Prairie Stream Surveys on BLM Public Lands in Eastern Montana 2013 Surveys

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Cover photo: Pumpkin Creek R4, Custer County, Montana. September 9, 2013.

Introduction

Since 2009 an inventory effort to survey all prairie streams intersecting Bureau of Land Management (BLM) public lands in eastern Montana and western North and South Dakota has been undertaken. Permanent benchmarks were installed along prairie streams that dissected one mile or more of BLM lands to allow for future monitoring in hopes of gaining a better understanding of the distribution and abundance of fishes that inhabit these prairie streams. The goal for prairie streams with permanent benchmarks is to establish a plan which aims to monitor these streams every five years. The BLM also has three primary streams, Pumpkin, Cedar, and Cherry Creeks, that intersect large contiguous pieces of BLM lands that have been monitored annually or bi-annually since 2010 (Chaffin 2011, Stuart and Chaffin 2013). Pumpkin Creek intersects nine miles of BLM lands and has four sampling reaches along the nine mile stretch of BLM with benchmarks that were installed in 2010. Cedar Creek intersects 19 miles of BLM lands and has six sampling reaches, four of which have benchmarks that were installed in 2010. Cherry Creek intersects three and a half miles of BLM lands and has three sampling reaches with benchmarks that were set up between 2009 and 2010. In 2013 survey efforts were only conducted along these three primary streams, Pumpkin, Cedar, and Cherry Creeks, in the Miles City field office (MCFO) once in early September to continue monitoring efforts.

Methods

Site Selection

Pumpkin, Cedar, and Cherry Creeks are primary sites that were established between 2009 and 2010. Sampling only occurred along these three primary streams in 2013. There are 13 reaches total, with four at Pumpkin Creek, six at Cedar Creek and three at Cherry Creek.

Fish and Habitat Surveys

This work followed an Index of Biological Integrity (IBI) protocol developed by Bramblett et al. (2005) with specific field methodology outlined in Bramblett (2003). Block nets were positioned at the upstream and downstream ends of the 300 m sample reach, except when natural barriers like dry channels or shallow riffles were present, to prevent fish movement outside the sample area. An appropriate sized seine net, based on the stream width to be sampled, was used to seine the sampling reach moving downstream. Fish were collected at appropriate intervals and held in five gallon buckets. Next fish were anesthetized, identified to the species taxonomic level using Holton and Johnson (2003) and taxonomic keys (Professor Bob Bramblett, MSU, unpublished data), enumerated, and released. A subsample of 20 individuals per species was measured (TL) to the nearest millimeter.

Habitat data were collected following Bramblett (2003). Eleven individually labeled pin flags were placed every 30 m along the 300 m sampling reach. Each flag location was a transect site where wetted width, depth and substrate size were recorded. Depth and substrate were recorded at five locations (left bank, left center, center, right center, right bank) at each transect within the wetted width. A thalweg profile was recorded by measuring ten thalweg (deepest part of channel) depths evenly spaced between each transect. A member of the crew walked along the stream bank of the entire sampling reach carrying a Trimble GPS unit collecting linear geographical information in order to store stream sinuosity and allow for future monitoring to take place at the exact same location.

Water quality parameters collected at each sampling site included dissolved oxygen content (percent saturation and mg/L or ppm), conductivity (µS/cm), and water temp (˚C) recorded with an YSI Model 85 water quality meter (YSI Inc. Yellow Spring, OH), pH recorded with an Extech meter (Extech Instruments, Waltham MA), and air temp was recorded with a handheld thermister.

Within the 300 m sampling reach we recorded qualitative observations such as riparian vegetation: native and exotic trees, shrubs, and grasses; evidence of land-use activities and anthropogenic influences; and wildlife observations to help assess stream condition. We also recorded percent of habitat type (run, riffle, pool,

dry channel, backwaters, secondary channels, etc.), percent of vegetation consumed by livestock, percent of sample reach covered by vegetation, occurrence of large woody debris in the stream and stream bank condition (incisement, floodplain development, active down-cutting).

Stream Cross Sections

All 13 reaches (from Pumpkin, Cedar, and Cherry Creeks) dissect more than a mile of BLM public lands and had permanent benchmarks installed between 2009 and 2010 except for Cedar Creek R1 and R2a. Benchmarks (rebar or fence posts) were installed outside the perceived flood-prone boundary on either side of the stream at the beginning, middle, and end of the 300 m sampling reach (0, 150, and 300 meters). An electronic data monitor or total station (Sokkia Co. Ltd) was used to survey elevation changes between each benchmark. Measurements were taken at two to five foot intervals between the benchmarks and at one foot intervals within the bank-full width. Two digital photos were taken at each cross-section standing in the middle of the stream, one looking up and the other down-stream so that photo-point surveys, alongside cross-section data, can be compared with future monitoring.

Database & Data Analysis

A database specific to this project was built in 2010 and continues to be upgraded. The database will allow easy extraction of data for resources managers within the BLM. The data will also be used to generate reports and can be shared with other agencies or researchers. The data will also be linked to GIS/GPS data so that everything is spatially explicit. Additionally, raw fish data will be sent to state agencies through requirements of their scientific collectors permit.

IBI scores were calculated following Bramblett et al. (2005). Watershed area calculations were conducted in GIS using ArcMap (ESRI, 2009) with Arc Hydro (ESRI, 2009) tools. Digital elevation models (DEM) were of 10 m resolution from USGS NED (National Elevation Dataset, accessed December 2012).

Results

Sites

In 2013 all primary sites (Pumpkin, Cedar, and Cherry Creeks) were surveyed once in the fall to continue monitoring efforts on BLM lands along these three prairie streams. There are a total of 13 fishing reaches, four on Pumpkin Creek, six on Cedar Creek, and three on Cherry Creek. We found fish at all reaches except for Cedar Creek R2. The water level was high and flowing very fast at Cedar Creek at the time of our sample at R2. Exceptionally fast flowing water makes seining difficult and inefficient which could have contributed to no fish being sampled at this reach. Even though we did not catch any fish at Cedar Creek R2, this reach is still recorded as a fish-bearing reach since we know this reach to be fish-bearing from survey data collected in previous years. The sites, dates, type of sampling conducted, stream reach length, watershed area, and IBI scores are listed in Table 1.

Table 1. Streams sampled in 2013, arranged alphabetically by Hydrologic Unit Code (HUC) name then by stream name. F=fish bearing, N=non-fish bearing; 1= Stream walked and inventoried along BLM public lands, 2=IBI Fish and Habitat Protocol, 3=Surveyed cross sections with benchmarks. Miles of stream refers to the stream length occurring on BLM public lands. Watershed area refers to all contributing land above the bottom point of the sampling reach. IBI scores calculated according to Bramblett et al. (2005) range from a 0-100 scale, 100 being of highest biological integrity.

Field Office	HUC Name Stream Reach	Date	Fish Present	Survey Type (1,2,3)	Miles of stream	Watershed Area (ha)	IBI Score
MCFO	**Lower Tongue**						
	Pumpkin Creek R1	9/13/2013	F	1,2	0.81	179,019	49
	Pumpkin Creek R2	9/13/2013	F	1,2,3*	3.2	178,434	47
	Pumpkin Creek R3	9/9/2013	F	1,2,3	2.58	165,910	45
	Pumpkin Creek R4	9/9/2013	F	1,2,3	1.57	164,040	57
	Lower Yellowstone						
	Cedar Creek R1	9/6/2013	F	1,2	0.33	54,473	60
	Cedar Creek R2	9/10/2013	F	1,2,3	2.37	45,488	N/A**
	Cedar Creek R2a	9/5/2013	F	1,2	0.55	44,455	62
	Cedar Creek R3	9/5/2013	F	1,2,3	4.38	42,807	66
	Cedar Creek R4	9/4/2013	F	1,2,3	9.9	41,471	54
	Cedar Creek R5	9/3/2013	F	1,2,3	1.06	30,279	56
	Cherry Creek R1a	9/11/2013	F	1,2,3	0.76	58,674	50
	Cherry Creek R1b	9/11/2013	F	1,2,3	1.26	58,503	62
	Cherry Creek R2	9/12/2013	F	1,2,3	1.51	56,579	69

* Only surveyed two cross sections at this site, 0 m cross section was not surveyed

** No fish were caught at this sight so an IBI score was not calculated

Fish and Habitat Surveys

A total of 3,470 fish were sampled in 2013, making up five families and 23 individual species. The catch was dominated by native fishes (92%) with 3,194 native individuals and 276 exotic individuals. The percent of native species recorded at all sampled sites, excluding Cedar Creek R2 which had no catch, ranged from 60% to 89%. At one sampling location more than 50% of the individuals sampled were exotic (Pumpkin Creek R3, 57%), at all other locations 21% or less of the total individuals sampled were exotic (Table 2). The most abundant species sampled was the plains minnow, a native species, with 1,169 individuals sampled. The most abundant exotic species observed was the green sunfish, with 102 individuals (Table 3). The most widely distributed species observed was the sand shiner, occurring at all sampled sites except for Cedar Creek R2 which had no catch. The most widely distributed exotic species was the plains killifish, occurring at 77% of our sampled sites, with common carp (70%), and green sunfish (54%) not far behind (Table 4). The number of species recorded at a site ranged from 0 to 17 (Cedar Creek R2 and Cherry Creek R2 respectively), while the number of individuals recorded at a site ranged from 0 to 745 (Cedar Creek R2 and Cedar Creek R3 respectively). The highest native species richness, 12, and highest exotic species richness, 5, was recorded at Cherry Creek R2. Appendix A has the species richness and total fish caught at each site, while Appendix B has the species count at each site for the different sampling events.

All sampled sites (n=13) had a mean wetted width of 4.8 m and an average center depth of 43 cm. All sampled sites had either flowing water (10) or interrupted standing pools of water (3) at the time of the sampling event. General habitat and water quality characteristics are presented in Appendix C and D.

Table 2. Species richness and total number of individual fish (separated out by natives and exotics) caught at each site in 2013, arranged alphabetically by HUC name then by stream name.

			Species Richness		**Total Individuals**	
Field Office	**HUC &** Stream Name	**Date**	**Native**	**Exotic**	**Native**	**Exotic**
MCFO	**Lower Tongue**					
	Pumpkin Creek R1	9/13/2013	7	3	60	7
	Pumpkin Creek R2	9/13/2013	8	4	98	26
	Pumpkin Creek R3	9/9/2013	4	2	6	8
	Pumpkin Creek R4	9/9/2013	8	1	30	2
	Lower Yellowstone					
	Cedar Creek R1	9/6/2013	10	2	582	5
	Cedar Creek R2	9/10/2013	0	0	0	0
	Cedar Creek R2a	9/5/2013	8	3	625	27
	Cedar Creek R3	9/5/2013	9	2	701	44
	Cedar Creek R4	9/4/2013	5	3	309	21
	Cedar Creek R5	9/3/2013	6	2	140	4
	Cherry Creek R1a	9/11/2013	3	2	69	6
	Cherry Creek R1b	9/11/2013	9	3	151	35
	Cherry Creek R2	9/12/2013	12	5	423	91

Table 3. Individual species count and origin arranged alphabetically by common species name.

Species	Native (n) or Exotic (e)	Count	% of Total Count
Bigmouth buffalo	n	8	0.23%
Black bullhead	e	33	0.95%
Channel catfish	n	59	1.70%
Common carp	e	70	2.02%
Creek chub	n	148	4.27%
Emerald shiner	n	74	2.13%
Fathead minnow	n	340	9.80%
Flathead chub	n	919	26.48%
Green sunfish	e	102	2.94%
Lake chub	n	43	1.24%
Largemouth bass	e	1	0.03%
Longnose dace	n	28	0.81%
Longnose sucker	n	10	0.29%
Plains killifish	e	68	1.96%
Plains minnow	n	1,169	33.69%
River carpsucker	n	51	1.47%
Sand shiner	n	280	8.07%
Shorthead redhorse	n	7	0.20%
Smallmouth bass	e	1	0.03%
Stonecat	n	3	0.09%
Western silvery minnow	n	47	1.35%
White crappie	e	1	0.03%
White sucker	n	8	0.23%
Total	**e = 7 n = 16 Total = 23**	**3,470**	**100%**

Table 4. Number of sampled sites each species was observed, along with the number of individuals recorded for each species, arranged alphabetically by common species name. Species with an asterisk (*) indicates an exotic species.

Species	Total # of individuals	# of Sites
Bigmouth buffalo	8	1
Black bullhead*	33	3
Channel catfish	59	8
Common carp*	70	9
Creek chub	148	7
Emerald shiner	74	5
Fathead minnow	340	9
Flathead chub	919	9
Green sunfish*	102	7
Lake chub	43	1
Largemouth bass*	1	1
Longnose dace	28	5
Longnose sucker	10	3
Plains killifish*	68	10
Plains minnow	1,169	10
River carpsucker	51	6
Sand shiner	280	12
Shorthead redhorse	7	3
Smallmouth bass*	1	1
Stonecat	3	2
Western silvery minnow	47	7
White crappie*	1	1
White sucker	8	1
Total	**3,470**	**n=13**

Discussion

Prairie streams are an endangered yet valuable resource in the Northern Great Plains Eco-region (Samson and Knopf 1994). Between 2009 and 2012 the BLM has installed permanent bench marks at sampling reaches along several prairie streams in eastern Montana and western North and South Dakota (Chaffin 2011, Stuart and Chaffin 2013) for future monitoring of these prairie streams. Previous studies on prairie streams in the Northern Great Plains have shown that prairie stream systems are very unpredictable, constantly changing from drying to flooding stages between seasons, sometimes even in a matter of days (Matthews 1988, Ostovar 2007), and shown the need for multiple spatial and temporal sampling to occur along each stream for an adequate understanding of prairie stream assemblages (Ostovar 2007). In order to gain a better understanding of the long term and seasonal distribution and abundance of prairie fishes the BLM has set up multiple sampling reaches along three prairie streams (Pumpkin, Cedar, and Cherry Creeks) in the Miles City field office (MCFO) that have been sampled twice a year since 2010 with the intent to continue sampling bi-annually.

In 2013 sampling only occurred at the 13 sampling reaches along these three primary streams once in early September. All sampling reaches had water present at the time of the sampling event, and all but one (Cedar Creek r2) had fish present. There was a moderate rainfall event about two days before Cedar Creek R2 was sampled, which left Cedar Creek with particularly high and fast moving water which could have contributed to the no catch. Swift moving and high water can make seining inefficient, as well as displace smaller prairie fish that do not have the swimming strength needed to endure the swift current (Dodds et al. 2004). Data from BLM surveys from 2010 to 2013 show how significantly prairie streams can change seasonally, which emphasizes the importance of multiple spatial and temporal sampling events in order to obtain important data on the distribution of prairie fishes. Cedar Creek R2 has gone from an average wetted width of 3.5 m in 2010 to 8.7 m in 2013 with a low of 0.7m in 2012 (Chaffin 2011, Stuart and Chaffin 2013) (Figure 1). Species composition on Cedar Creek R2 has gone from 12 and 10 species in 2010 (spring and fall sample) to 11 and 8 species in 2012 (spring and fall samples). Excluding 2013, the total number of individuals observed in Cedar Creek R2 has been from a low of 447 in 2010 (spring sample) to a high of 4,344 individuals in 2012 (spring sample) (Chaffin 2011, Stuart and Chaffin 2013).

Overall, IBI scores were consistent with previous years with an average of 56 out of 100 for 2013. Since 2010, IBI scores have averaged anywhere from 52 to 57 (Table 5). At the time of this report a detailed analysis of IBI scores has not been performed. Some variables that might explain patterns in aquatic wildlife and their habitat include grazing history, other various land-use impacts (e.g. oil and gas development), number or percent of reservoirs/ water pits blocking the natural flow regime in a watershed, roads and particularly non fish-passable culverts, and climate change. A more detailed statistical analysis may help elucidate driver variables affecting stream bio-integrity and presence or absence of species.

Figure1. Cedar Creek R2 photo point survey at 300 m cross section facing downstream in 2012 (left) and 2013 (right).

Table 5. IBI scores for Pumpkin, Cedar, and Cherry Creeks from 2010 to 2013, arranged alphabetically by HUC name then by stream name. Asterisk (*) indicates sampling reaches that were not sampled during that year or season, N/A indicates sampling occurred but no IBI calculated due to no catch.

HUC Name Stream Reach	**2010 Spring**	**2010 Fall**	**2011 Summer**	**2011 Fall**	**2012 Spring**	**2012 Fall**	**2013 Fall**
Lower Tongue							
Pumpkin Creek R1	59	47	58	40	60	56	49
Pumpkin Creek R2	49	47	49	50	56	53	47
Pumpkin Creek R3	45	42	48	52	50	56	45
Pumpkin Creek R4	51	43	50	53	53	58	57
Lower Yellowstone							
Cedar Creek R1	*	51	*	59	58	54	60
Cedar Creek R2	67	62	*	65	63	57	N/A
Cedar Creek R2a	54	63	*	65	66	56	62
Cedar Creek R3	52	55	*	60	63	55	66
Cedar Creek R4	55	55	*	56	51	53	54
Cedar Creek R5	56	*	*	57	61	55	56
Cherry Creek R1a	52	53	56	61	53	63	50
Cherry Creek R1b	48	46	57	63	58	62	62
Cherry Creek R2	*	60	*	60	59	62	69
Average IBI score:	53	52	53	57	58	57	56

Stream Cross Sections

All of the sampling reaches along Pumpkin, Cedar, and Cherry Creeks have permanent benchmarks installed except for Cedar Creeks R1 and R2a. All benchmarks were surveyed in 2013 except for Pumpkin Creek R1 and the 0 m cross section of Pumpkin Creek R2. We can compare the cross section data across different years at each site to observe the amount of erosion or deposition that occurs along each cross section (Figure 2). The BLM is in the process of entering all cross section data into GIS for access by other resource managers within the BLM. At the time of this report a detailed analysis of the stream morphology has not been conducted. A detailed analysis would be improved with multiple years of data. Consistent survey work (e.g. every 2-5 years) at our cross section locations would provide an important understanding of physical processes and the effects of land-use through time in prairie streams.

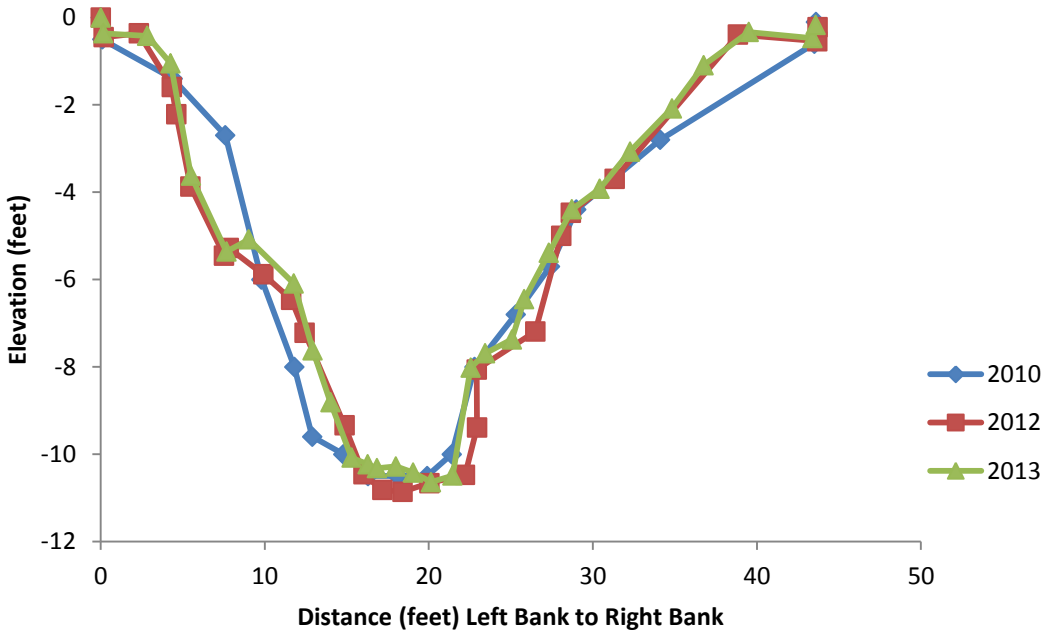

Figure 2. Cross section (300 m) data collected from 2010, 2012, and 2013 on Pumpkin Creek R3

Database

In 2013, modifications and improvements were made to the fisheries database. Several queries were added in to the database to generate reports which are now linked to Excel files to allow for easy extraction of data by resource managers within the BLM. Fisheries data were also linked to a geodatabase in GIS where two layer files were created, which display general sampling data and IBI scores. These layer files are now available for other resource managers within the BLM to help guide restoration projects and to provide a monitoring framework for various resource/land-use activities.

Stream Restoration

The riparian-shrub planting project that was started on Pumpkin Creek in 2011 (Chaffin 2011, Stuart and Chaffin 2013) was continued this spring, April 2013, along R1 and R2 of Pumpkin Creek, the furthest downstream reaches. There were over 4000 willow cuttings planted along with 1,150 rooted stock plants: 250 redosier dogwood, 250 boxelder, 200 golden currant, and 450 cottonwood seedlings. The seedlings were planted with small enclosures to help protect the seedlings. Starting in summer 2014 adjacent uplands on BLM public lands will also undergo a native prairie restoration/habitat improvement project. This project will replace non-native vegetation with native shrubs and grasses that will greatly improve habitat not only for migratory and upland game birds, but also big game species and other small mammals as well.

Lone Tree Creek is a small ephemeral/intermittent system south of Ekalaka, MT that was inventoried in 2011. When inventoried, the BLM found Lone Tree Creek to be fish-bearing but with habitat fragmentation, due to reservoirs, which probably does not allow fish and other aquatic species to migrate up and down stream. The BLM began planning for dam removal (Blackfoot reservoir) and stream rehabilitation projects in 2011 (Chaffin 2011) which were completed over the summer of 2013. There are two sampling reaches on Lone Tree Creek, R3 which is just downstream of Blackfoot reservoir and R2 which is about another half mile downstream. Permanent benchmarks were installed in 2011 on both reaches to allow for future monitoring of the Lone Tree Creek system alongside the dam removal and stream rehabilitation projects. Lone Tree Creek R2 and R3 were inventoried, including surveying the cross sections, in 2011 and 2012 to gather data (species composition/distribution and stream morphology) before the Blackfoot reservoir retention dam was removed (Chaffin 2011, Stuart and Chaffin 2013). Now that the dam has been removed, the BLM will plan to inventory/monitor (stream survey and survey cross sections) Lone Tree Creek in the future to gather species composition and distribution as well as any changes in the geomorphic features of Lone Tree Creek R2 and R3.

Prairie stream data collected through this inventory project, started in 2009, will provide a monitoring framework for various resource/land-use activities and can help guide restoration projects. With permanent benchmarks in place in locations such as Lone Tree Creek and Pumpkin Creek where major restoration/habitat improvement projects are currently ongoing, the BLM can monitor the geomorphology and biota of these stream systems through the restoration process and beyond. From consistent survey data collected at cross section locations we can also gain a better understanding of how restoration activities may influence the geomorphology of streambeds. Prairie streams and their adjacent riparian areas provide spawning, rearing, feeding, transient, and cover habitat for many aquatic and terrestrial species across the Northern Great Plains Eco-region. With prairie grasslands and prairie streams being one of the most endangered resources in North America (Samson and Knopf 1994, Dodds et al. 2004) and the potential impacts of climate change, it is ever more important to expand our knowledge of prairie streams and enhance and conserve these fragile systems when possible.

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Appendix A. Species richness and total number of individual fish caught at each site in 2013, arranged alphabetically by HUC name then by stream name.

Field Office	HUC & Stream Name	Date	Species Richness	Total Individuals
MCFO	**Lower Tongue**			
	Pumpkin Creek R1	9/13/2013	10	67
	Pumpkin Creek R2	9/13/2013	12	124
	Pumpkin Creek R3	9/9/2013	6	14
	Pumpkin Creek R4	9/9/2013	9	32
	Lower Yellowstone			
	Cedar Creek R1	9/6/2013	12	587
	Cedar Creek R2	9/10/2013	0	0
	Cedar Creek R2a	9/5/2013	11	652
	Cedar Creek R3	9/5/2013	11	745
	Cedar Creek R4	9/4/2013	8	330
	Cedar Creek R5	9/3/2013	8	144
	Cherry Creek R1a	9/11/2013	5	75
	Cherry Creek R1b	9/11/2013	12	186
	Cherry Creek R2	9/12/2013	17	514

Appendix B. Number of individuals per fish species caught at individual sites, arranged alphabetically by HUC name then by stream name.

Sampling Reach	Bigmouth buffalo	Black bullhead	Channel catfish	Common carp	Creek chub	Emerald shiner	Fathead minnow	Flathead chub	Green sunfish	Lake chub	Largemouth bass	Longnose dace	Longnose sucker	Plains killifish	Plains minnow	River carpsucker	Sand shiner	Shorthead redhorse	Smallmouth bass	Stonecat	Western silvery minnow	White crappie	White sucker
MCFO																							
Lower Tongue																							
Pumpkin Creek R1			12	1		16	4		3					3	14	1	7				6		
Pumpkin Creek R2		2	6	6		22	5	3	17						8		50			2	2	1	
Pumpkin Creek R3			1	7				2	1								1				2		
Pumpkin Creek R4			3				3	1				2	1	2			11	2			7		
Lower Yellowstone																							
Cedar Creek R1			21	4	3	6		170				6		1	339	33	2			1	1		
Cedar Creek R2																							
Cedar Creek R2a			4	20	6		31	348	1			15		6	211	1	9						
Cedar Creek R3			9	28	4		23	258				4		16	377	3	19				4		
Cedar Creek R4		1	3	2			21	103						18	167		15						
Cedar Creek R5				1	6		37	31		43				3	22		1						
Cherry Creek R1a					17				2					4	4		48						
Cherry Creek R1b					69	20	16	3	22				4	12	3	3	32	1	1				
Cherry Creek R2	8	30		1	43	10	200		56		1	1	5	3	24	10	85	4			25		8

Appendix C. Physical habitat characteristics of sites arranged alphabetically by HUC name then by stream name. Left and right bank depths were measured 5 cm from the water's edge. Wetted width, left bank, center, and right bank are the average of 11 individual measurements. Thalweg is an average of 100 individual measurements.

HUC Stream Name	**Date**	**Wetted Width (m)**	**Left Bank (cm)**	**Center (cm)**	**Right Bank (cm)**	**Thalweg (cm)**
MCFO						
Lower Tongue						
Pumpkin Creek R1	9/13/2013	9.49	7.09	57.45	11.18	76.85
Pumpkin Creek R2	9/13/2013	4.59	30.09	68.73	21.09	75.27
Pumpkin Creek R3	9/9/2013	3.97	8.91	111.82	25.91	109.76
Pumpkin Creek R4	9/9/2013	5.27	23.45	59.82	6.55	75.33
Lower Yellowstone						
Cedar Creek R1	9/6/2013	4.58	4.27	18.45	2.09	20.71
Cedar Creek R2	9/10/2013	8.69	10.09	61.09	24.73	81.52
Cedar Creek R2a	9/5/2013	2.61	16.36	18.91	19.18	24.10
Cedar Creek R3	9/5/2013	2.44	5.18	21.55	14.64	30.87
Cedar Creek R4	9/4/2013	3.42	4.73	14.18	5.36	23.94
Cedar Creek R5	9/3/2013	0.92	14.91	32.18	13.27	37.94
Cherry Creek R1a	9/11/2013	6.35	3.73	25.64	2.45	25.02
Cherry Creek R1b	9/11/2013	5.27	3.73	32.55	7.55	27.96
Cherry Creek R2	9/12/2013	4.30	17.73	36.91	13.45	48.89

Appendix D. Water quality characteristics of sites arranged alphabetically by HUC name then by stream name.

HUC Stream Name	Date	Conductivity (µS/cm)	pH	DO (%sat)	Water Temp (°C)	Air Temp (°F)
MCFO						
Lower Tongue River						
Pumpkin Creek R1	9/13/2013	973	8.02	76.7	21.4	68
Pumpkin Creek R2	9/13/2013	1153	8.09	70.1	18.1	64
Pumpkin Creek R3	9/9/2013	1378	8.42	70	20.5	80
Pumpkin Creek R4	9/9/2013	2306	8.58	75	20.3	62
Lower Yellowstone River						
Cedar Creek R1	9/6/2013	5180	8.4	81.3	25.2	90
Cedar Creek R2	9/10/2013	4220	8.13	85.6	18.4	68
Cedar Creek R2a	9/5/2013	12980	7.93	115.5	29	99
Cedar Creek R3	9/5/2013	4003	8.5	112.3	28.8	94
Cedar Creek R4	9/4/2013	17230	8.3	108.2	29	92
Cedar Creek R5	9/3/2013	6170	7.68	120	24.7	84
Cherry Creek R1a	9/11/2013	3862	7.74	71.1	18.8	68
Cherry Creek R1b	9/11/2013	4815	7.67	81.3	26.6	91
Cherry Creek R2	9/12/2013	4317	8.23	72.1	16.7	58