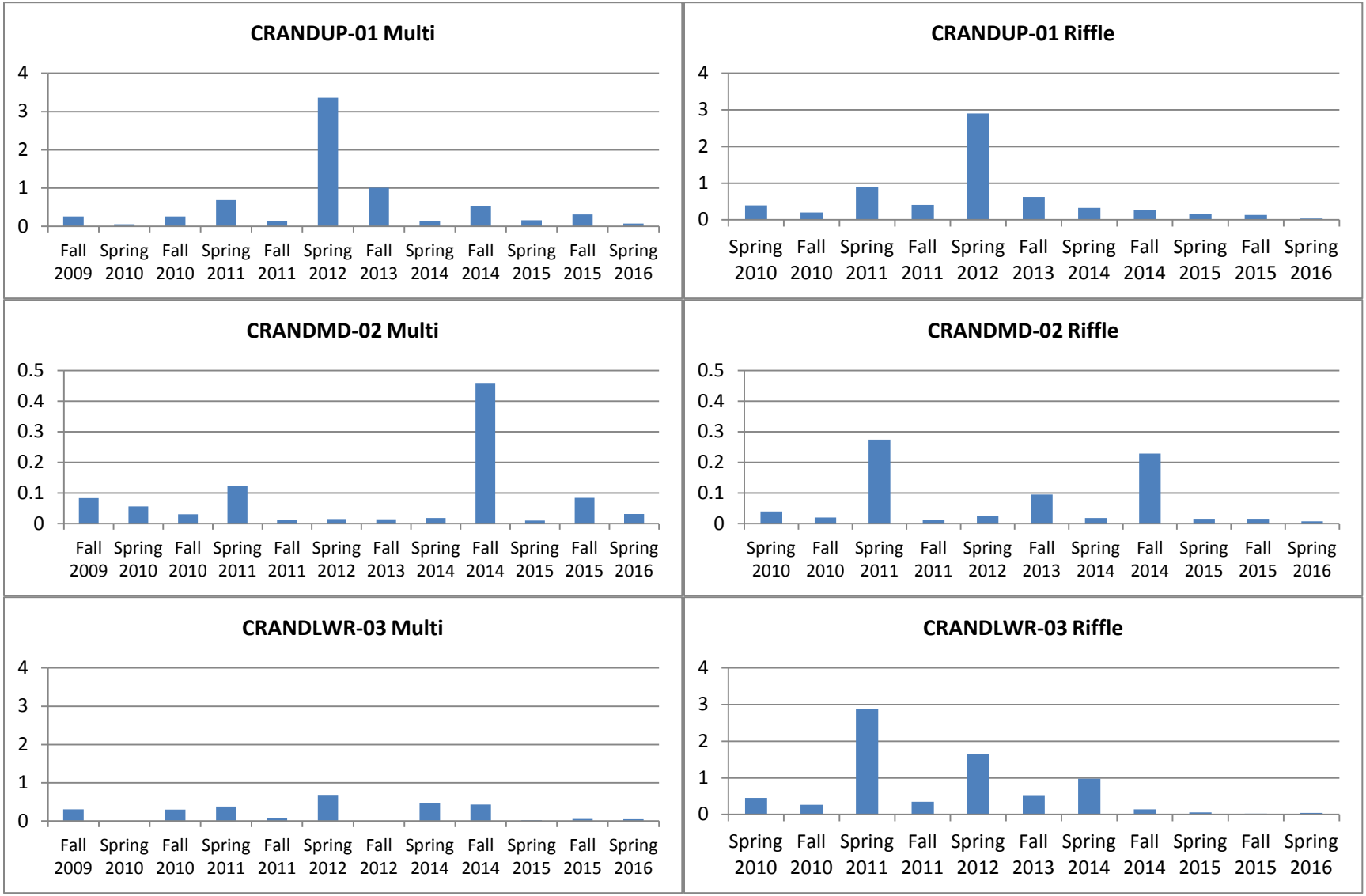
Figures 13c. Number of intolerant taxa for each reach and habitat type from 2010-2016



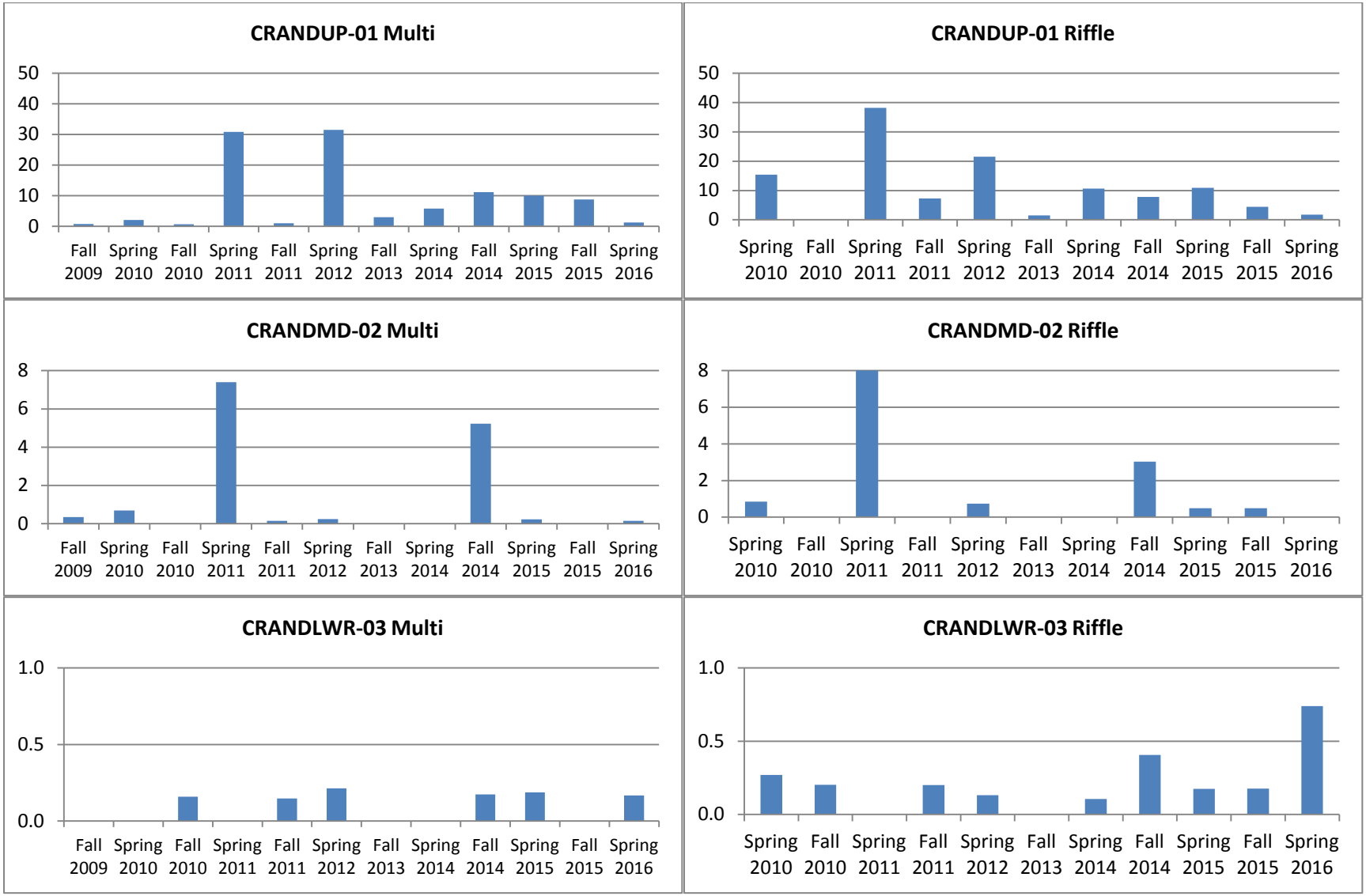
Figures 14c. Percent intolerant organisms for each reach and habitat type from 2010-2016



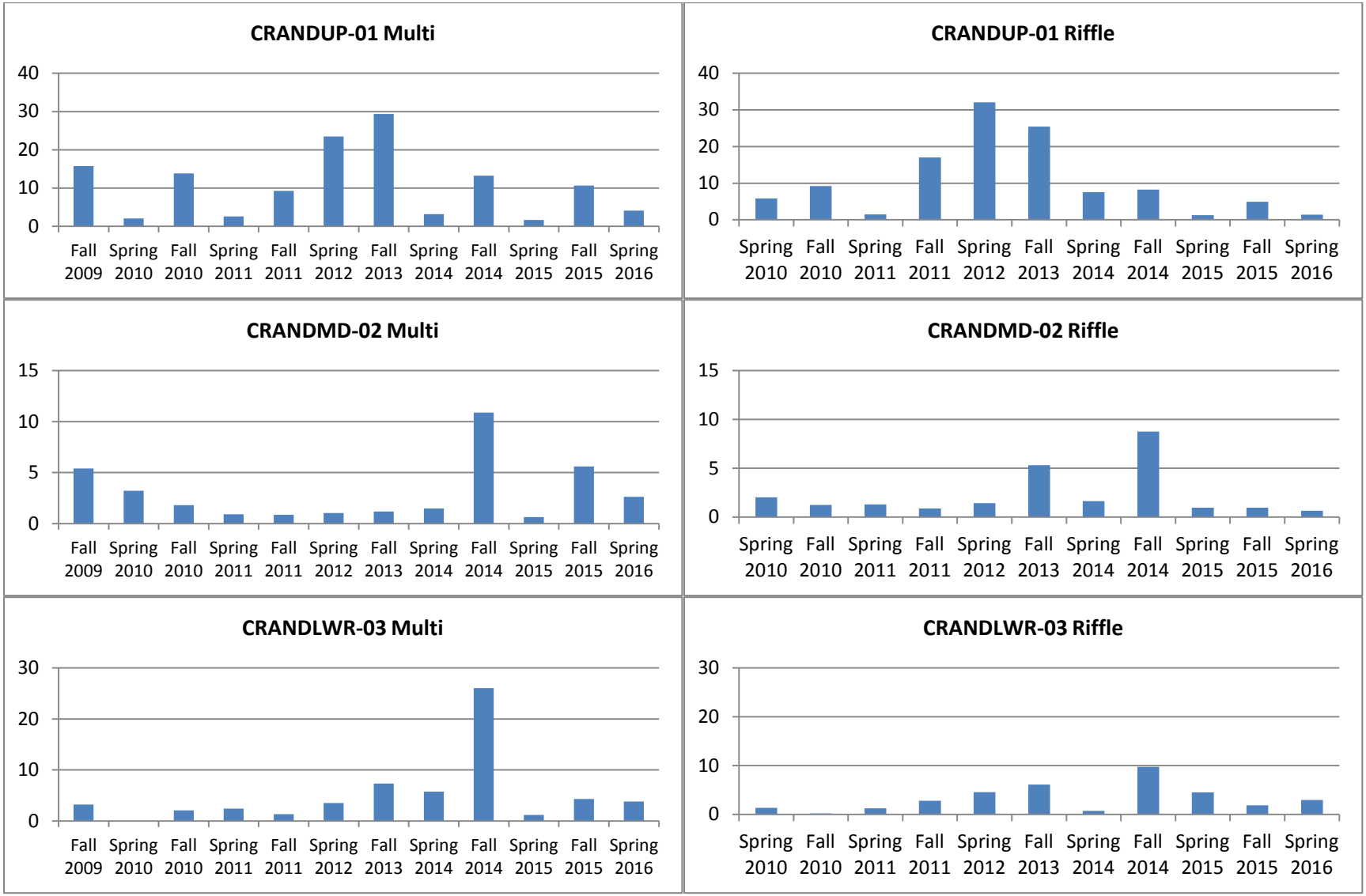
Figures 15c. Ratio of specialist feeders to generalist feeders for each reach and habitat type from 2010-2016



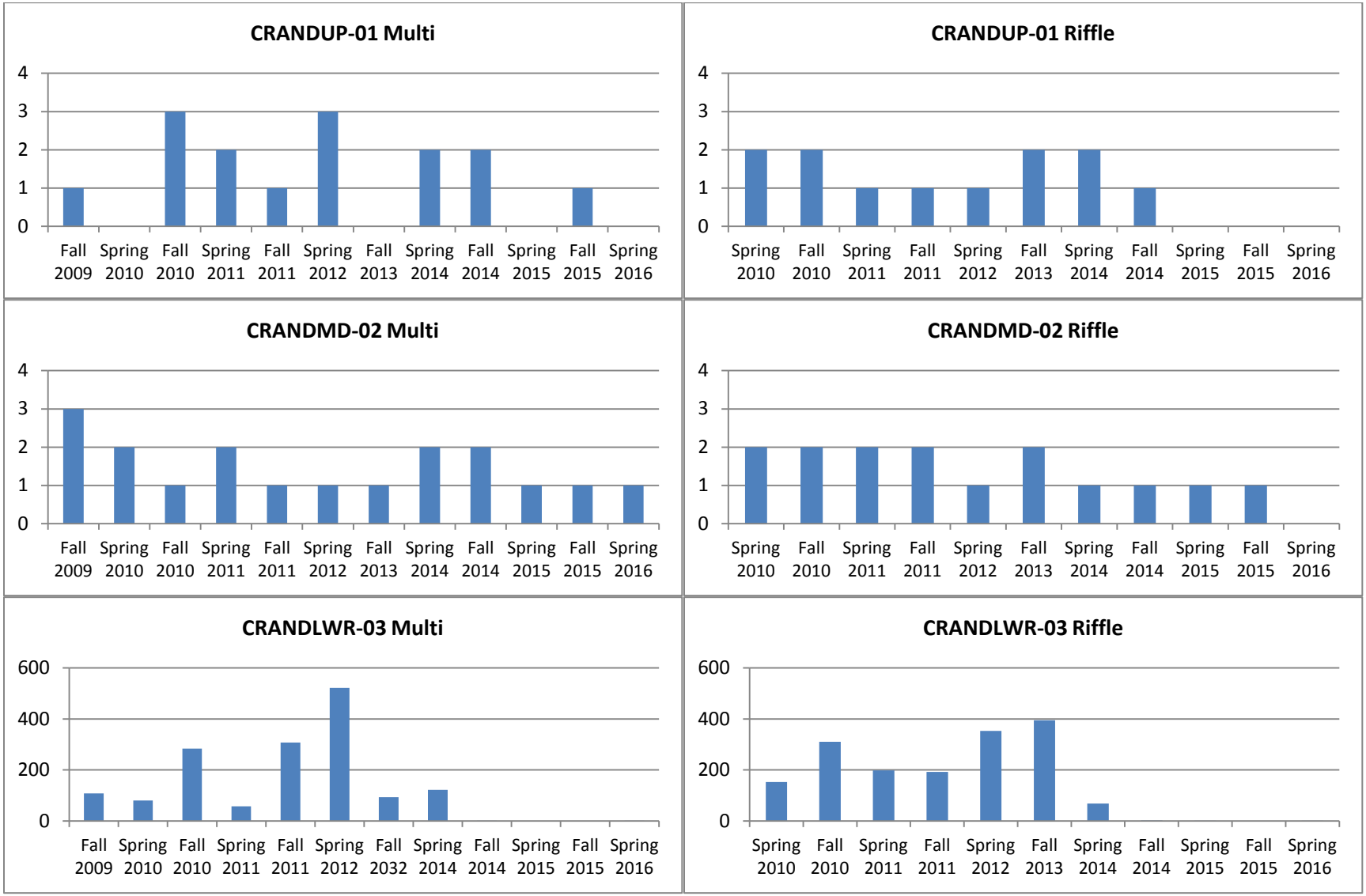
Figures 16c. Percent scrapers for each reach and habitat type from 2010-2016



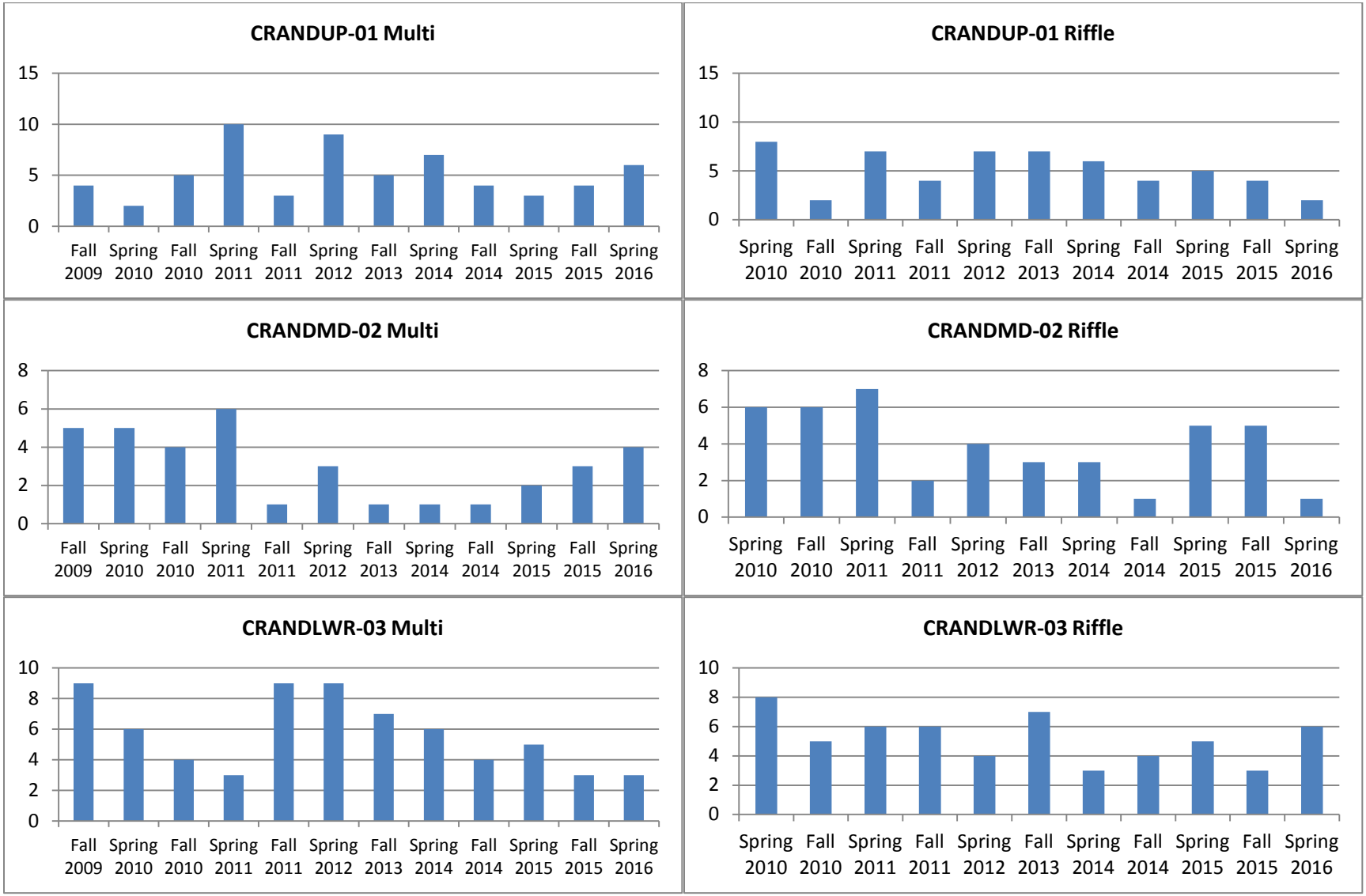
Figures 17c. Percent shredders for each reach and habitat type from 20010-2016



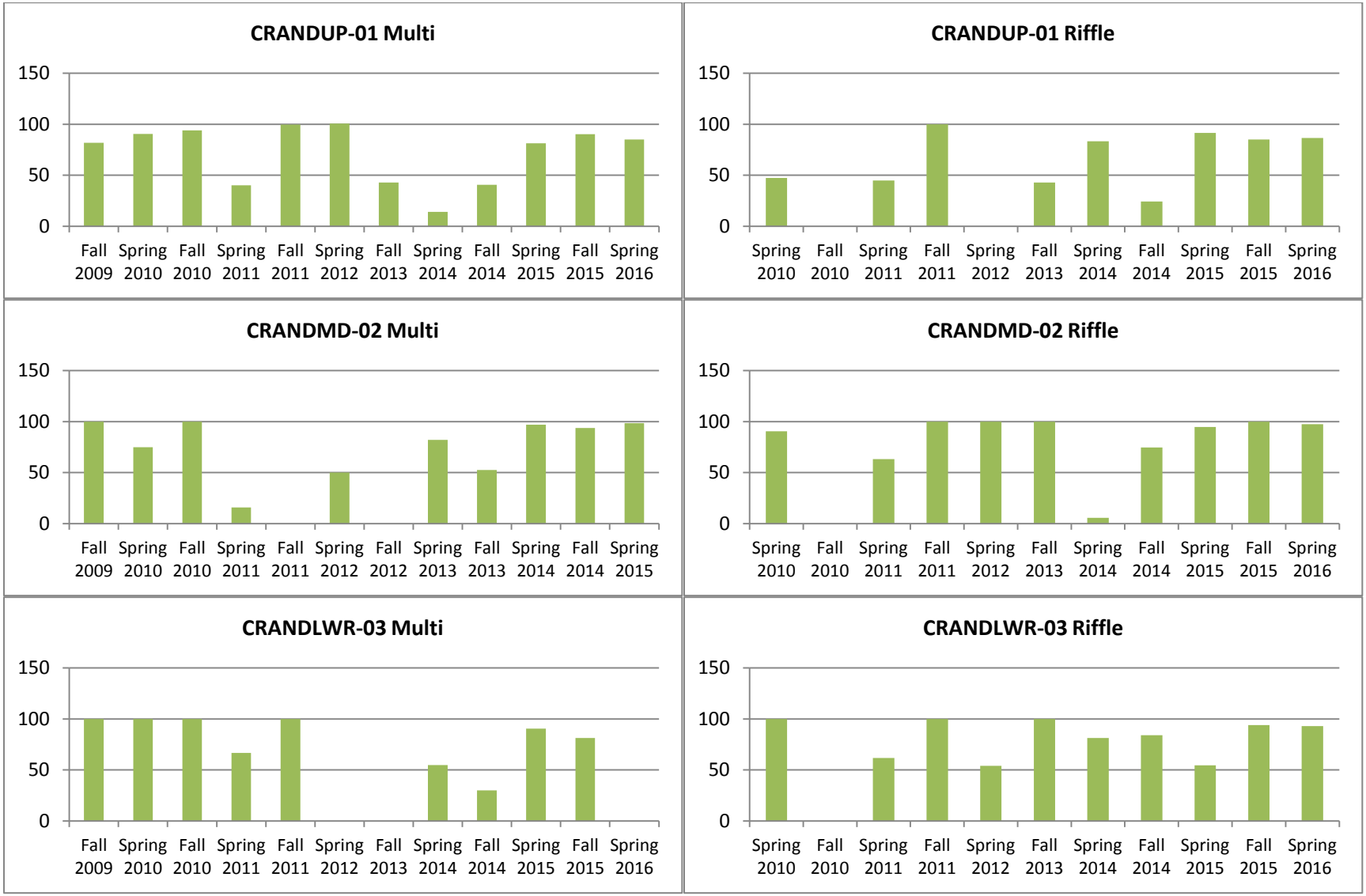
Figures 18c. Number of long-lived taxa for each reach and habitat type from 2010-2016



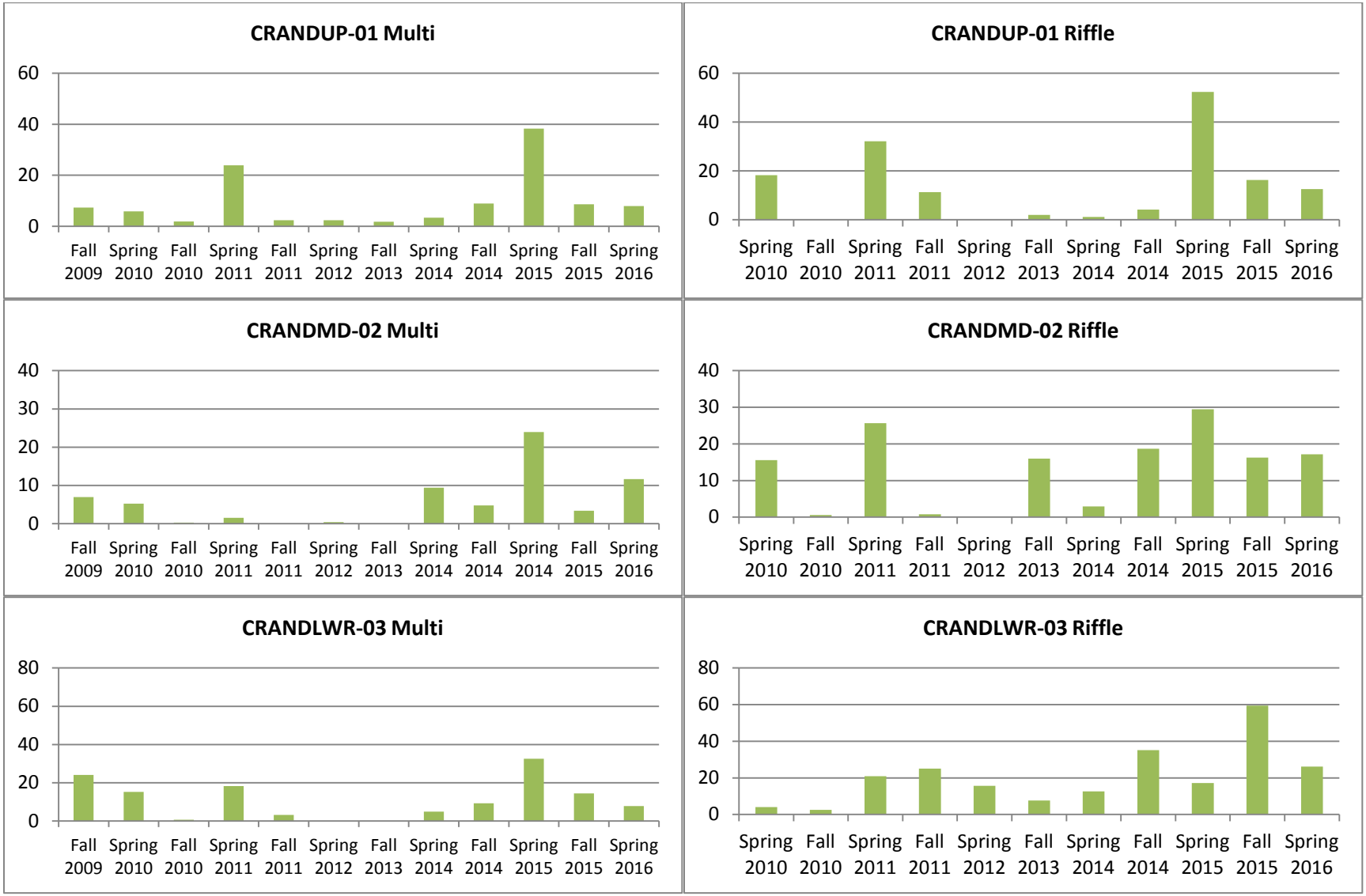
Figures 19c. Number of clinger taxa for each reach and habitat type from 2010-2016



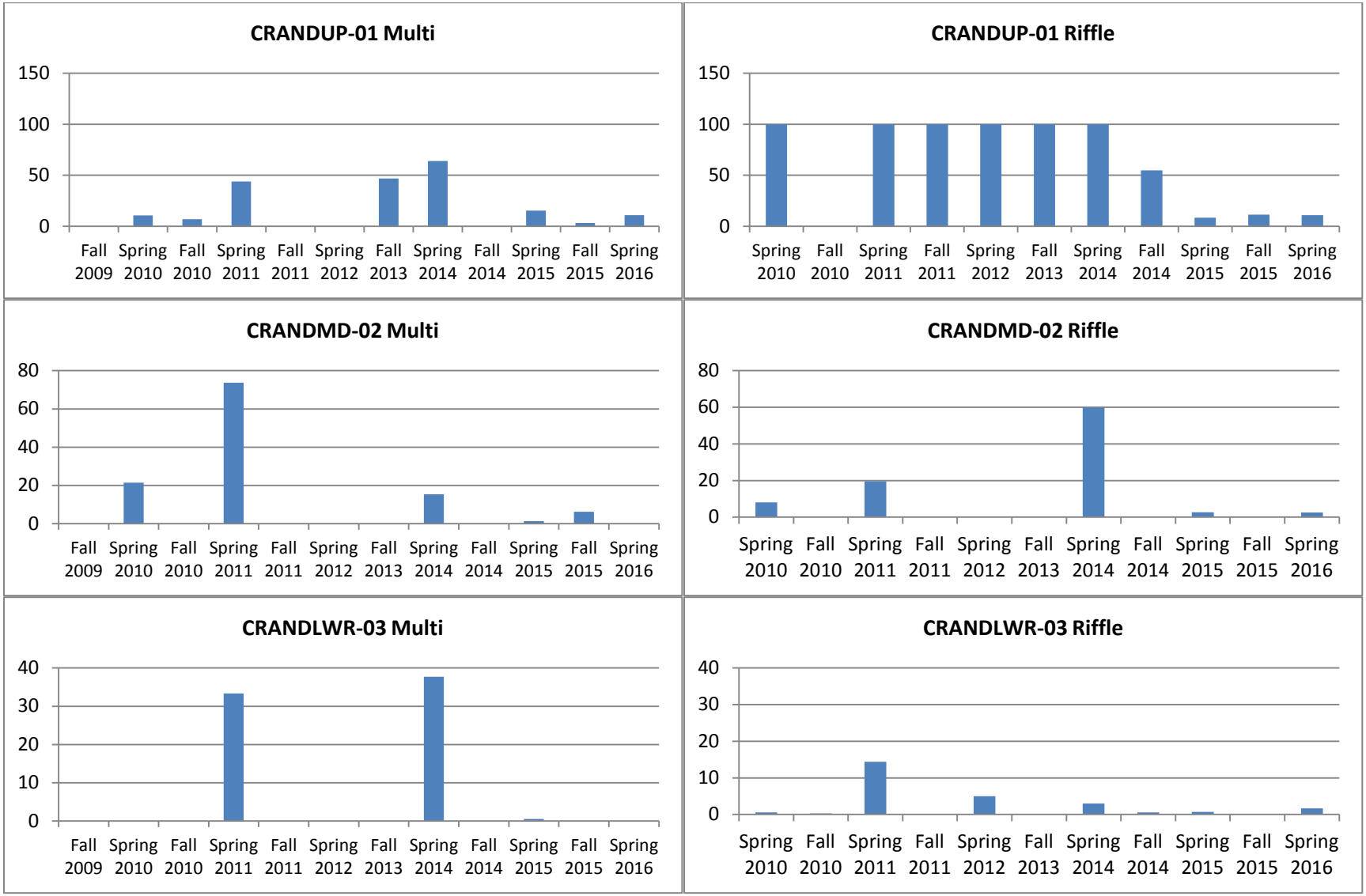
Figures 20c. Percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2010-2016



Figures 21c. Percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2010-2016



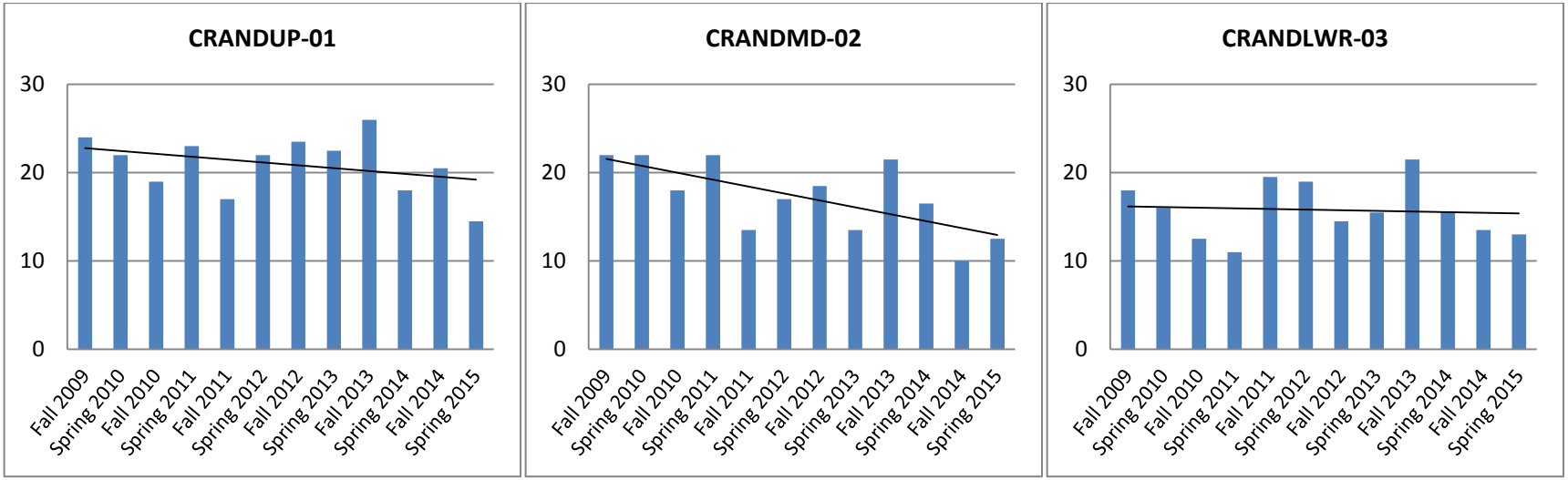
Figures 22c. Percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2010-2016



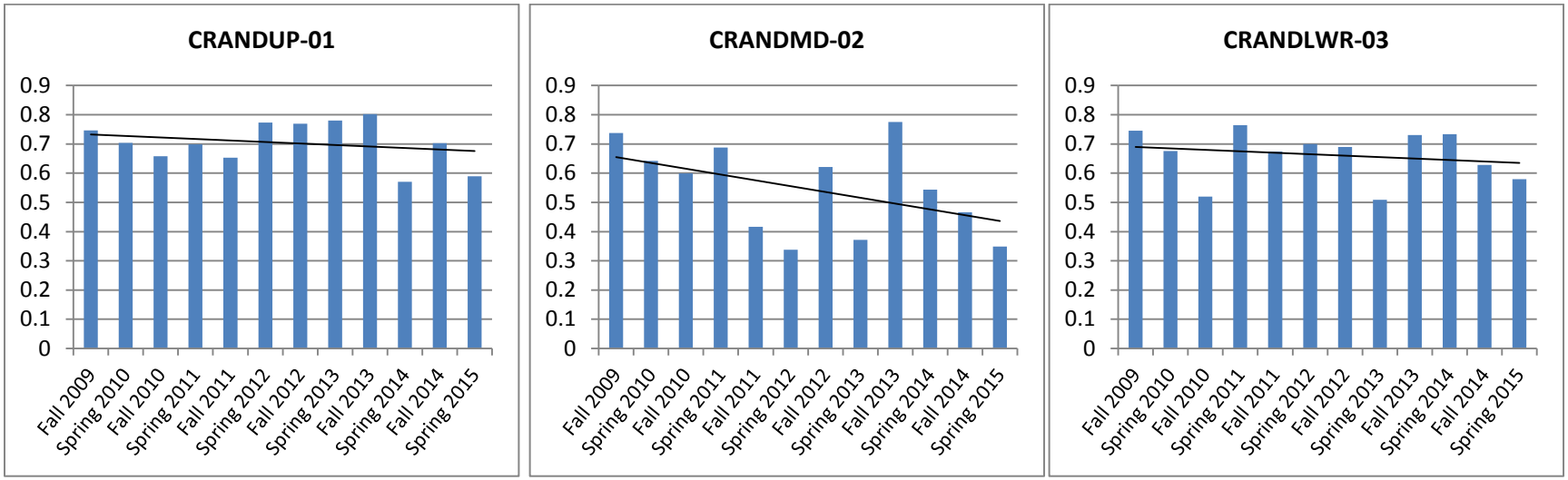
APPENDIX D

MACROINVERTEBRATE FIGURES FALL 2009- SPRING 2016 AVERAGED

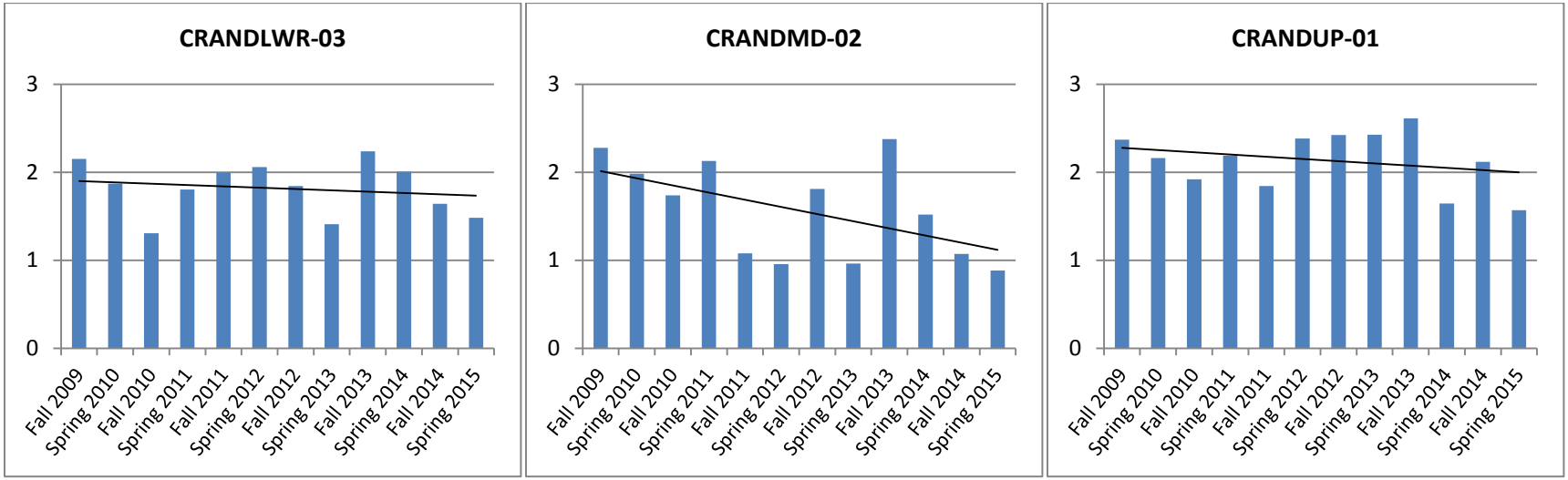
Figures 1d. Average richness in each reach from Fall 2009- Spring 2016



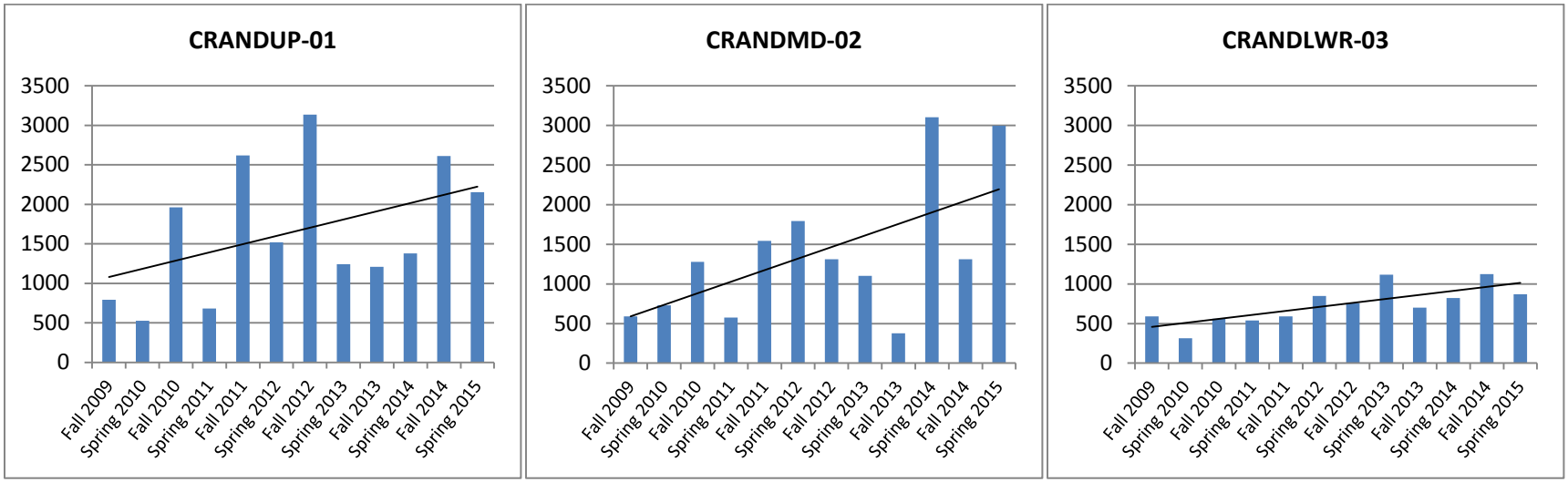
Figures 2d. Average evenness in each reach from Fall 2009- Spring 2016



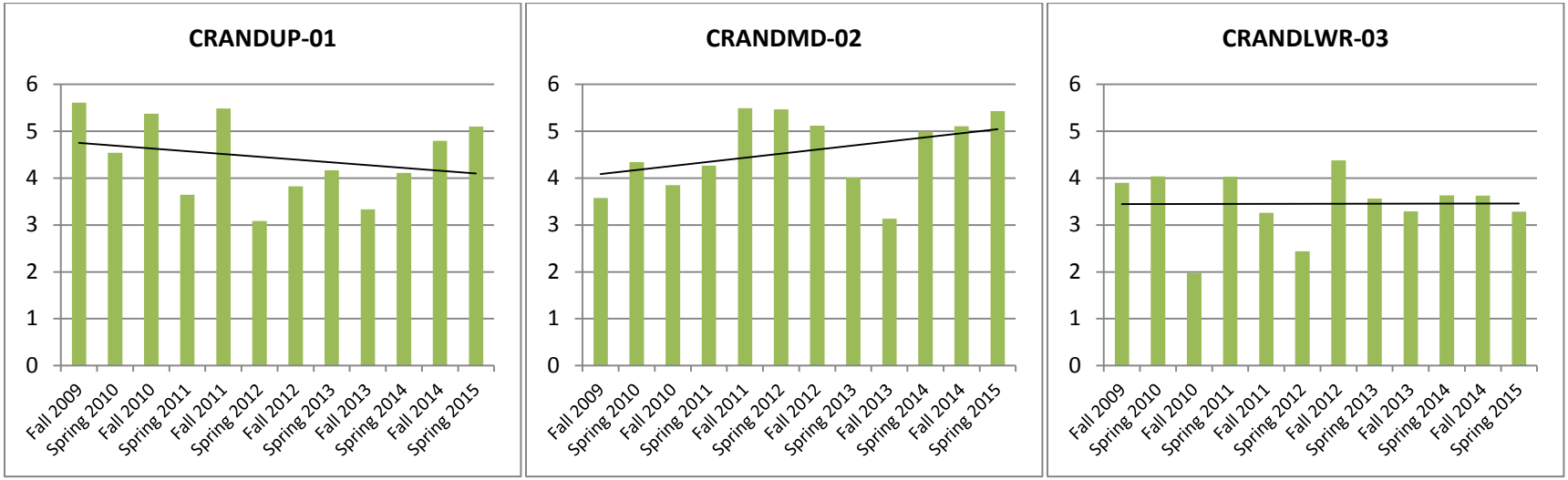
Figures 3d. Average Shannon's Diversity in each reach from Fall 2009- Spring 2016



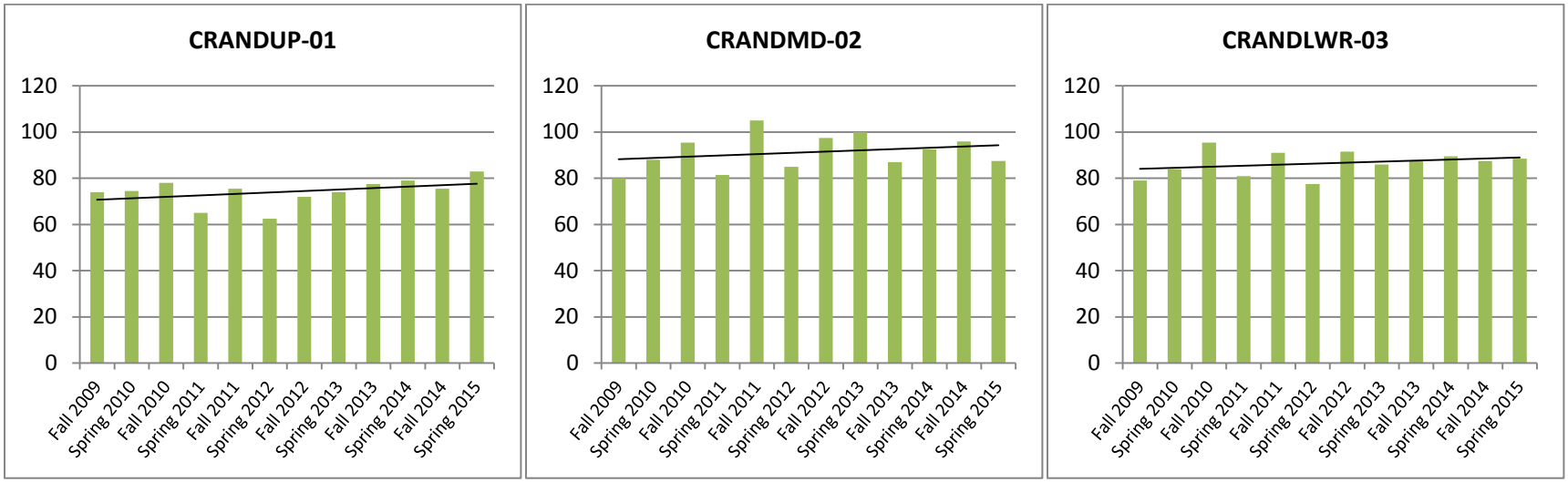
Figures 4d. Average abundance in each reach from Fall 2009- Spring 2016



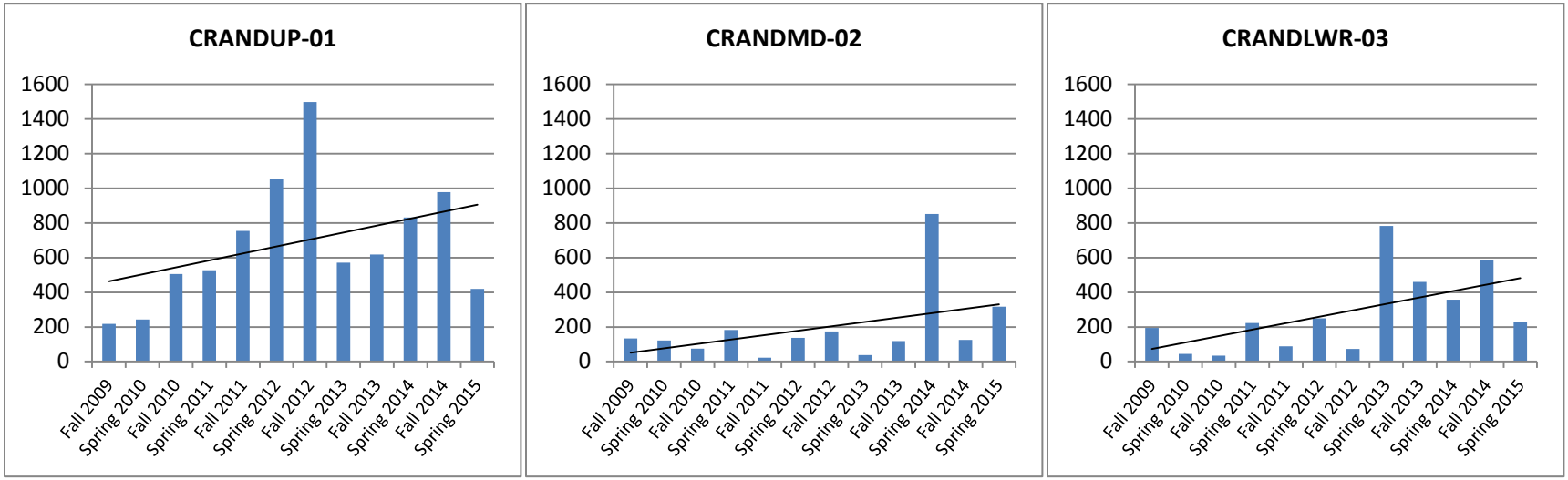
Figures 5d. Average Hilsenhoff Biotic Index in each reach from Fall 2009- Spring 2016



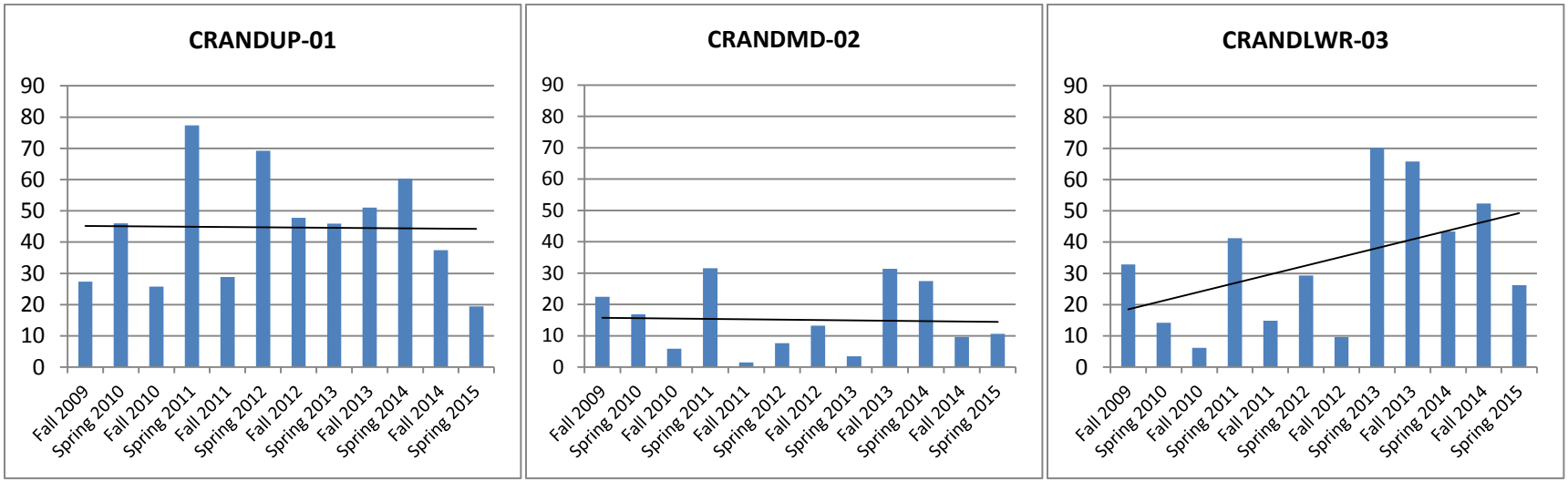
Figures 6d. Average USFS community tolerant quotient (CTQd) in each reach from Fall 2009- Spring 2016



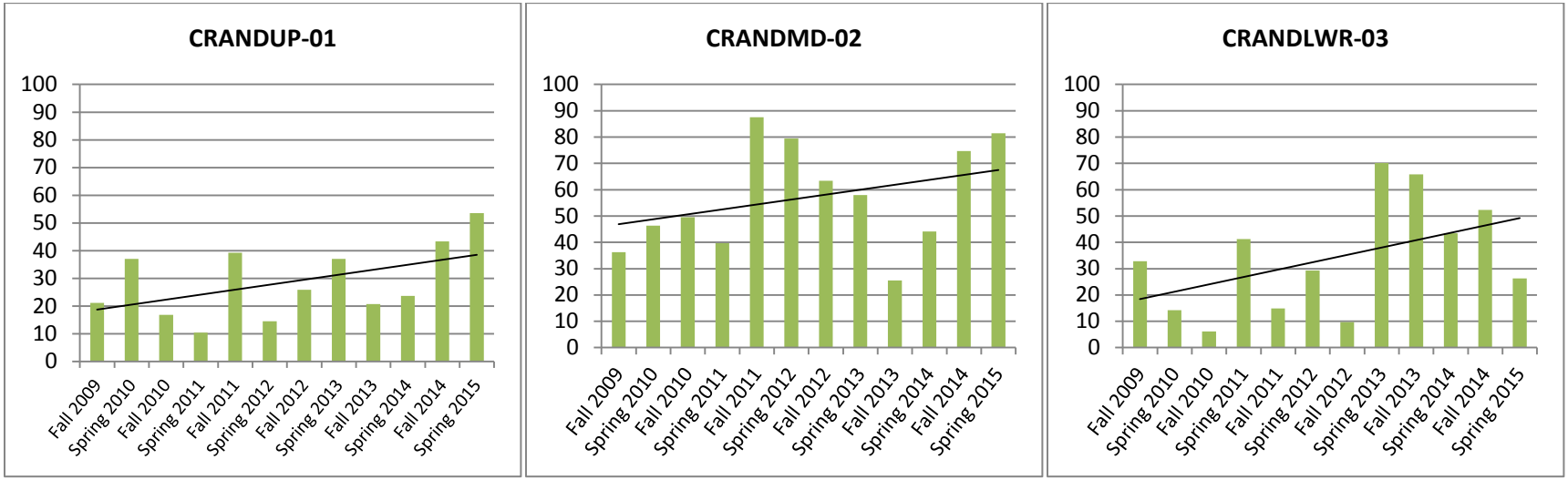
Figures 7d. Average EPT taxa abundance in each reach from Fall 2009- Spring 2016



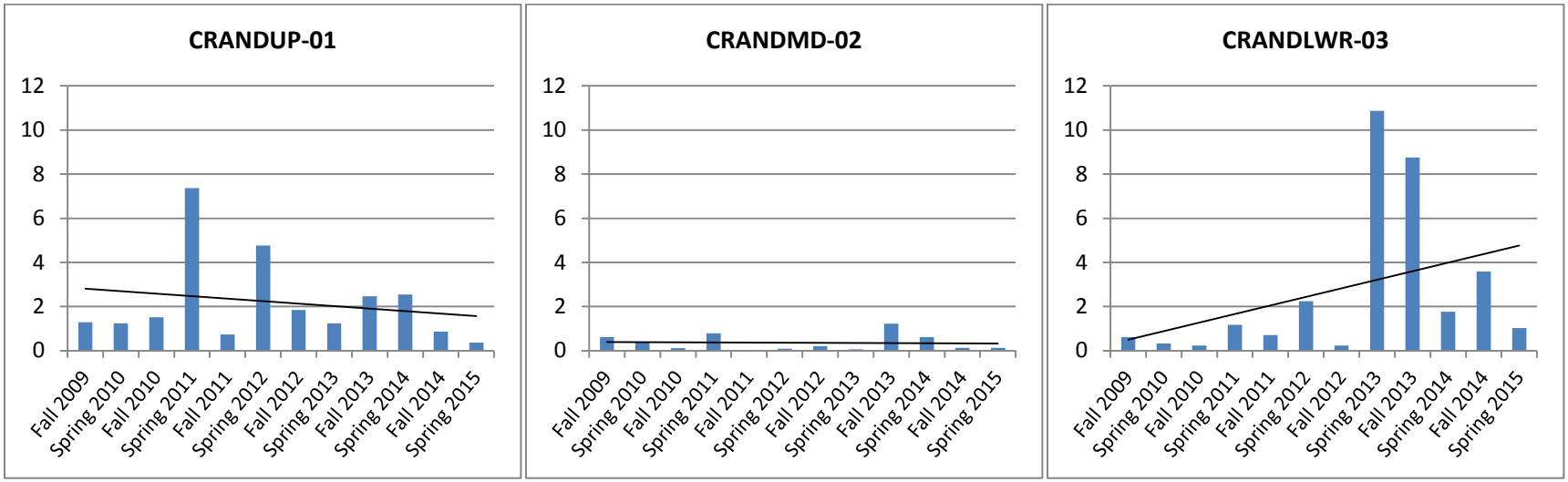
Figures 8d. Average percent EPT in each reach from Fall 2009- Spring 2016



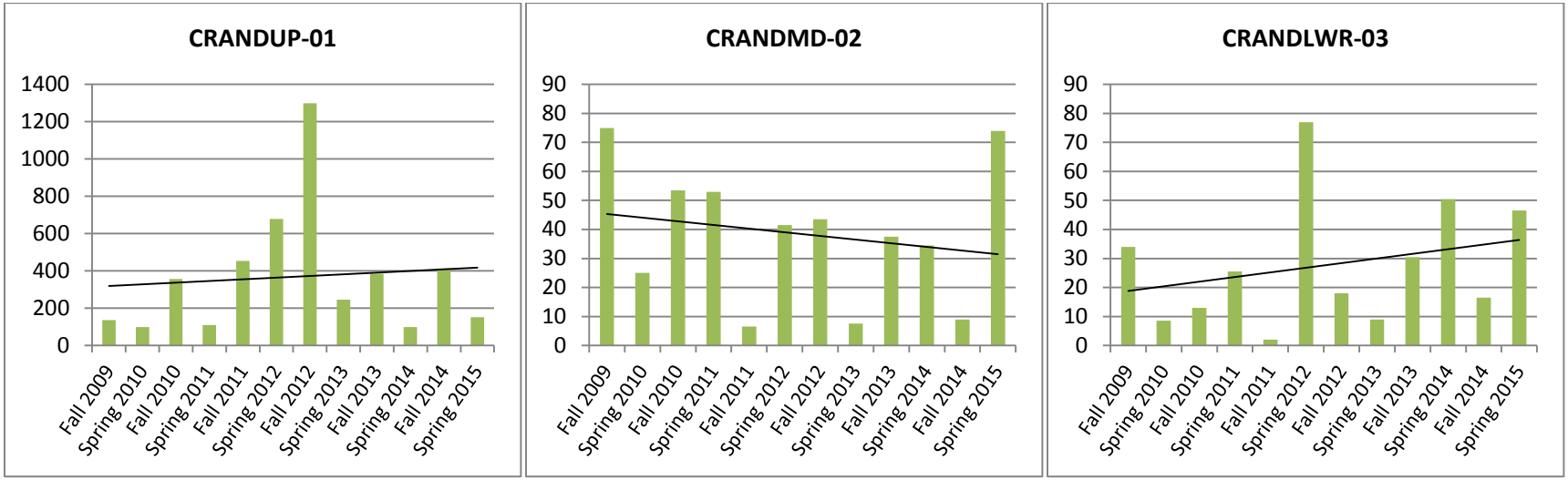
Figures 9d. Average percent Chironomids in each reach from Fall 2009- Spring 2016



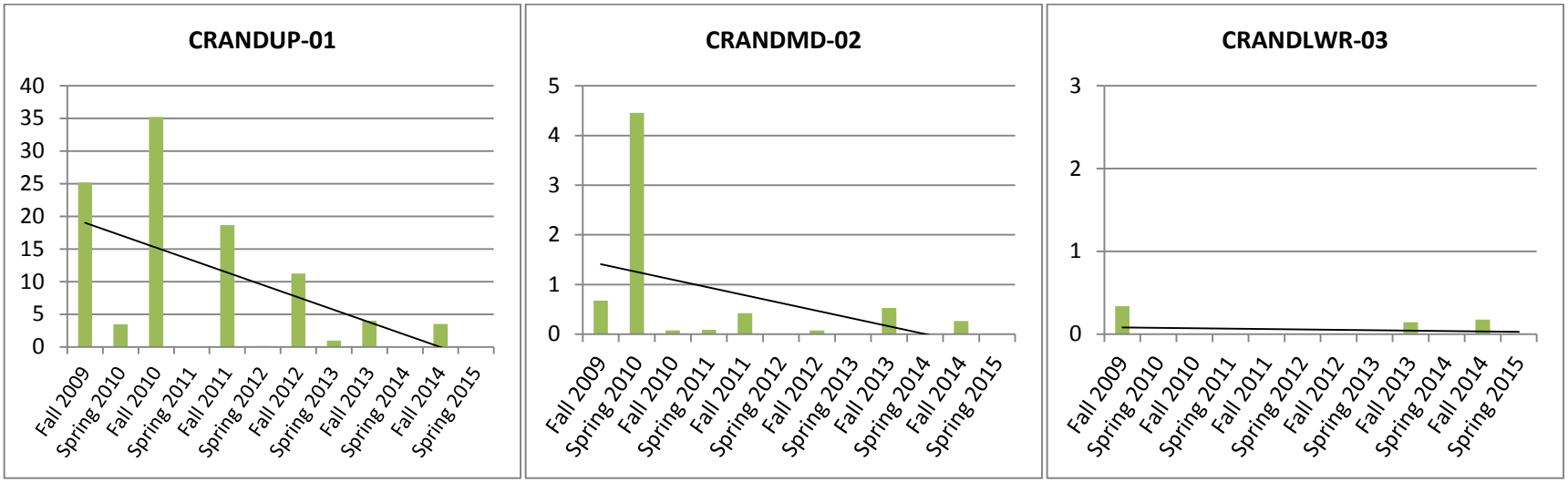
Figures 10d. Average ratio of EPT to Chironomids in each reach from Fall 2009- Spring 2016



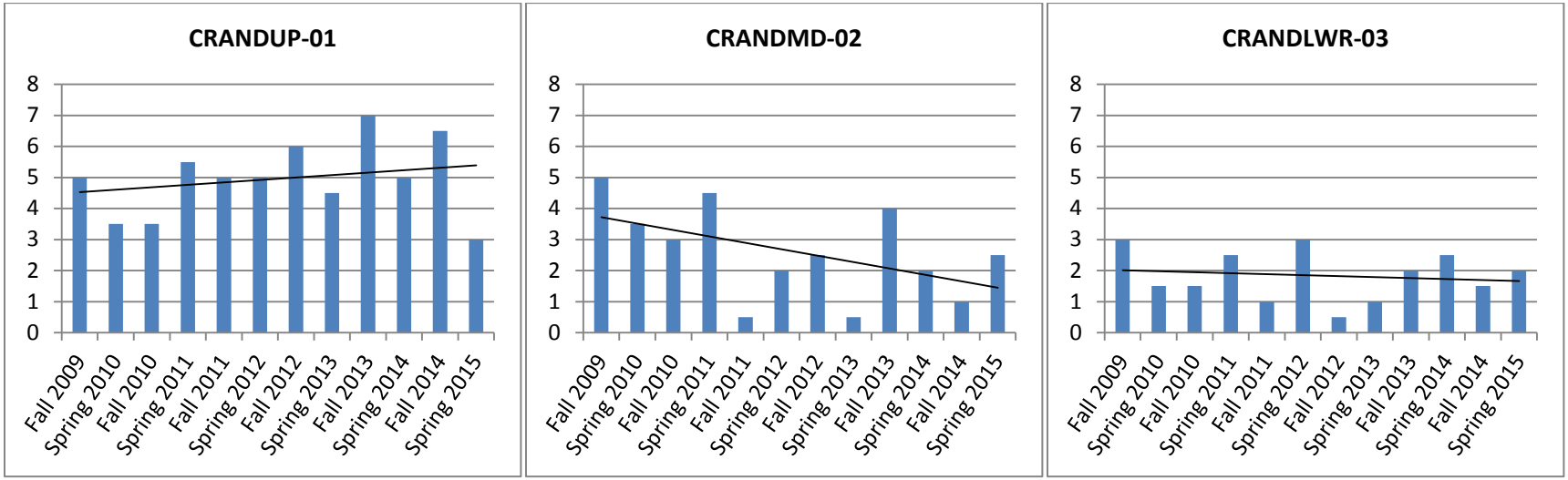
Figures 11d. Average number of tolerant taxa in each reach from Fall 2009- Spring 2016



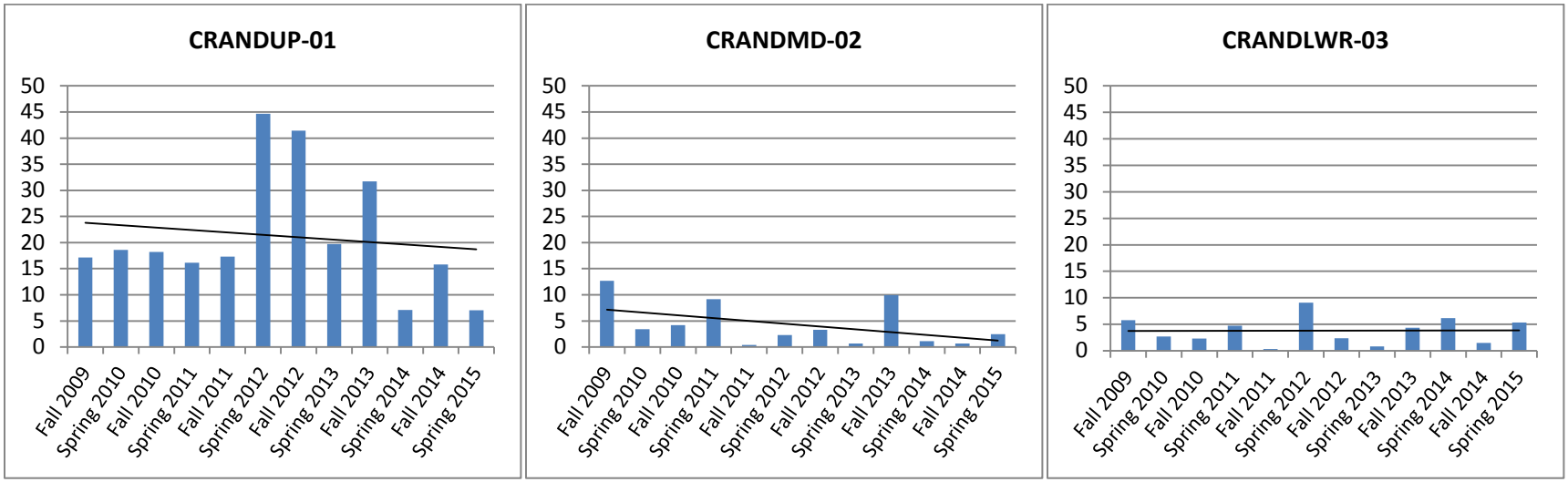
Figures 12d. Average percent tolerant organisms in each reach from Fall 2009- Spring 2016



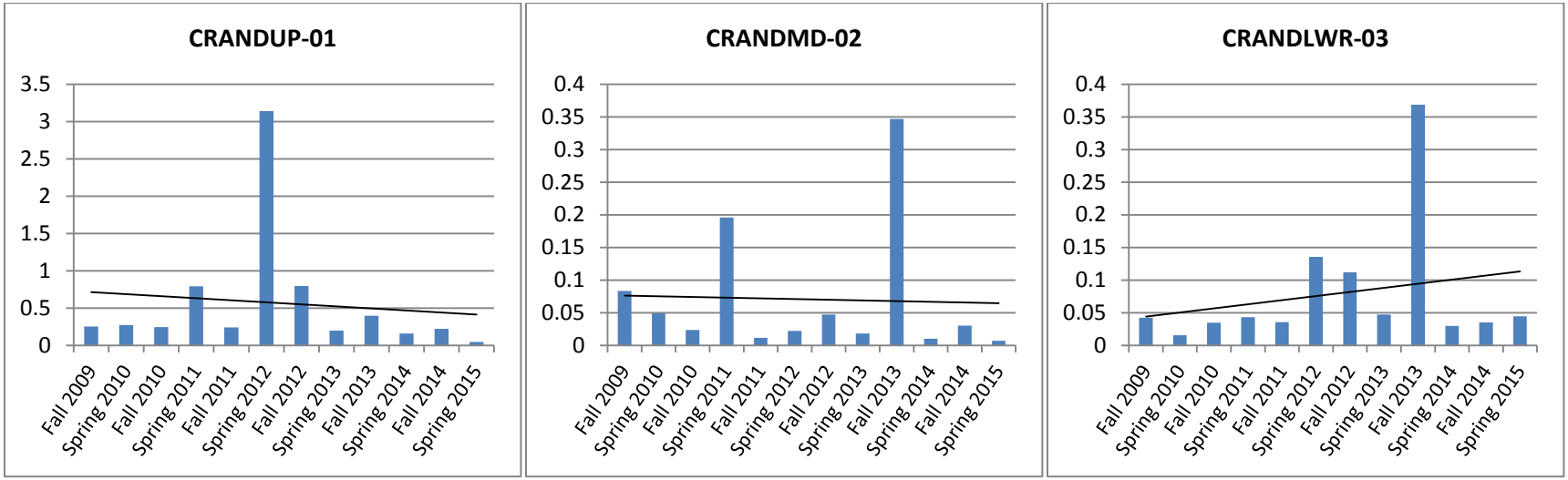
Figures 13d. Average number of intolerant taxa in each reach from Fall 2009- Spring 2016



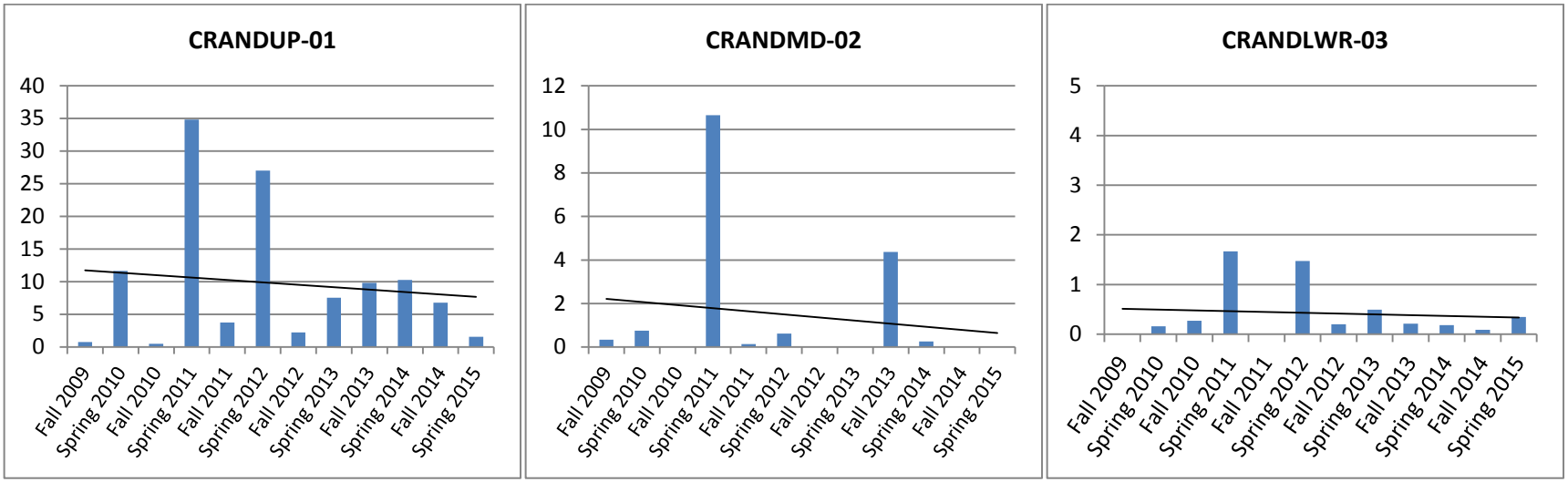
Figures 14d. Average percent intolerant organisms in each reach from Fall 2009- Spring 2016



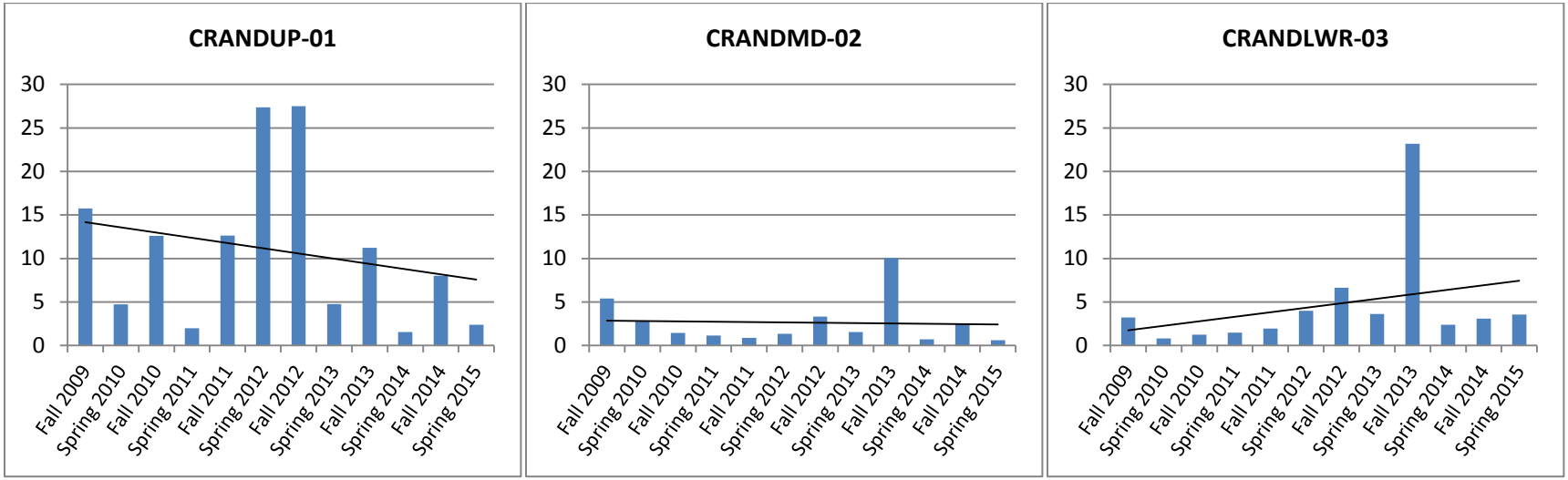
Figures 15d. Average ratio of specialist feeders to generalist feeders in each reach from Fall 2009- Spring 2016



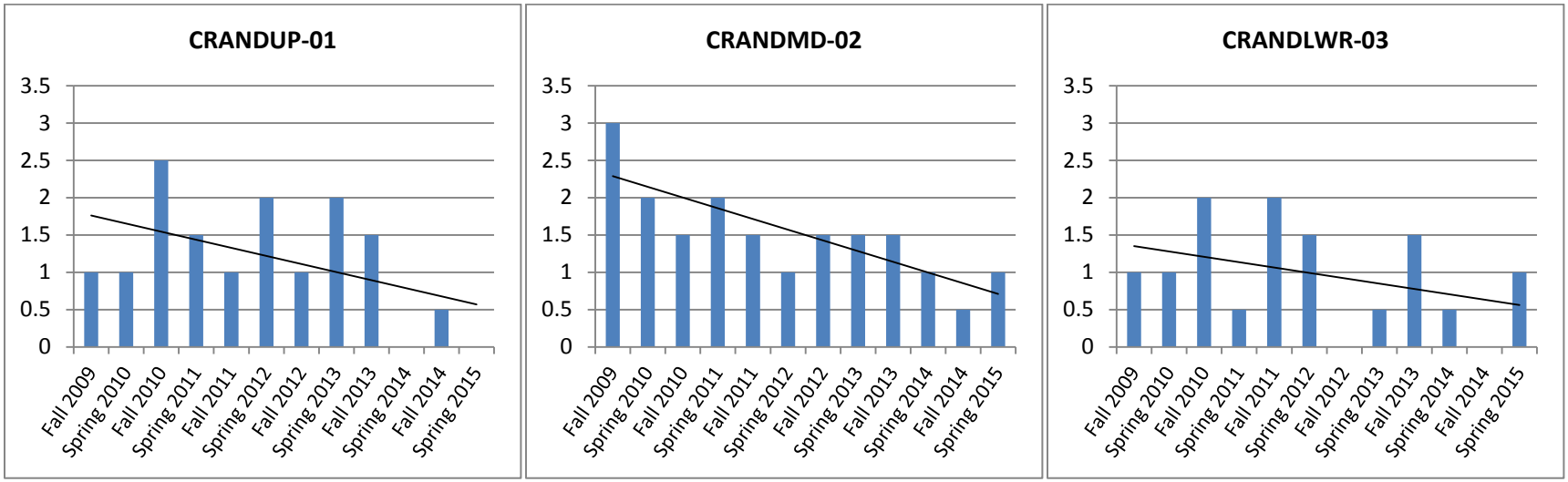
Figures 16d. Average percent scrapers in each reach from Fall 2009- Spring 2016



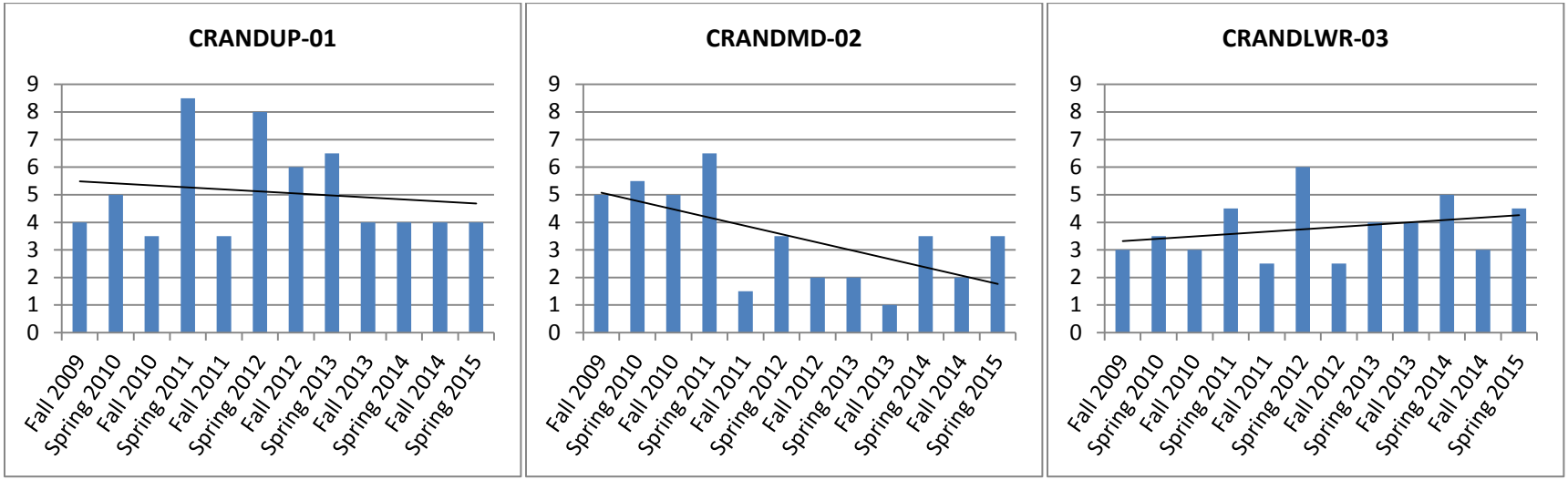
Figures 17d. Average percent shredders in each reach from Fall 2009- Spring 2016



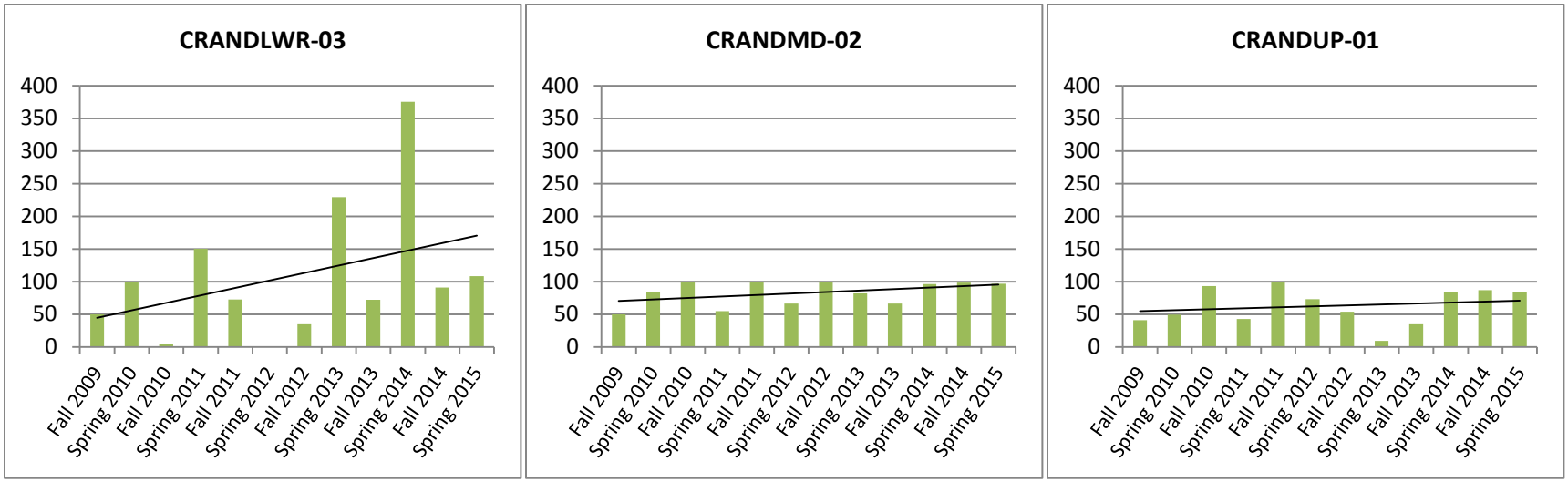
Figures 18d. Average number of long-lived taxa in each reach from Fall 2009- Spring 2016



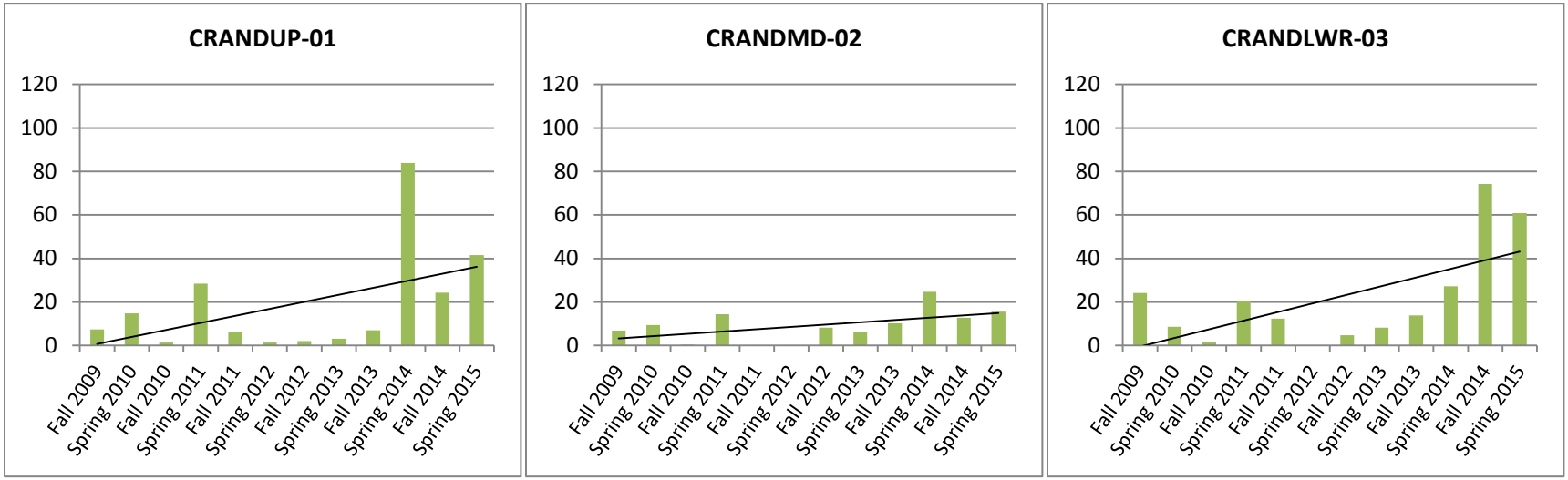
Figures 19d. Average number of clinger taxa reach from Fall 2009- Spring 2016



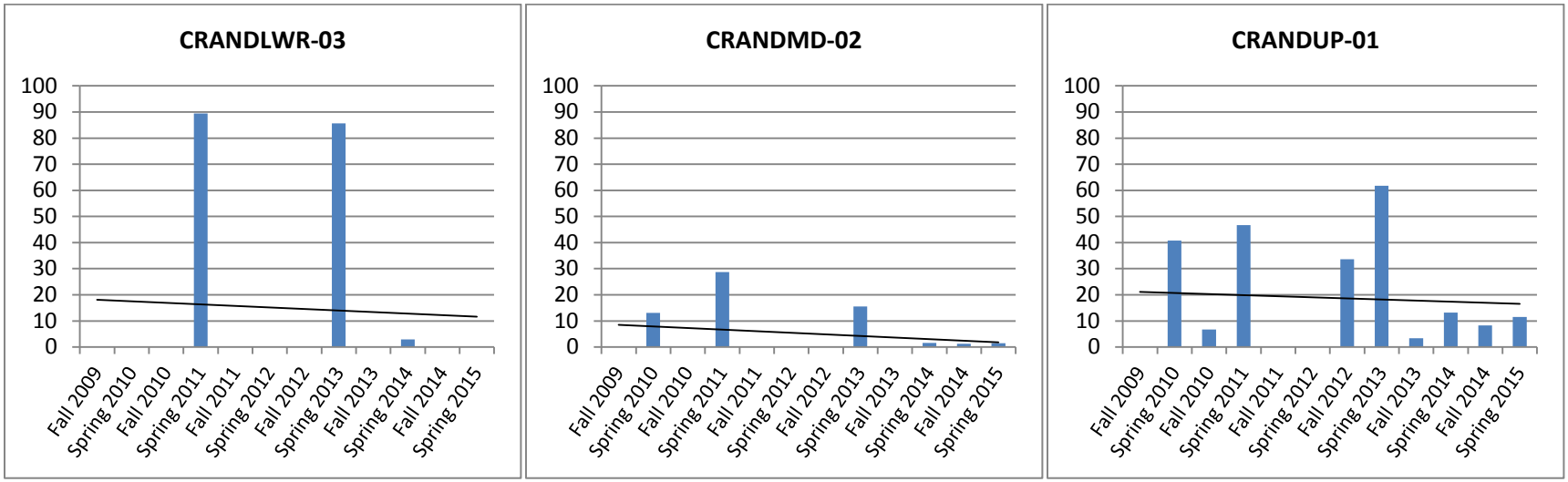
Figures 20d. Average percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2009-2016



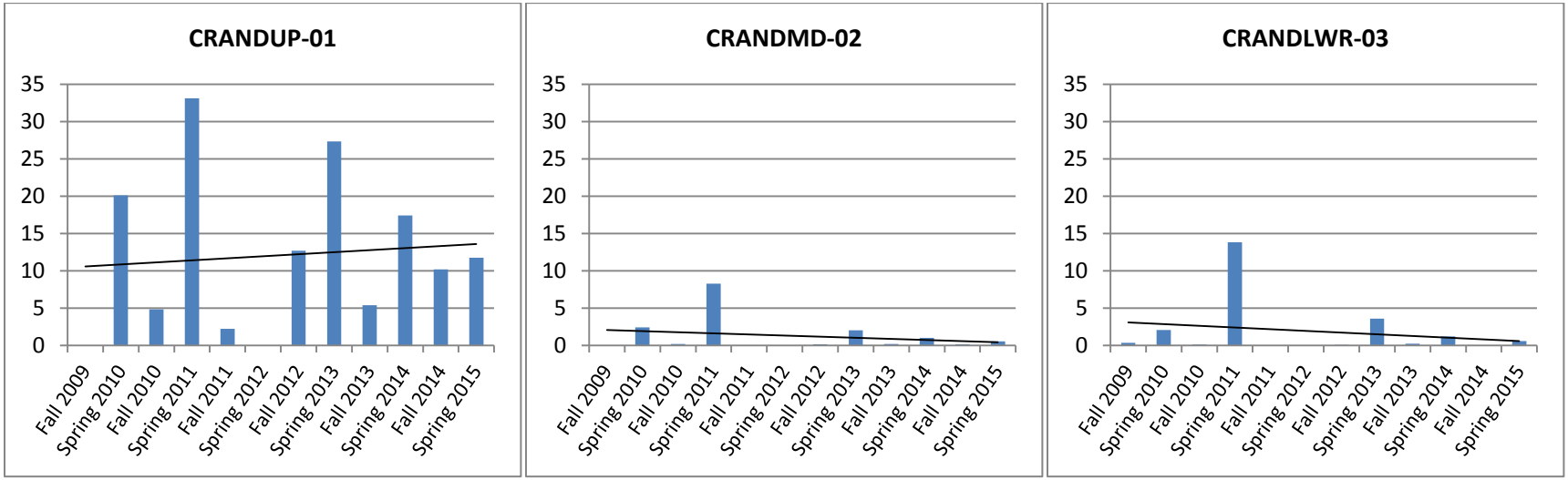
Figures 21d. Average percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2016



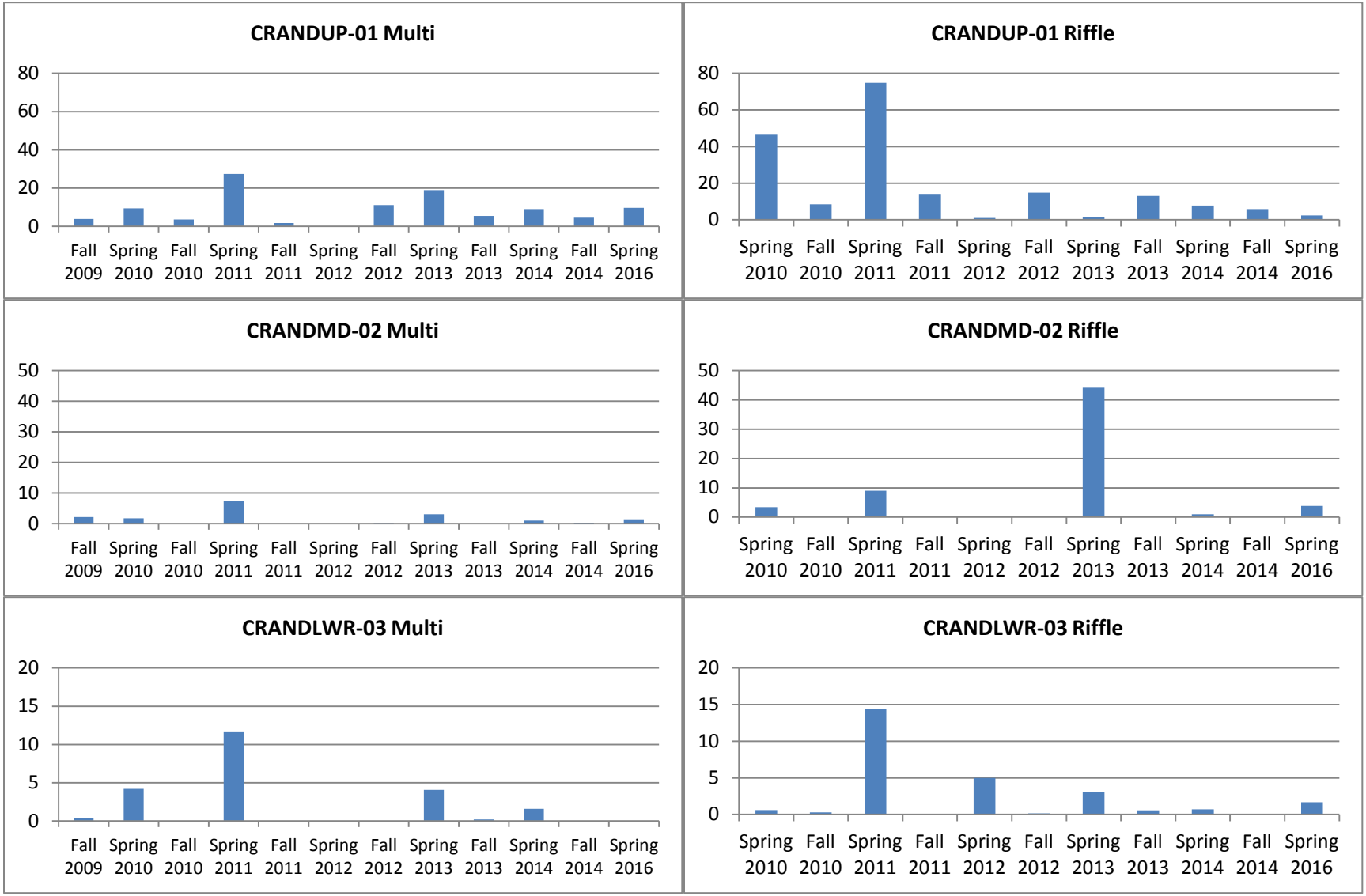
Figures 22d. Average percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2016



Figures 23d. Average percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2016



Figures 23c. Percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2016



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 16th and 17th, 2016. 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						4	133
Arthropoda	Arachnida	Trombidiformes					6	31
			Lebertiidae		Lebertia		5	7
			Sperchonidae		Sperchon		4	4
			Torrenticolidae		Torrenticola		1	255
	Insecta	Coleoptera	Dytiscidae	Agabinae	Agabus		1	9
			Elmidae		Narpus	concolor	2	66
					Optioservus		2	8
			Haliplidae		Brychius		1	4
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		4	4
			Chironomidae				3	7
				Chironominae			4	2
				Orthocladiinae			6	4
				Tanypodinae			2	22
			Empididae				2	42
					Neoplasta		6	46
				Hemerodromiinae	Chelifera		6	348
			Psychodidae		Pericoma		1	4030
			Simuliidae				1	127
				Simuliinae	Prosimulium		1	17
					Simulium		6	167
			Stratiomyidae				1	176
			Tipulidae		Dicranota		3	53
				Limoniinae	Antocha	monticola	2	14
					Limnophila		1	194
				Tipulinae	Tipula		2	134
		Ephemeroptera	Ameletidae		Ameletus		1	190
			Baetidae				1	4
					Baetis		6	32
					Diphetor	hageni	2	75
			Ephemerellidae		Drunella		2	4
						grandis	1	9
			Heptageniidae		Cinygmula		3	2
					Epeorus		2	58
			Leptophlebiidae		Paraleptophlebia		1	17
		Plecoptera	Chloroperlidae	Chloroperlinae	Suwallia		1	28
			Nemouridae				1	1635
					Zapada		2	82
						cinctipes	1	40
				Amphinemurinae			3	276
					Amphinemura		1	60
			Perlodidae				1	2
				Isoperlinae	Isoperla		3	57
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche	elsis	1	15
				Hydropsychinae	Hydropsyche		2	18
			Limnephilidae				1	90
				Limnephilinae	Hesperophylax		1	9
					Psychoglypha		1	126
			Rhyacophilidae		Rhyacophila		6	18
						angelita group	4	36
						rotunda group	1	7
						vofixa group	3	135
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		2	13
Total:	Taxa:	**53**	Families:	**25**	Genera:	**34**		**8942**

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 17th, 2016 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, 78.25% was identified and retained. A total of 559 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 154329. OTU= Operational Taxonomic Unit

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	17
Arthropoda	Arachnida	Trombidiformes					Adult	11
			Lebertiidae		Lebertia		Adult	36
			Sperchonidae		Sperchon		Adult	17
	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	14
			Chironomidae				Pupae	8
				Chironominae			Larvae	19
				Orthocladiinae			Larvae	679
			Empididae		Neoplasta		Larvae	19
				Hemerodromiinae	Chelifera		Larvae	14
			Psychodidae		Pericoma		Larvae	3
			Simuliidae	Simuliinae	Simulium		Larvae	336
			Tipulidae		Dicranota		Larvae	6
				Limoniinae	Antocha	monticola	Larvae	6
				Tipulinae	Tipula		Larvae	22
		Ephemeroptera	Baetidae		Baetis		Larvae	124
			Ephemerellidae		Drunella		Larvae	3
			Heptageniidae		Cinygmula		Larvae	16
			Leptophlebiidae		Paraleptophlebia		Larvae	3
		Plecoptera	Nemouridae		Zapada		Larvae	19
						cinctipes	Larvae	6
			Nemouridae	Amphinemurinae			Larvae	17
			Perlodidae				Larvae	11
				Isoperlinae	Isoperla		Larvae	22
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche	elsis	Larvae	5
			Rhyacophilidae		Rhyacophila		Larvae	3
			Rhyacophilidae			angelita gı	Larvae	6
						vofixa gro	Larvae	130
Total:	OTU Taxa:	**28**	Families:	**18**	Genera:	**18**		**1572**

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 17th, 2016 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, 31.25% was identified and retained. A total of 631 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 154330. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes					Adult	4
			Lebertiidae		Lebertia		Adult	30
			Sperchonidae		Sperchon		Adult	13
	Insecta	Coleoptera	Dytiscidae	Agabinae	Agabus		Adult	4
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	22
			Chironomidae	Chironominae			Larvae	17
				Orthocladiinae			Larvae	1578
				Tanypodinae			Larvae	4
			Empididae		Neoplasta		Larvae	52
				Hemerodromiinae	Chelifera		Larvae	65
			Simuliidae	Simuliinae	Prosimulium		Larvae	17
					Simulium		Larvae	441
			Tipulidae	Tipulinae	Tipula		Larvae	17
		Ephemeroptera	Ameletidae		Ameletus		Larvae	9
			Baetidae		Baetis		Larvae	346
			Ephemerellidae		Drunella	grandis	Larvae	1
			Heptageniidae		Cinygmula		Larvae	39
					Epeorus		Larvae	4
		Plecoptera	Nemouridae				Larvae	17
					Zapada		Larvae	4
		Trichoptera	Rhyacophilidae		Rhyacophila		Larvae	30
						rotunda group	Larvae	6
						vofixa group	Larvae	17
Total:	OTU Taxa:	**23**	Families:	**14**	Genera:	**16**		**2737**

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 16th, 2016 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, 87.50% was identified and retained. A total of 561 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 154331. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	17
Arthropoda	Arachnida	Trombidiformes					Adult	25
			Lebertiidae		Lebertia		Adult	25
	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	7
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	7
			Chironomidae				Pupae	17
				Chironominae			Larvae	7
				Orthocladiinae			Larvae	1028
			Empididae		Neoplasta		Larvae	7
				Hemerodromiinae	Chelifera		Larvae	5
			Simuliidae				Pupae	5
				Simuliinae	Simulium		Larvae	7
			Tipulidae		Dicranota		Larvae	7
		Ephemeroptera	Baetidae		Baetis		Larvae	164
			Ephemerellidae		Drunella		Larvae	2
		Plecoptera	Nemouridae	Amphinemurinae	Amphinemura		Larvae	10
		Trichoptera	Limnephilidae				Larvae	27
				Limnephilinae	Psychoglypha		Larvae	2
			Rhyacophilidae		Rhyacophila		Larvae	10
						angelita group	Larvae	17
						vofixa group	Larvae	2
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	5
Total:	OTU Taxa:	**22**	Families:	**13**	Genera:	**13**		**1407**

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 16th, 2016 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, 18.75% was identified and retained. A total of 635 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 154332. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	108
Arthropoda	Arachnida	Trombidiformes					Adult	14
			Lebertiidae		Lebertia		Larvae	22
	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	14
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	43
			Chironomidae				Pupae	29
				Orthocladiinae			Larvae	3791
				Tanypodinae			Larvae	7
			Empididae				Pupae	7
					Neoplasta		Larvae	79
				Hemerodromiinae	Chelifera		Larvae	29
			Simuliidae	Simuliinae	Simulium		Larvae	29
			Stratiomyidae				Larvae	7
			Tipulidae		Dicranota		Larvae	7
		Ephemeroptera	Baetidae		Baetis		Larvae	285
			Heptageniidae		Epeorus		Larvae	7
		Trichoptera			Rhyacophila		Larvae	50
						angelita group	Larvae	56
Total:	OTU Taxa:	**18**	Families:	**10**	Genera:	**10**		**4586**

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 16th, 2016 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 552 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 154333. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes					Adult	2
			Lebertiidae		Lebertia		Adult	2
			Sperchonidae		Sperchon		Adult	11
			Torrenticolidae		Torrenticola		Adult	2
	Insecta	Coleoptera	Elmidae		Optioservus		Larvae	2
		Diptera	Chironomidae	Chironominae			Larvae	4
				Orthocladiinae			Larvae	200
			Empididae		Neoplasta		Larvae	4
				Hemerodromiinae	Chelifera		Larvae	33
			Simuliidae	Simuliinae	Simulium		Larvae	17
			Tipulidae	Limoniinae	Limnophila		Larvae	9
		Ephemeroptera	Baetidae		Baetis		Larvae	93
					Diphetor	hageni	Larvae	89
		Plecoptera	Nemouridae	Amphinemurinae			Larvae	41
			Perlodidae	Isoperlinae	Isoperla		Larvae	9
		Trichoptera	Hydropsychidae	Hydropsychinae	Hydropsyche		Larvae	4
			Limnephilidae	Limnephilinae	Hesperophylax		Larvae	4
			Rhyacophilidae		Rhyacophila		Larvae	4
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	667
Total:	OTU Taxa:	**19**	Families:	**15**	Genera:	**15**		**1200**

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 16th, 2016 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 400 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 154334. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	32
Arthropoda	Arachnida	Trombidiformes					Adult	1
			Sperchonidae		Sperchon		Adult	12
	Insecta	Coleoptera	Elmidae		Optioservus		Larvae	1
			Haliplidae		Brychius		Larvae	1
		Diptera	Chironomidae	Orthocladiinae			Larvae	242
			Empididae				Pupae	3
					Neoplasta		Larvae	11
				Hemerodromiinae	Chelifera		Larvae	19
			Simuliidae	Simuliinae	Simulium		Larvae	1
			Tipulidae	Limoniinae	Antocha	monticola	Larvae	5
		Ephemeroptera	Baetidae				Larvae	1
					Baetis		Larvae	142
					Diphetor	hageni	Larvae	9
			Heptageniidae		Cinygmula		Larvae	1
		Plecoptera	Chloroperlidae	Chloroperlinae	Suwallia		Larvae	1
			Nemouridae	Amphinemurinae			Larvae	16
			Perlodidae	Isoperlinae	Isoperla		Larvae	7
		Trichoptera	Hydropsychidae	Hydropsychinae	Hydropsyche		Larvae	18
			Rhyacophilidae		Rhyacophila		Larvae	8
						angelita group	Larvae	7
Total:	OTU Taxa:	**21**	Families:	**14**	Genera:	**14**		**541**

Crandall Canyon Mine Macroinvertebrate Study Fall 2016

March 2017

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1.0 INTRODUCTION

EIS Environmental & Engineering Consulting (EIS) collected benthic macroinvertebrate samples from Crandall Creek on September 22nd and 23rd, 2016. The creek is located near Huntington, Utah. From 2009 to 2012, the creek was sampled by JBR Environmental Consultants, Inc. (JBR). Samples were collected from three different reaches of Crandall Creak. These three reaches were located directly upstream of the Crandall Canyon mine (CRANDUP-01), in the middle reach (CRANDMD-02) which is immediately downstream of the mine's discharge location, and a lower reach (CRANDLWR-03) located at the end of the creek before the confluence of Crandall Creek and Huntington Creek. Each reach was 150 meters long.

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

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

1.1 Background

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

In 2009, DOGM required the mine to contract a qualified biologist to sample macroinvertebrates in Crandall Creek twice yearly (Spring and Fall) to monitor water quality and provide reports

documenting the survey results. The first seven surveys were completed by JBR (JBR 2012). They included surveys from the Fall of 2009 until the Fall of 2012. EIS has since completed two surveys a year (Spring and Fall) starting in the Spring of 2013. This report provides the results of the Fall survey of 2016. The samples were collected September 22nd and 23rd, 2016. 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 23rd, 2016 - Upstream

CRANDMD-02 September 23rd, 2016– Upstream

CRANDLWR-03 September 22nd, 2016 - 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 Courtwright 2016) 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 2016) are incorporated into the tables of the following appendices. As with assessment, multiple metrics and datasets should be relied upon to make a finding of whether any impact or nonimpact has occurred between the mine's groundwater discharge and Crandall Creek. Numerous metrics should be used in evaluating what may be happening in the creek. In this study, the natural variability of any of these metrics is not known due to limited number of samples sites, absence of replicates, and partial historical baseline information. Therefore, it is difficult to determine whether there is an impact between sites from analyzing only one metric. This section and its associated appendices will review these metrics within this season's individual sample, spatially among each reach and habitat type, and any temporal changes since 2009. In the appendices, a blue colored graph is used when an increase in values indicate a more desirable habitat. A green colored graph is used when the lower the number, or a decline, specifies a healthier steam. Data is compared from the reference reach (CRANDUP-01) to the other two reaches. Additionally, a comparison between the middle reach directly below the mine (CRANDMD-02) and the lowest reach (CRANDLWR-03) can be made to assess the spatial limit and overall condition. The metrics evaluated include the various measurement types recommended by EPA (Barbour et al 1999). They include tolerance indices (HBI, CTQd), diversity (Shannon's), community composition (% EPT), and functional feeding groups (Percent Scraper/Shredders).

Appendix A of the report includes a summarization of the raw and standardized data for the samples collected in September 2016. The following Appendices (B-D) graph the previously mentioned matrices to show a visual comparison. Appendix B begins with a graph showing the distribution of the dominate orders within each reach and sample type (Figure 1b) as well as the numerical values (Table 1b). It is followed by numerous graphs that represent the Fall 2016 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 46 operational taxonomic units (OTU) were identified in the Fall 2016 sample set. There were 25 families and 31 genera present. The insect orders most commonly found in

macroinvertebrate communities were found in each reach, orders Diptera, Ephemeroptera, Plecoptera, and Trichoptera. The order Coleoptera was only found in the middle reach, located directly below the mine. Non-insect invertebrates were also identified in all of the six samples.

The richness value is used to evaluate the community structure and stream health based on the number of distinct taxa. The decrease in the number of distinct taxa could indicate a decline in water quality. In the upper reach multi habitat there was 20 distinct taxa found and 18 found in the riffle habitat. In both habitat types in the middle reach there were 12 distinct taxa found in the sample. In the lower reach there were 13 distinct taxa found in the multi habitat and 12 in the riffle.

A dominance of any single order or taxon greater than 50 percent suggests environmental stress. The data indicated that most reaches and habitat types had one dominate order that made up the sample, with the exception of the upper reach riffle habitat. In the upper reach multi habitat, Diptera made up 55 percent of the sample and 49 percent of the riffle habitat. In the middle reach multi habitat Diptera made up 61 percent and the riffle habitat sample was composed of 76 percent of the same order. In the lower reach, both habitat types were dominated by the Ephemeroptera order, the multi habitat sample had 82 percent and the riffle had 74 percent (Figure 1b, Table 1b). The order Diptera may suggest an impaired condition, whereas the order Ephemeroptera is one that is commonly considered sensitive to pollution (Karr & Chu 1999).

As mentioned previously, the order Ephemeroptera is considered sensitive and can be an indicator of stream health, similar with the orders Plecoptera and Trichoptera (EPT). In the upper reach the orders EPT made up 39.3 percent of the multi habitat and 46.2 percent of the riffle habitat. In the middle reach, EPT made up 10.1 in the multi habitat and 9.5 percent in the riffle habitat. In the lowest reach, EPT made up a majority of the sample with 94 percent of the multi habitat and 88 percent of the riffle habitat (Figure 9b).

A number of tolerance (biotic) indices were also evaluated among the six samples. Individual taxa have been assigned a value based on their tolerance to a number of pollutants; some of these include nutrient levels, temperature, and fine sediments. The Hilsenhoff Biotic Index (HBI) was developed to measure the tolerance certain taxa have to such pollutants. HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 indicates polluted conditions. Taxon with a value of <2 are considered an ‘intolerant’ taxa and require clean water conditions. All of the reaches and habitats had HBI values between 3.85 and 4.89, which indicates slightly enriched to enriched condition, however, each reach also contained at least one intolerant taxa found in the sample (Figure 14b).

The three reaches sampled all have overall habitat characteristics that could be influencing the results of this study. The upper reach is the section used as the reference point as it has likely not

been impacted by the operations of the mine. This section of the steam is very narrow compared to the middle reach (located directly below the mine), and is comparable to the lowest reach. Both the upper and middle reaches are only a few feet wide, whereas in the middle reach a significant part of it is composed of beaver dams and the stream is far greater than 10 feet wide. The substrates in both the upper and lower reaches are largely composed of bedrock overlaid with large cemented rock, whereas the middle rich is largely composed of fine sandy sediment and muck. This lack of interstitial spaces can result in poorer habitat conditions for macroinvertebrates (Mize and Deacon 2002). The upper and lower reaches have a very heavy overstory of willows and other trees and the middle section is generally more open to the elements. It is important to note that the changes in the stream morphology of Crandall Creek as a whole is continuing to change. There seems to be more colonization of beaver and subsequent dams each year.

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 since 2012, 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 found in Appendix B display the differences between the two habitats within this dataset (September 2016). The graphs in Appendix C display the temporal trends of between the two habitat types since 2009.

In this seasons dataset, in the upper reach there was 20 distinct taxa (richness) found in the multi habitat whereas there were 18 found in the riffle habitat. In the middle reach, both habitat types had 12 distinct taxa in the sample. In the lower reach, the multi habitat had 13 distinct taxa and the riffle sample had 12 (Figure 2b). The richness values do not indicate significant difference between the two habitat types.

Shannon's Diversity (Shannon-Wiener Diversity Index) is a measure of community structure and examines the relationship between the number of distinct taxa and their relative abundances.

The numbered value is found to decrease with increasing amount of perturbation. In the upper reach multi habitat the Shannon's Diversity was found to be 2.40, whereas it was 1.75 in the riffle. In the middle reach it was found to be 1.79 in the multi and 1.43 in the riffle. In the lowest reach it was found to be 1.20 in the multi and 1.11 in the riffle (Figure 3b). Although not substantial, it does appear that the multi habitats within each reach have a higher value, which could indicate that those habitats may have a better community structure.

Evenness is the measure of distribution of taxa within a community. The values range from 0-1 and the lower the value suggests that a single taxon is becoming more dominate, which may indicate poor stream quality. In the upper reach multi habitat the evenness value was found to be 0.74 and 0.70 in the riffle habitat. In the middle reach multi habitat evenness was found to be 0.80 and .55 in the riffle habitat. In the lowest reach, the multi habitat had an evenness value of 0.49 and the riffle habitat had a value of 0.38 (Figure 4b). As with Shannon's diversity, while not considerable, the multi habitat does appear to have slightly higher values in all the three reaches.

The overall abundance of the habitat types within each reach were also provided to us by the Buglab. The abundance in the upper reach multi habitat was found to be 268 and 228 in the riffle habitat. In the middle reach it was found to be 135 in the multi habitat and 59 in the riffle habitat. In the lower reach the abundance was found to be 1023 in the multi habitat and 2496 in the riffle habitat. In this instance, the upper and middle multi habitats did have a higher abundance than their riffle habitats, however the opposite was found in the lower habitat (Figure 5b).

The Hilsenhoff Biotic Index (HBI) can also be used to determine the tolerance of macroinvertebrates to pollutants. As with other indices, families are given a value from 0 to 10 whereas the higher the number is, the more tolerant that family is to severely pollutant water. The HBI in the upper reach multi habitat was found to be 4.90 and 4.82 in the riffle habitat. In the middle reach multi habitat it was 4.04 and 4.68 in the riffle habitat. In the lower reach multi habitat it was 3.86 and 4.20 in the riffle habitat (Figure 6b). There was no discernable trend in comparing HBI in the multi and riffle habitats.

The USFS Community Tolerance Quotient (CTQd) is another value found to measure quality of water. Taxa are assigned a number from 2, which indicate high quality unpolluted waters, up to 108, which would indicate taxa that can only live in highly polluted waters. In the upper reach multi habitat the CTQd value was found to be 72 and 83 in the riffle habitat. In the middle reach multi habitat the value was found to be 100 and 92 in the riffle habitat. In the lowest reach the CTQd in the multi habitat was 78 and 85 in the riffle habitat (Figure 7b).
More specific detail on all the values and metrics provided are graphed in Appendices A and B for visual comparison. In addressing any temporal or spatial trends, both the riffle and multi

habitat results were averaged and those values were used (Appendix D).

4.2 Spatial Variation in Macroinvertebrate Community

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

In the richness metrics, the upper reach had 19 distinct taxa, averaged between the multi and riffle habitats. In the middle reach there was 12 distinct taxa found, and in the lower reach there was 12.5 (Figures 1d). The average evenness for the upper reach was 0.71, in the middle reach it was 0.65, and in the lower reach it was 0.42 (Figures 2d). The averaged Shannon's Diversity in the upper reach was 2.08, it was 1.62 in the middle reach, and 1.06 in the lowest reach Figures 3d). The average abundance in the upper reach this sample was found to be 653, in the middle reach it was 180, and in the lower reach it was 2385 (Figures 4d).

In the tolerance (biotic) indices where the lower values indicate more desirable conditions, the HBI was found to be 4.86 in the upper reach, 4.36 in the middle reach, and 4.03 in the lower reach (Figures 5d). The CTQd in the upper reach was 77.5, in the middle reach it was 96, and in the lowest reach it was 81.5 (Figures 6d).

The average number of the pollution sensitive orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) abundance was found to be 273 in the upper reach, 18 in the middle reach, and 2137.5 in the lowest reach (Figures 7d). The orders EPT made up a total of 42 percent of total taxa in the upper reach, 10 percent in the middle reach, and 41 percent in the lower reach (Figure 8d).

Overall, it appears that the quality of water in the middle and lower reaches may be in decline when compared to the upper reach. However, the lower reach biotic values indicate more desirable conditions as well as had considerably higher overall abundance than the other two reaches. In discussing the spatial variations of the three reaches it is important to revisit the overall characteristics of the middle reach. It would be difficult to say with any certainty whether the declining water quality is a result of the mine operations or the middle reaches overall habitat differing considerably from that of the upper and lower habitats. The middle reach has large sections that have been becoming increasingly damned by beaver and debris over the years, resulting in slower water flow and a substrate that consists of fine sandy sediment rather than the swifter flows and concreted substrate found in the other two reaches. These conditions and other underlying factors present in the middle reach could be adding to the less favorable conditions.

found in the macroinvertebrate community.

4.3 Temporal Variation in Macroinvertebrate Community

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

The upper reach, which should not have any impact due to the mine's operations, has had great variability within the metrics graphed and evaluated. The average richness shows a declining trend, in 2009 there were 24 distinct taxa, these values have fluctuated over the years, in this sample the average was 19 (Figures 1d). The average evenness is also indicating unfavorable conditions over the years, in 2009 the average evenness was 0.75 and in this sample it was 0.71 (Figures 2d). The Shannon's Diversity value in 2009 was 2.37, has fluctuated greatly through the years (went up to 2.61 in the Fall 2013 sample) and is currently 2.08 in this sample (Figures 3d). The average abundance also has dropped considerably in this sample, from numbers in the thousands in prior years, to 653 in this sample (Figures 4d). Of the 23 metrics graphed, 15 indicated less desirable conditions in the upper reach of the stream, 6 indicated favorable or improving conditions, and 2 indicated stable conditions (Appendix D).

The middle reach also has had variation within the metrics throughout the years. In the Fall 2009 and Spring 2010 samples, there were an average of 22 distinct taxa, fluctuated throughout the years, and this sample provided only 11 distinct taxa (Figures 1d). The evenness value was similar, in the 2009 sample it was 0.74 and has slowly been declining to the current value of 0.41 (Figures 2d). Out of the 23 graphed metrics, 17 indicated declining conditions in the middle reach, 4 indicated increasing conditions, and 2 indicated stable conditions since 2009 (Appendix D).

The lowest reach has shown signs of improved conditions as compared to the middle reach. As with the other two reaches, the numbers have varied greatly throughout the years. The number of distinct taxa was 18 in 2009, went up to 22 in the Fall 2013 sample, had is currently at 13 (Figures 1d). The evenness value in 2009 was 0.74 and was found to be 0.60 in this sample. The average abundance has gone up over the years. In the Fall 2009 sample it was 590 and in this sample it was 997. The HBI value has also indicated improved conditions throughout the years, in 2009 it was 3.90 and this sample found the value to be 3.46 (decrease indicates improving conditions). Of the 23 metrics graphed; 13 indicated a declining trend, 8 indicated increasing quality, and 2 indicated stable conditions (Appendix D).

5.0 CONCLUSION

The samples for the 2016 Fall Macroinvertebrate Study were collected on September 22nd and 23rd, 2016 from each of the three reaches of Crandall Creek. The upper reach is located upstream from the mine and is should not be influenced from ground water discharge from the mine, therefore it is considered as a reference of how conditions should be. The middle and lower reaches are below the mine water discharge. The objective of the survey was to collect macroinvertebrate samples as indicators of water quality in Crandall Creek. The samples collected were sorted and identified to the lowest taxa possible by the BugLab. Abundances of taxa and community composition relationships from the samples are provided to assess the water quality of Crandall Creek.

The survey results show variability among all the sampled reaches and generally show reduced habitat quality and less than optimal conditions in all sampled locations, even the upper reach, which has not been impacted by the mine operations and is therefore considered to be the a reference for the lower two reaches. If the reference reach is declining, similar results can be expected downstream. With that said, while the sample indicates that the middle reach is declining in water quality, there were metrics present that indicated improvement as well. As were comparable results in the lower reach, the metrics generally indicated less than favorable conditions than the upper reach, however there are many metrics indicating increasing condition since this study began in 2009.

The data for all three reaches fluctuate from year to year and season to season. It is important to note that the substrate and habitat differs greatly between reaches and should be taken into consideration in the results. The changes in stream morphology due to increased beaver dams in the middle reach should also be considered, as well as the environmental impacts from the fire in 2012 and catastrophic flooding in Huntington Canyon as a result.

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APPENDIX A

BUGLAB REPORT

Report prepared for:

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December 15, 2016

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
155473	CRANDUP-01	9/23/2016	Reachwide	Kick net	0.46	100	382
155474	CRANDUP-01	9/23/2016	Targeted Riffle	Kick net	0.74	100	352
155475	CRANDMD-02	9/23/2016	Reachwide	Kick net	0.46	100	127
155476	CRANDMD-02	9/23/2016	Targeted Riffle	Kick net	0.74	100	62
155477	CRANDLWR-03	9/22/2016	Reachwide	Kick net	0.46	100	599
155478	CRANDLWR-03	9/22/2016	Targeted Riffle	Kick net	0.74	25	640

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
155473	9/23/2016	CRANDUP-01 Multi	830	326	Chironomidae	34.10
155474	9/23/2016	CRANDUP-01 Riffle	476	220	Chironomidae	37.39
155475	9/23/2016	CRANDMD-02 Multi	276	28	Chironomidae	47.10
155476	9/23/2016	CRANDMD-02 Riffle	84	8	Chironomidae	64.29
155477	9/22/2016	CRANDLWR-03 Multi	1302	1224	Baetidae	82.49
155478	9/22/2016	CRANDLWR-03 Riffle	3468	3051	Baetidae	74.31
Mean			1072.7	809.5		56.61

Diversity Indices

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

Sample ID	Collection Date	Station	Total taxa richness	Total genera richness	Total family richness	EPT taxa richness
155473	9/23/2016	CRANDUP-01 Multi	28	24	18	14
155474	9/23/2016	CRANDUP-01 Riffle	23	21	16	13
155475	9/23/2016	CRANDMD-02 Multi	16	12	13	3
155476	9/23/2016	CRANDMD-02 Riffle	13	11	12	4
155477	9/22/2016	CRANDLWR-03 Multi	20	18	12	11
155478	9/22/2016	CRANDLWR-03 Riffle	16	15	12	8
Mean			19.3	16.8	13.8	8.833333

Table 5a. Diversity indicies based on standardized OTU

Sample ID	Collection Date	Station	Total taxa richness	EPT taxa richness	Shannon diversity index	Evenness
155473	9/23/2016	CRANDUP-01 Multi	20	10	2.316605	0.773302
155474	9/23/2016	CRANDUP-01 Riffle	18	10	1.852923	0.641067
155475	9/23/2016	CRANDMD-02 Multi	12	2	1.825444	0.734613
155476	9/23/2016	CRANDMD-02 Riffle	12	4	1.415715	0.569726
155477	9/22/2016	CRANDLWR-03 Multi	13	6	1.132351	0.441471
155478	9/22/2016	CRANDLWR-03 Riffle	12	5	0.999604	0.40227
Mean			14.5	6	1.59044	0.593741

Table 6a. Genera richness by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
155473	9/23/2016	CRANDUP-01 Multi	0	10	3	0	0	0	6	5	0	0	0
155474	9/23/20156	CRANDUP-01 Riffle	0	8	5	0	0	0	3	5	0	0	0
155475	9/23/2016	CRANDMD-02 Multi	1	7	1	0	0	0	1	1	0	0	1
155476	9/23/2016	CRANDMD-02 Riffle	1	6	1	0	0	0	1	2	0	0	0
155477	9/22/2016	CRANDLWR-03 Multi	0	6	3	0	0	0	3	5	1	0	0
155478	9/22/2016	CRANDLWR-03 Riffle	0	6	2	0	0	0	1	5	0	0	1
Mean			0.3	7.2	2.5	0.0	0.0	0.0	2.5	3.8	0.2	0.0	0.3

Table 7a. Total Abundance by major taxonomic group

Sample ID	Collection Date	Station	Coleoptera	Diptera	Ephemerotpera	Heteroptera	Megaloptera	Odonata	Plecoptera	Trichoptera	Annelida	Custacea	Mollusca
155473	9/23/2016	CRANDUP-01 Multi	0	459	98	0	0	0	130	98	0	0	0
155474	9/23/2016	CRANDUP-01 Riffle	0	235	159	0	0	0	22	39	0	0	0
155475	9/23/2016	CRANDMD-02 Multi	2	167	7	0	0	0	2	20	0	0	9
155476	9/23/2016	CRANDMD-02 Riffle	3	64	1	0	0	0	3	4	0	0	0
155477	9/22/2016	CRANDLWR-03 Multi	0	37	1074	0	0	0	43	107	28	0	0
155478	9/22/2016	CRANDLWR-03 Riffle	0	395	2577	0	0	0	22	453	0	0	5
Mean			1	226	653	0	0	0	37.0	120.0	4.7	0.0	2.4

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
155473	9/23/2016	CRANDUP-01 Multi	4.896667	Some organic pollution	72
155474	9/23/2016	CRANDUP-01 Riffle	4.823333	Some organic pollution	83
155475	9/23/2016	CRANDMD-02 Multi	4.043103	Some organic pollution	100
155476	9/23/2016	CRANDMD-02 Riffle	4.677419	Some organic pollution	92
155477	9/22/2016	CRANDLWR-03 Multi	3.856667	Potential slight organic pollution	78
155478	9/22/2016	CRANDLWR-03 Riffle	4.196667	Some organic pollution	85
Mean			4.415643		85.00

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	Intolerant Taxa Percent	Intolerant Taxa Abundance	Intolerant Taxa Percent	Tolerant Taxa Richness	Tolerant Taxa Percent	Tolerant Taxa Abundance	Tolerant Taxa Percent
155473	9/23/2016	CRANDUP-01 Multi	6	30	222	27	1	5	0	0
155474	9/23/2016	CRANDUP-01 Riffle	6	33	55	12	1	6	0	0
155475	9/23/2016	CRANDMD-02 Multi	1	8	2	1	1	8	0	0
155476	9/23/2016	CRANDMD-02 Riffle	2	17	5	6	0	0	0	0
155477	9/22/2016	CRANDLWR-03 Multi	2	15	46	4	0	0	0	0
155478	9/22/2016	CRANDLWR-03 Riffle	1	8	27	1	0	0	0	0
Mean			3.0	19	59.5	8	0.5	3	0.0	0

Functional Feeding Groups

Table 10a. Taxa richness by functional feeding groups

Sample ID	Collection Date	Station	Shredders		Scrapers		Collector-filterers		Collector-gatherers		Predators		Unknown	
			Richness	Percent	Richness	Percent	Richness	Percent	Richness	Percent	Richness	Percent	Richness	Percent
155473	9/23/2016	CRANDUP-01 Multi	5	25	0	0	2	10	2	10	6	30	5	25
155474	9/23/2016	CRANDUP-01 Riffle	2	11	0	0	2	11	2	11	6	33	6	33
155475	9/23/2016	CRANDMD-02 Multi	1	8	0	0	1	8	1	8	4	33	5	42
155476	9/23/2016	CRANDMD-02 Riffle	1	8	0	0	0	0	0	0	6	50	5	42
155477	9/22/2016	CRANDLWR-03 Multi	3	23	0	0	2	15	2	15	4	31	2	15
155478	9/22/2016	CRANDLWR-03 Riffle	0	0	1	8	2	17	2	17	3	25	4	33
Mean			2.0	12.6	0.2	1.4	1.5	10.2	1.5	10.2	4.8	33.7	4.5	31.7

Table 11a. Taxa abundance by functional feeding group

Sample ID	Collection Date	Station	Shredders		Scrapers		Collector-filterers		Collector-gatherers		Predators		Unknown	
			Abundance	Percent	Abundance	Percent	Abundance	Percent	Abundance	Percent	Abundance	Percent	Abundance	Percent
155473	9/23/2016	CRANDUP-01 Multi	83	10	22	3	15	2	320	39	391	47	0	0
155474	9/23/2016	CRANDUP-01 Riffle	9	2	12	3	9	2	342	72	103	22	1	0
155475	9/23/2016	CRANDMD-02 Multi	22	8	0	0	9	3	120	43	124	45	1	0
155476	9/23/2016	CRANDMD-02 Riffle	1	1	0	0	0	0	57	68	23	27	3	4
155477	9/22/2016	CRANDLWR-03 Multi	76	6	0	0	63	5	1109	85	54	4	0	0
155478	9/22/2016	CRANDLWR-03 Riffle	5	0	38	1	626	18	2685	77	114	3	0	0
Mean			32.7	4.5	12.0	1.0	120.3	5.0	772.2	64.1	134.8	24.7	0.8	0.7

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 2016

Figure 1b. Percent Predominant Taxonomic Groups Fall 2016 Samples

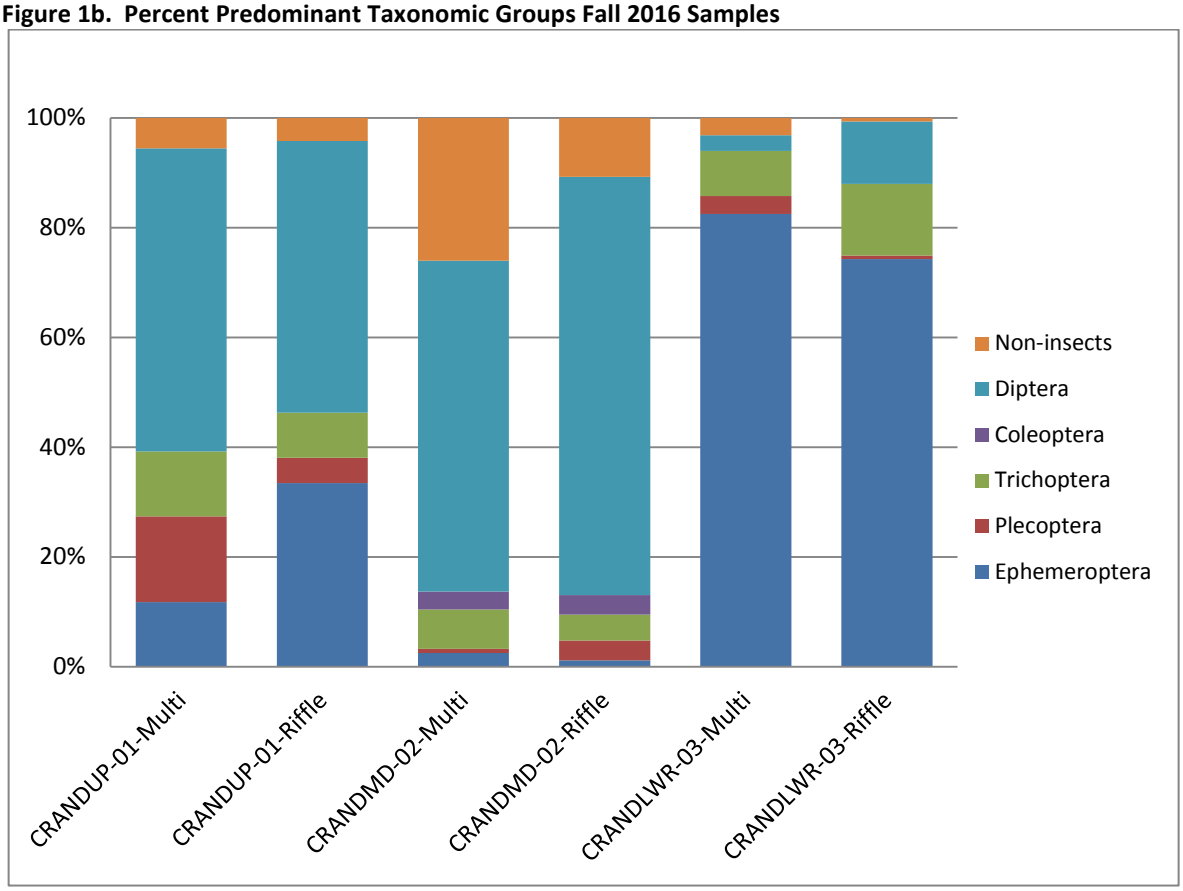


Table 1b. Percent Predominant Taxonomic Groups in the Fall 2016 Samples

	CRANDUP-01-Multi	CRANDUP-01-Riffle	CRANDMD-02-Multi	CRANDMD-02-Riffle	CRANDLWR-03-Multi	CRANDLWR-03-Riffle
Non-insects	6	4	26	11	3	1
Diptera	55	49	61	76	3	11
Coleoptera	0	0	3	4	0	0
Trichoptera	12	8	7	5	8	13
Plecoptera	16	5	1	4	3	1
Ephemeroptera	12	33	3	1	82	74

Figure 2b. Richness

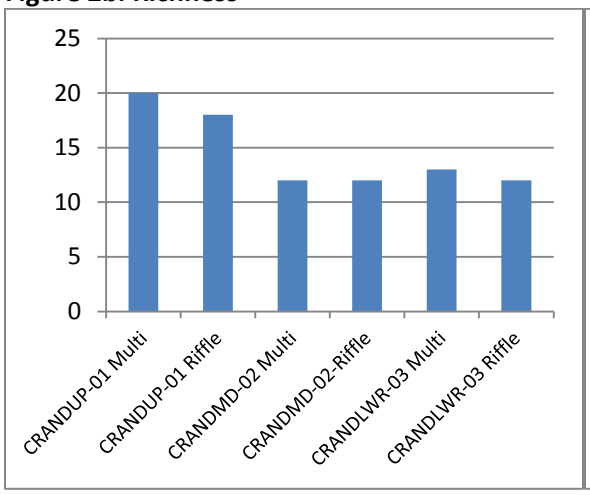


Figure 3b. Shannon's Diversity

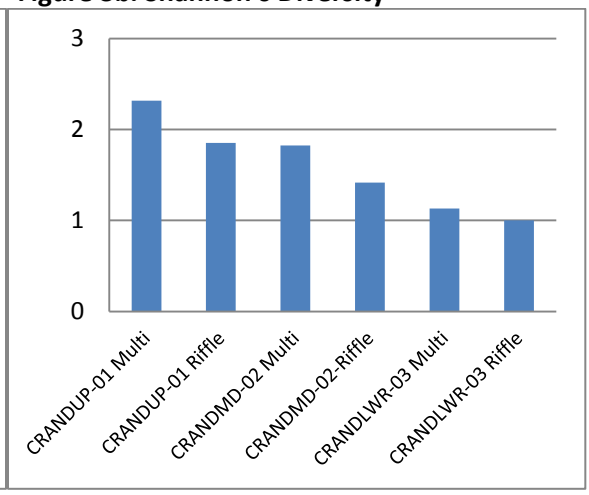


Figure 4b. Evenness

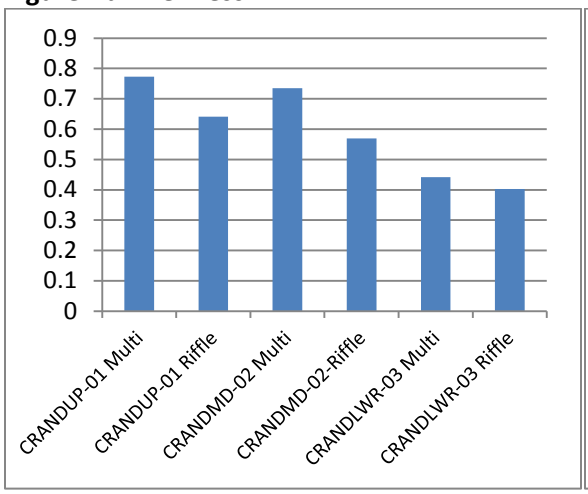


Figure 5b. Abundance

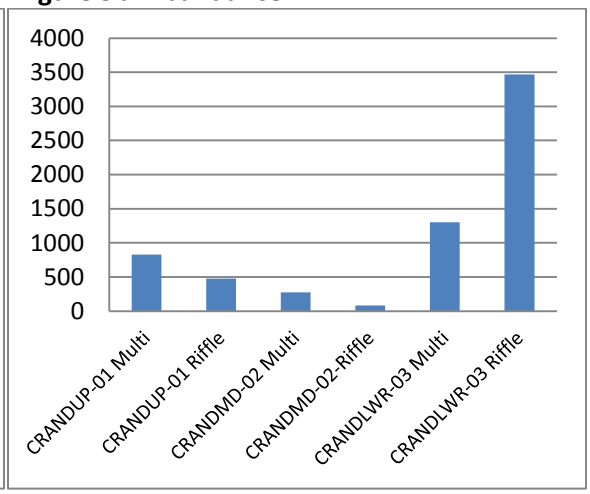


Figure 6b. HBI*

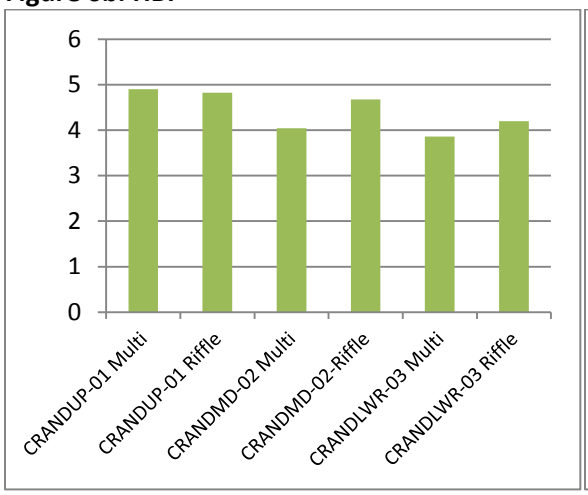
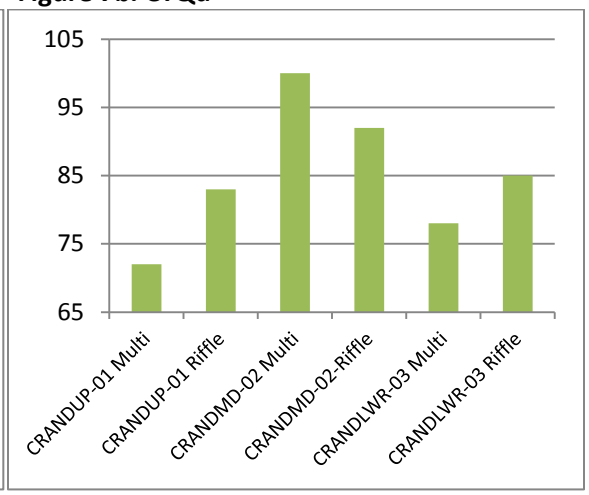


Figure 7b. CTQd*



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

Figure 8b. EPT Taxa Abundance

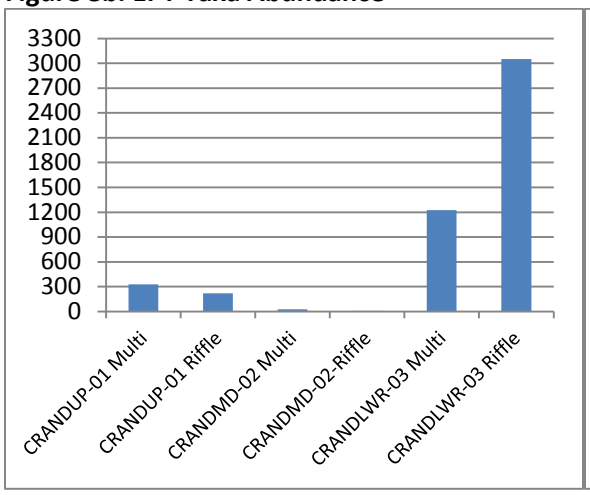


Figure 9b. Percent EPT

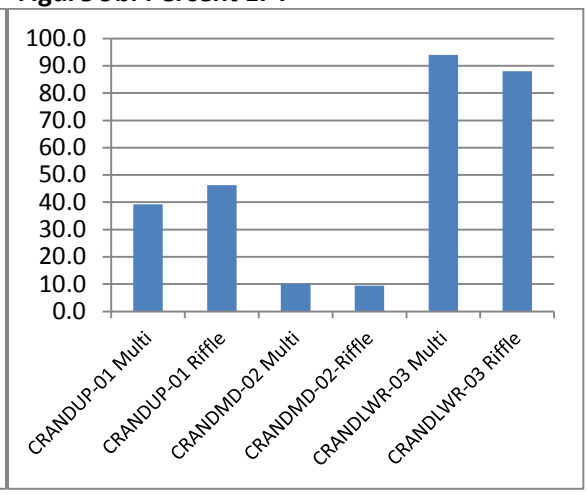


Figure 10b. Percent Chironomids

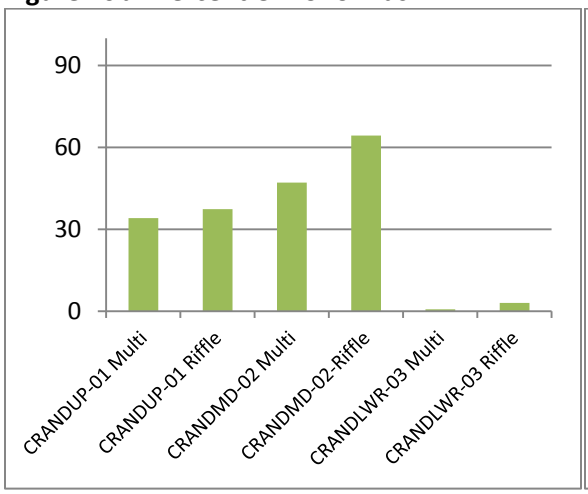


Figure 11b. Ratio of EPT to Chironmonids

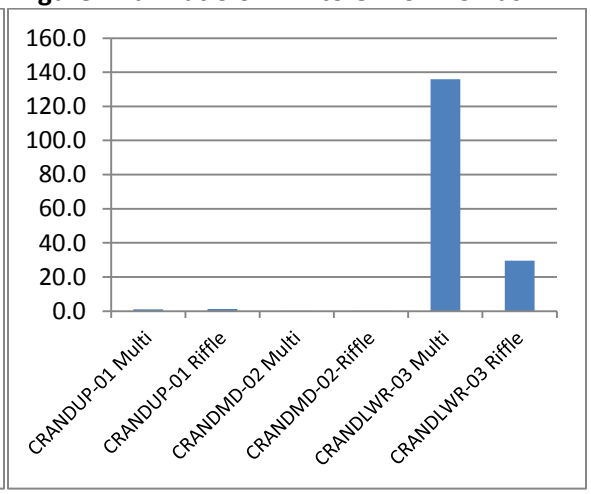


Figure 12b. Number of Tolerant Taxa*

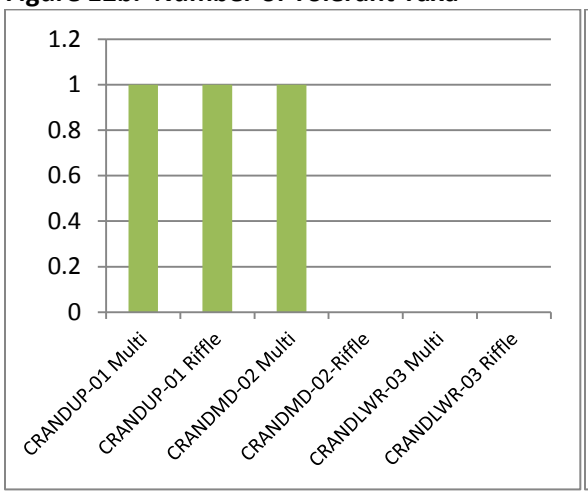
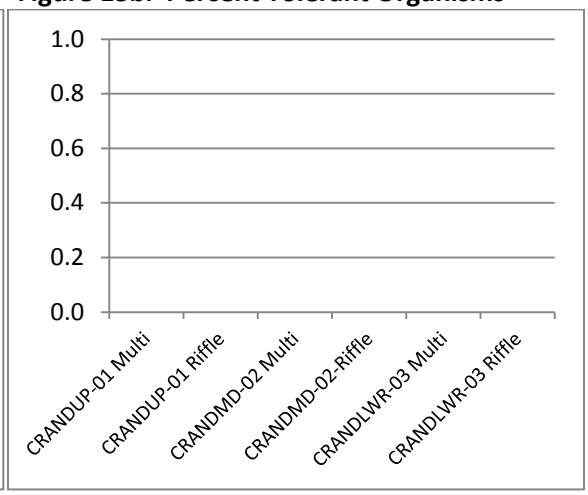


Figure 13b. Percent Tolerant Organisms*



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

Figure 14b. Number of Intolerant Taxa

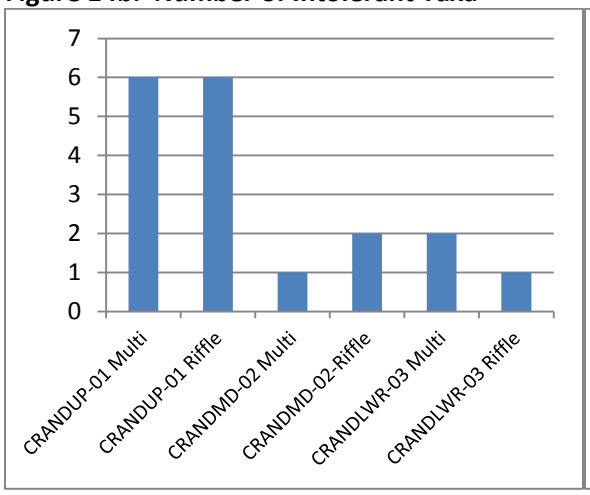


Figure 15b. Percent Intolerant Organisms

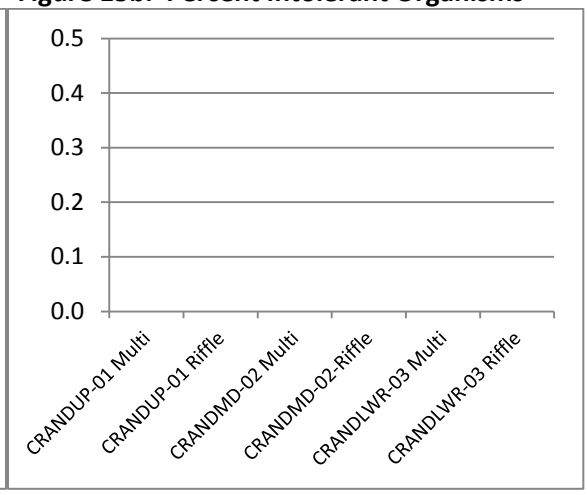


Figure 16b. Specialist Feeders: Generalist Feeders

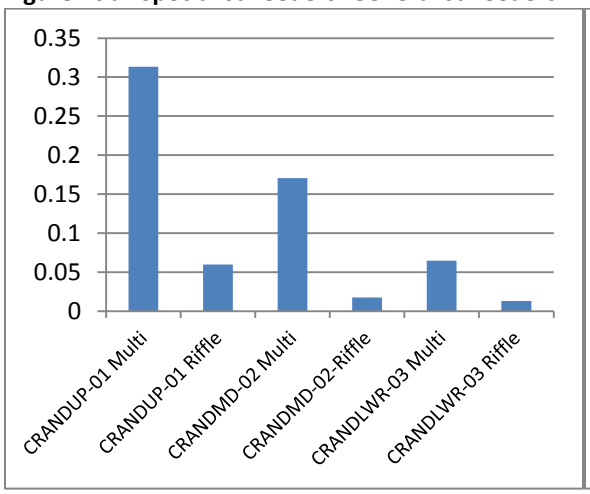


Figure 17b. Percent Shredders

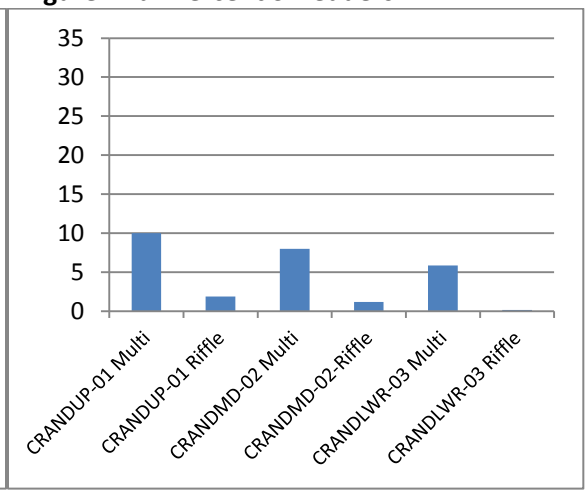


Figure 18b. Percent Scrapers

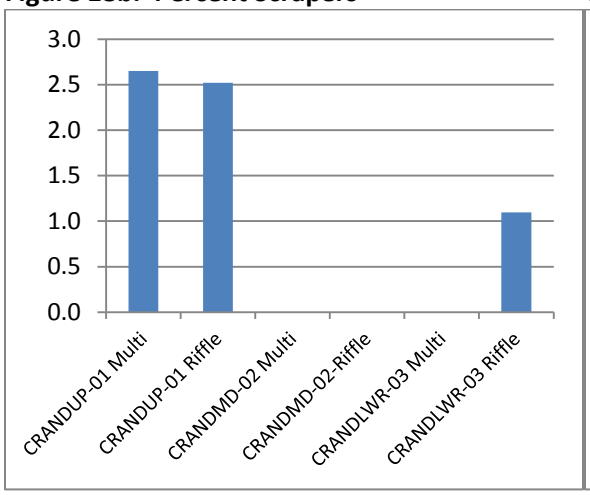
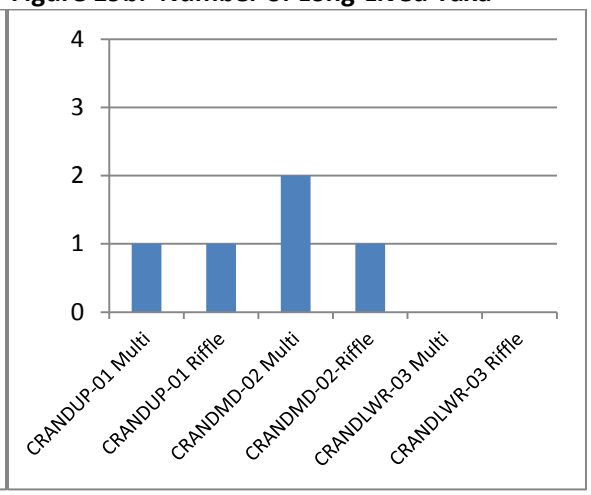


Figure 19b. Number of Long-Lived Taxa



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

Figure 20b. Number of Clinger Taxa

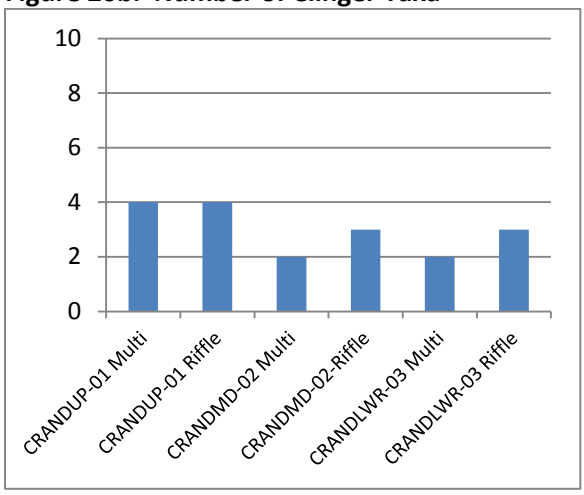


Figure 21b. Baetis:All Ephemetroptera (Percent)*

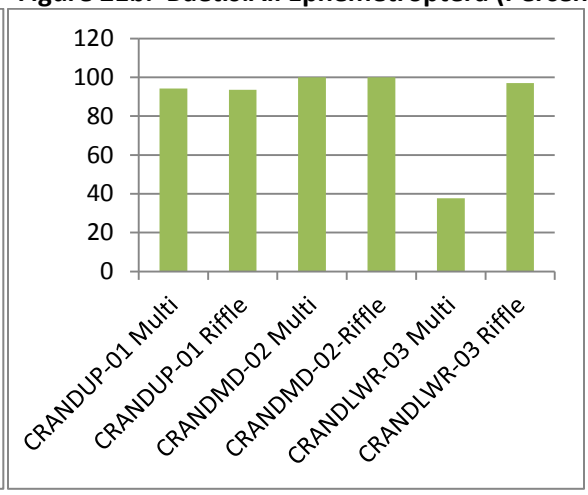


Figure 22b. Baetis, Hydropsychidae & Orthocladiinae (Percent)*

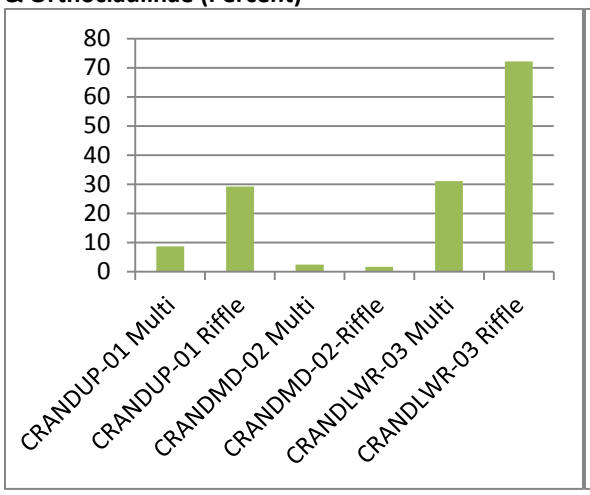


Figure 23b. Heptageniidae: All Ephemeroptera (Percent)

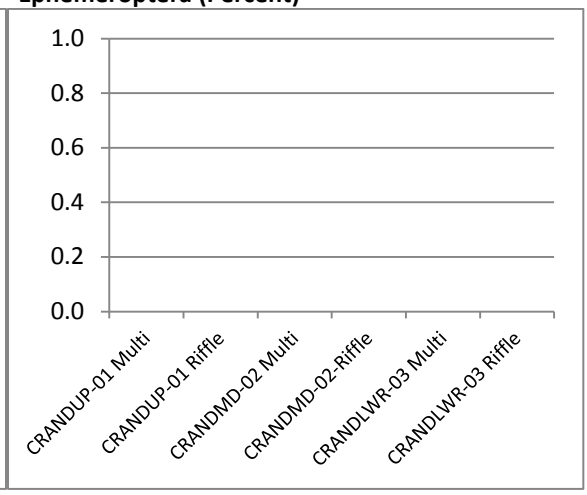
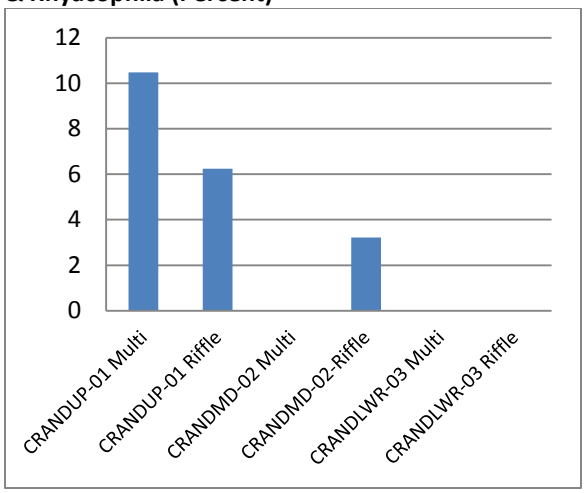


Figure 24b. Heptageniidae, Chloroperlidae & Rhyacophila (Percent)

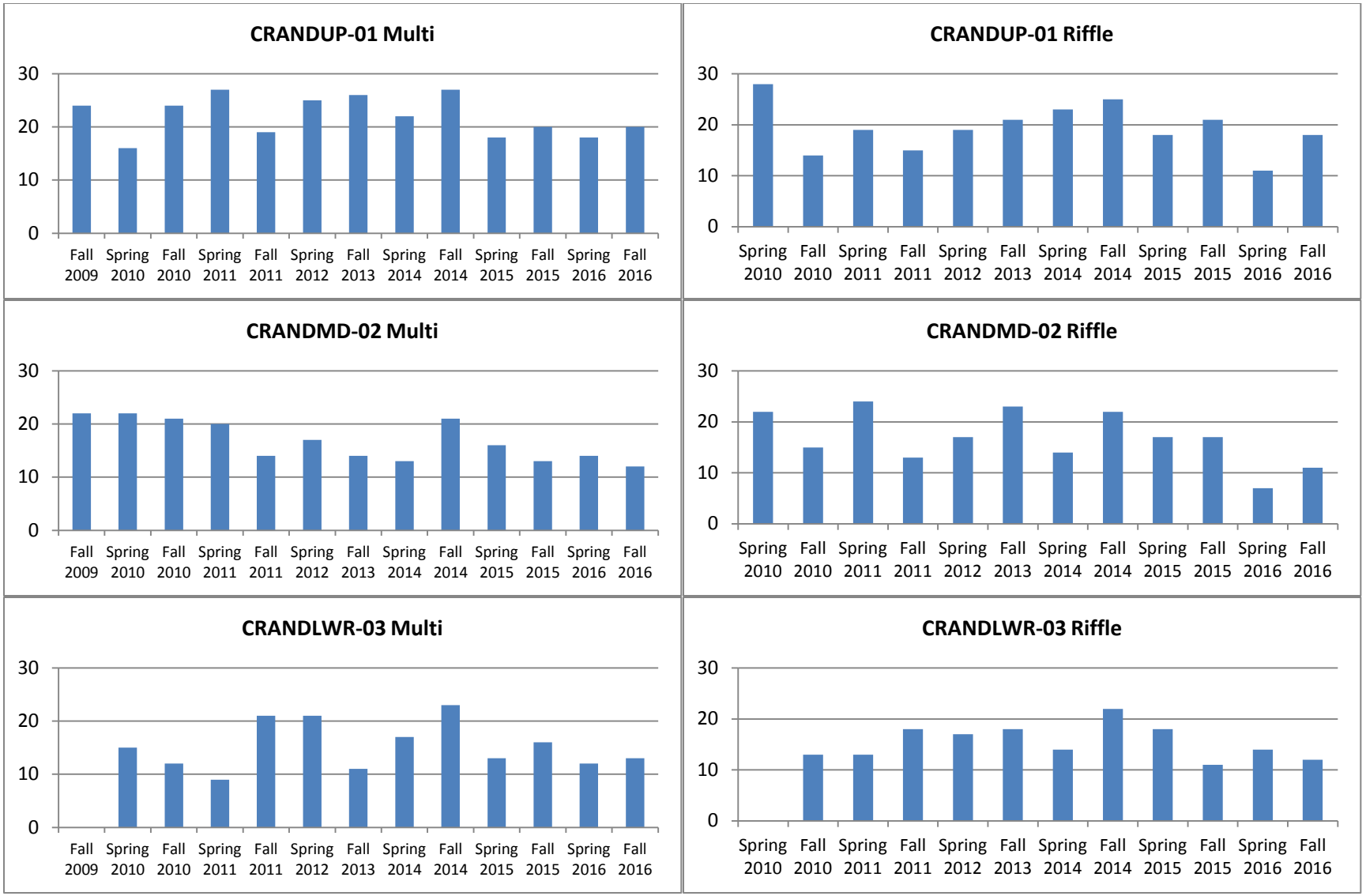


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

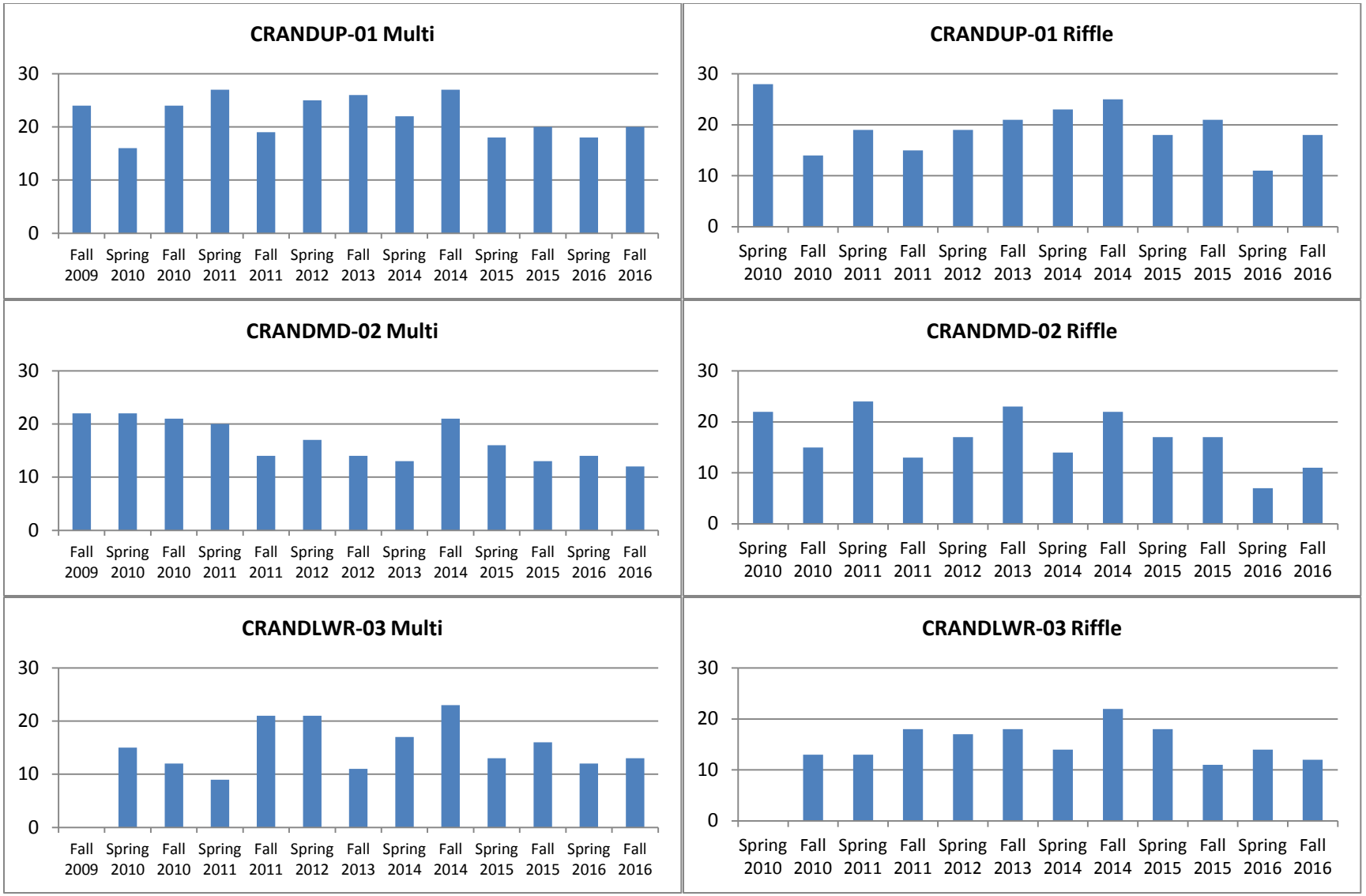
APPENDIX C

MACROINVERTEBRATE FIGURES FALL 2010- FALL 2016

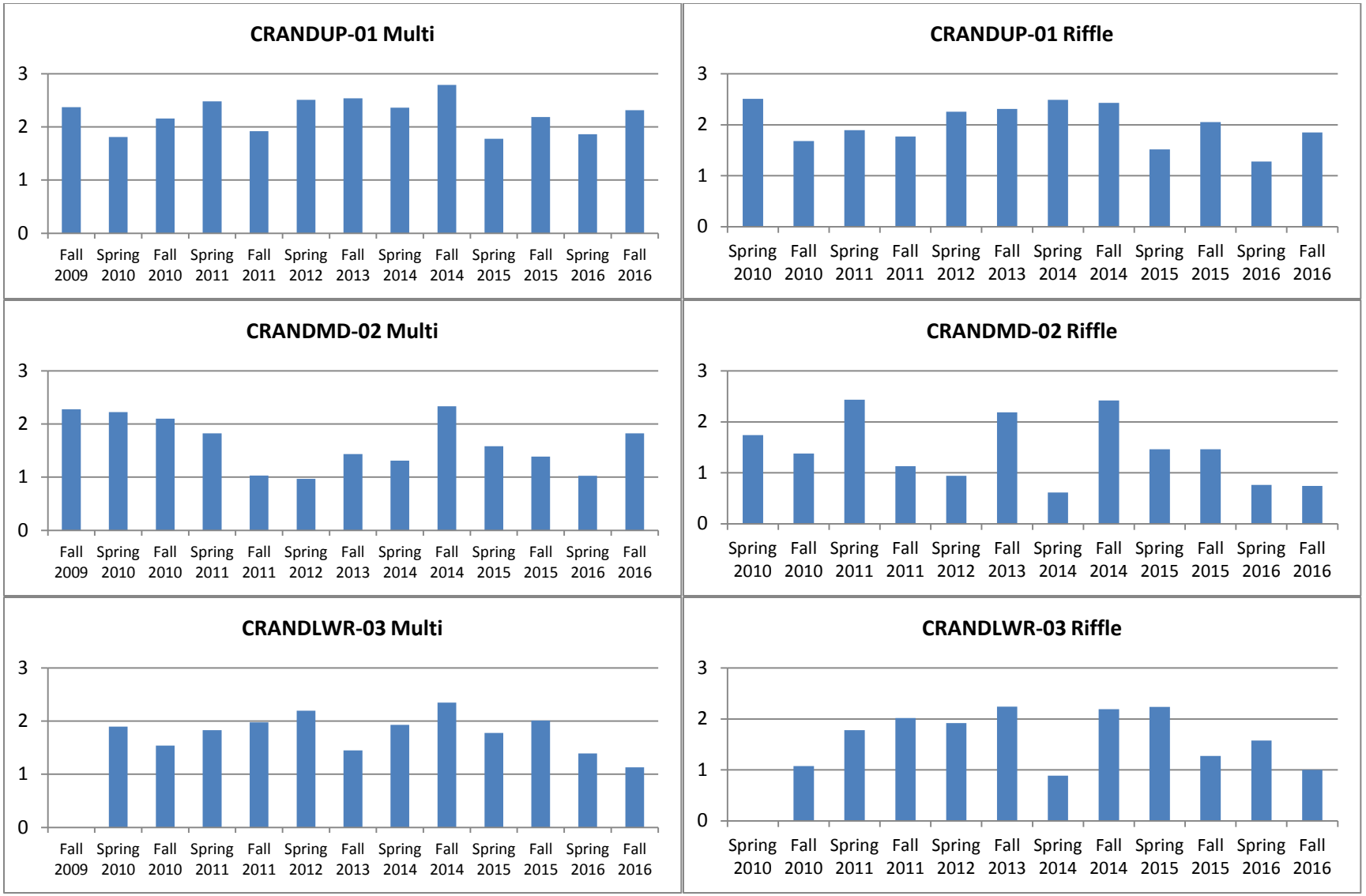
Figures 1c. Richness values for each reach and habitat type from 2010-2016



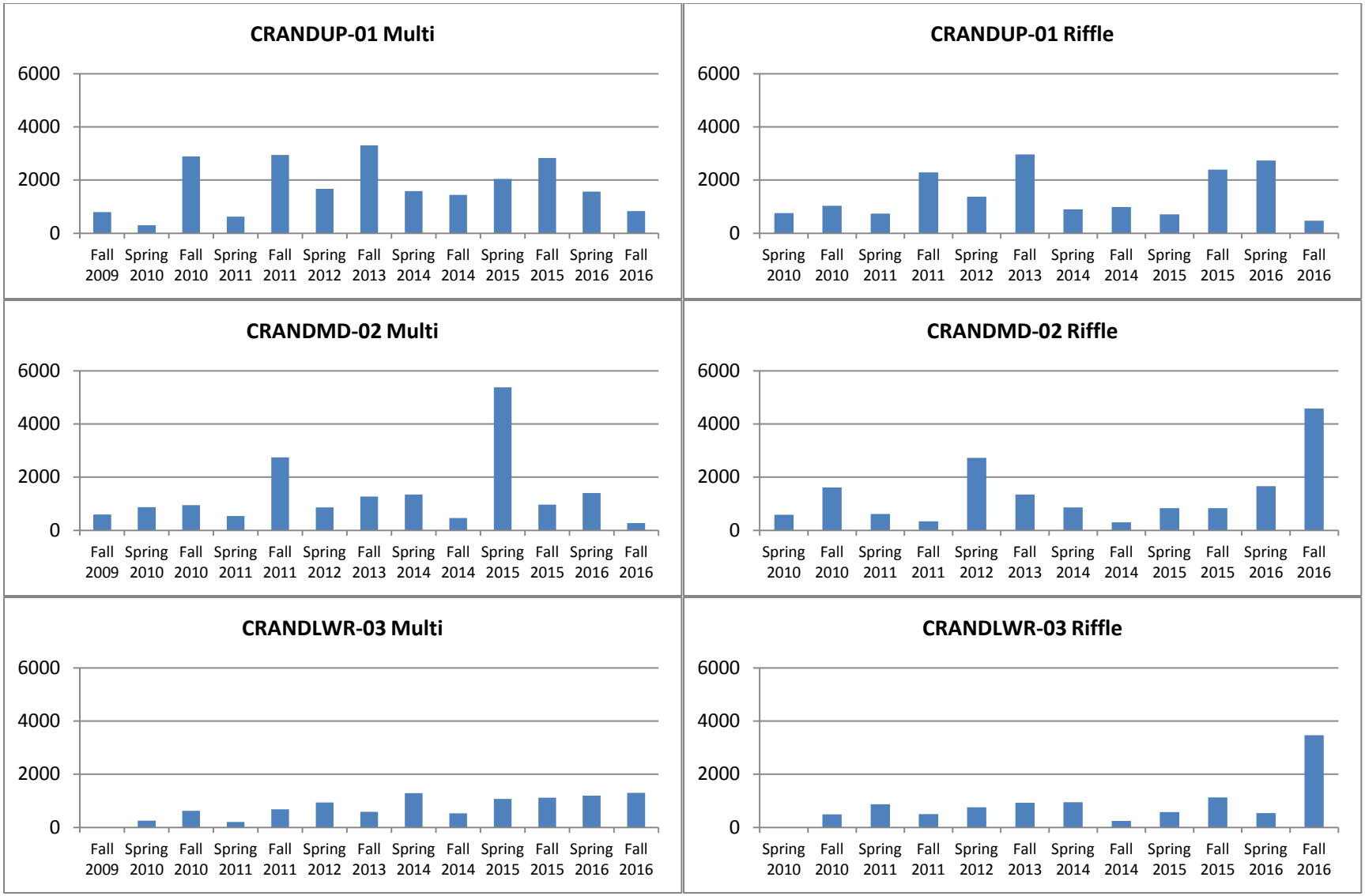
Figures 2c. Evenness values for each reach and habitat type from 2010-2016



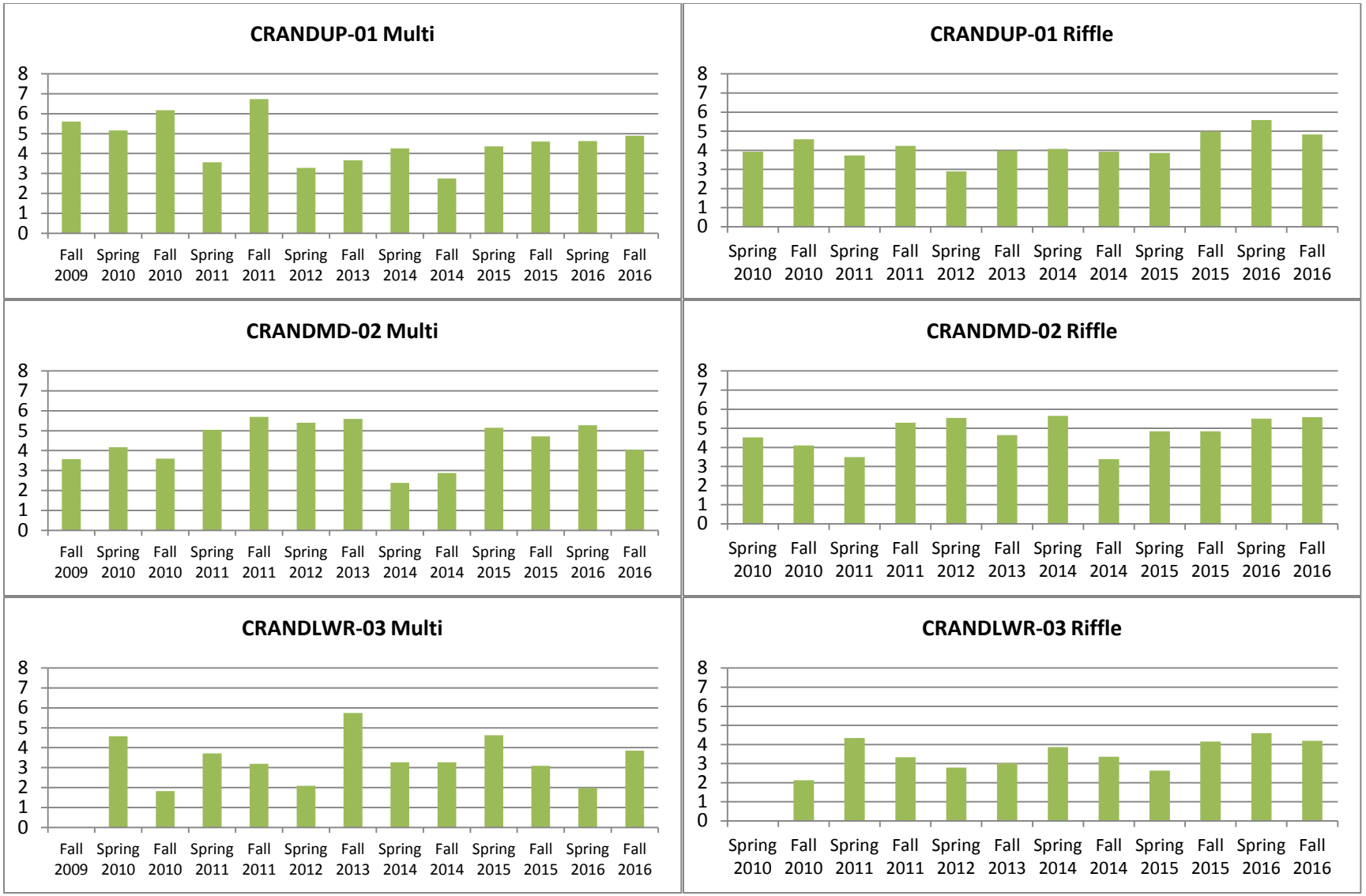
Figures 3c. Shannon's Diversity values for each reach and habitat type from 2010-2016



Figures 4c. Abundance values for each reach and habitat type from 2010-2016

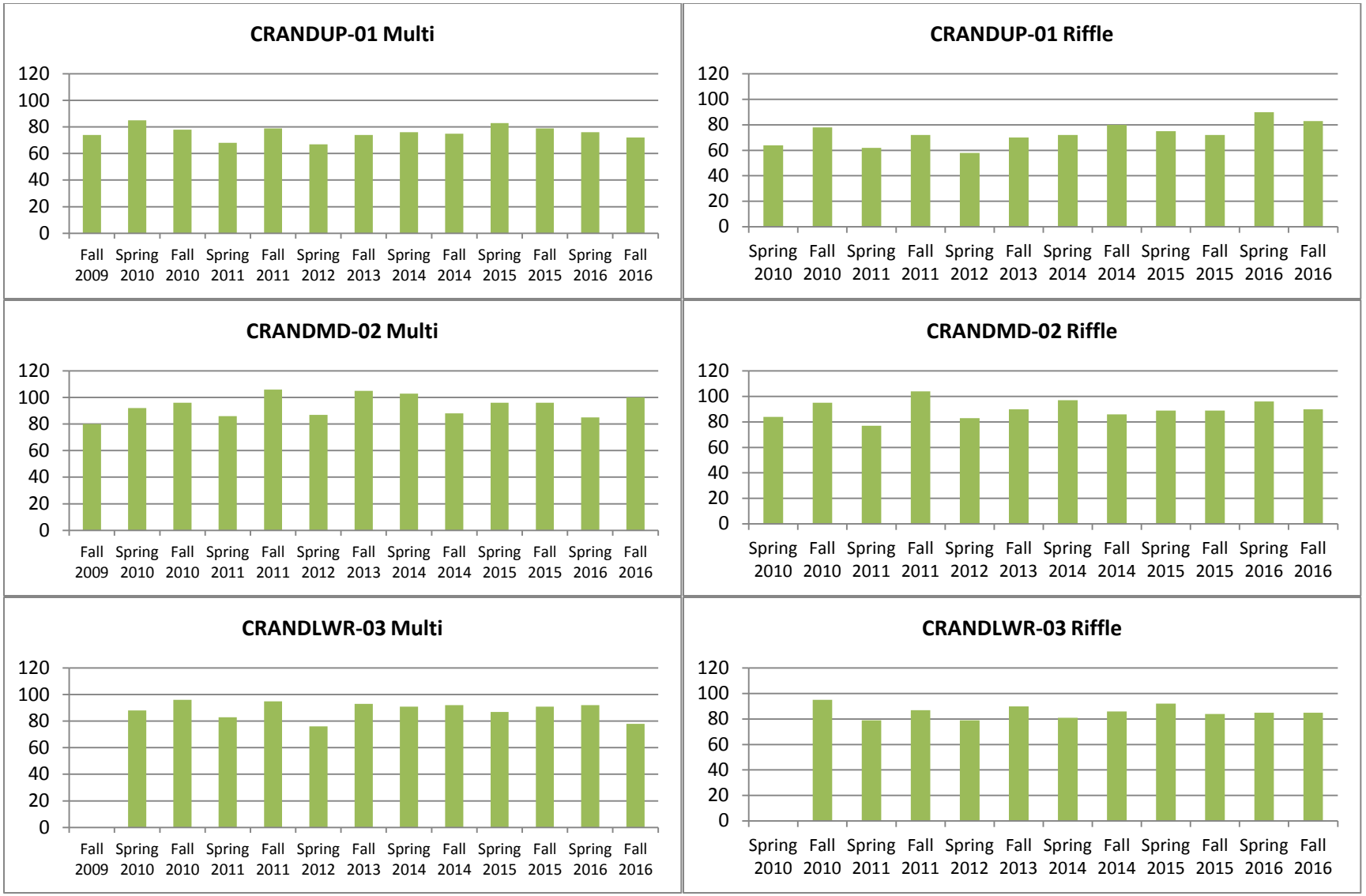


Figures 5c. Hilsenhoff Biotic Index values for each reach and habitat type from 2010-2016*



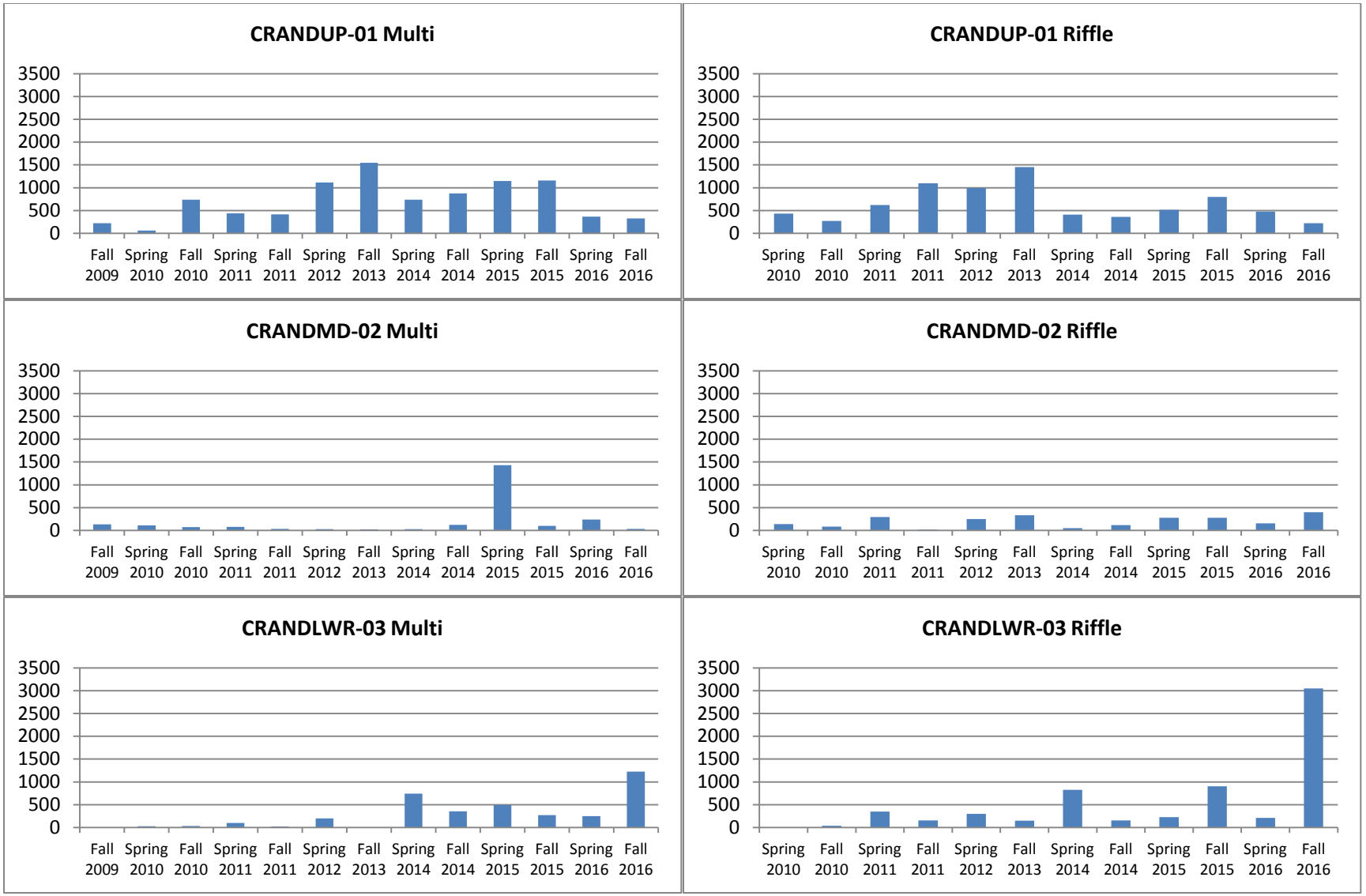
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 6c. USFS Community Tolerance Quotient (CTQd) values for each reach and habitat type from 2009-2015

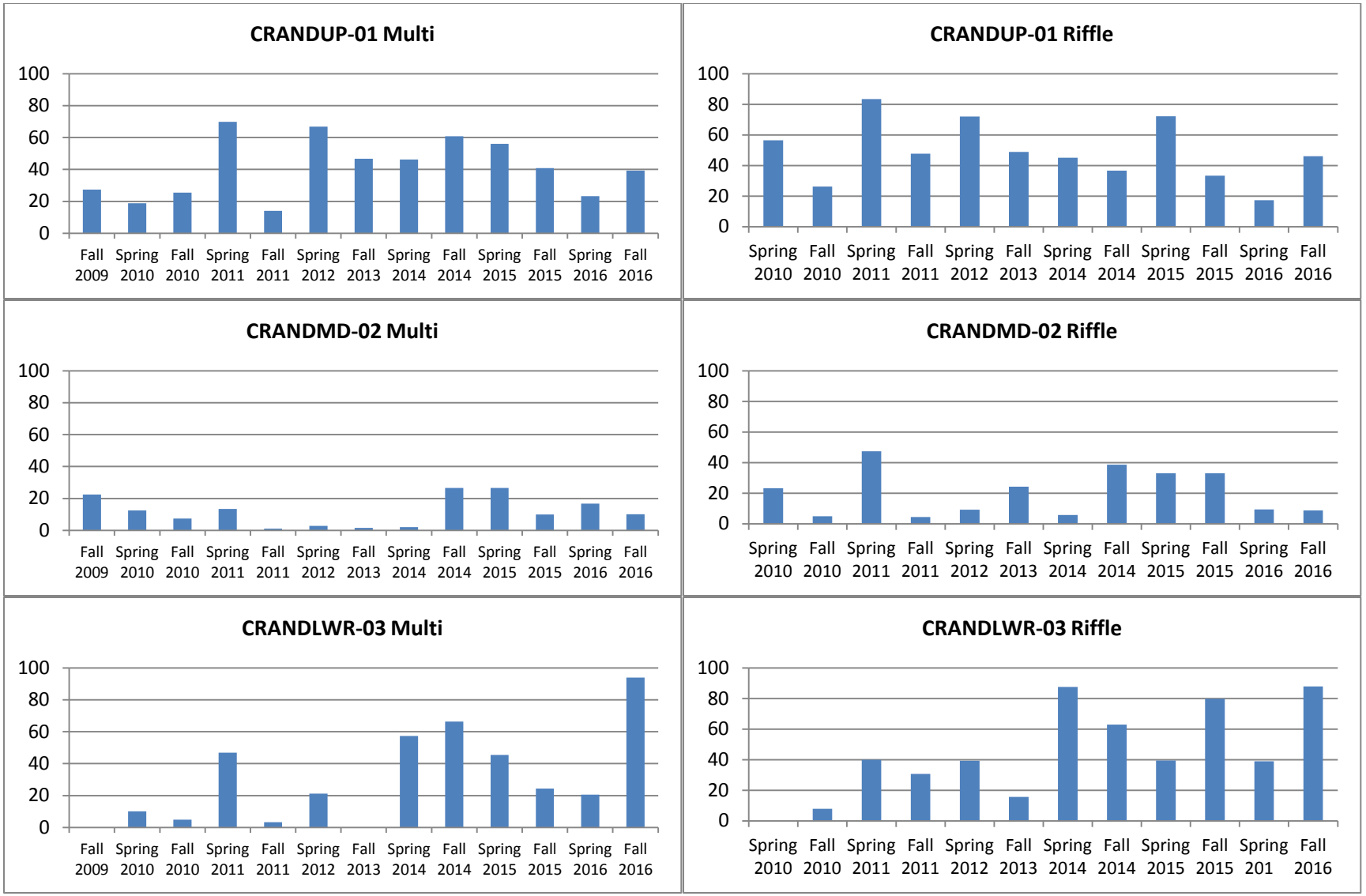


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

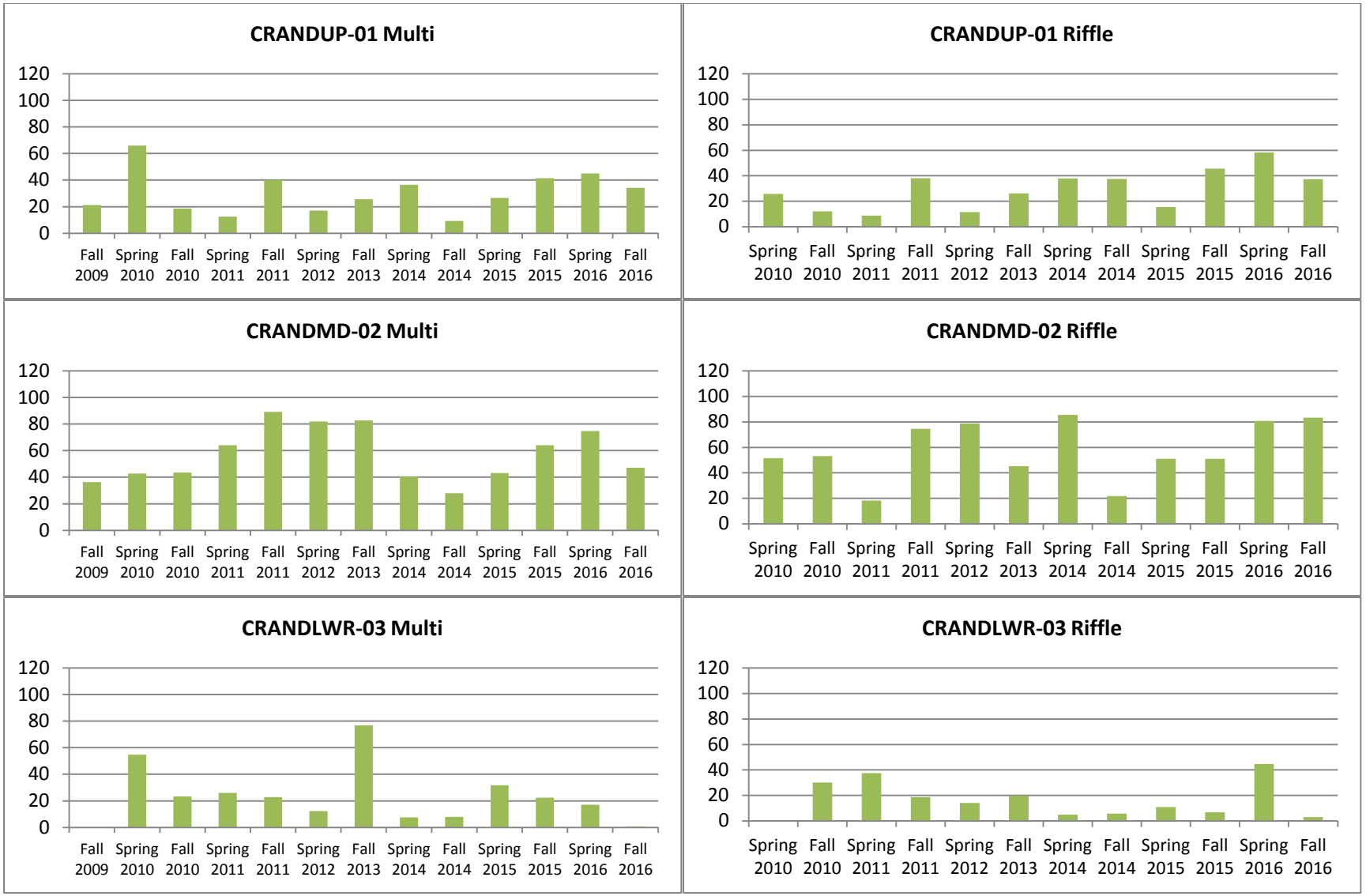
Figures 7c. EPT taxa abundance values for each reach and habitat type from 2010-2016



Figures 8c. Percent EPT for each reach and habitat type from 2010-2016

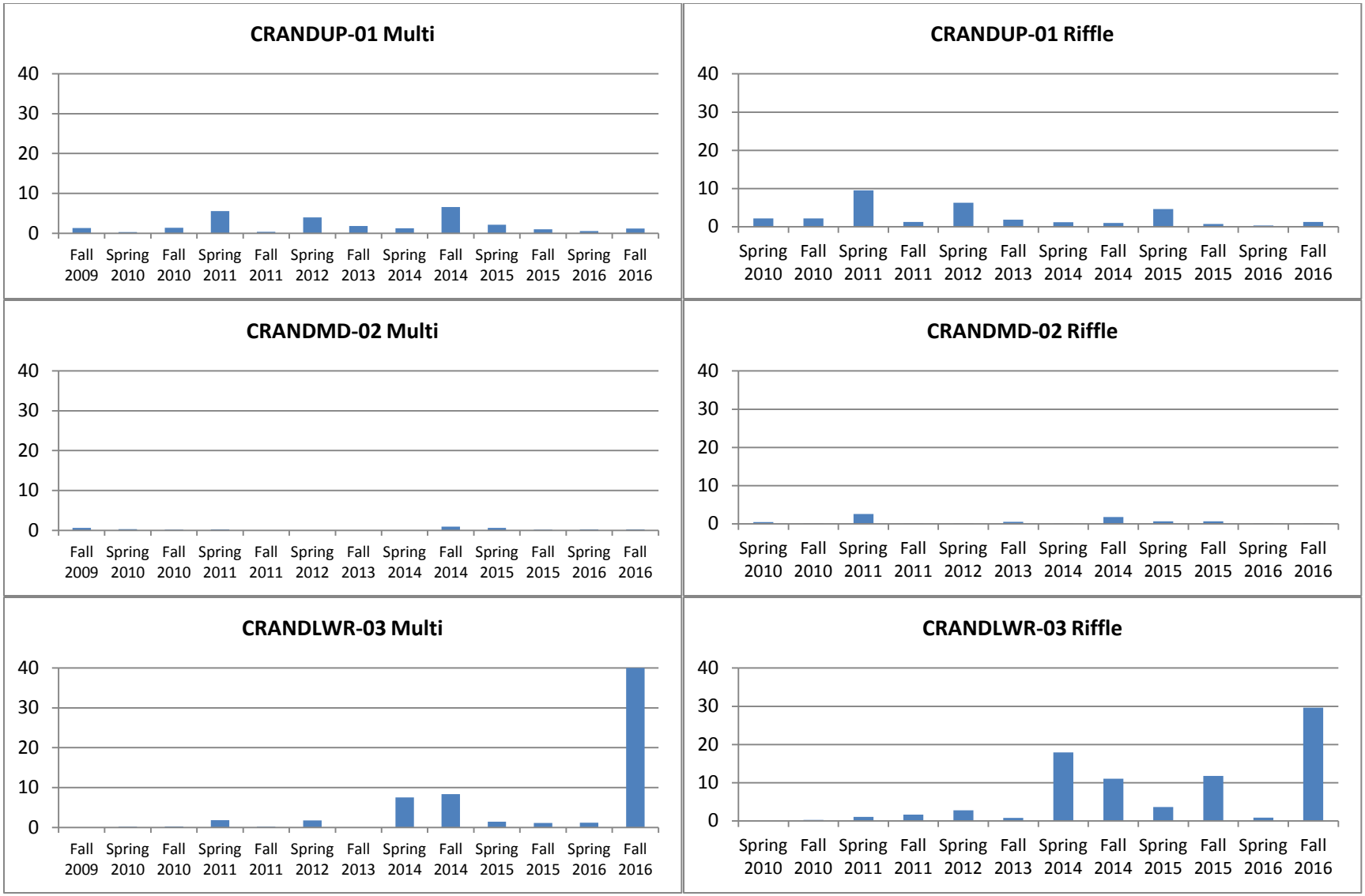


Figures 9c. Percent Chironomids for each reach and habitat type from 2010-2016*

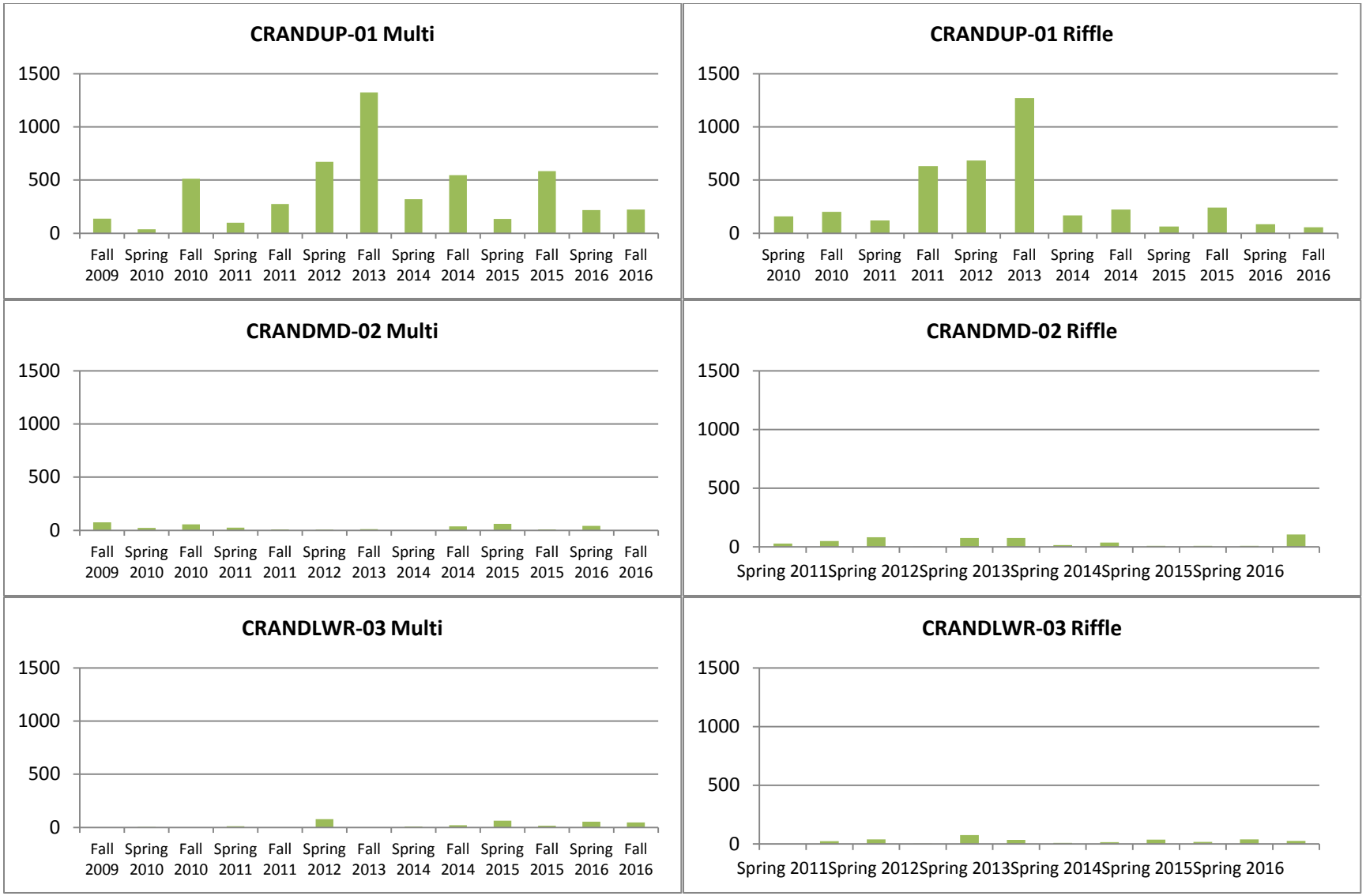


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 10c. Ratio of EPT to Chironmoids values for each reach and habitat type from 2010-2016

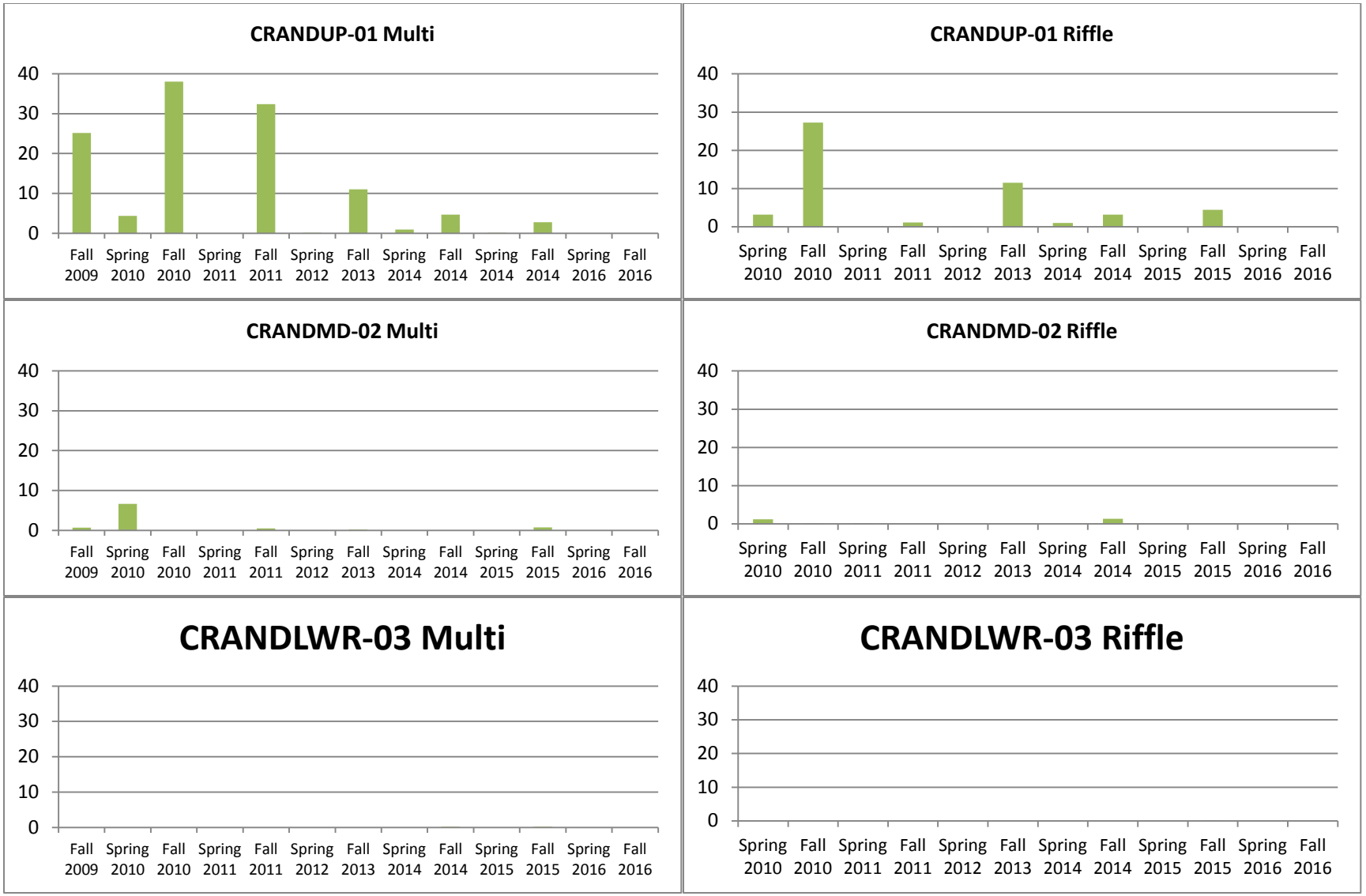


Figures 11c. Number of tolerant taxa for each reach and habitat type from 2010-2016



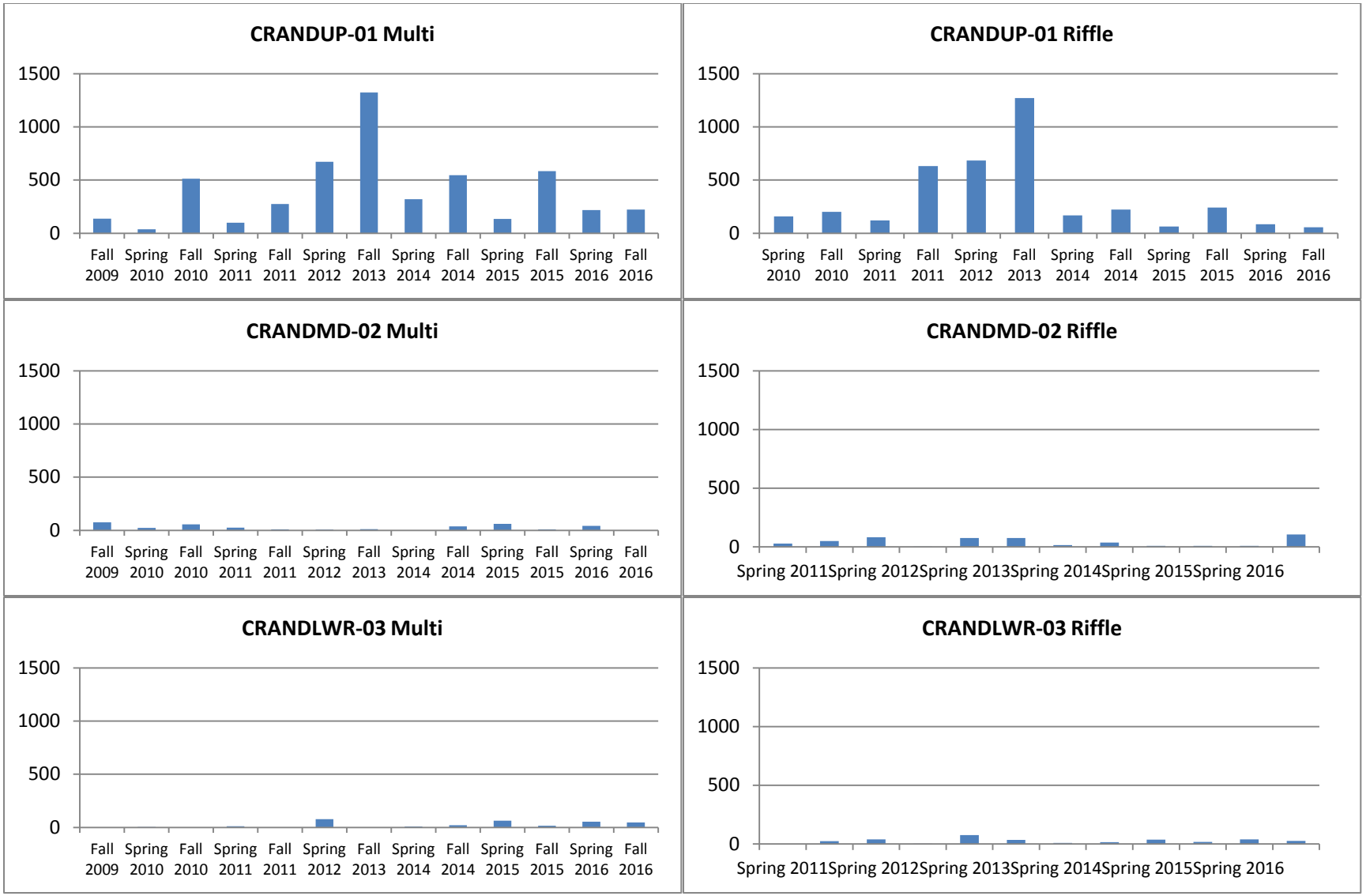
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 12c. Percent tolerant organisms for each reach and habitat type from 2010-2016

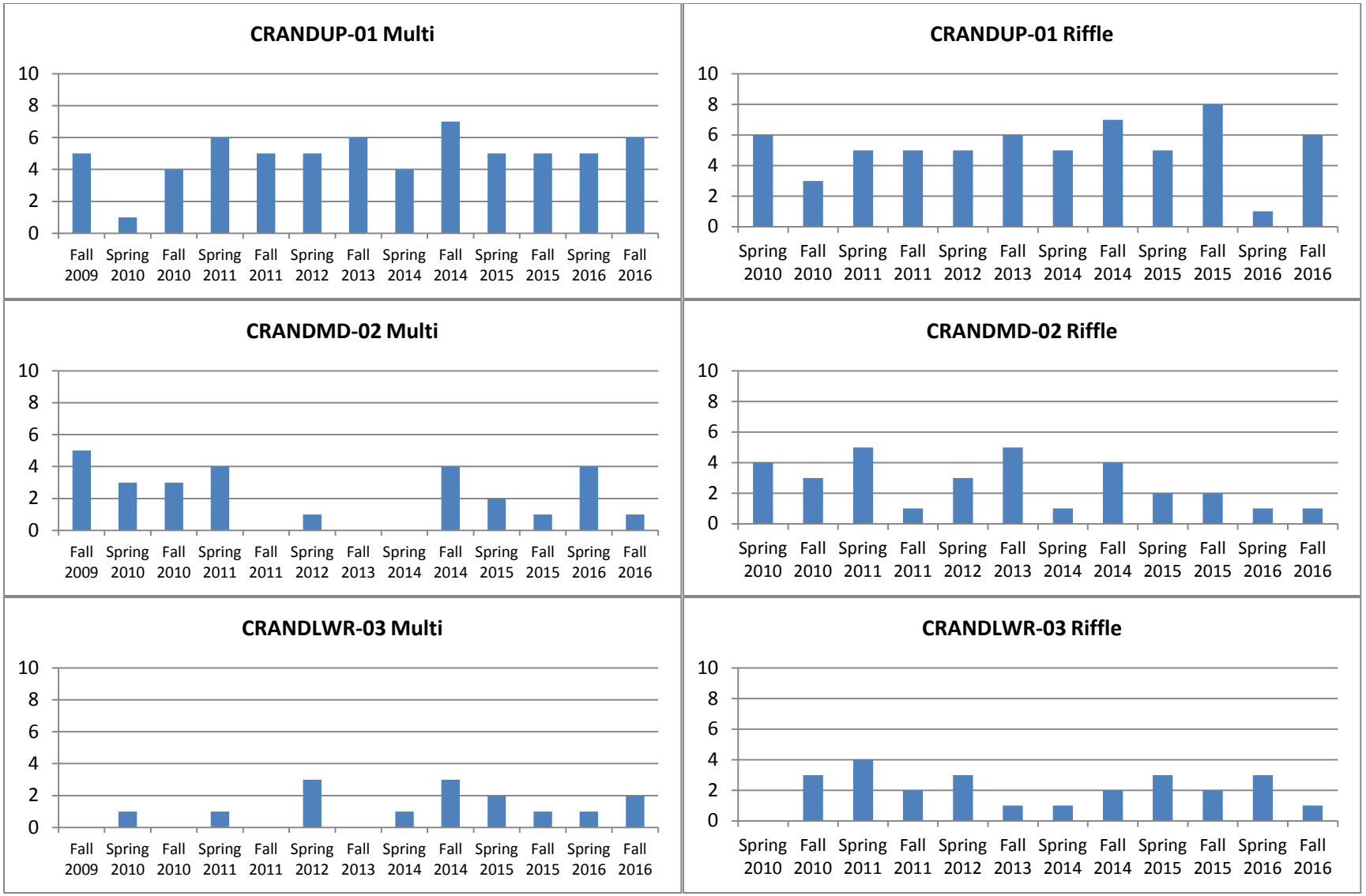


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

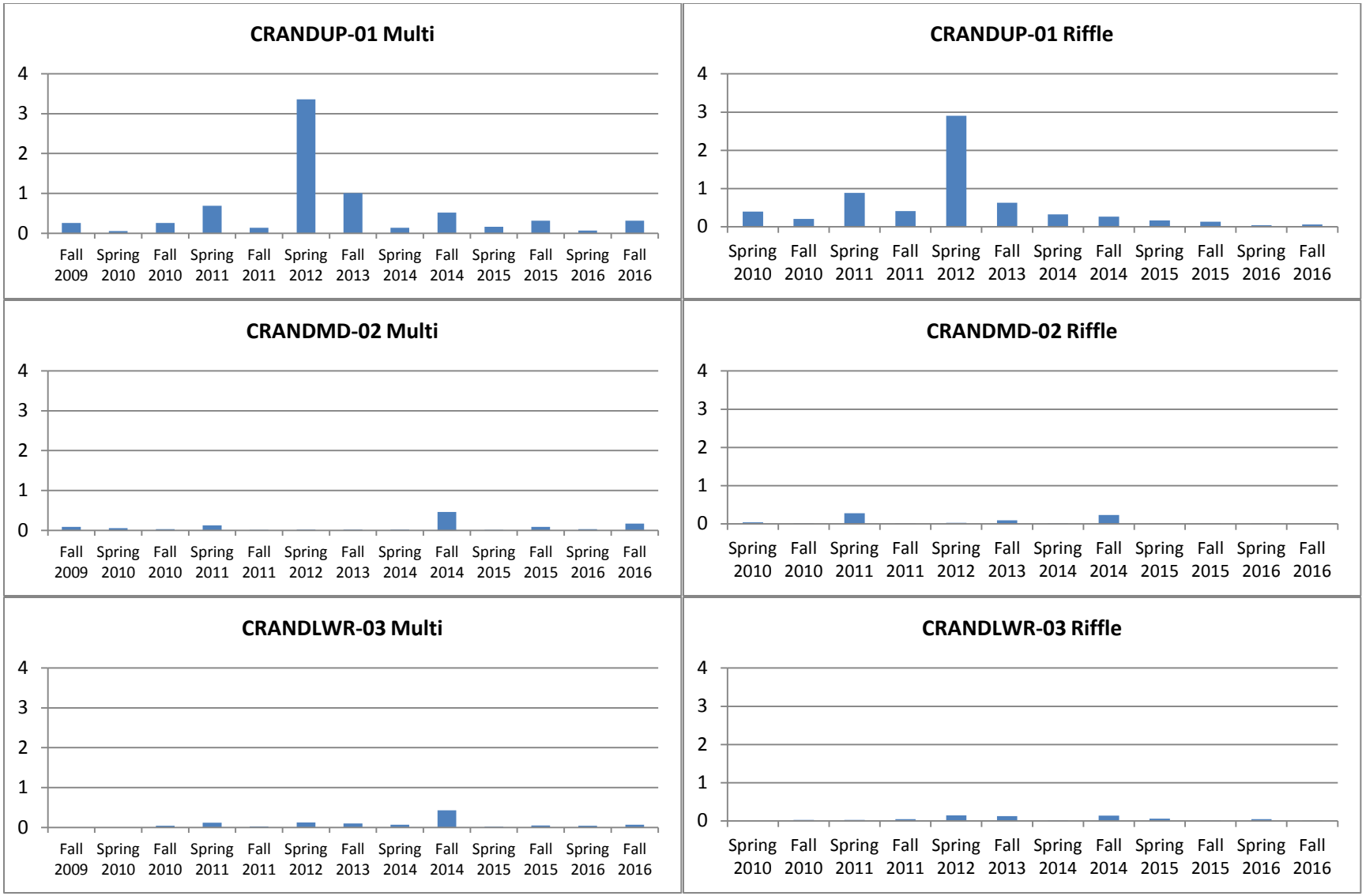
Figures 13c. Number of intolerant taxa for each reach and habitat type from 2010-2016



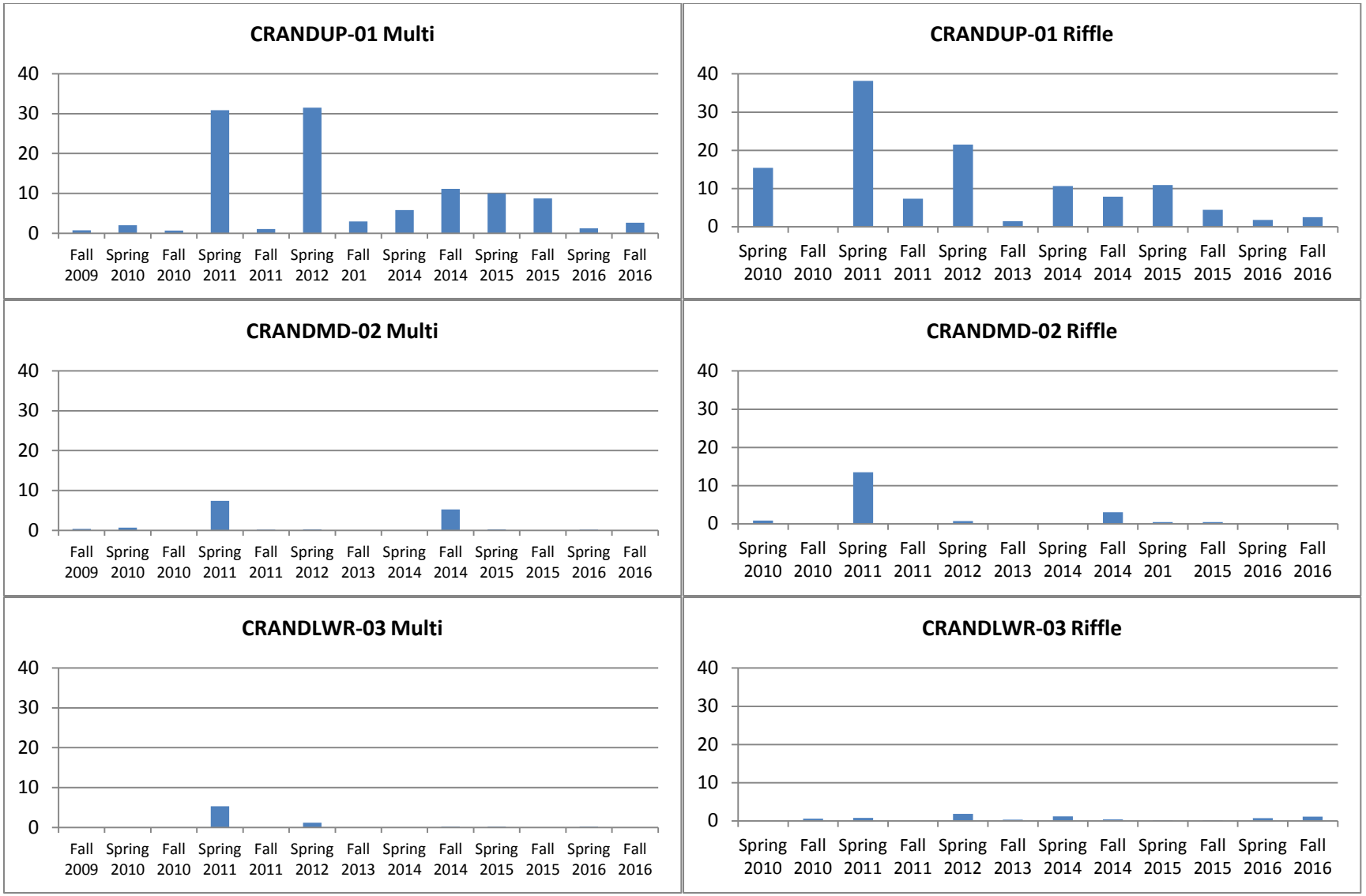
Figures 14c. Percent intolerant organisms for each reach and habitat type from 2010-2016



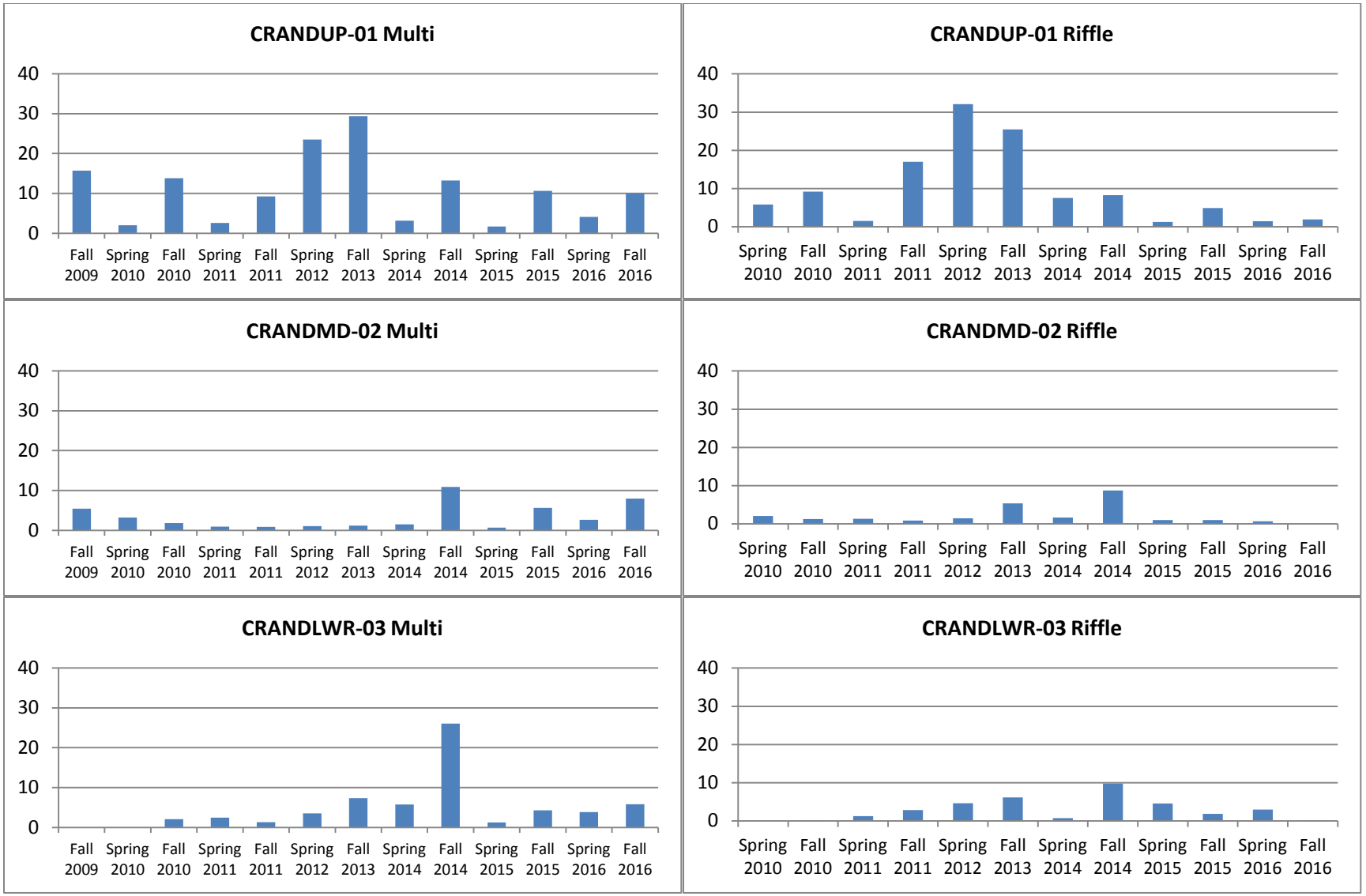
Figures 15c. Ratio of specialist feeders to generalist feeders for each reach and habitat type from 2010-2016



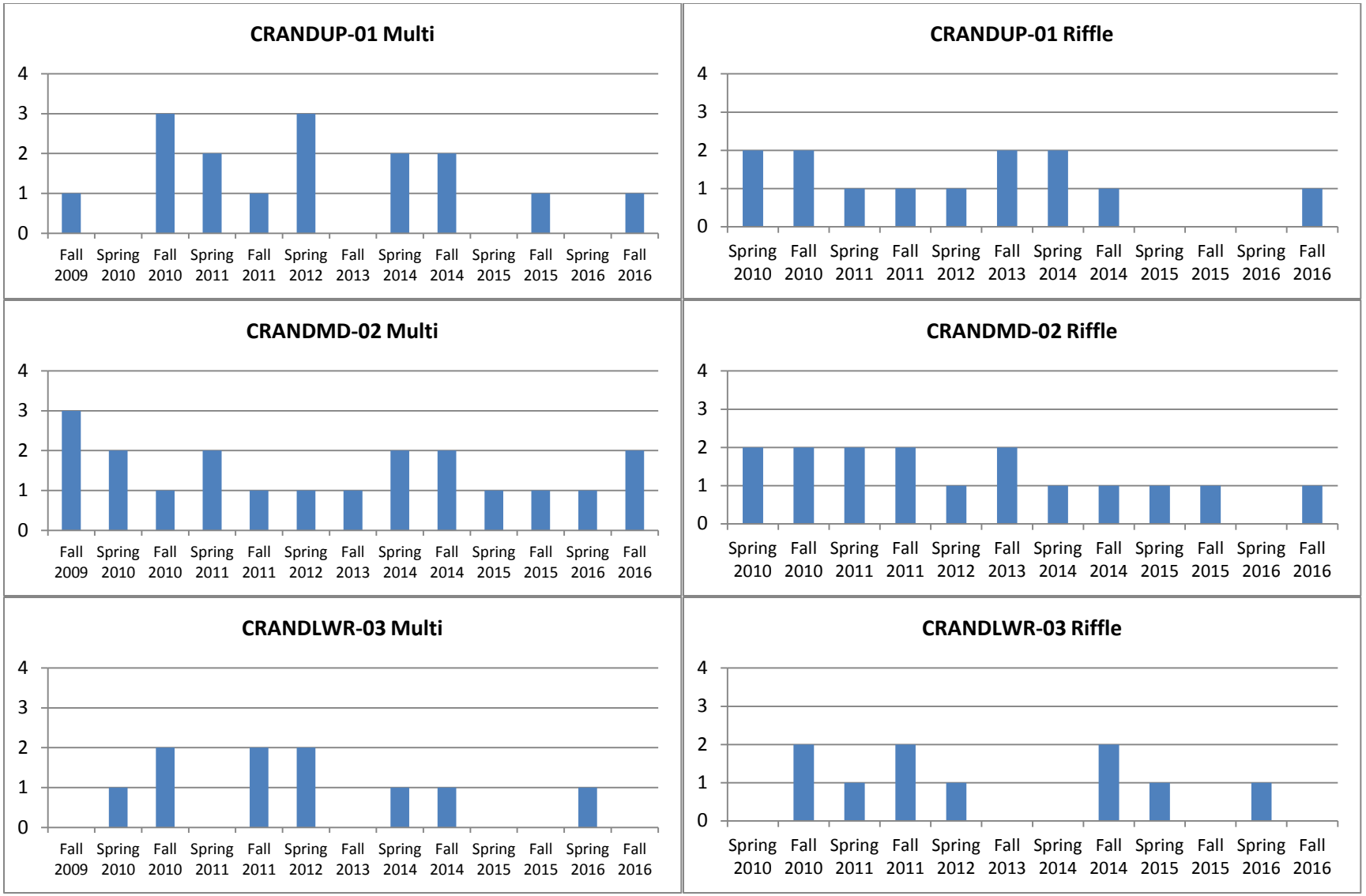
Figures 16c. Percent scrapers for each reach and habitat type from 2010-2016



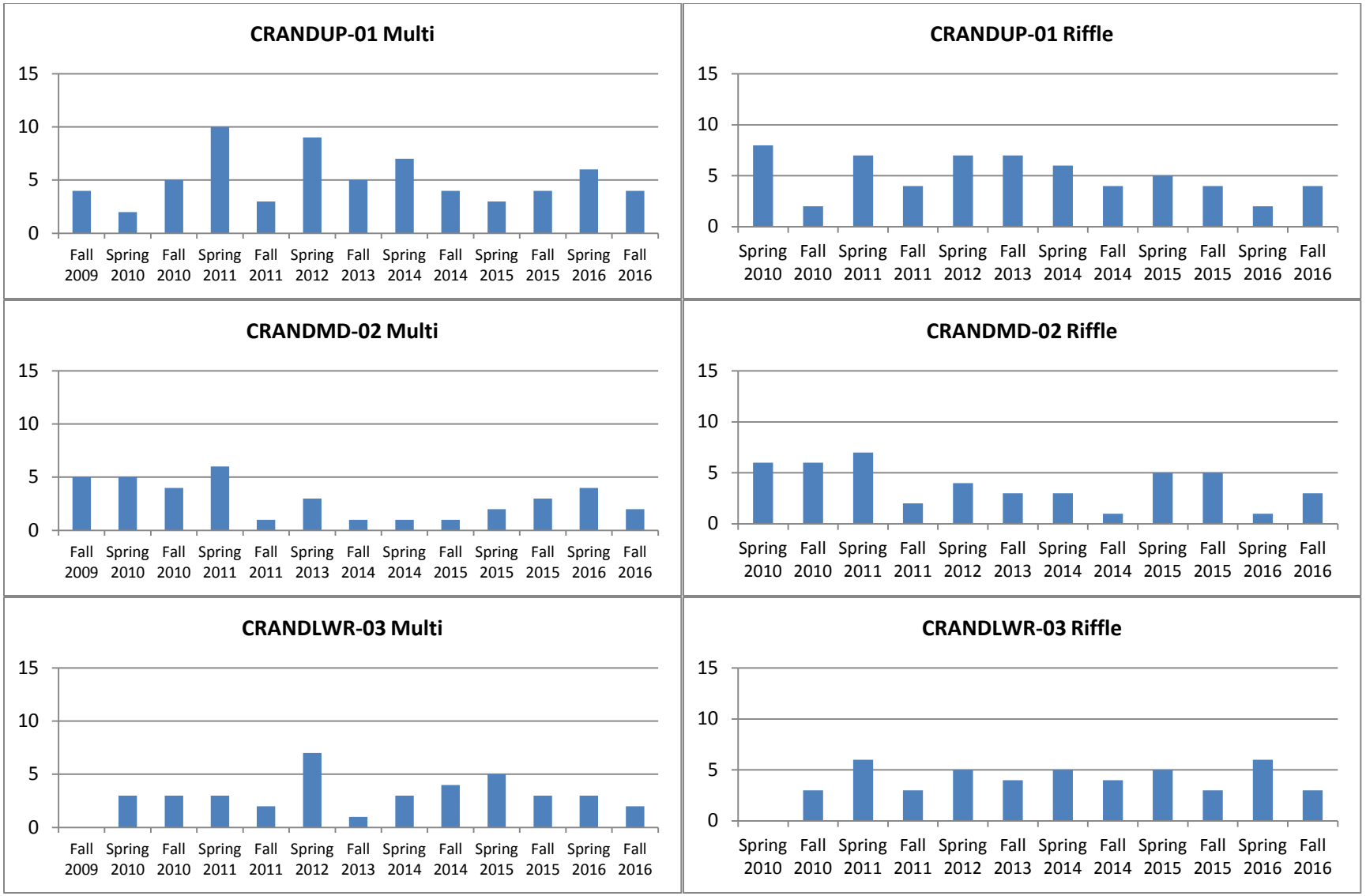
Figures 17c. Percent shredders for each reach and habitat type from 2010-2016



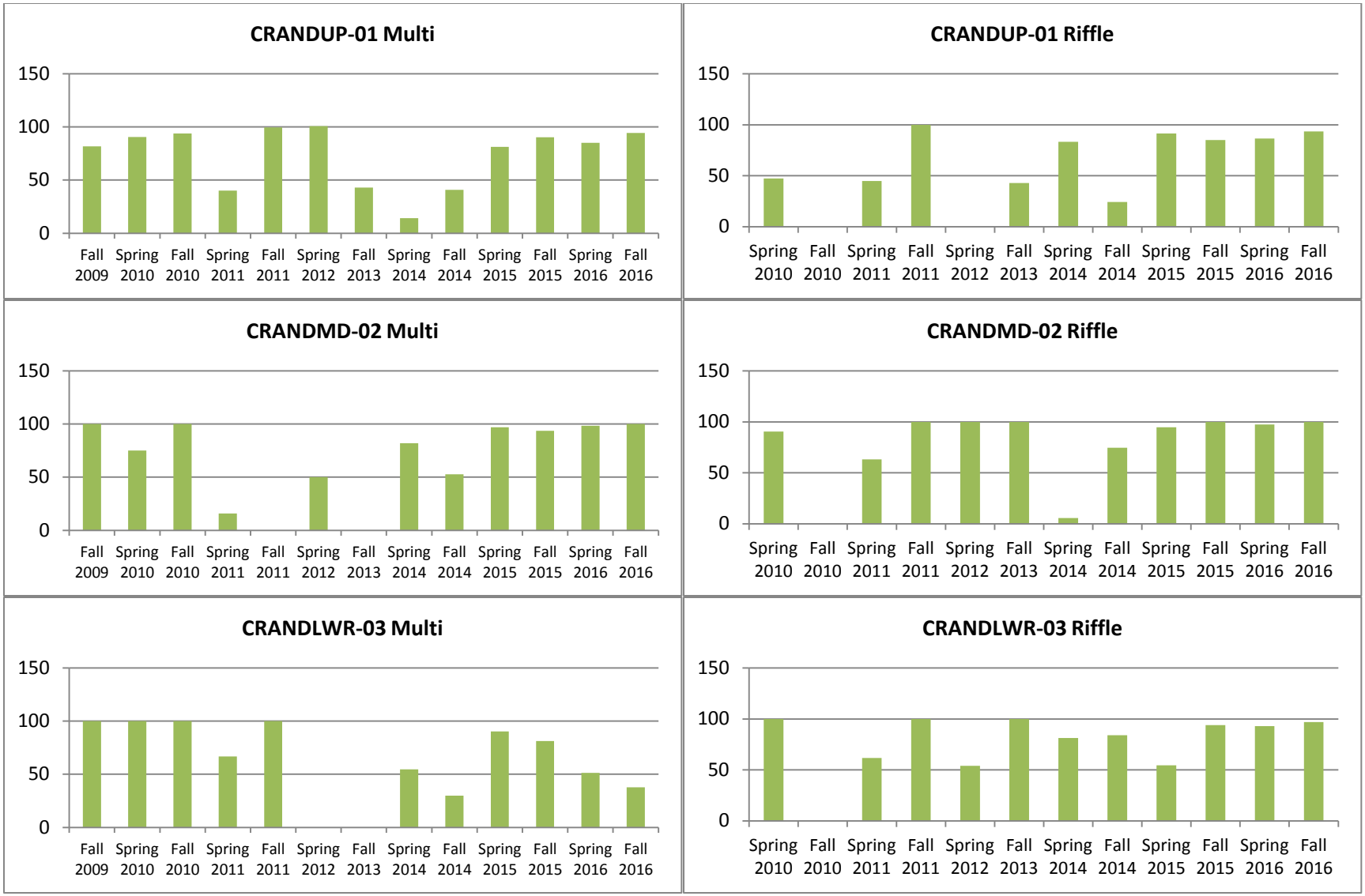
Figures 18c. Number of long-lived taxa for each reach and habitat type from 2010-2016



Figures 19c. Number of clinger taxa for each reach and habitat type from 2010-2016

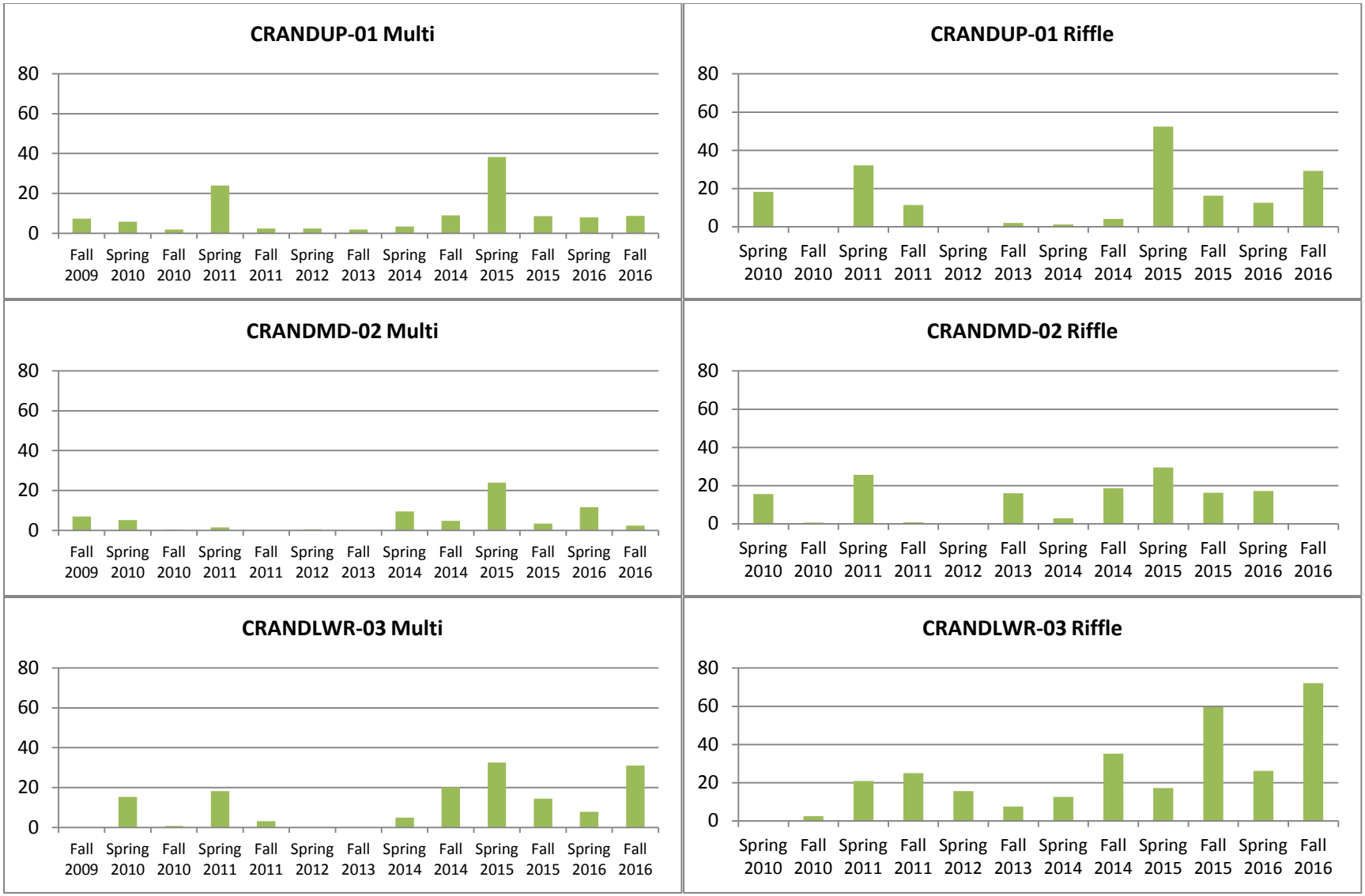


Figures 20c. Percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2010-2015



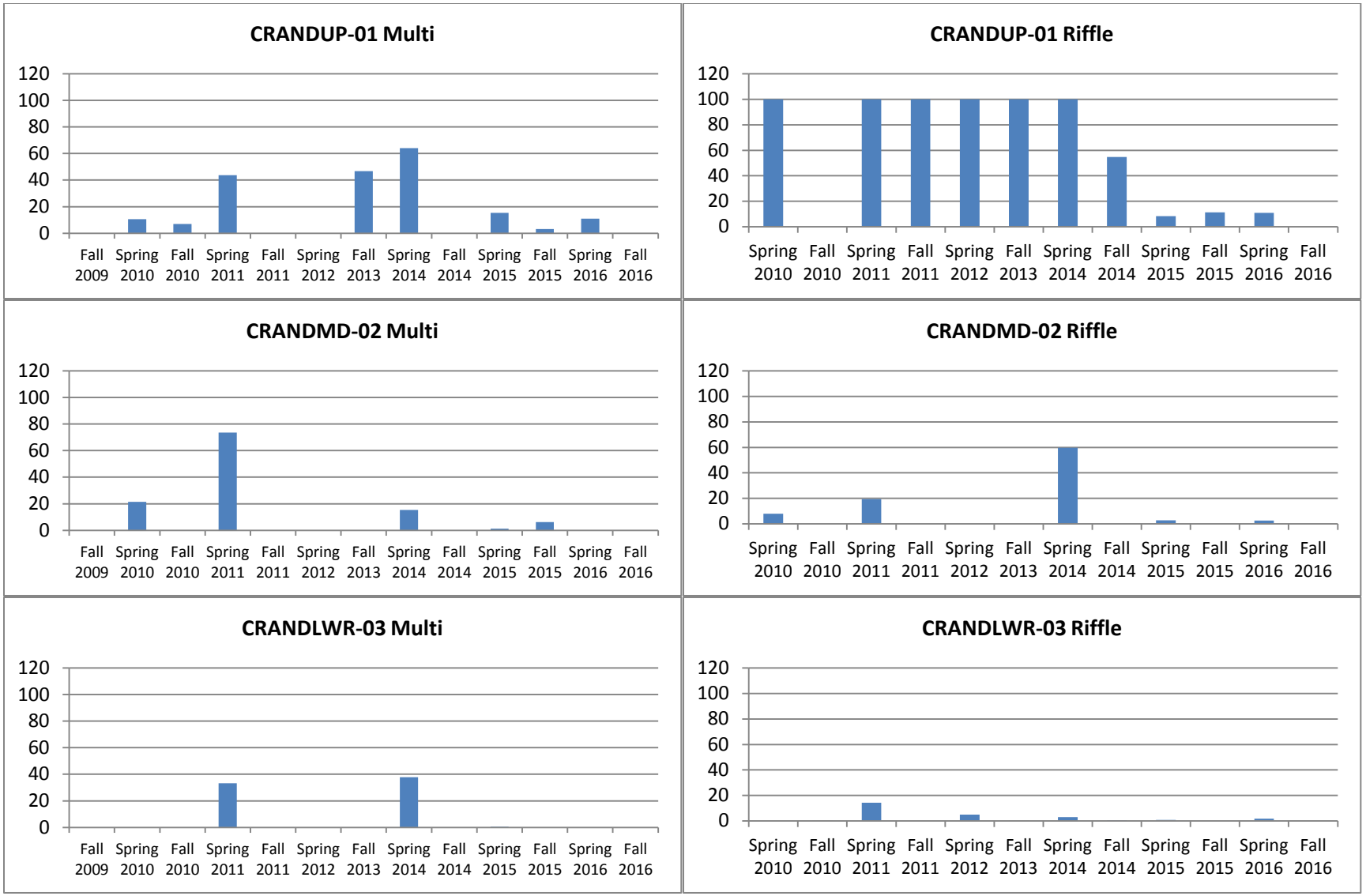
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 21c. Percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2010-2016

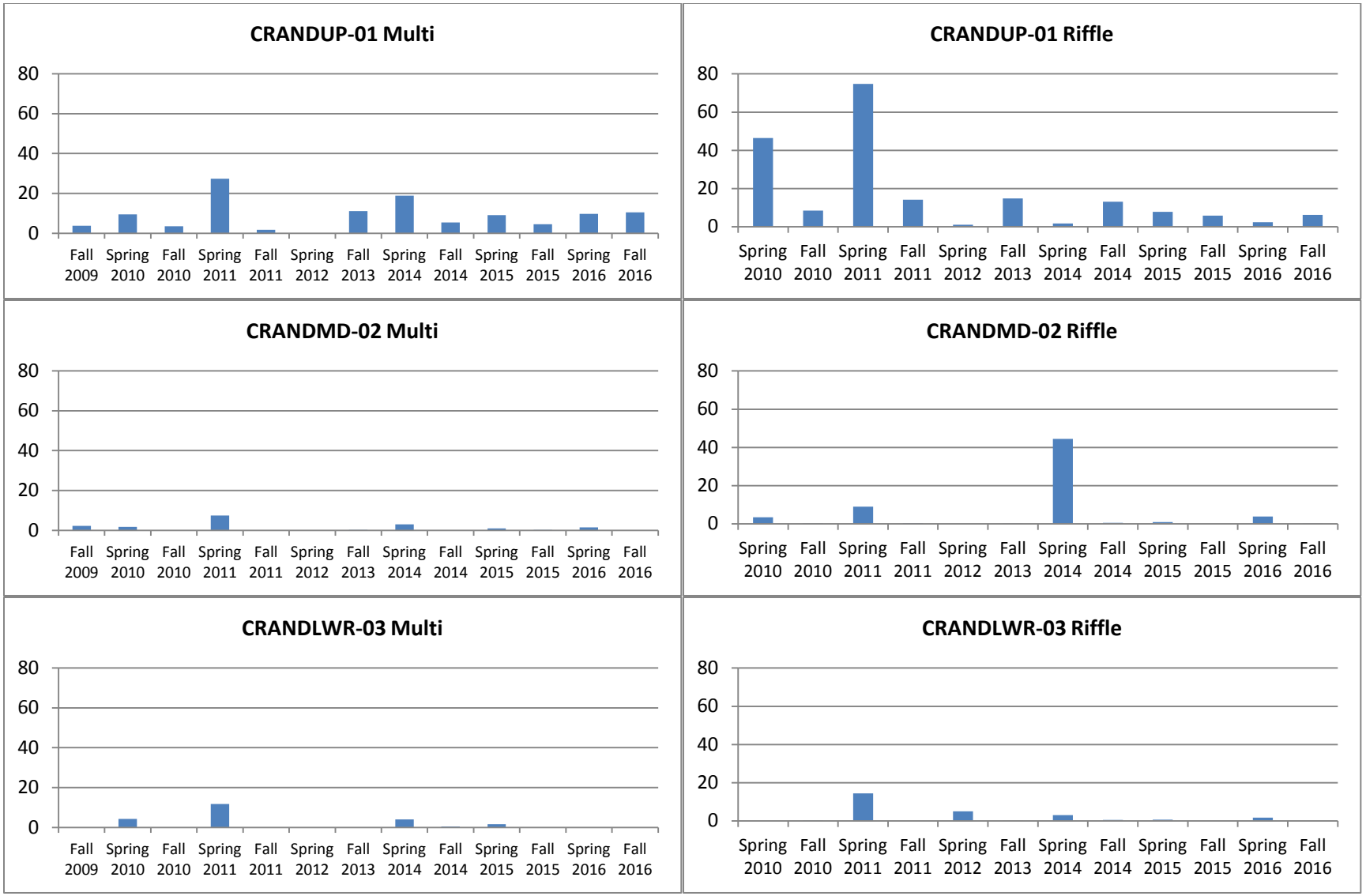


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 22c. Percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2010-2016



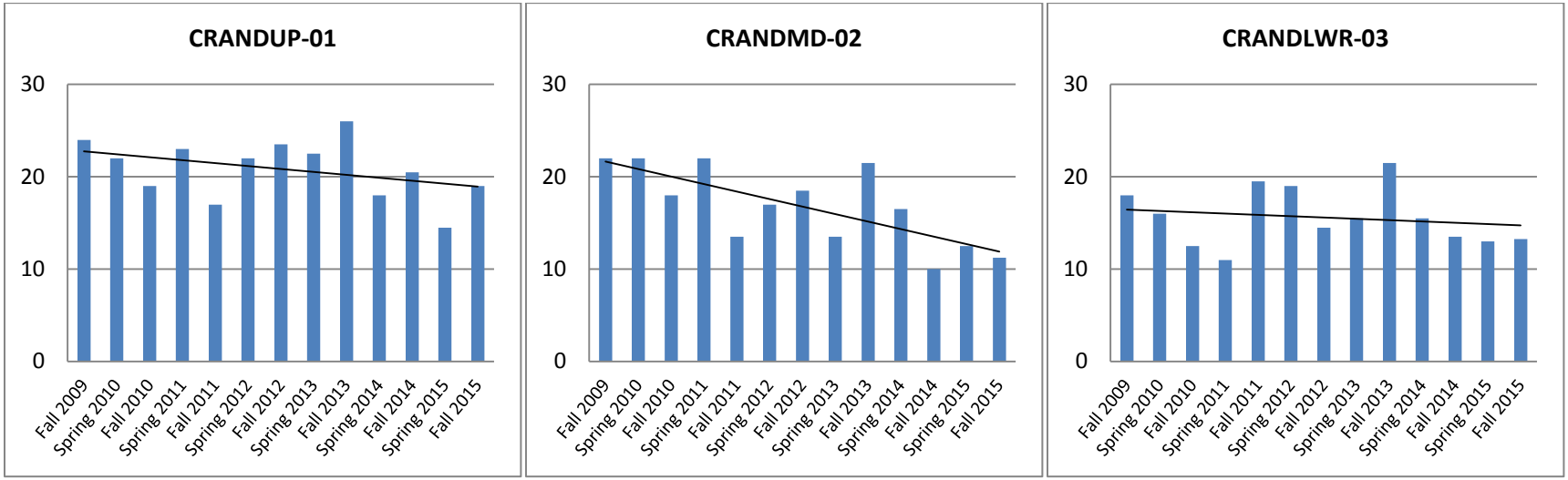
Figures 23c. Percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2010-2016



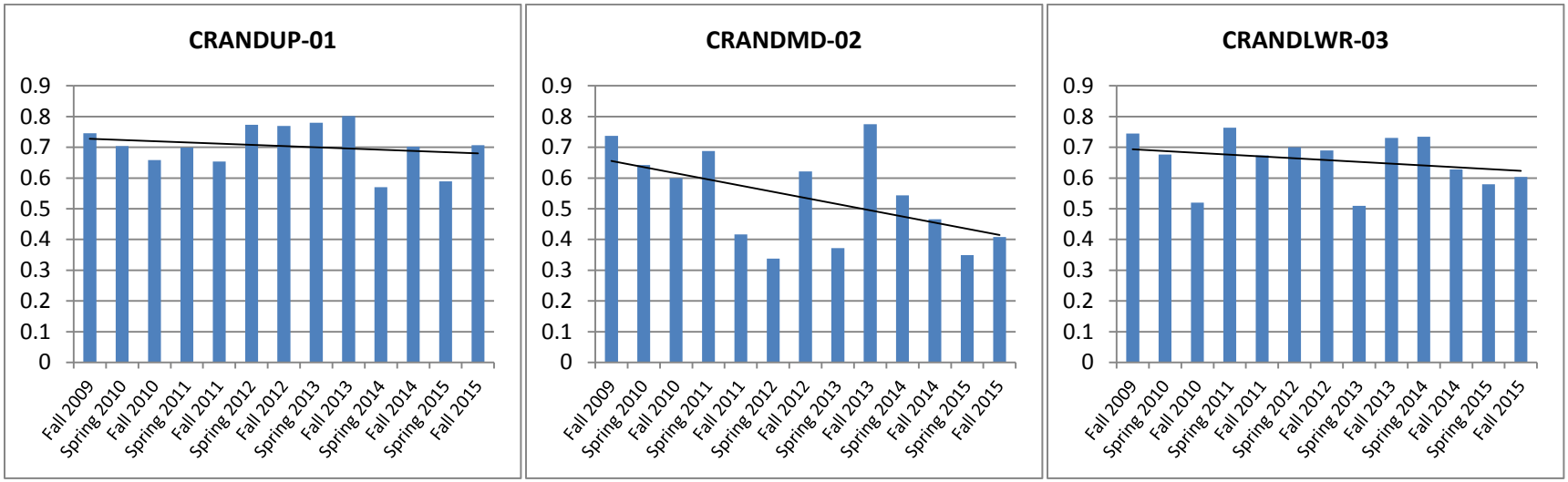
APPENDIX D

MACROINVERTEBRATE FIGURES FALL 2009- FALL 2016 AVERAGED

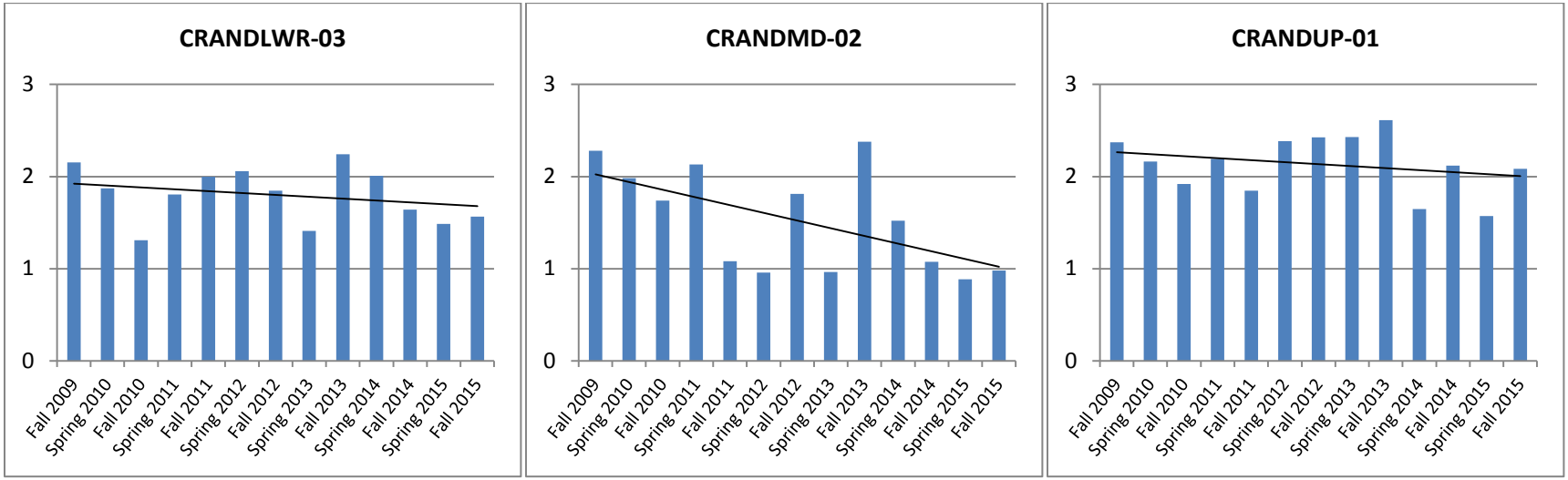
Figures 1d. Average richness in each reach from Fall 2009- Fall 2016



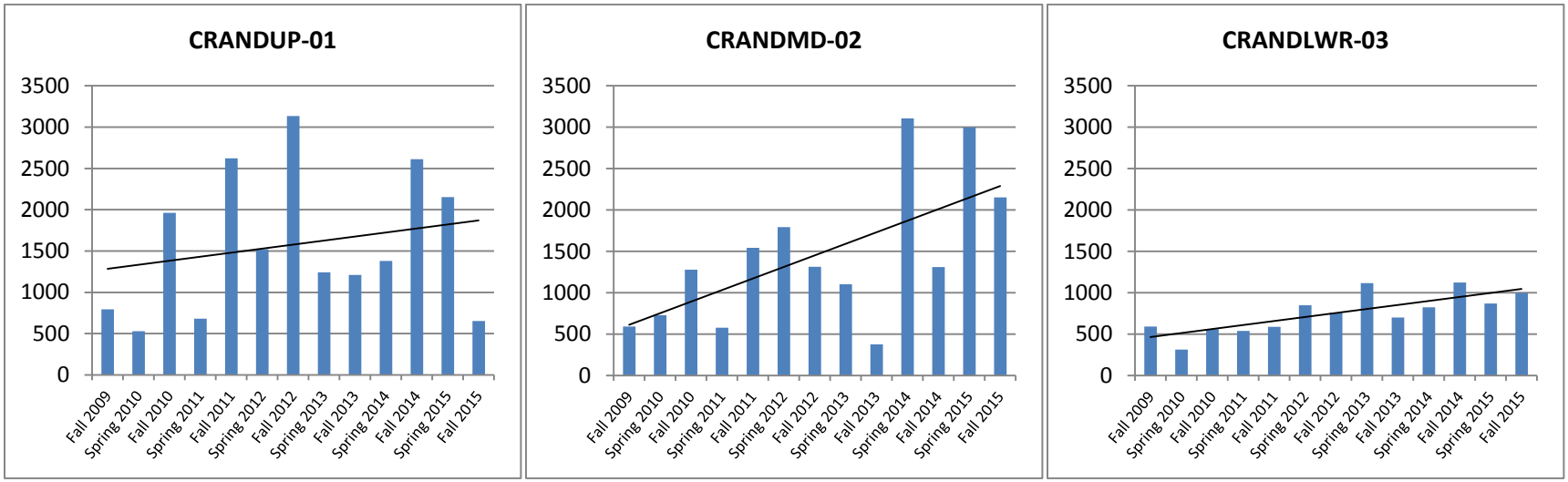
Figures 2d. Average evenness in each reach from Fall 2009- Fall 2016



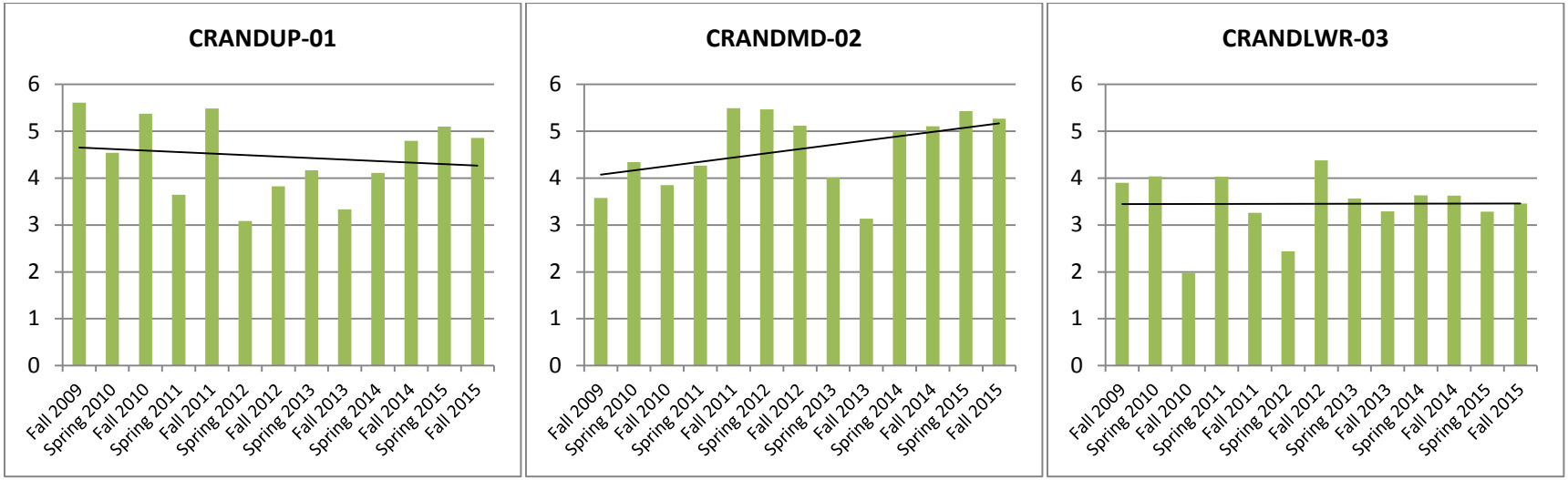
Figures 3d. Average Shannon's Diversity in each reach from Fall 2009- Fall 2016



Figures 4d. Average abundance in each reach from Fall 2009- Fall 2016

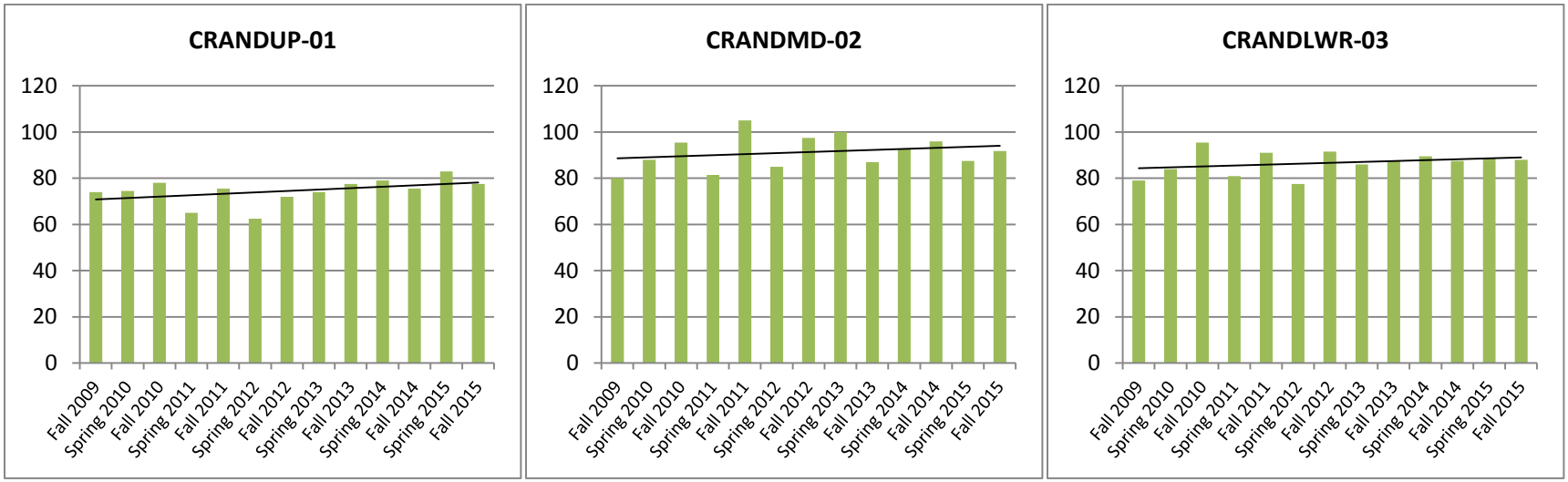


Figures 5d. Average Hilsenhoff Biotic Index in each reach from Fall 2009- Fall 2016*



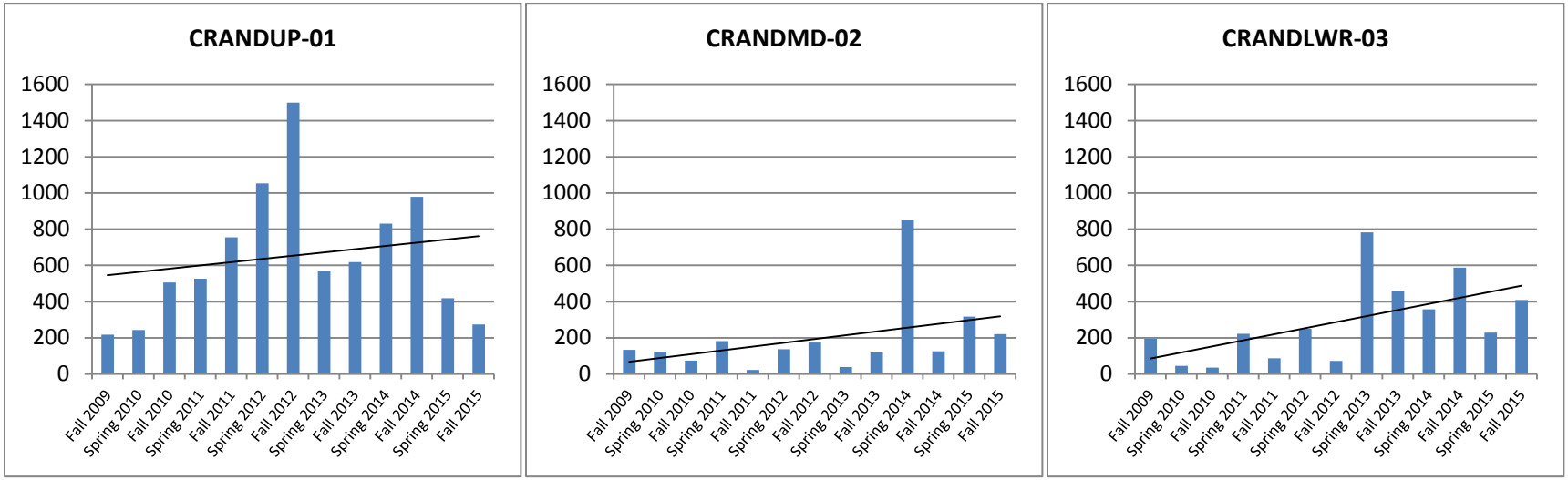
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 6d. Average USFS community tolerant quotient (CTQd) in each reach from Fall 2009- Fall 2016*

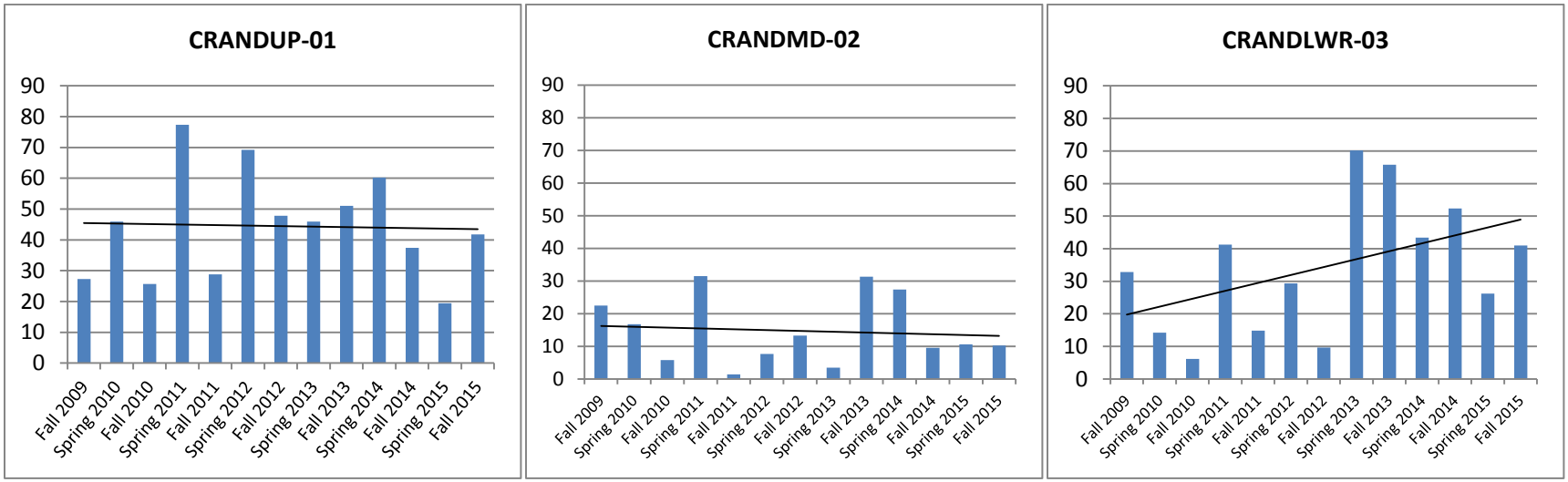


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

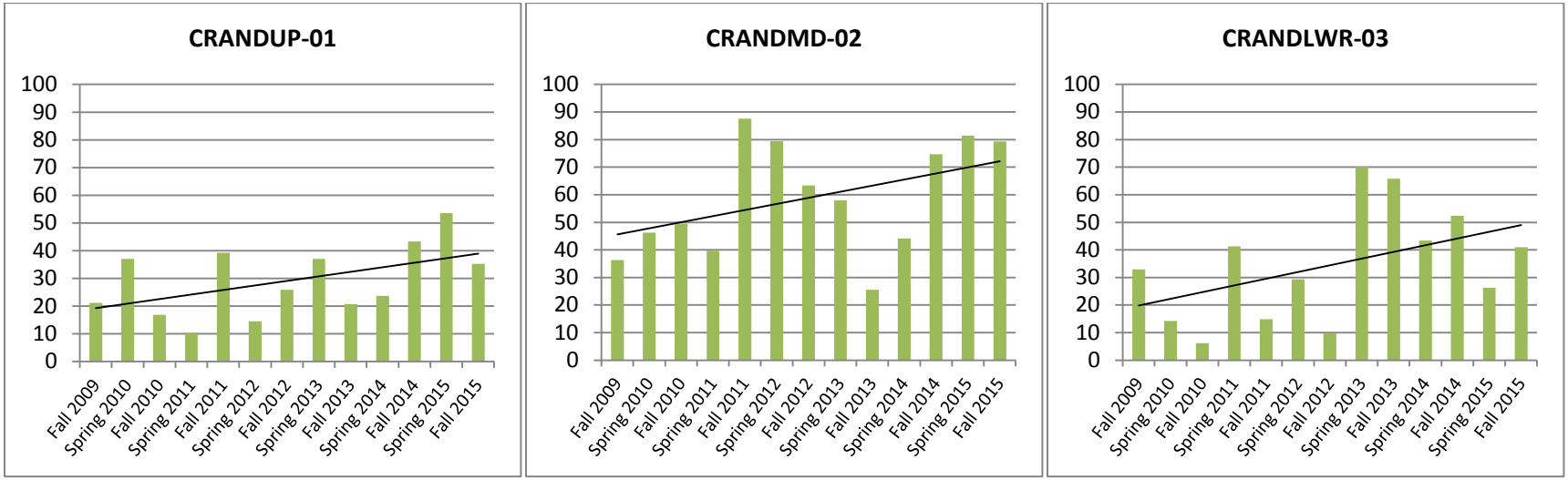
Figures 7d. Average EPT taxa abundance in each reach from Fall 2009- Fall 2016



Figures 8d. Average percent EPT in each reach from Fall 2009- Fall 2016

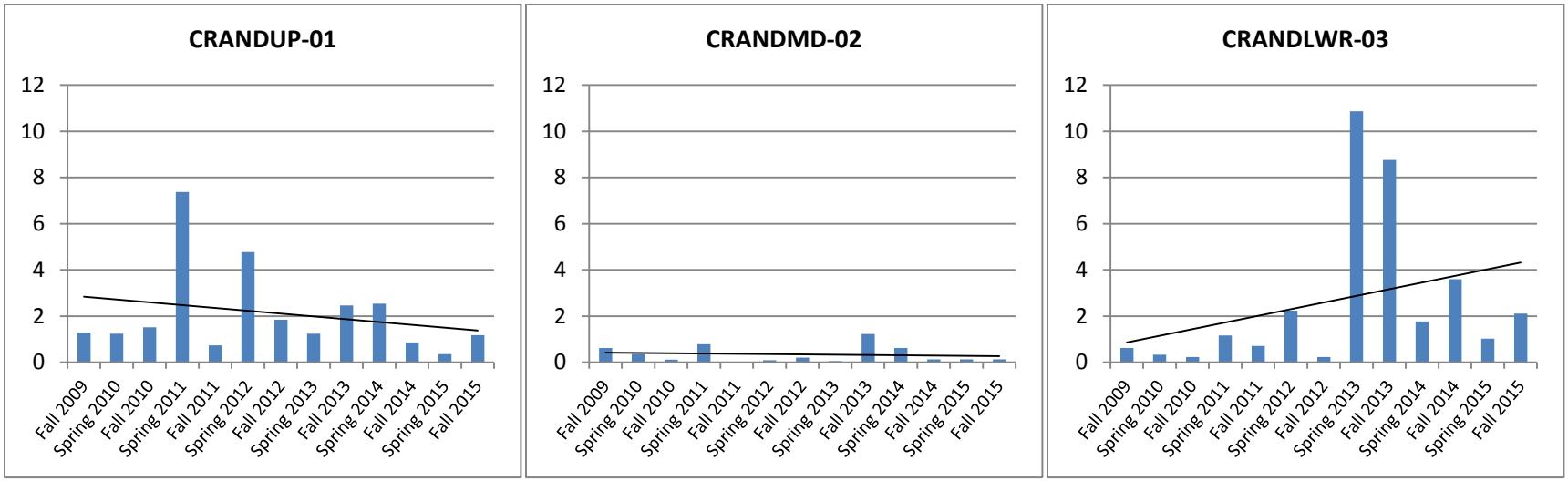


Figures 9d. Average percent Chironomids in each reach from Fall 2009- Fall 2016*

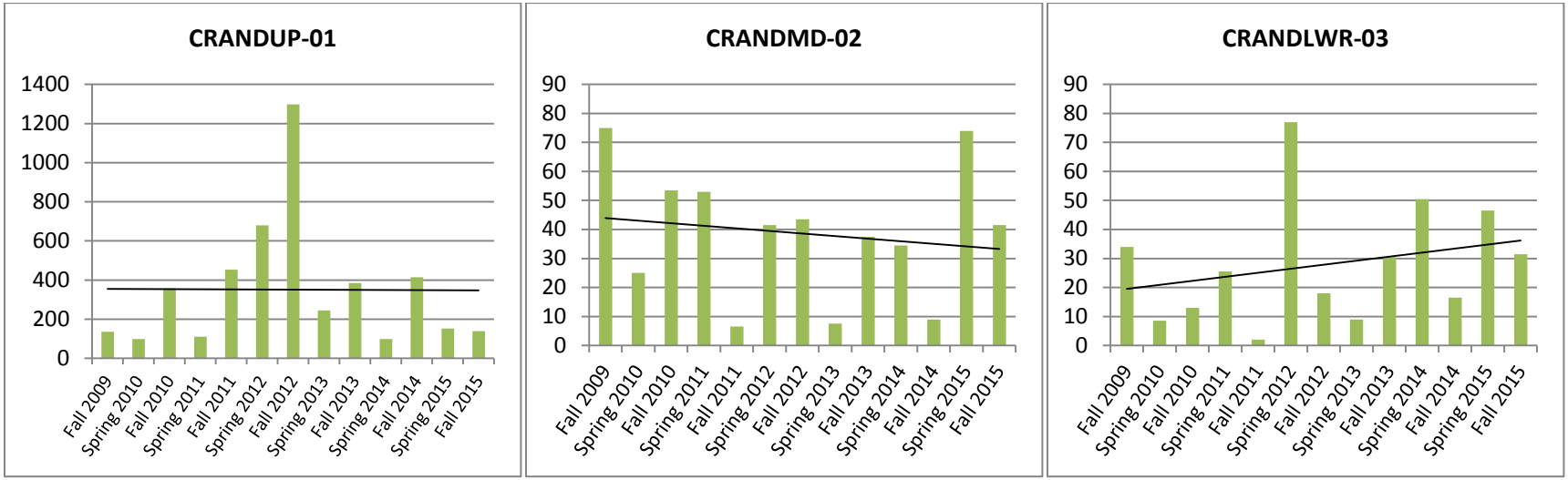


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 10d. Average ratio of EPT to Chironomids in each reach from Fall 2009- Fall 2016

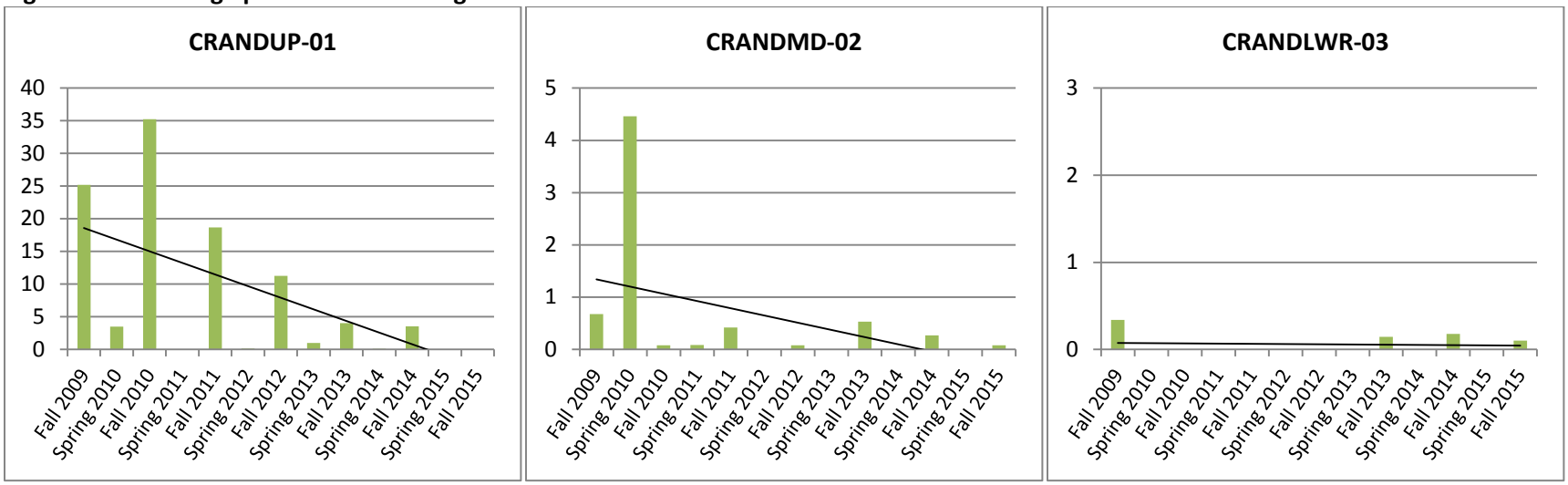


Figures 11d. Average number of tolerant taxa in each reach from Fall 2009- Fall 2016*



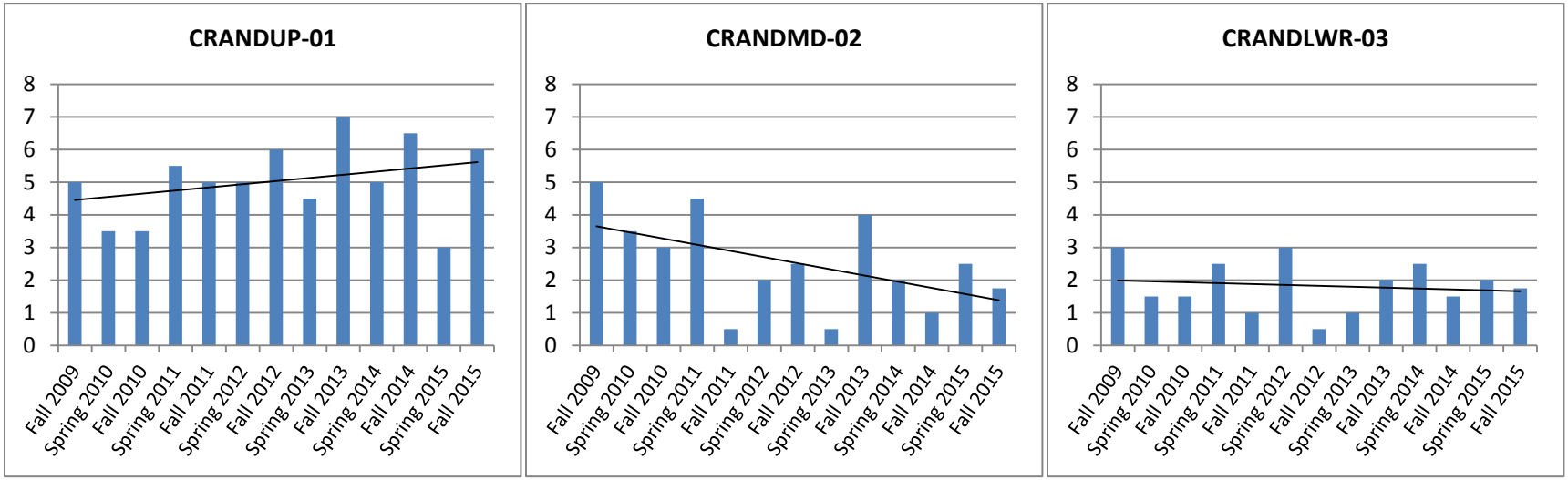
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 12d. Average percent tolerant organisms in each reach from Fall 2009- Fall 2016*

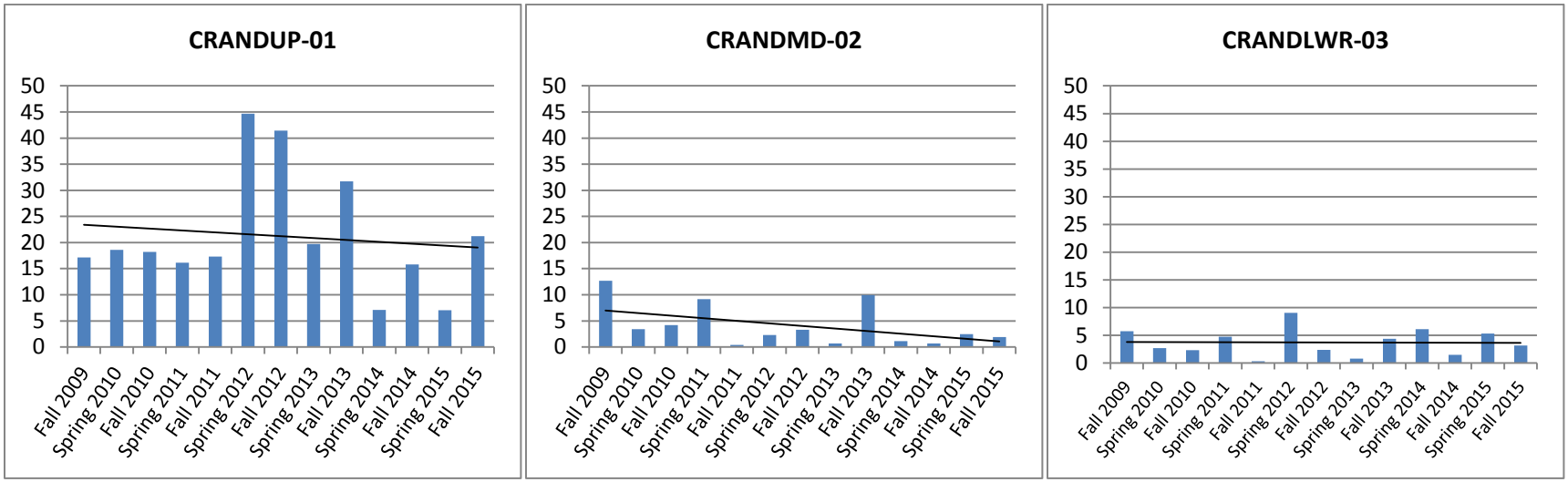


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

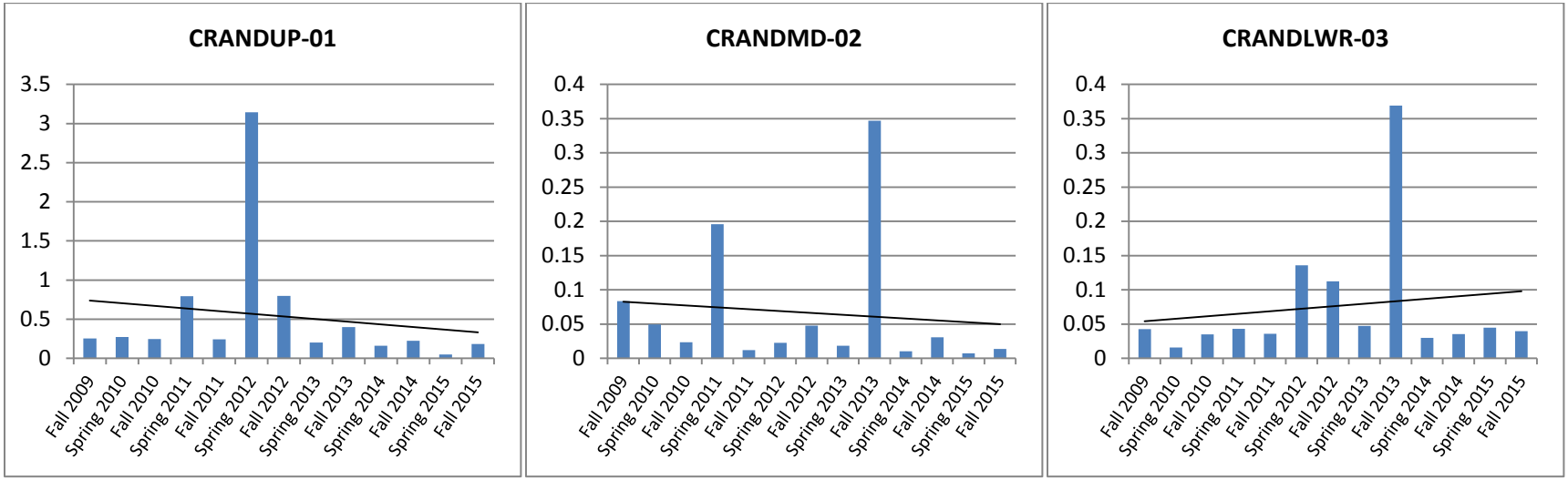
Figures 13d. Average number of intolerant taxa in each reach from Fall 2009- Fall 2016



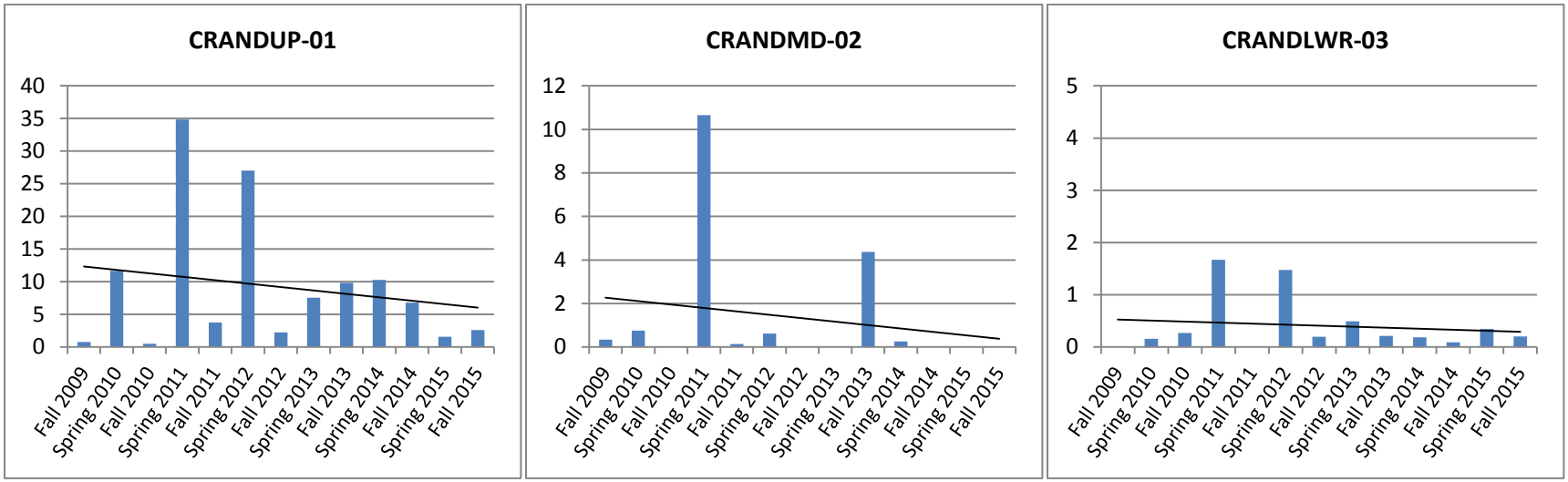
Figures 14d. Average percent intolerant organisms in each reach from Fall 2009- Fall 2016



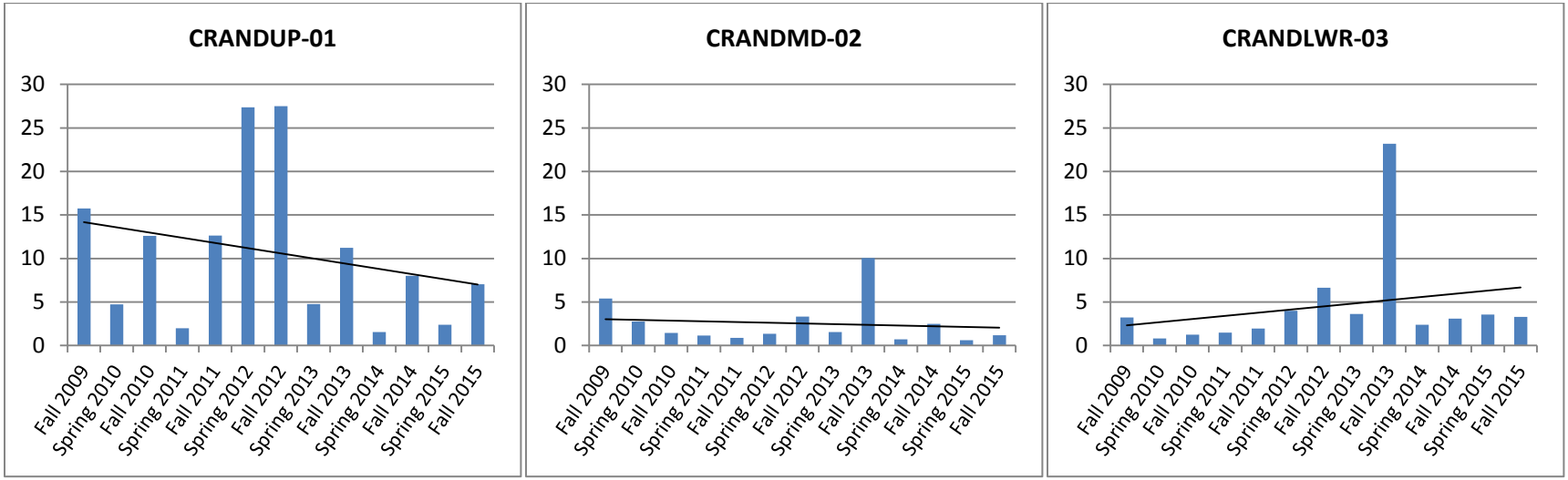
Figures 15d. Average ratio of specialist feeders to generalist feeders in each reach from Fall 2009- Fall 2016



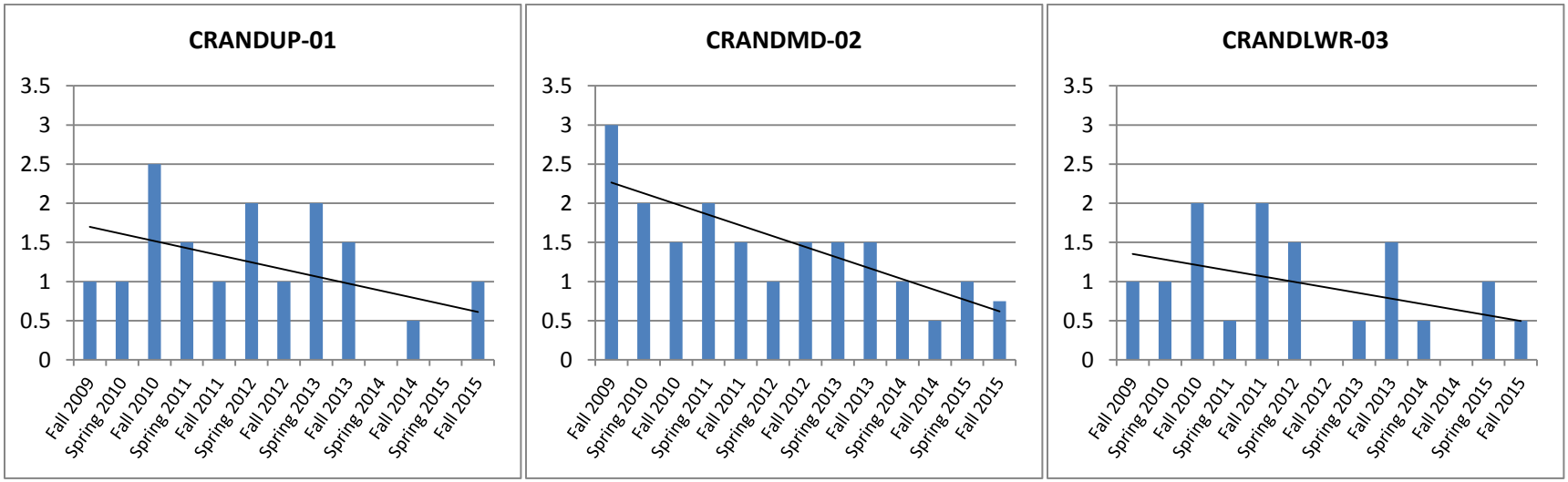
Figures 16d. Average percent scrapers in each reach from Fall 2009- Fall 2016



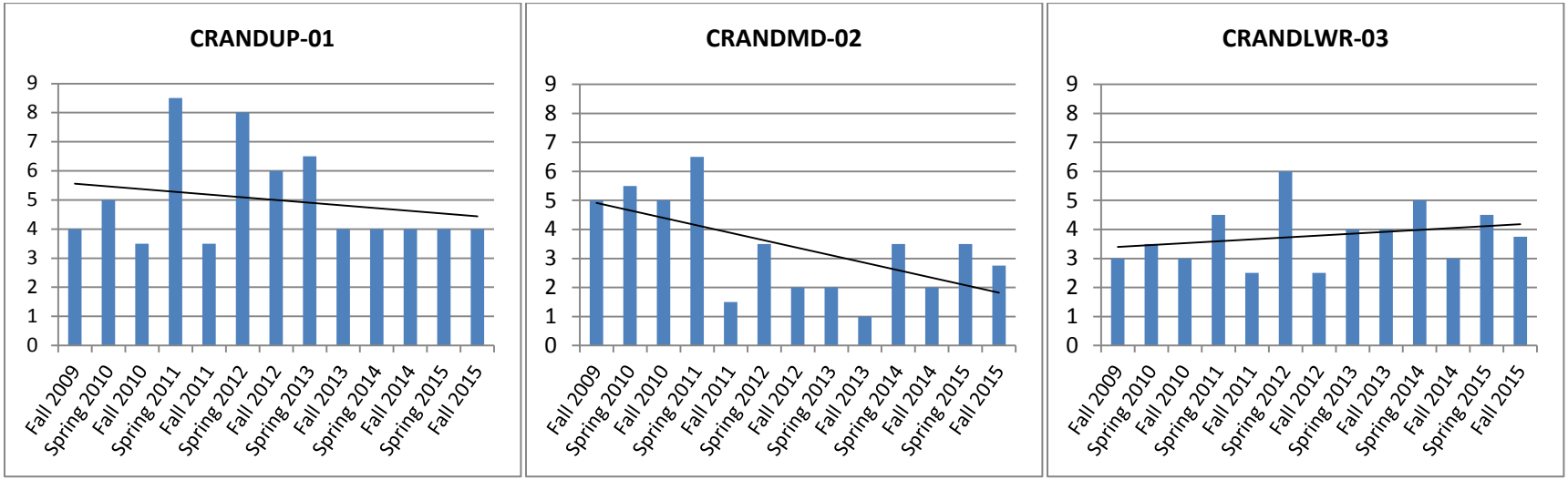
Figures 17d. Average percent shredders in each reach from Fall 2009- Fall 2016



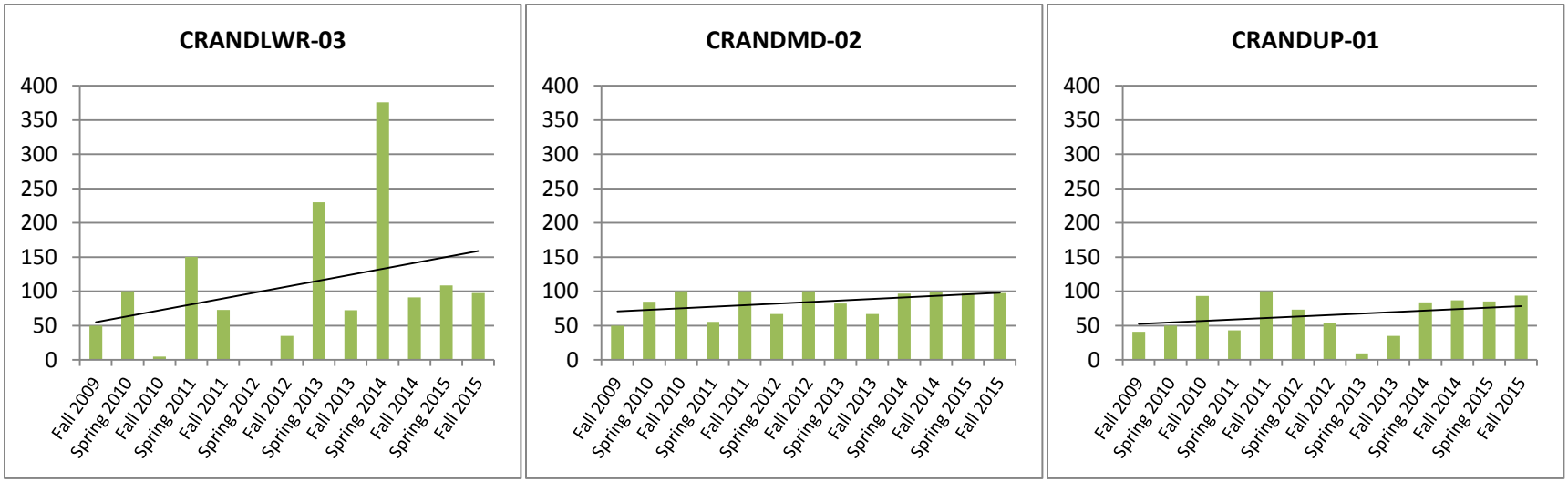
Figures 18d. Average number of long-lived taxa in each reach from Fall 2009- Fall 2016



Figures 19d. Average number of clinger taxa reach from Fall 2009- Fall 2016

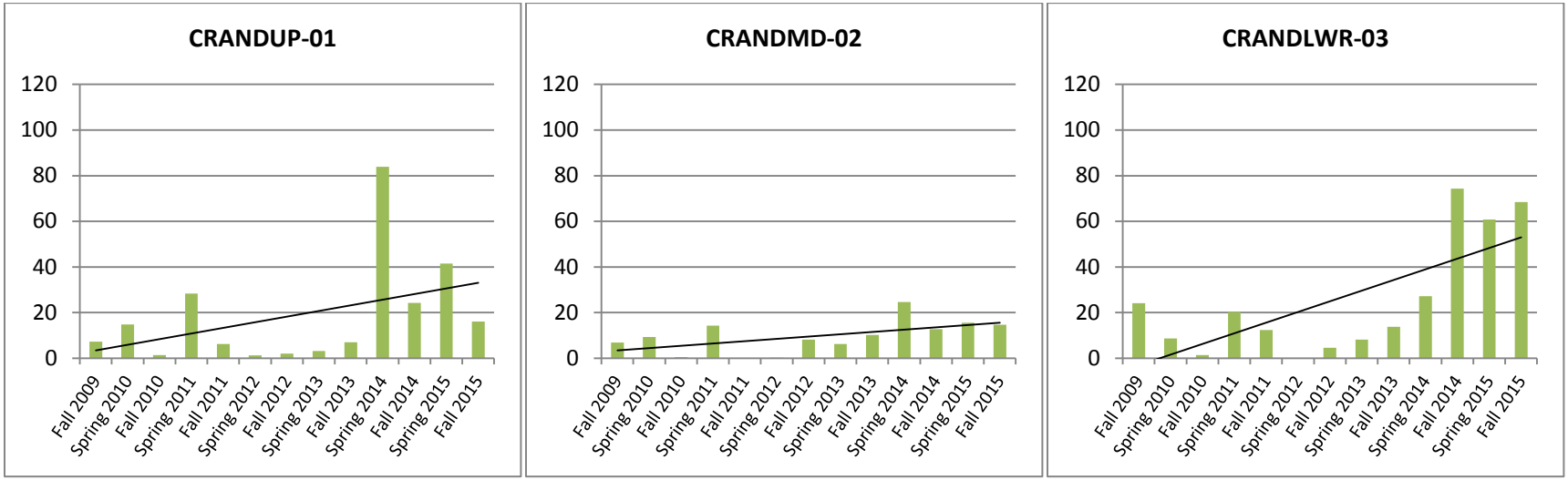


Figures 20d. Average percent ratio of *Baetis* to all Ephemetroptera for each reach and habitat type from 2009-2016*



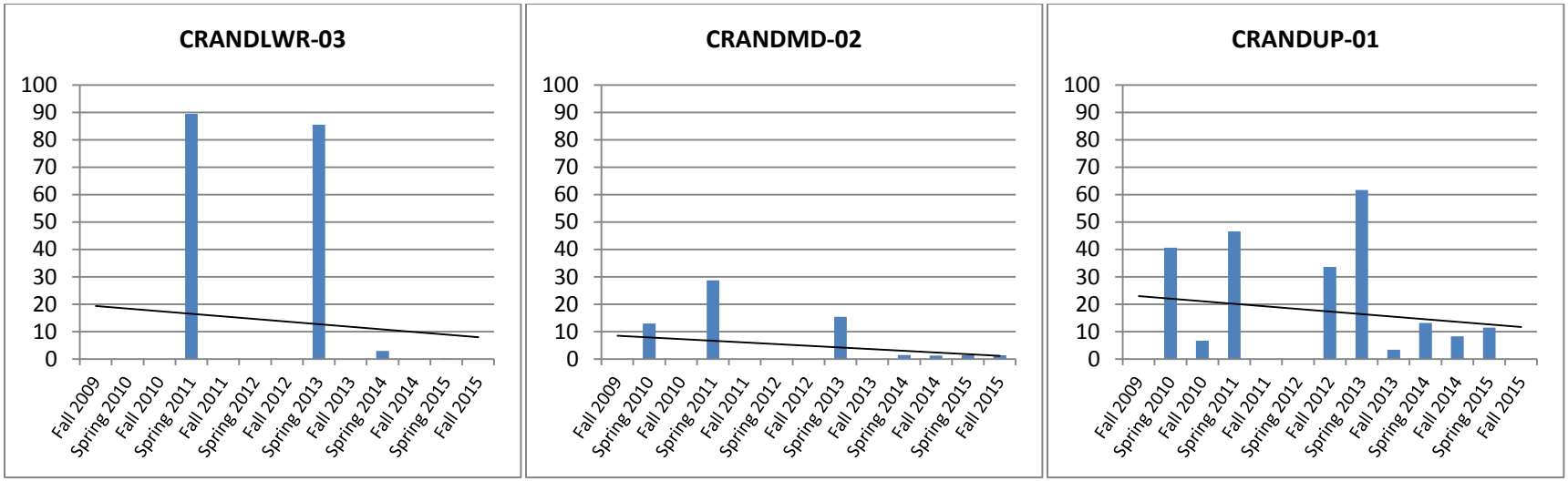
***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 21d. Average percent *Baetis,* Hydropsychidae, and Orthocladinaefor each reach and habitat type from 2009-2016*

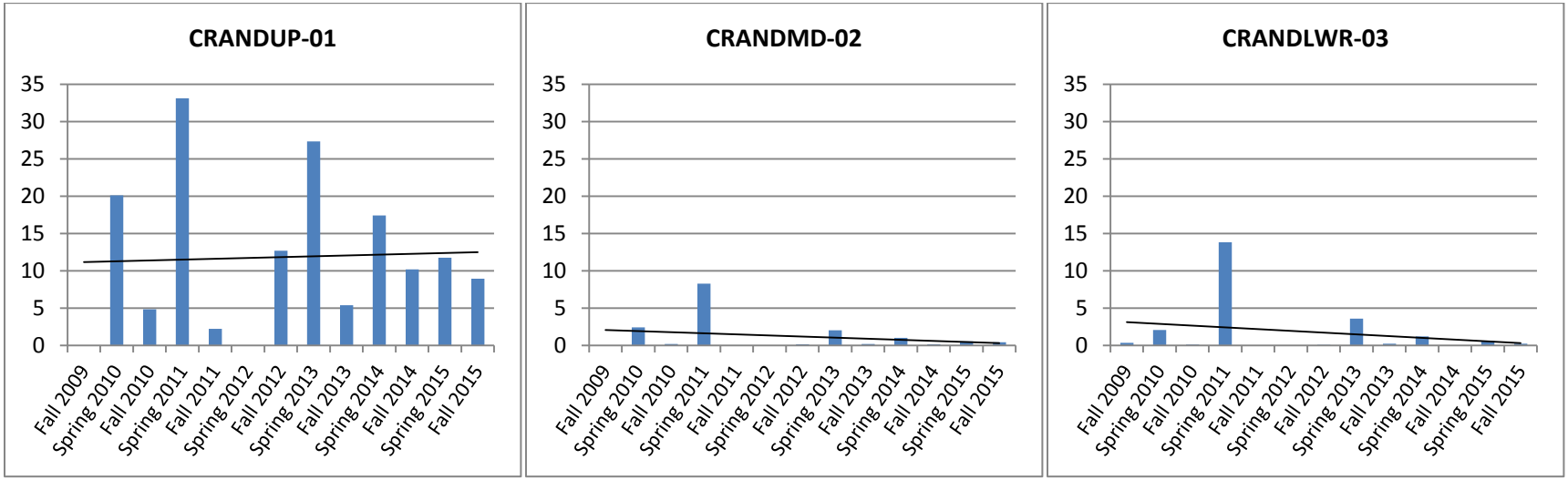


***Green graphs indicate that lower values, or a declining trend, specify more desirable conditions.**

Figures 22d. Average percent ratio of Heptageniidae to all Ephemeroptera for each reach and habitat type from 2009-2016



Figures 23d. Average percent Heptageniidae, Chloroperlidae, & Rhyacophila for each reach and habitat type from 2009-2016



Taxa Lists for Individual Samples Fall 2016

Following is the taxonomic list and the number of individuals found of each species for the 6 samples collected on September 22nd and 23rd, 2016. 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						1	28
Arthropoda	Arachnida	Trombidiformes					1	4
			Arrenuridae		Arrenurus		2	4
			Hygrobatidae				1	4
			Lebertiidae		Lebertia		5	115
			Sperchonidae		Sperchon		5	40
	Insecta	Coleoptera	Dytiscidae	Hydroporinae	Oreodytes		1	7
			Elmidae		Narpus	concolor	2	5
		Diptera	Ceratopogonidae				1	4
				Ceratopogoninae	Probezzia		6	66
			Chironomidae	Chironominae			4	38
				Orthocladiinae			6	519
				Tanypodinae			4	200
			Empididae		Neoplasta		3	72
				Hemerodromiinae	Chelifera		2	12
			Psychodidae		Pericoma		3	153
			Ptychopteridae		Ptychoptera		1	4
			Simuliidae	Simuliinae	Simulium		4	246
			Stratiomyidae		Euparyphus		1	1
			Tipulidae		Dicranota		3	10
				Limoniinae	Antocha	monticola	1	5
					Limnophila		1	1
				Tipulinae	Tipula		3	24
		Ephemeroptera	Ameletidae		Ameletus		1	1
			Baetidae		Baetis		6	3125
					Callibaetis		1	2
					Diphetor	hageni	4	753
			Heptageniidae				2	33
			Leptophlebiidae		Paraleptophlebia		1	3
		Plecoptera	Capniidae	Capniinae			2	21
			Nemouridae				1	2
					Zapada	cinctipes	1	39
				Amphinemurinae	Amphinemura		2	22
			Perlodidae				3	76
					Megarcys		2	11
				Isoperlinae	Isoperla		4	50
		Trichoptera	Hydropsychidae				2	269
				Arctopsychinae	Parapsyche		2	6
				Hydropsychinae	Hydropsyche		2	187
			Limnephilidae				4	69
				Dicosmoecinae	Dicosmoecus		1	38
				Limnephilinae	Hesperophylax		4	20
			Rhyacophilidae		Rhyacophila		3	12
						rotunda group	3	30
						vofixa group	2	89
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		2	14
Total:	Taxa:	**46**	Families:	**25**	Genera:	**31**		**6436**

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 23rd, 2016 at the station CRANDUP-01, Crandall Creek, Upstream, Emery County, Utah. The sample was collected from the reachwide habitat using a Kick Net. The total area sampled was 0.46 square meters. Of the collected sample, 100% was identified and retained. A total of 382 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 155473.
OTU= Operational Taxonomic Unit

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes					Adult	4
			Hygrobatidae				Adult	4
			Lebertiidae				Adult	26
			Sperchonidae		Sperchon		Adult	11
	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	17
			Chironomidae	Chironominae			Larvae	9
				Orthocladiinae			Larvae	107
				Tanypodinae			Larvae	167
			Empididae	Hemerodromiinae	Chelifera		Larvae	2
			Psychodidae		Pericoma		Larvae	124
			Ptychopteridae		Ptychoptera		Larvae	4
			Simuliidae	Simuliinae	Simulium		Larvae	11
			Tipulidae		Dicranota		Larvae	2
				Tipulinae	Tipula		Larvae	15
		Ephemeroptera	Baetidae		Baetis		Larvae	72
					Diphetor		Larvae	4
			Heptageniidae				Larvae	22
		Plecoptera	Capniidae	Capniinae			Larvae	20
			Nemouridae				Larvae	2
					Zapada		Larvae	39
				Amphinemurinae	Amphinemura		Larvae	4
			Perlodidae				Larvae	57
					Megarcys		Larvae	9
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche		Larvae	4
			Limnephilidae	Limnephilinae	Hesperophylax		Larvae	2
			Rhyacophilidae		Rhyacophila		Larvae	4
							Larvae	9
							Larvae	78
Total:	OTU Taxa:	**28**	Families:	**18**	Genera:	**17**		**830**

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 23rd, 2016 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 352 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 155474. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	15
			Sperchonidae		Sperchon		Adult	5
	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	4
			Chironomidae	Chironominae			Larvae	164
				Orthocladiinae			Larvae	11
				Tanypodinae			Larvae	9
			Empididae		Neoplasta		Larvae	27
				Hemerodromiinae	Chelifera		Larvae	8
			Psychodidae		Pericoma		Larvae	139
			Simuliidae	Simuliinae	Simulium		Larvae	11
		Ephemeroptera	Ameletidae		Ameletus		Larvae	3
			Baetidae		Baetis		Larvae	1
					Diphetor	hageni	Larvae	1
			Heptageniidae				Larvae	18
			Leptophlebiidae		Paraleptophlebia		Larvae	3
		Plecoptera	Capniidae	Capniinae			Larvae	1
			Perlodidae				Larvae	7
					Megarcys		Larvae	1
		Trichoptera	Hydropsychidae	Arctopsychinae	Parapsyche		Larvae	5
			Limnephilidae				Larvae	8
				Limnephilinae	Hesperophylax		Larvae	11
			Rhyacophilidae		Rhyacophila	rotunda group	Larvae	4
						vofixa group	Larvae	19
Total:	OTU Taxa:	**23**	Families:	**16**	Genera:	**15**		**476**

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 23rd, 2016 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 127 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 155475. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		Arrenurus		Adult	57
			Lebertiidae		Lebertia		Adult	4
			Sperchonidae		Sperchon		Adult	7
	Insecta	Coleoptera	Dytiscidae	Hydroporinae	Oreodytes		Larvae	2
			Elmidae		Narpus	concolor	Larvae	4
		Diptera	Ceratopogonidae				Larvae	20
				Ceratopogoninae	Probezzia		Larvae	91
			Chironomidae	Chironominae			Larvae	20
				Orthocladiinae			Larvae	2
				Tanypodinae			Larvae	2
			Psychodidae		Pericoma		Larvae	7
			Tipulidae	Tipulinae	Tipula		Larvae	2
		Ephemeroptera	Baetidae		Baetis		Larvae	20
		Plecoptera	Perlodidae	Isoperlinae	Isoperla		Adult	9
		Trichoptera	Limnephilidae				Larvae	28
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Adult	2
Total:	OTU Taxa:	**16**	Families:	**13**	Genera:	**11**		**276**

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 23rd, 2016 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 62 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 155476. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes	Lebertiidae		Lebertia		Adult	7
			Sperchonidae		Sperchon		Adult	3
	Insecta	Coleoptera	Elmidae		Narpus	concolor	Larvae	3
		Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	54
			Chironomidae	Orthocladiinae			Larvae	1
			Empididae		Neoplasta		Larvae	1
			Stratiomyidae		Euparyphus		Larvae	1
			Tipulidae		Dicranota		Larvae	1
				Limoniinae	Limnophila		Larvae	3
		Ephemeroptera	Baetidae		Baetis		Larvae	1
		Plecoptera	Perlodidae	Isoperlinae	Isoperla		Larvae	3
		Trichoptera	Limnephilidae	Limnephilinae	Hesperophylax		Larvae	3
			Rhyacophilidae		Rhyacophila	rotunda group	Larvae	3
Total:	OTU Taxa:	**13**	Families:	**12**	Genera:	**12**		**84**

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 22nd, 2016 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 599 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 155477. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Annelida	Clitellata						Adult	28
Arthropoda	Arachnida	Trombidiformes	Arrenuridae		Arrenurus		Adult	11
			Lebertiidae		Lebertia		Larvae	7
	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	2
			Chironomidae	Orthocladiinae			Larvae	11
				Tanypodinae			Larvae	7
			Simuliidae	Simuliinae	Simulium		Larvae	7
			Tipulidae		Dicranota		Larvae	404
				Tipulinae	Tipula		Larvae	2
		Ephemeroptera	Baetidae		Baetis		Larvae	17
					Callibaetis		Larvae	2
					Diphetor	hageni	Larvae	24
		Plecoptera	Nemouridae	Amphinemurinae	Amphinemura		Larvae	26
			Perlodidae				Larvae	26
				Isoperlinae	Isoperla		Larvae	37
		Trichoptera	Hydropsychidae				Larvae	15
				Hydropsychinae	Hydropsyche		Larvae	2
			Limnephilidae				Larvae	667
				Limnephilinae	Hesperophylax		Larvae	4
			Rhyacophilidae		Rhyacophila		Adult	2
Total:	OTU Taxa:	**20**	Families:	**12**	Genera:	**14**		**1302**

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 22nd, 2016 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, 25% was identified and retained. A total of 640 individuals were separated from the total sample, identified and retained for future reference. The sample identification number is 155478. OTU= Operational Taxonomic Unit.

Phylum	Class	Order	Family	SubFamily	Genus	Species	Life Stage	Density
Arthropoda	Arachnida	Trombidiformes	Sperchonidae		Sperchon		Adult	16
	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		Larvae	5
			Chironomidae	Chironominae			Larvae	97
				Orthocladiinae			Larvae	216
			Empididae		Neoplasta		Larvae	5
			Simuliidae	Simuliinae	Simulium		Larvae	2501
			Tipulidae	Limoniinae	Antocha	monticola	Larvae	22
		Ephemeroptera	Baetidae		Baetis		Larvae	243
					Diphetor	hageni	Larvae	161
		Plecoptera	Perlodidae	Isoperlinae	Isoperla		Larvae	5
		Trichoptera	Hydropsychidae				Larvae	38
				Hydropsychinae	Hydropsyche		Larvae	5
			Limnephilidae				Adult	5
				Dicosmoecinae	Dicosmoecus		Larvae	76
			Rhyacophilidae		Rhyacophila		Larvae	5
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidiinae	Pisidium		Larvae	65
Total:	OTU Taxa:	**16**	Families:	**12**	Genera:	**12**		**3468**

WARE SURVEYING, L.L.C.

1344 North 1000 West – Price, UT 84501
Office: 435-820-4335
Email: waresurveying@emerytelcom.net

Karin,

Here's a brief summary of the Burma sediment survey:

- Set up a total station (theodolite/distance meter) with reflectorless capabilities on top of the pond.
- Shot a prism on the spillway to verify the survey control and elevation benchmark.
- Shot a prism at the edge of the sediment. Also shot the same point using reflectorless. Elevation difference was +/-0.02'.
- Used reflectorless measurements at all 4 corners and also the center of the pond. All elevations were within +/-0.1'.
- Using the spillway elevation of 6519.5' the top of the sediment elevation is 6516.1'.

Let me know if you have any questions or need anything else.

Sincerely,

Cody Ware, PLS

PROFESSIONAL LAND SURVEYOR
9-8-14
No. 4940688
M. CODY WARE
STATE OF UTAH

Sludge Monitoring
at the
Burma Evaporation Basin

2016

for the
Crandall Canyon Mine

Prepared by

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by

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Robert E. Long, CPSS

for

GENWAL RESOURCES, INC.
P.O. Box 910
East Carbon, Utah 84520

January 2017

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INTRODUCTION

The Crandall Canyon Mine in Emery County, Utah was discharging water into Crandall Creek, a tributary of Huntington Creek, which was above the Utah Pollutant Discharge Elimination System (UPDES) compliance limit for iron. Consequently, Genwal Resources constructed a water treatment facility at the mine site to reduce the iron to acceptable legal discharge levels. The treatment includes utilization of an aeration unit and chemical injection system to coagulate and flocculate iron where the discharged water enters into a settling basin to allow the precipitated iron to accumulate. At regular time intervals the iron sludge material in the pond is removed and disposed of off-site. Located in lower Huntington Canyon about 10 miles from the mine site, the Burma Evaporation Basin was created for off-site disposal of the material.

Accumulated sludge material in the Burma Evaporation Basin is required to be sampled and analyzed for specific parameters every 5 years or when the solid waste reaches approximately 7.5 inches (MRP Appendix 7-66) [1]. Following sampling and analyses, excess dried sludge material is then taken to another approved disposal site.

This report describes the methods and results from sampling the sludge material in the Burma Evaporation Basin in 2016.

METHODS

Grab samples were taken from the Burma Evaporation Basin on September 8, 2016. Ten (10) samples were taken uninterrupted to depth at random locations in the basin. The 10 samples were then combined into a clean 2-gallon sample container to create a single composite sludge sample. This composite sample was then sent to Inter-Mountain Labs, Inc. in Sheridan, Wyoming using chain of custody forms and prepared at the laboratory using TCLP Method 1311[(2)]. The sample was analyzed for all RCRA metals, The mean sample depth for the 10 samples that were combined to make 1 composite sample was 7.85 inches.

Table 1, using EPA Method 200.7[3] or 200.8 to monitor for hazardous concentrations in accordance with the Code of Federal Regulations, General Waste Analysis (40 CFR 264.13) .

Figure 1. Burma evaporation basin when sampled on September 8, 2016.

The analyses included the following metals of agronomic concern: aluminum by Synthetic Precipitation Leaching Procedure (SPLP, SW846 Method 1312)[4] and plant available iron, zinc, and nickel analyzed by DTPA extractable. Parameters and methods (or equivalent methods) described in the State of Utah, Division Oil, Gas and Mining's, *Guidelines for Topsoil and Overburden*[5] were also analyzed (Table 2).

The mean sample depth for the 10 samples that were combined to make 1 composite sample was 7.85 inches.

Table 1. Regulatory limits for RCRA metals[6].

Metal	Allowable Regulatory Concentration
	mg/L (ppm)
Arsenic	5.0
Barium	100.0
Cadmium	1.0
Chromium	5.0
Lead	5.0
Mercury	0.2
Selenium	1.0
Silver	5.0
Source: United States Environmental Protection Agency (EPA). Dec 2016. SW-846 Compendium, Chapter 7, Table 7-1.	

Sample Analysis

Table 3 summarizes the laboratory analysis of the Burma sludge sample in relation to regulatory levels. The full laboratory report is attached to this report (see Appendix).

Discussion of Results

The pH and conductivity results are in the *Poor* category based on the Utah DOGM *Guidelines for Management of Topsoil and Overburden* (Utah DOGM 2008)[5].

Sodium adsorption ratio (SAR) is in excess of the Utah DOGM *Unacceptable* standard in *Guidelines for Management of Topsoil and Overburden* (Utah DOGM 2008)[5]. The MRP states that this material will be covered with a minimum of four feet of suitable fill at the time of final reclamation.

The soluble selenium, available boron, and acid-base potential are within the Utah DOGM suitability standards in *Guidelines for Management of Topsoil and Overburden* (Utah DOGM 2008)[5].

The RCRA metals (TCLP arsenic, barium, cadmium, chromium, lead, selenium, and silver) results are all below the detectable limits for each metal and below the established EPA regulatory standards (SW-846)[6].

Table 2. Parameters and suitability limits for parameters listed in Tables 3, 4, 7, and 8 of the *Guidelines for Management of Topsoil and Overburden* (Utah DOGM 2008)[5].

Criteria	Units	Good	Fair	Poor	Unacceptable
Saturation	%	25 to 55	≥ 56 to 80	< 25 > 80	
pH	s.u.	6.5 to 8.2	6.0 to 6.4 8.2 to 8.5	5.5 to 6.0 8.6 to 9.0	< 5.5 > 9.0
Electrical Conductivity	mS/cm (dS/m)	0 to 4	4 to 8	8 to 15	> 15
Sodium Adsorption Ratio (SAR)	s.u.	0 to 4	4 to 10	10 to 14	> 14
Calcium Carbonate ($CaCO_3$)	%	< 15	15 to 30	> 30	
Texture		Sandy loam Loam Silt Loam Sandy Clay Loam Very Fine Sandy Loam Fine Sandy Loan	Clay Loam Clay Silt Clay Loam Sandy Clay Loamy Sand Loamy Fine Sand	Silty Clay Sand Sandy Clay Coarse Sand Fine Sand Very Fine Sand	Gravel Very Coarse Sand
Total Organic Carbon	%	< 10			≥ 10
Available Water Capacity	Inches per inch	> 0.10	0.5 to 0.10	< 0.05	
K factor		< 0.37	0.37	> 0.37	
Selenium, soluble	mg/kg				≤ 0.15[a] ≤0.10 [b,c]
Boron, Available	mg/kg				≥ 5.0
Acid/Base Potential	Tons $CaCO_3$/ 1000 tons				≤ 0 tons $CaCO_3$/ 1000 tons

a. Unacceptable level for the rooting zone (top sour feet of fill) and/or ephemeral drainages with 100 year flood plains, top 4 feet fill.
b. Unacceptable level for the top 4 feet of fill in surface-water impoundments.
c. Unacceptable level for intermittent/perennial drainages including 100 year flood plains.

Table 3. Summary of laboratory analysis of Burma evaporative pond sludge sample collected on September 8, 2016.

Sample ID	pH	Saturation	Electrical Conductivity	Field Capacity	Wilting Point	Available Water Capacity	Organic Matter
	s.u.	%	dS/m	%	%	%	%
Burma-1-16	8.6	108	20.0	71.8	48.1	23.7	3.1
DOGM	Good	Fair	Poor	Unacceptable			

Sample ID	CaCO3	SAR	Sand	Silt	Clay	Texture	Very Fine Sand
	%		%	%	%		%
Burma-1-16	14.5	37.0	78.0	18.0	4.0	Loamy Sand	<0.1
DOGM	Good	Fair	Poor	Unacceptable			

Sample ID	DTPA Iron	DTPA Nickel	DTPA Zinc	Boron	Phosphorus	Selenium
	ppm	ppm	ppm	ppm	ppm	ppm
Burma-1-16	34.8[a]	0.54[a]	14.4[a]	1.66	2	<0.02
DOGM	Good/Acceptable	Fair	Poor	Unacceptable		

Sample ID	Nitrate (as N)	Available Potassium	Total Organic Carbon	T.S. Acid Potential	Neutral. Potential	T.S. Acid Base Potential	Total Sulfur	Pyritic Sulfur
	ppm	meq/100g	%	t/1000t	t/1000t	t/1000t	%	%
Burma-1-16	1.7	8.39	2.1	64.5	145	80.1	2.06	<0.01

Sample ID	SPLP Aluminum	TCLP Arsenic	TCLP Barium	TCLP Cadmium	TCLP Chromium	TCLP Lead	TCLP Selenium	TCLP Silver
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Burma-1-16	<0.5[1]	<0.2[b]	<0.5[b]	<0.05[b]	<0.01[b]	<0.2[b]	<0.2[b]	<0.05[b]

a. Not compared against any regulatory standards. b. Compared to EPA regulatory levels in SW-846.

Literature Cited

[1] Mining and Reclamation Plan for the Crandall Canyon Mine. Appendix 7-66. Genwal Resources, Inc. East Carbon, UT.

[2] United States Environmental Protection Agency (EPA). July 1992. Method 1311: Toxicity Characteristic Leaching Procedure, part of Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (PDF).

[3] United States Environmental Protection Agency (EPA). 1994. Method 200.7: Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry

[4] United States Environmental Protection Agency (EPA). September 1994. SW-846 Test Method 1312: Synthetic Precipitation Leaching Procedure, part of Test Method for Evaluating Solid Waste, Physical/Chemical Methods (PDF)

[5] Guidelines for Management of Topsoil and Overburden. 2008. State of Utah, Division Oil, Gas and Mining. Salt Lake City, UT.

[6] United States Environmental Protection Agency (EPA). Dec 2016. SW-846 Compendium, Chapter 7, Table 7-1.

Appendix

Laboratory Report

Inter-Mountain Labs
Your Environmental Monitoring Partner
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Date: 10/13/2016

CLIENT: Mt. Nebo Scientific, Inc.
Project: Sludge Sample Analysis
Lab Order: S1609217

CASE NARRATIVE

Report ID: S1609217001

Sample Burma-1-16 was received on September 14, 2016.

Samples were analyzed using the methods outlined in the following references:

U.S.E.P.A. 600/2-78-054 "Field and Laboratory Methods Applicable to Overburden and Mining Soils", 1978
American Society of Agronomy, Number 9, Part 2, 1982
USDA Handbook 60 "Diagnosis and Improvement of Saline and Alkali Soils", 1969
Wyoming Department of Environmental Quality, Land Quality Division, Guideline No. 1, 1984
New Mexico Overburden and Soils Inventory and Handling Guideline, March 1987
State of Utah, Division of Oil, Gas, and Mining: Guidelines for Management of Topsoil and Overburden for Underground and Surface Coal Mining, April 1988
Montana Department of State Lands, Reclamation Division: Soil, Overburden, and Regraded Spoil Guidelines, December 1994
State of Nevada Modified Sobek Procedure
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW846, 3rd Edition

All Quality Control parameters met the acceptance criteria defined by EPA and Inter-Mountain Laboratories except as indicated in this case narrative.

Reviewed by: Karen A Secor
Karen Secor, Soil Lab Supervisor

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Soil Analysis Report

Mt. Nebo Scientific, Inc.
P.O. Box 337
Springville, UT 84663

Report ID: S1609217001

Project: Sludge Sample Analysis
Date Received: 9/14/2016

Date Reported: 10/13/2016
Work Order: S1609217

Lab ID	Sample ID	pH	Saturation	Electrical Conductivity	Field Capacity	Wilting Point	Organic Matter	CaCO3
		s.u.	%	dS/m	%	%	%	%
S1609217-001	Burma-1-16	8.6	108	20.0	71.8	48.1	3.1	14.5

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Secor
Karen Secor, Soil Lab Supervisor

Inter-Mountain Labs
1673 Terra Avenue, Sheridan, Wyoming 82801 ph: (307) 672-8945

Your Environmental Monitoring Partner

Soil Analysis Report

Mt. Nebo Scientific, Inc.

P.O. Box 337
Springville, UT 84663

Report ID: S1609217001

Project: Sludge Sample Analysis

Date Reported: 10/13/2016

Date Received: 9/14/2016

Work Order: S1609217

Lab ID	Sample ID	Calcium PE meq/L	Magnesium PE meq/L	Potassium PE meq/L	Sodium PE meq/L	SAR	Sand %	Silt %	Clay %	Texture	Very Fine Sand %
S1609217-001	Burma-1-16	4.87	36.5	20.5	168	37.0	78.0	18.0	4.0	Loamy Sand	<0.1

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate

Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential

Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Secor

Karen Secor, Soil Lab Supervisor

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Date Reported: 10/13/2016

Date Received: 9/14/2016

Work Order: S1609217

Lab ID	Sample ID	DTPA Iron ppm	DTPA Nickel ppm	DTPA Zinc ppm	Boron ppm	Phosphorus ppm	Selenium ppm	Nitrate(as N) ppm	Available Potassium meq/100g	Total Carbon %	TOC %
S1609217-001	Burma-1-16	34.8	0.54	14.4	1.66	2	<0.02	1.7	8.39	3.8	2.1

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate

Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential

Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Secor

Karen Secor, Soil Lab Supervisor

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Report ID: S1609217001

Project: Sludge Sample Analysis
Date Received: 9/14/2016

Date Reported: 10/13/2016
Work Order: S1609217

Lab ID	Sample ID	Total Sulfur %	T.S. AB t/1000t	Neutral. Potential t/1000t	T.S. ABP t/1000t	Pyritic Sulfur %	SPLP Aluminum mg/L
S1609217-001	Burma-1-16	2.06	64.5	145	80.1	<0.01	<0.5

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Secor
Karen Secor, Soil Lab Supervisor

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Your Environmental Monitoring Partner

Soil Analysis Report

Mt. Nebo Scientific, Inc.
P.O. Box 337
Springville, UT 84663

Report ID: S1609217001

Project: Sludge Sample Analysis
Date Received: 9/14/2016

Date Reported: 10/13/2016
Work Order: S1609217

Lab ID	Sample ID	TCLP Arsenic mg/L	TCLP Barium mg/L	TCLP Cadmium mg/L	TCLP Chromium mg/L	TCLP Lead mg/L	TCLP Selenium mg/L	TCLP Silver mg/L	TCLP Mercury mg/L
S1609217-001	Burma-1-16	<0.2	<0.5	<0.05	<0.01	<0.2	<0.2	<0.05	<0.005

These results apply only to the samples tested.

Abbreviations for extractants: PE= Saturated Paste Extract, H20Sol= water soluble,AB-DTPA= Ammonium Bicarbonate-DTPA, AAO= Acid Ammonium Oxalate
Abbreviations used in acid base accounting: T.S.= Total Sulfur, AB= Acid Base, ABP= Acid Base Potential, PyrS= Pyritic Sulfur, Pyr+Org= Pyritic Sulfur + Organic Sulfur, Neutral. Pot.= Neutralization Potential
Miscellaneous Abbreviations: SAR= Sodium Adsorption Ratio, CEC= Cation Exchange Capacity, ESP= Exchangeable Sodium Percentage

Reviewed by: Karen A Secor
Karen Secor, Soil Lab Supervisor

Inter-Mountain Labs, Inc
1673 Terra Ave, Sheridan, Wyoming, 82801
(307) 672-8945

Soil Analysis Report
Mt. Nebo Scientific, Inc.
P.O. Box 337
Springville, Utah 84663

Project ID: Sludge Sample Analysis
Date Received: 9/14/2016

Report ID: S1609217001
Date Reported: 10/13/2016
Work Order: S1609217

Lab ID	Sample ID	Organic Matter %	Sand %	Silt %	Clay %	Very Fine Sand %	Texture	K-factor (t.ac.h/100acft.tf.in)	Structure s	Permeability p	M	Description
S1609217-001	Burma-1-16	3.1	78.0	18.0	4.0	0.1	Loamy Sand	0.03	1	2	1737.6	

These Results apply only to the samples tested.

Reviewed by: Karen Secor
Karen Secor, Soil Lab Supervisor

Inter-Mountain Labs
Sheridan, WY and Gillette, WY

- CHAIN OF CUSTODY RECORD -

All shaded fields must be completed.
This is a legal document; any misrepresentation may be construed as fraud.

mtNebo 091416

Client Name	Project Identification	Sampler (Signature/Attestation of Authenticity)	Telephone #
Mt. Nebo Scientific, Inc.	Sludge Sample Analysis	P.D. Collins	801.489.6937

Report Address
P.O. Box 337 Springville, UT 84663

Contact Name
Patrick Collins/Bob Long
Email mt.nebo@xmission.com
Phone 801.489.6937

Invoice Address
P.O. Box 337 Springville, UT 84663

Purchase Order # n/a
Quote # 1363

ANALYSES / PARAMETERS
See Quote 1363

ITEM	LAB ID (Lab Use Only)	DATE SAMPLED	TIME SAMPLED	SAMPLE IDENTIFICATION	Matrix	# of Containers	REMARKS
1	S1609217-001	9/8/16	11:30am	Burma-1-16			see quote 1363
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							

LAB COMMENTS

Relinquished By (Signature/Printed)	DATE	TIME	Received By (Signature/Printed)	DATE	TIME
Patrick Collins Patrick Collins	9/9/16		Karen A Secor	9/14/16	1000
	10 am				

SHIPPING INFO
- ☒ UPS
- ☐ Fed Express
- ☐ US Mail
- ☐ Hand Carried
- ☐ Other_____

MATRIX CODES

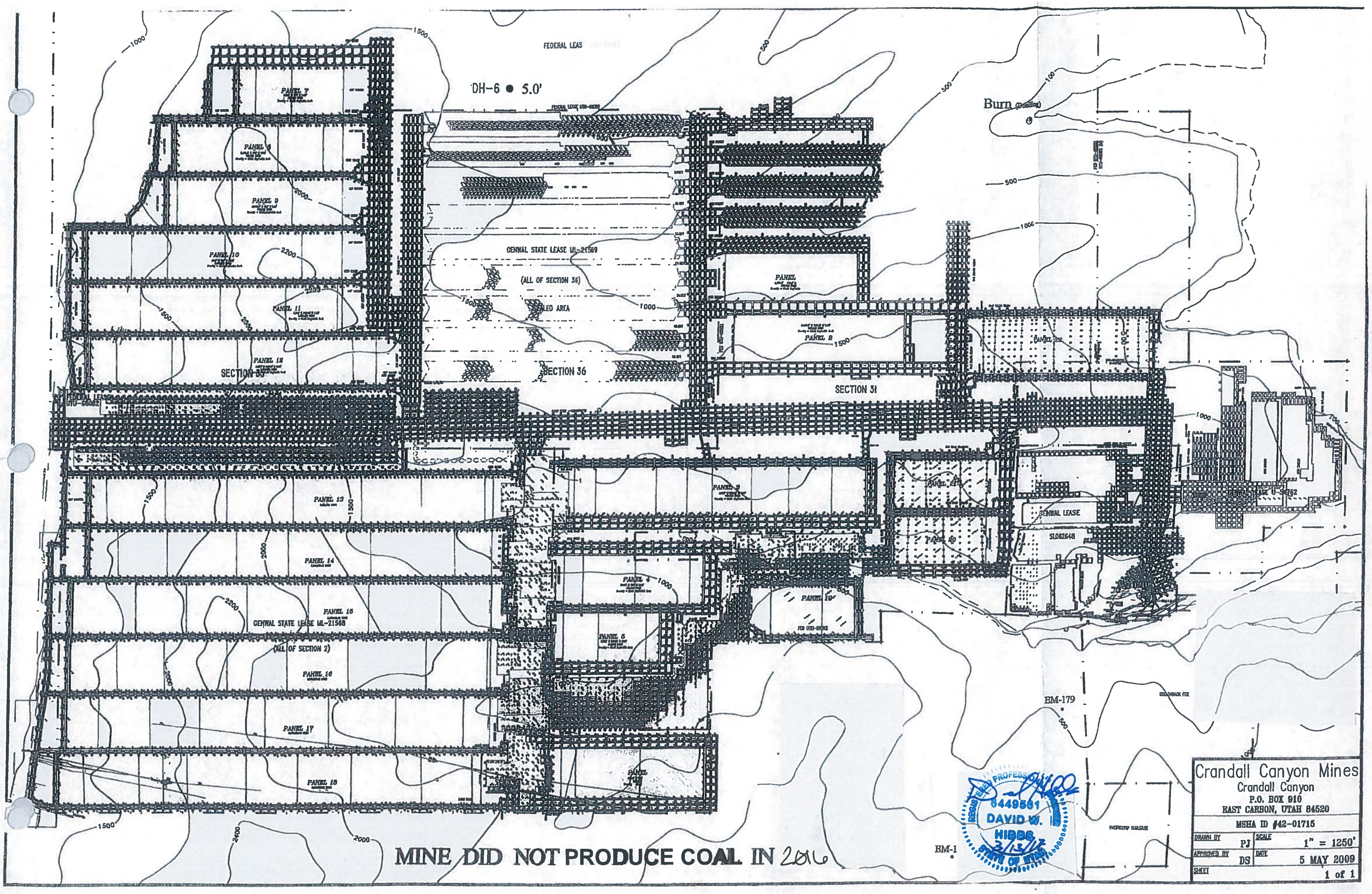
Water	WT
Soil	SL
Solid	SD
Filter	FT
Other	OT

TURN AROUND TIMES
Check desired service
- ☒ Standard turnaround
- ☐ **RUSH - 5 Working Days**
- ☐ **URGENT - < 2 Working Days**

Rush & Urgent Surcharges will be applied

COMPLIANCE INFORMATION
Compliance Monitoring ? Y / N
Program (SDWA, NPDES,...)
PWSID / Permit #
Chlorinated? Y / N
Sample Disposal: Lab Client

ADDITIONAL REMARKS
Please email a PDF file and an Excel file to:
Patrick mt.nebo@xmission.com
Bob Long lrcsoils@msn.com


FEDERAL LEAS
DH-6 ● 5.0'
Burn (pooling)
PANEL 7
PANEL 8
PANEL 9
PANEL 10
PANEL 11
PANEL 12
SECTION 35
GENWAL STATE LEASE ML-21569
(ALL OF SECTION 36)
SECTION 36
PANEL 8
SECTION 31
PANEL 13
PANEL 14
PANEL 15
GENWAL STATE LEASE ML-21568
(ALL OF SECTION 2)
PANEL 16
PANEL 17
PANEL 18
PANEL 4
PANEL 5
PANEL 6
PANEL 9
PANEL 10
GENWAL LEASE
SL062648
BM-179
BM-1
MINE DID NOT PRODUCE COAL IN 2016
REGISTERED PROFESSIONAL ENGINEER
6449501
DAVID W.
HIBBS
3/13/17
STATE OF UTAH
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