Prairie Stream Surveys on BLM Public Lands in Eastern Montana and North Dakota: 2010

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Cover photo: Redwater River, McCone County, August 25, 2010

Introduction

Prairie streams in this region balance between flooding, drying, and ice stages. Organisms are adapted to turbid water, extremes of hot and cold temperatures, perennial pools of intermittent streams, and highly conductive conditions. These streams can have high resident biodiversity and may also be important spawning, rearing, and feeding habitat for some migratory species. Compared to the more popular sport-fish rivers in the region, prairie streams have received much less attention in terms of primary research, inventory, and monitoring. Dodds et al. (2004) describe prairie streams as inherently fragile systems that are now on the brink of collapse in many cases due to a legacy of varied land use disturbances. With the potential impacts of climate change it is ever more important to further our knowledge on these delicate systems and when possible enhance and conserve prairie streams.

The BLM manages approximately 488 miles of fish-bearing stream habitat across approximately 3,466,000 surface acres in eastern MT and the Dakotas (Figure 1). These stream mile numbers are tentative and we plan to have more accurate figures and expect the number to increase pending the results of this inventory program over the next couple years. This includes four field offices Miles City (MCFO), Billings, (BiFO), North Dakota (NDFO), and South Dakota (SDFO). The BLM has never completed a thorough inventory of the streams that cross through BLM surface in this larger area. Surveys have been performed as the need arises, with varying methodologies, and across a wide temporal spectrum. This is a concern when resource managers are responsible for preserving aquatic wildlife habitat, stream function, and the native biodiversity within these systems. It is also difficult to determine the impacts of land-use activities without a quantitative monitoring system that specifically targets understanding some basic stream ecology principles within the managed landscape. Besides Elser et al. (1980) most fisheries work in prairie streams, in this region, has taken place within the past ten years and has concentrated on areas close to county roads with easy access.

In 2009 stream surveys were conducted to begin examining methods to complete a thorough stream inventory effort and also to explore methods that would be repeatable in the future allowing for monitoring. In 2010, BLM set out to start a complete inventory of prairie streams in the four different field offices with four main objectives:

(1) Inventory 90% or more of all streams on BLM surface including small streams typically assumed non-fish bearing and those streams far from roads.
(2) Conduct surveys that are repeatable, quantitative, and efficient; design the surveys so they are spatially explicit and will expedite future monitoring efforts.
(3) Identify and record locations where streams are degraded and would be enhanced with future stream restoration projects.
(4) Build a database (general and GIS) that stores all this data. This will assist BLM resource managers by having similar, current, and spatially explicit data across this larger area.

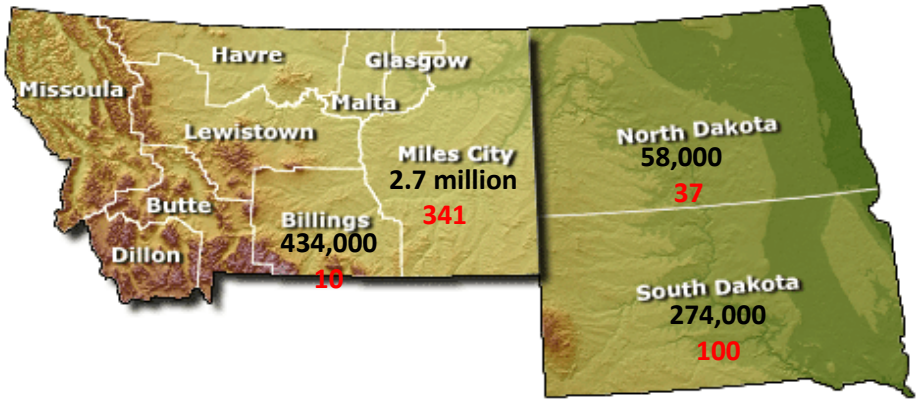

Figure 1. BLM field offices where prairie stream surveys are being conducted. Black numbers indicate the surface acres, while red numbers indicate the approximate "prairie fish bearing stream miles" that occur on BLM public lands within the field offices that stream surveys are being conducted. Field offices with no numbers are not included in this project.

Methods

Site Selection

The goal was to sample as many sites as possible. The BLM's disarrayed pattern of land ownership makes for a somewhat random distribution of sites. This should be beneficial in terms of random site selection. More detailed surveys were conducted at streams that dissect one mile or greater of BLM public lands, while those that are generally less than a mile but larger than a half mile were sampled for fish and habitat only. Unless it was in the range of a sensitive species or extended a longitudinal gradient sampling scheme on a particular stream, BLM public land less than a half mile was generally not sampled.

Prairie streams were the main target for this inventory effort. Rivers like the Musselshell, Powder, and Tongue Rivers were excluded from this project. Stagliano (2006) found the IBI approach may not be applicable for a watershed the size of the Middle Powder River. Two rivers, the Redwater and Little Missouri were included.

Upon visiting a site the entire stream reach was walked and stream reaches were broken up when necessary. Within this area qualitative observations were made: Riparian vegetation: native and exotic trees, shrubs, and grasses; any evidence of land-use activities and anthropogenic influence; and wildlife observations. An actual sampling location was determined by choosing a 300 meter location that was representative of the stream reach.

Stream cross sections

At the 300 m location a stream cross section was set-up at 0, 150, and 300 meters. Rebar benchmarks were installed outside the perceived flood-prone boundary on either side of the stream. An electronic data monitor or total station (Sokkia Co. Ltd) was used to survey the cross sections. Measurements were taken at two to five foot intervals and at one foot intervals within 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. A Trimble Recon GPS unit was used to store point geographical data for the benchmarks. The data was also differentially corrected in the office to provide the most accurate point data possible for locating benchmarks during future monitoring.

Fish Surveys and Habitat

Dissolved oxygen content (percent saturation and mg/L or ppm), conductivity (µS/cm), and water temp (˚C) were recorded with an YSI Model 85 water quality meter (YSI Inc. Yellow Spring, OH). pH was recorded with an Extech meter (Extech Instruments, Waltham MA). Air temp was recorded with a handheld thermister. When water was flowing, the discharge was recorded with a Swoffer Velocity Meter, Model 2100 (Swoffer Instruments, Inc Seattle, WA). The entire fishing reach was walked with a Trimble GPS unit collecting linear geographical information. This will allow future monitoring to take place at the exact same location and will also store the sinuosity of the stream at the time of this sampling event.

Our work followed an Index of Biological Integrity (IBI) protocol developed by Bramblett et al. (2005). The specific field methodology is outlined in Bramblett (2003). The entire 300 meter sampling location was blocked using block nets or natural blocks were used, such as dry portions of the stream or exceptionally shallow riffles. The reach was then fished where two personnel stretched the seine to either side of the stream and moved downstream. The fish were collected at appropriate intervals and dumped into 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 to the nearest millimeter. In rare cases voucher samples were collected to verify identification in the lab.

Habitat was collected also following Bramblett (2003). The 300 m sample reach was marked using a measuring tape following the stream channel with a set of 11 pin flags (labeled A-K) placed every 30 meters. At these transect sites wetted width, depth, and substrate size were recorded. Depth and substrate were recorded at five locations along the transect. Between each transect (A-K) a thalweg profile was also conducted where 10 random location are measured for depth and substrate size.

Database & Data Analysis

A database specific to this project was built for the storage of all data. This 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 GPS data so that everything is spatially explicit. For example,

Pumpkin Creek Reach 1 IBI score can be accessed through GIS. Additionally, raw fish data will be sent to state agencies through requirements of their scientific collectors permit.

For this report data analysis consists of presenting general data and trends. IBI scores were calculated following Bramblett et al. (2005). Ten different fish assemblage metrics include: number of native fish species, number of native fish families, number of native catostomid and ictalurid species, proportion of tolerant individuals, proportion of invertivorous cyprinid individuals, number of benthic invertivorous species, proportion of litho-obligate reproductive guild individuals, proportion of tolerant reproductive guild individuals, proportion of native individuals, number of native species with long-lived individuals. Watershed area is used to standardize the five taxa richness metrics. The sum of the metric scores then gives an overall IBI score (0-100) for that particular stream reach. Watershed area calculations were conducted in a GIS using ArcMap (ESRI, 2009) with Arc Hydro (ESRI, 2009) tools. Digital elevation models (DEM) were of 10m resolution from USGS NED (National Elevation Dataset, accessed January 2011). This analysis provides the most accurate watershed area numbers, using the most current data and best resolution for a project of this scale (see: Figure 2).

A more thorough analysis after the 2011 field season will also involve asking several additional questions: (1) How does habitat, fish distribution, and IBI change with land-use patterns? (2) How does fish distribution and IBI change with watershed size and other habitat variables? (3)How does fish distribution and habitat change with number of reservoirs in a watershed? (4) How can resource managers efficiently improve and monitor prairie streams? This data and future analysis will also be used as a baseline to understand and predict which future resource improvement projects (e.g.: culvert repair, etc.) will enhance prairie stream bio-integrity.

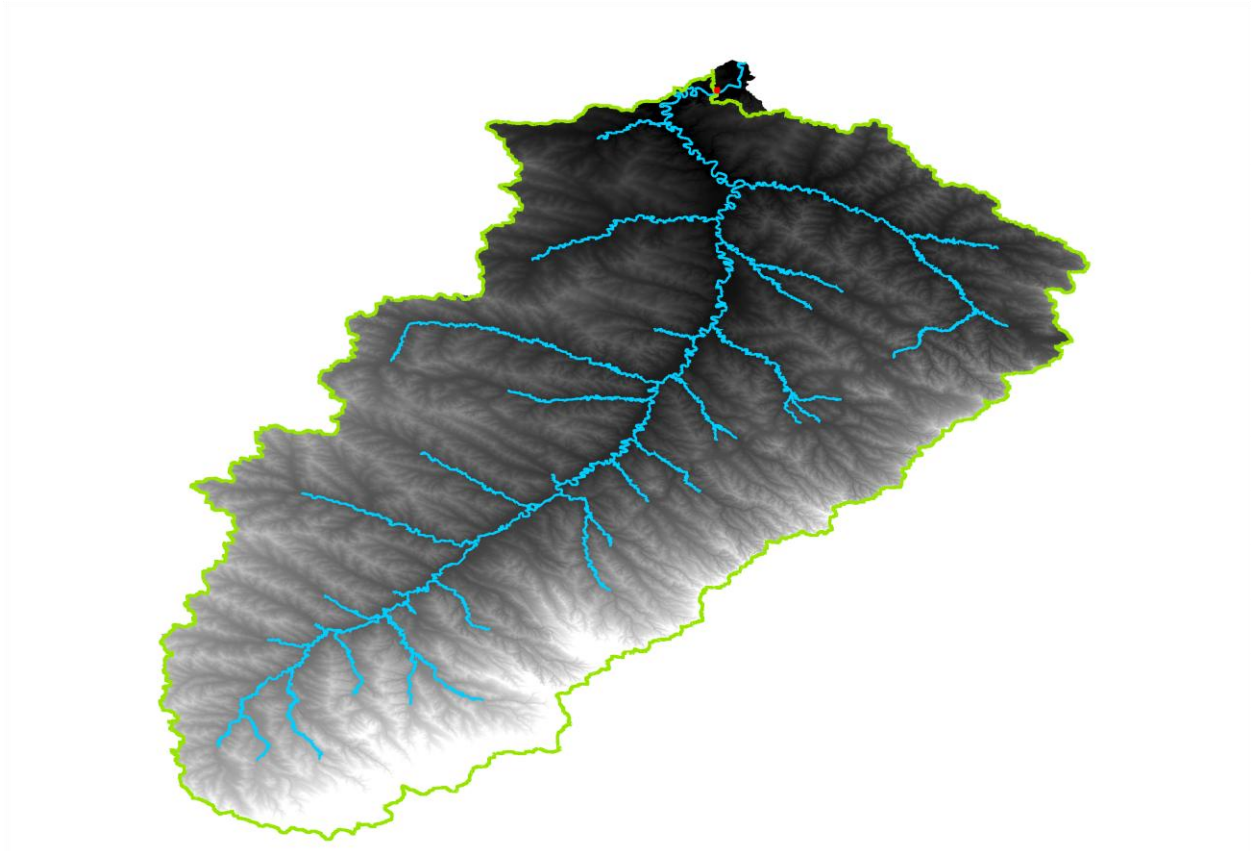

Figure 2. Redwater River R2 site. The background imagery is the 10m resolution NED dataset. The red dot indicates the beginning of the fishing reach. The green outline indicates the contributing watershed area (544,196 hectares) to the fishing reach.

Results

A total of 66 sites were surveyed in 2010. Of those sites 42 were sampled and 24 were found to be non-fish bearing. The non-fish bearing sites were completely dry, ephemeral drainages, small coulees, or had small pools with very low clear water (e.g. less than 0.25 meter) where we could verify visually there were no fish. We caught fish at every site we sampled, except Hart Creek. Waist deep mud made sampling at Big Muddy Creek very inefficient. Fly Creek had high irrigation returns at the time of sampling and it's flow regime in general is compromised by a series of canals thus also inefficient to sample. These two sites were excluded from further analysis, except to present what was found at those locations. The sites, type of sampling conducted, stream reach length, and watershed area are in Table 1.

Table 1. Streams sampled in 2010, arranged alphabetically by HUC. F=fish bearing, N=non-fish bearing; 1= Stream walked and surveyed along BLM public lands, 2=IBI Fish and Habitat Protocol, 3=Surveyed cross sections with benchmarks. The letters and a & b within a reach (R) number designate above (b) and below (a) active road crossings. Stream reach length 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 or non fish-bearing reach. n/a= Watershed area not calculated.

Field Office	HUC Name Stream reach	Date	Fish Bearing	Survey Type	Stream reach length (miles)	Watershed Area (hectares)
MCFO	**Big Muddy Creek HUC**					
	Big Muddy Creek R2	08/24/10	F	1,2	0.27	n/a
	Sand Creek	08/24/10	N	1	0.32	1,963
	Fort Peck Reservoir HUC					
	Big Dry Creek R1	07/19/10	F	1,2	0.37	674,935
	Big Dry Creek R2	07/20/10	F	1,2	1.09	342,308
	Big Dry Creek R3	07/21/10	F	1,2,3	3.06	158,600
	Hart Creek	08/10/10	N	1,2,3	3.85	2,833
	Hell Creek R1	08/13/10	F	1,2,3	5.44	13,600
	South Fork Rock Creek R1	08/23/10	F	1,2,3	1.30	3,720
	Lower Musselshell HUC					
	Bridge Coulee	08/09/10	N	1	2.70	390
	Calf Creek R1	08/11/10	F	1,2,3	1.35	54,270
	Calf Creek R2	08/11/10	F	1,2	0.47	49,033
	Sandage Coulee	08/09/10	N	1	3.69	1,580
	Smith Coulee	08/09/10	N	1	2.69	688
	Williams Coulee	08/09/10	N	1	7.00	2,080
	Lower Powder HUC					

	Coal Creek	07/09/10	N	1	7.92	12,799
	Deep Creek	07/09/10	N	1	4.19	643
	Tenmile Creek R1	07/13/10	F	1,2,3	1.61	12,410
	Tenmile Creek R2	07/07/10	F	1,2,3	3.23	11,538
	Lower Tongue HUC					
	Pumpkin Creek R1	5/19/2010, 10/19/10	F	1,2,3	0.81	179,019
	Pumpkin Creek R2	5/21/2010, 10/19/10	F	1,2,3	3.19	178,434
	Pumpkin Creek R3	5/19/2010, 10/20/10	F	1,2,3	2.58	165,910
	Pumpkin Creek R4	6/8/2010, 10/20/10	F	1,2,3	1.85	164,040
	Lower Yellowstone HUC					
	Cedar Creek R1	07/13/10	F	1,2,3	0.33	54,473
	Cedar Creek R2	6/23/10, 9/22/10	F	1,2,3	2.37	45,488
	Cedar Creek R2a	7/1/10, 9/22/10	F	1,2,3	0.55	44,455
	Cedar Creek R3	6/24/10, 9/21/10	F	1,2,3	4.38	42,807
	Cedar Creek R4	6/28/10, 9/21/10	F	1,2,3	9.90	41,471
	Cedar Creek R5	09/20/10	F	1,2,3	1.06	30,279
	Cherry Creek R1a	6/16/10, 9/23/10	F	1,2,3	0.76	58,,674
	Cherry Creek R1b	6/22/10, 9/23/10	F	1,2,3	1.26	58,503
	Cherry Creek R2	06/21/10	F	1,2,3	1.51	56,579
	Cottonwood Creek	08/05/10	N	1	4.48	13,293
	Hatcher Creek	08/05/10	N	1	4.66	3,116
	Pine Creek	08/05/10	N	1	3.95	892
	Lower Yellowstone-Sunday HUC					
	Deadman Creek	05/26/10	F	1,2,3	1.77	5,969
	O'Fallon Creek HUC					
	Pennel Creek R1	08/02/10	F	1,2,3	1.11	50,088
	Pennel Creek R2	07/14/10	F	1,2,3	2.46	12,580
	Pennel Creek R3	07/14/10	F	1,2	1.78	8,908

	Pine Creek	07/15/10	N	1	2.46	12,705
	Prairie Elk Wolf HUC					
	Hungry Creek	08/23/10	N	1	7.98	9,106
	Pasture Creek	08/23/10	N	1	2.40	650
	West Fork Hungry Creek	08/23/10	N	1	0.47	2,407
	West Fork Nickwall Creek	08/24/10	N	1	3.86	421
	Redwater River HUC					
	Lisk Creek	08/26/10	N	1	4.70	3,480
	Redwater River R1	08/25/10	F	1,2	0.87	546,662
	Redwater River R2	08/25/10	F	1,2	0.82	544,196
	Redwater River R3	08/25/10	F	1,2	0.4	543,330
	West Duck Creek	08/26/10	N	1	4.30	6,023
	Upper Little Missouri HUC					
	Cottonwood Creek R2	09/07/10	F	1,2,3	1.79	23,574
	Little Beaver Creek R2	08/31/10	F	1,2,3	1	64,039
	Little Missouri River R3	09/08/10	F	1,2	0.94	294,993
	South Cottonwood Creek R1	09/07/10	F	1,2	1.65	17,258
BiFO	**Clarks Fork Yellowstone HUC**					
	Bear Creek R1	07/28/10	F	1,2	0.12	8,778
	Middle Musselshell River HUC					
	Willow Creek R1	07/29/10	F	1,2	1.55	32,090
	Shoshone River HUC					
	Sage Creek R1	07/28/10	N	1	2.64	50,311
	Sage Creek R2	07/28/10	F	1,2	0.79	28,715
	Upper Yellowstone River HUC					
	Fly Creek R1	07/29/10	F	1,2	0.81	n/a
NDFO	**Lower Little Missouri River HUC**					
	Rough Creek	09/13/10	N	1	1.19	3,359

	Upper Little Missouri River HUC					
	Big Gumbo Creek R1	09/14/10	F	1,2,3	3.82	5,346
	Cedar Ridge No-name Creek 1	09/08/10	N	1	9.76	514
	Cedar Ridge No-name Creek 2	09/08/10	N	1	6.69	396
	Cedar Ridge No-name Creek 3	09/08/10	N	1	30.09	3,093
	Cedar Ridge No-name Creek 4	09/08/10	N	1	14.33	3,967
	Kid Creek R1	09/09/10	F	1,2	1.73	2416
	Little Missouri River R1	09/02/10	F	1,2	3.23	699,856
	Skull Creek R1	09/15/10	F	1,2	0.65	8,313
		Total	**F=42 N=24**		**212.35**	

A total of 18,996 fish were sampled. Native fishes accounted for 90% of the total catch where 17,100 individuals were native and 1,896 individuals were exotic. There were 33 species total recorded, where 22 were native and 11 were exotic making 33% of all recorded species exotic. Fathead minnow was the most common species recorded, accounting for over 40% of all individuals encountered. Table 2 has the different species in relation to total counts. There was an average of 7.6 species per site. Even when the rivers (Little Missouri and Redwater River) were excluded the average species richness only dropped to 7.3 species. However, the Redwater River and Little Missouri River averaged 11.0 species per site. The most species recorded at an individual site was 17 species (5 exotic) at Skull Creek, a small tributary to the Little Missouri River in North Dakota. Appendix A has the species richness and total fish caught at each site, while Appendix B has the specific species and number of each caught at each site on each date.

Table 2. 2010 individual species count and origin arranged alphabetically by common species name.

Species	Native (n) or Exotic (e)	Count	% of Total Count
Bigmouth buffalo	n	2	0.011
Black bullhead	e	718	3.546
Brassy minnow	n	20	0.106
Brook stickleback	n	412	2.174
Channel catfish	n	262	1.383
Common carp	e	526	2.776
Creek chub	n	234	1.235
Emerald shiner	n	19	0.100
Fathead minnow	n	7722	40.749
Flathead chub	n	667	3.520
Freshwater drum	n	1	0.005
Golden shiner	e	75	0.396
Goldeye	n	47	0.248
Green sunfish	e	149	0.786
Iowa darter	n	2	0.011
Lake chub	n	618	3.261

Longnose dace	n	232	1.224
Longnose sucker	n	16	0.084
Northern pike	e	3	0.016
Plains killifish	e	378	1.995
Plains minnow	n	2542	13.414
Pumpkinseed	e	19	0.100
River carpsucker	n	60	0.317
Sand shiner	n	2333	12.311
Sauger	n	2	0.011
Shorthead redhorse	n	29	0.153
Smallmouth bass	e	1	0.005
Stonecat	n	16	0.084
Walleye	e	2	0.011
Western silvery minnow	n	1395	7.361
White sucker	n	469	2.475
Yellow bullhead	e	1	0.005
Yellow perch	e	24	0.127
Total	**e=11 n=22 Total=33**	**18996**	**100**

Cedar, Cherry, and Pumpkin creeks were sampled in the spring and the fall. Not all sites within these creeks were sampled twice due to logistical complications. Specifically, Cedar Creek R1, Cedar Creek R5, and Cherry Creek R2 were only sampled once. Generally species richness and native species richness did not vary dramatically between seasons (Figure 3). However, Pumpkin Creek R4 total species richness did decline greater than twofold from spring to fall. Also Cherry Creek R1a total species richness more than doubled from s=4 in the spring to s=9 in the fall. At this site 4 exotic (common carp, green sunfish, plains killifish, & yellow bullhead) and one native species (white sucker) were encountered in the fall which were not present in the spring.

The total number of fish caught and density of individuals changed seasonally (Figure 4). In several stream reaches the number of individuals increased by a factor of two up to nearly and order of magnitude. For example, in Pumpkin Creek R2 total catch and density increased spring to fall from 101 to 895 individuals and from 0.08 to 0.77 individuals/m^2, respectively. The area sampled at this site only decreased from 1336 to 1156 m^2 from spring to fall (Appendix C). Interestingly, conductivity (µS) and dissolved oxygen (% saturation) changed from 1556 to 3379 and 90.0 to 56.8, respectively, (Appendix D) from spring to fall. The same general pattern occurred at Cedar R2a & R4, although conductivity and dissolved oxygen were not recorded due to equipment malfunction.

General habitat and water quality characteristics are presented in Appendix C and D, but are not discussed in detail for this report.

IBI scores are presented in Table 3. These scores are for general information, but at the time of this report detailed analysis of the scores, has not been conducted.

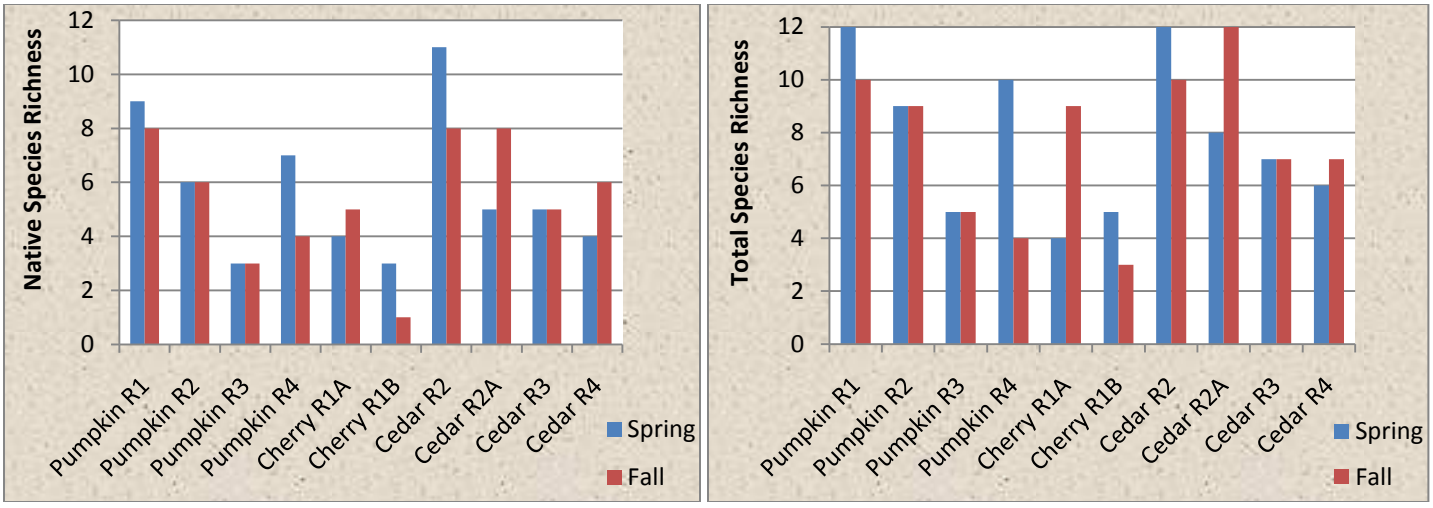

Figure 3. Native species richness (left panel) and total species richness (right panel) in the spring and fall.

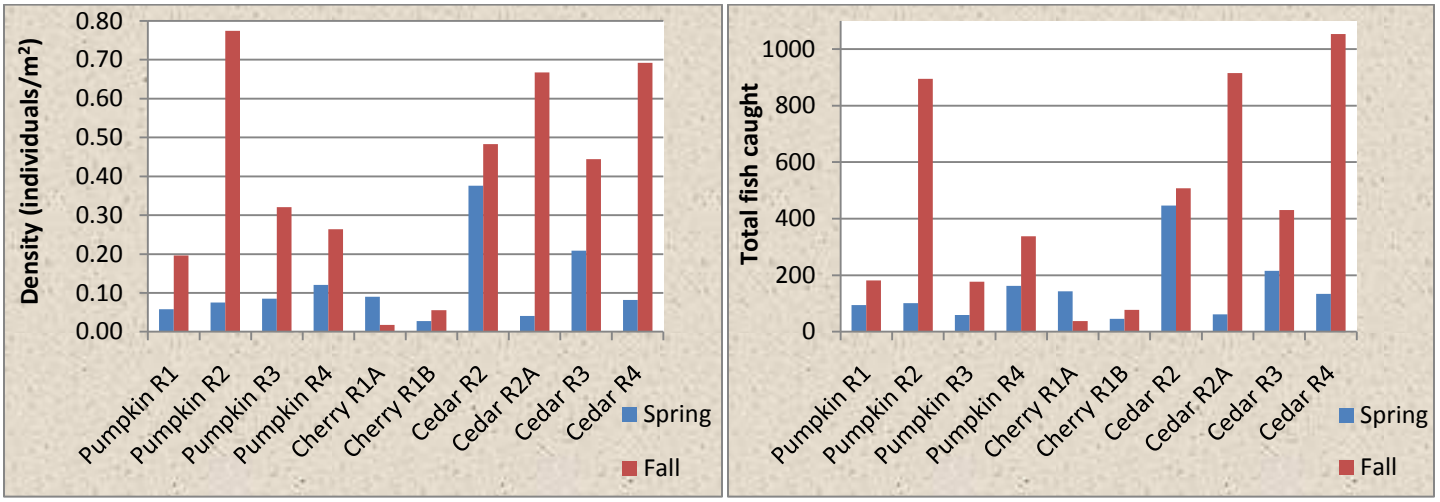

Figure 4. Density of fish (left panel) and total individuals per meter squared (right panel) in the spring and fall.

Table 3. IBI scores. * Score manually lowered to 10 because there were fewer than 10 individuals. **There were only 23 individual fathead minnows at this site.

Stream Reach	IBI Score
Bear Creek R1	46
Big Dry Creek R1	66
Big Dry Creek R2	62
Big Dry Creek R3	65
Big Gumbo Creek R1	44
Calf Creek R1	59**
Calf Creek R2	61
Cedar Creek R1	61
Cedar Creek R2- Spring	47
Cedar Creek R2- Fall	50
Cedar Creek R2a-Spring	58
Cedar Creek R2a-Fall	49
Cedar Creek R3-Spring	59
Cedar Creek R3-Fall	56
Cedar Creek R4-Spring	57

Cedar Creek R4-Fall	57
Cedar Creek R5	56
Cherry Creek R1a -Spring	60
Cherry Creek R1a -Fall	61
Cherry Creek R1b- Spring	64
Cherry Creek R1b -Fall	65
Cherry Creek R2	51
Cottonwood Creek R2	50
Deadman Creek R1	51**
Hart Creek R1	48
Hell Creek R1	51
Kid Creek R1	39
Little Beaver Creek R2	58
Little Missouri River R1	58
Little Missouri River R3	55
Pennel Creek R1	59
Pennel Creek R2	49
Pennel Creek R3	48
Pumpkin Creek R1-Spring	54
Pumpkin Creek R1-Fall	64
Pumpkin Creek R2-Spring	61
Pumpkin Creek R2-Fall	64
Pumpkin Creek R3-Spring	66
Pumpkin Creek R3-Fall	69
Pumpkin Creek R4-Spring	59
Pumpkin Creek R4-Fall	68
Redwater River R1	63
Redwater River R2	75
Redwater River R3	69
Sage Creek R2	59
Skull Creek R1	28
South Cottonwood Creek R1	41
South Fork Rock Creek R1	10*
Tenmile Creek R1	39
Tenmile Creek R2	53
Willow Creek R1	55

Discussion

Prairie streams are an important resource across eastern Montana, the Dakotas, and beyond. Prairie stream surveys by MFWP from 2003-2006 (Ostovar, 2007), spatiotemporal studies (Mullen, 2007) and others in eastern MT and beyond has improved our baseline understanding of distribution and abundance of prairie stream fishes and their habitat. However, prairie stream fish and other aquatic wildlife move across a landscape of drying, flooding, and iced-over conditions often taking advantage of temporary or transient refuges. Indeed our results begin to demonstrate the ability of fish movement in prairie streams. For example, species richness more than doubled at Cherry Creek R1a from spring to fall and density increased five times from spring to fall in Pumpkin Creek R2.

An intermittent refuge-pool may be filled in with sediment during a spate while another refuge-pool may be scoured out a mile away. Local climate changes may leave an entire watershed deprived of enough water to sustain aquatic wildlife or larger scale regional drought may change refuge locations for aquatic wildlife. Thus, a single sampling point or location is not adequate to properly establish baseline data (Ostovar, 2007) or give resource managers enough information to properly manage prairie streams. In Table 1 we classified some streams as non-fish bearing. This does

not mean that this particular creek has never been fish-bearing or that it never will be fish bearing. Likely, there is tremendous elasticity in using the terms fish-bearing and non-fish bearing prairie streams in the Northern Great Plains Ecoregion. Also the reach of BLM public land itself could have been non-fish bearing while downstream or even upstream sections may be fish-bearing and connected during high-flow events.

Many of the sites targeted by this project have not been sampled at all or not sampled within 20+ years. This project targets all sites regardless of distance to any accessible road, in some cases sampling equipment had to be hiked by backpack into sites over a couple miles away. This will help fill important data gaps or include areas where sampling has been biased by proximity to roads. Additionally, recent surveys from MFWP (Ostovar, 2007) occurred during a drought cycle whereas this project occurring during a wet cycle. Sampson (2006) points out that the results may be very different during these regional weather pattern changes. In order for fisheries managers to achieve regional persistence of Great Plains fishes (particularly fishes declining in abundance), managers must not only determine the critical habitats, but also understand the entire spatial and temporal range of life history as well as processes that create and maintain habitat (Sheurer et al. 2003). In other words a combination of large scale efforts targeting all streams in a region (such as this one) down to more focused work targeting specific ecological questions will help elucidate the information gaps still prevalent for prairie stream fishes.

The Redwater and Little Missouri River are the largest of our targeted streams. This project has and will primarily sample smaller streams, many of which border on their ability to support aquatic wildlife. Streams that do not sustain aquatic wildlife are an important piece of information, and this project will help clarify basic habitat suitability and criteria in prairie streams. By sampling at the periphery of suitable habitat, management agencies can begin to understand which watersheds are important for conservation. For example, in Deadman Creek we captured only 23 fathead minnows and at South Fork Rock Creek we captured only 3 fathead minnows. At the culmination of our project a deeper analysis will give a more thorough understanding of where physical-chemical and watershed area thresholds intersect with land-use patterns and how this influences prairie fish and their habitat. Additionally, this will provide a broader baseline dataset for university and other research institutes interested in deeper ecological questions.

Management implications

During 2010 we documented 10 restoration points or areas to consider for future stream restoration projects (Figure 3). The primary problems we encountered included culverts in disrepair such as road crossings contributing to erosion and potential fish passage barriers. Our goal, starting in 2012, will be to start working with MFWP on permitting and plans with an objective of getting on the ground restoration work beginning in 2012.

Figure 3. The left panel is a culvert contributing to erosion in William Coulee, tributary to the Musselshell near Fort Peck Reservoir. The right panel is blown-out culvert /road crossing on Johnson Creek just as it enters Pumpkin Creek R2.

Acknowledgments
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Appendix A. Species richness and total number of individual fish caught at each site in 2010, arranged by HUC name.

Sampling reach	Date	Species Richness	Total Individuals
Big Muddy Creek HUC			
Big Muddy Creek R2	8/24/2010	4	455
Fort Peck Reservoir HUC			
Big Dry Creek R1	7/19/2010	13	363
Big Dry Creek R2	7/20/2010	11	238
Big Dry Creek R3	7/21/2010	8	934
Hell Creek R1	8/13/2010	5	62
South Fork Rock Creek R1	8/23/2010	1	3
Lower Musselshell HUC			
Calf Creek R1	8/11/2010	8	462
Calf CreekR 2	8/11/2010	4	16
Lower Powder HUC			
Tenmile Creek R1	7/13/2010	12	298
Tenmile Creek R2	7/7/2010	3	165
Lower Tongue HUC			
Pumpkin Creek R1	5/19/2010	12	94
Pumpkin Creek R1	10/19/2010	10	182
Pumpkin Creek R2	5/21/2010	9	101
Pumpkin Creek R2	10/19/2010	9	895
Pumpkin Creek R3	5/19/2010	5	59
Pumpkin Creek R3	10/20/2010	5	177
Pumpkin Creek R4	6/8/2010	10	162
Pumpkin Creek R4	10/20/2010	4	338
Lower Yellowstone HUC			
Cedar Creek R1	7/13/2010	6	303
Cedar Creek R2 (6/23)	6/23/2010	12	447
Cedar Creek R2 (9/22)	9/22/2010	10	508
Cedar Creek R2a (7/1)	7/1/2010	8	62
Cedar Creek R2a (9/22)	9/22/2010	12	915
Cedar Creek R3 (6/24)	6/24/2010	7	216

Cedar Creek R3 (9/21)	9/21/2010	7	431
Cedar Creek R4 (6/28)	6/28/2010	6	131
Cedar Creek R4 (9/21)	9/21/2010	7	1053
Cedar Creek R5	9/20/2010	5	274
Cherry Creek R1a (6/16)	6/16/2010	4	143
Cherry Creek R1a	9/23/2010	9	38
Cherry Creek R1b (6/22)	6/22/2010	5	46
Cherry Creek R1b (9/23)	9/23/2010	3	77
Cherry Creek R2	6/21/2010	11	1684
Lower Yellowstone-Sunday HUC			
Deadman Creek	5/26/2010	1	23
O'Fallon Creek HUC			
Pennel Creek R1	8/2/2010	7	2388
Pennel Creek R2	7/14/2010	6	187
Pennel Creek R3	7/14/2010	6	46
Redwater River HUC			
Redwater River R1	8/25/2010	13	153
Redwater River R2	8/25/2010	6	196
Redwater River R3	8/25/2010	10	569
Upper Little Missouri HUC			
Cottonwood Creek R2	9/7/2010	9	258
Little Beaver Creek R2	8/31/2010	7	37
Little Missouri River R3	9/8/2010	12	774
South Cottonwood Creek R1	9/7/2010	13	728
Clarks Fork Yellowstone HUC			
Bear Creek R1	7/28/2010	2	27
Middle Musselshell River HUC			
Willow Creek R1	7/29/2010	4	78
Shoshone River HUC			
Sage Creek R2	7/28/2010	2	108
Upper Yellowstone River HUC			
Fly Creek R1	7/29/2010	3	11

Upper Little Missouri River HUC			
Big Gumbo Creek R1	9/14/2010	6	564
Kid Creek R1	9/9/2010	6	609
Little Missouri River R1	9/2/2010	13	228
Skull Creek R1	9/15/2010	17	680

Appendix B. Number of individuals per fish species caught at individual sites, arranged by HUC Name. Date of 2010 sampling event in parenthesis, next to reach name. Number arranged longitudinally (e.g. there are 438 fathead minnows captured at Big Muddy Creek).

Sampling reach (date)	Bigmouth Buffalo	Black bullhead	Brassy Minnow	Brook Stickleback	Channel Catfish	Common Carp	Creek Chub	Emerald Shiner	Fathead Minnow	Flathead Chub	Freshwater Drum	Golden Shiner	Goldeye	Green Sunfish	Iowa Darter	Lake Chub	Longnose Dace	Longnose Sucker	Northern Pike	Plains killifish	Plains Minnow	Pumpkinseed	River Carpsucker	Sand Shiner	Sauger	Shorthead Redhorse	Smallmouth bass	Stonecat	Walleye	Western Silvery Minnow	White Sucker	Yellow Bullhead	Yellow Perch
Big Muddy Creek HUC																																	
Big Muddy Creek R2 (8/24)	2			10		5			438																								
Fort Peck Reservoir HUC																																	
Big Dry Creek R1 (7/19)		4			11		1		65	16						4	9			1	30		10	201					2		9		
Big Dry Creek R2 (7/20)		10			6	8	15		135	7						23					5		1	22							6		
Big Dry Creek R3 (7/21)		540		140		72			166												1			7						7	1		
Hell Creek R1 (8/13)																8	10				13			30						1			
South Fork Rock Creek R1 (8/23)									3																								
Lower Musselshell HUC																																	
Calf Creek reach 1 (8/11)									19					12		21								13						87	2		
Calf Creek reach 2 (8/11)						308			6																					1	9		
Lower Powder HUC																																	
Tenmile Creek R1 (7/13)		13			1	4	19		119	9				3			1				61			53						12	3		
Tenmile Creek R2 (7/7)									155												9	1											
Lower Tongue HUC																																	
Pumpkin Creek R1 (5/19)		1			6	1			16	6			1	2							1			27		1				25	7		
Pumpkin Creek R1 (10/19)		2			5		1		89	3				4							8			61						8	1		
Pumpkin Creek R2 (5/21)		4			3	1			38					1									3	17						33	1		
Pumpkin Creek R2 (10/19)		1			17	2			250					2							41			270						310	2		

Bigmouth Buffalo, Black bullhead, Brassy Minnow, Brook Stickleback, Channel Catfish, Common Carp, Creek Chub, Emerald Shiner, Fathead Minnow, Flathead Chub, Freshwater Drum, Golden Shiner, Goldeye, Green Sunfish, Iowa Darter, Lake Chub, Longnose Dace, Longnose Sucker, Northern Pike, Plains killifish, Plains Minnow, Pumpkinseed, River Carpsucker, Sand Shiner, Sauger, Shorthead Redhorse, Smallmouth bass, Stonecat, Walleye, Western Silvery Minnow, White Sucker, Yellow Bullhead, Yellow Perch

	Bigmouth Buffalo	Black bullhead	Brassy Minnow	Brook Stickleback	Channel Catfish	Common Carp	Creek Chub	Emerald Shiner	Fathead Minnow	Flathead Chub	Freshwater Drum	Golden Shiner	Goldeye	Green Sunfish	Iowa Darter	Lake Chub	Longnose Dace	Longnose Sucker	Northern Pike	Plains killifish	Plains Minnow	Pumpkinseed	River Carpsucker	Sand Shiner	Sauger	Shorthead Redhorse	Smallmouth bass	Stonecat	Walleye	Western Silvery Minnow	White Sucker	Yellow Bullhead	Yellow Perch
Pumpkin Creek R2 (10/19)		1			17	2			250					2							41			270						310	2		
Pumpkin Creek R3 (5/19)					7				22					1										19						10			
Pumpkin Creek R3 (10/20)					35				32					1										108			1						
Pumpkin Creek R4 (6/8)		5			1	5			66	4				2							7			32						39	1		
Pumpkin Creek R4 (10/20)					4				259															68						7			
Lower Yellowstone HUC																																	
Cedar Creek R1 (7/13)					1	30			18	42											199			13									
Cedar Creek R2 (6/23)					2		8		78	42							3	1		12	275			20		2				2	2		
Cedar Creek R2 (9/22)					20	2			157	165						9	3			44	71			34							3		
Cedar Creek R2a (7/1)		3							17	9				1		5				5	21										1		
Cedar Creek R2a (9/22)		3			25	2			139	105				3		36	18			44	527			10							3		
Cedar Creek R3 (6/24)						1			123	8						2				5	76									1			
Cedar Creek R3 (9/21)					61	1			177	106						10				41	35												
Cedar Creek R4 (6/28)									38	9										1	82					1							
Cedar Creek R4 (9/21)					1		1		559	2						13				118	359												
Cedar Creek R5 (9/20)					1				35							214					16									8			
	Bigmouth Buffalo	Black bullhead	Brassy Minnow	Brook Stickleback	Channel Catfish	Common Carp	Creek Chub	Emerald Shiner	Fathead Minnow	Flathead Chub	Freshwater Drum	Golden Shiner	Goldeye	Green Sunfish	Iowa Darter	Lake Chub	Longnose Dace	Longnose Sucker	Northern Pike	Plains killifish	Plains Minnow	Pumpkinseed	River Carpsucker	Sand Shiner	Sauger	Shorthead Redhorse	Smallmouth bass	Stonecat	Walleye	Western Silvery Minnow	White Sucker	Yellow Bullhead	Yellow Perch

	Bigmouth Buffalo	Black bullhead	Brassy Minnow	Brook Stickleback	Channel Catfish	Common Carp	Creek Chub	Emerald Shiner	Fathead Minnow	Flathead Chub	Freshwater Drum	Golden Shiner	Goldeye	Green Sunfish	Iowa Darter	Lake Chub	Longnose Dace	Longnose Sucker	Northern Pike	Plains killifish	Plains Minnow	Pumpkinseed	River Carpsucker	Sand Shiner	Sauger	Shorthead Redhorse	Smallmouth bass	Stonecat	Walleye	Western Silvery Minnow	White Sucker	Yellow Bullhead	Yellow Perch
Cedar Creek R3 (6/24)						1			123	8						2				5	76									1			
Cherry Creek R1a (6/16)									34														2	94		13							
Cherry Creek R1a (9/23)						2			16					2						5			6	3		1					2	1	
Cherry Creek R1b (6/22)		1							9	1										7				28									
Cherry Creek R1b (9/23)						1			3											73													
Cherry Creek R2 (6/21)		5					70		1233	7				14		9	18			22	50			189							67		
Lower Yellowstone-Sunday HUC																																	
Deadman Creek (5/26)									23																								
O'Fallon Creek HUC																																	
Pennel Creek R1 (8/2)		46	18			2	55		21611																					76	30		
Pennel Creek R2 (7/14)			2				30		100					2							24										29		
Pennel Creek R3 (7/14)		1					2		30					1		10															2		
Redwater River HUC																																	
Redwater River R1 (8/25)					4	12			1	13	1		15				1				25		2	42		3				32	2		
Redwater River R2 (8/25)						3			2	4							12							157							18		
Redwater River R3 (8/25)						2		19	1	4				2			97		1					408		3					32		
Upper Little Missouri HUC (MT)																																	
Cottonwood Creek R2 (9/7)		1				28			129	15				2			4							71						3	5		

	Bigmouth Buffalo	Black bullhead	Brassy Minnow	Brook Stickleback	Channel Catfish	Common Carp	Creek Chub	Emerald Shiner	Fathead Minnow	Flathead Chub	Freshwater Drum	Golden Shiner	Goldeye	Green Sunfish	Iowa Darter	Lake Chub	Longnose Dace	Longnose Sucker	Northern Pike	Plains killifish	Plains Minnow	Pumpkinseed	River Carpsucker	Sand Shiner	Sauger	Shorthead Redhorse	Smallmouth bass	Stonecat	Walleye	Western Silvery Minnow	White Sucker	Yellow Bullhead	Yellow Perch

	Bigmouth Buffalo	Black bullhead	Brassy Minnow	Brook Stickleback	Channel Catfish	Common Carp	Creek Chub	Emerald Shiner	Fathead Minnow	Flathead Chub	Freshwater Drum	Golden Shiner	Goldeye	Green Sunfish	Iowa Darter	Lake Chub	Longnose Dace	Longnose Sucker	Northern Pike	Plains killifish	Plains Minnow	Pumpkinseed	River Carpsucker	Sand Shiner	Sauger	Shorthead Redhorse	Smallmouth bass	Stonecat	Walleye	Western Silvery Minnow	White Sucker	Yellow Bullhead	Yellow Perch
Little Beaver Creek R2 (8/31)		17				6			3					7	1				2									1					
Little Missouri River R3 (9/2)					15	1			2	1			24				7				42	2	7	1171		2		1			7		
S. Cottonwood Creek R1 (9/7)		8				23			128	55						35	14				126	16	7	171				2		78	65		
Clarks Fork Yellowstone HUC																																	
Bear Creek R1 (7/28)																3	9	15															
Middle Musselshell River HUC																																	
Willow Creek R1 (7/29)							12									9	4													53		
Shoshone River HUC																																	
Sage Creek R2 (7/28)									73							35																	
Upper Yellowstone River HUC																																	
Fly Creek R1 (7/29)										4														3							4		
Upper Little Missouri River HUC(ND)																																	
Big Gumbo Creek R1 (9/14)									87	1				16		22	7				431												
Kid Creek R1 (9/9)				260					239			74		10																	25		1
Little Missouri River R1 (9/8)					36				6	24			3				7						22	4	2	3		10		655	2		
Skull Creek R1 (9/15)		53		2		4	20		223	5		1	4	61	1	150	8				7			41				2			75		23

	Bigmouth Buffalo	Black bullhead	Brassy Minnow	Brook Stickleback	Channel Catfish	Common Carp	Creek Chub	Emerald Shiner	Fathead Minnow	Flathead Chub	Freshwater Drum	Golden Shiner	Goldeye	Green Sunfish	Iowa Darter	Lake Chub	Longnose Dace	Longnose Sucker	Northern Pike	Plains killifish	Plains Minnow	Pumpkinseed	River Carpsucker	Sand Shiner	Sauger	Shorthead Redhorse	Smallmouth bass	Stonecat	Walleye	Western Silvery Minnow	White Sucker	Yellow Bullhead	Yellow Perch

Appendix C. **Physical habitat characteristics of sites arranged alphabetically by HUC. Left and right bank depths were measured 5cm from the water's edge and length of sampling reach was always 300m. n=a particular metric was not measured. All measurements, except area, are the average of ten individual measurements.**

	Date	Wetted width (m)	Area (m^2)	Left bank depth (cm)	Center depth (cm)	Right bank depth (cm)
Big Muddy Creek HUC						
Big Muddy Creek R2	8/24/2010	19.1	5738.2	n	40.8	n
Fort Peck Reservoir HUC						
Big Dry Creek R1	7/19/2010	10	2989.1	4	31.7	5.5
Big Dry Creek R2	7/20/2010	6.2	1873.6	9.7	33.5	10.6
Big Dry Creek R3	7/21/2010	8.2	2457.3	12.9	52.2	11
Hart Creek R1	8/10/2010	1.3	378	6.8	17.3	10.1
Hell Creek R1	8/13/2010	2	591.8	20.3	72.1	21.7
South Fork Rock Creek R1	8/23/2010	1	297.3	9.9	24.2	12.8
Lower Musselshell HUC						
Calf Creek R1	8/11/2010	2.8	845.5	7.6	25	7.6
Calf Creek R2	8/11/2010	0.7	210	0.6	6.7	0.9
Lower Powder HUC						
Tenmile Creek R1	7/13/2010	3.5	1047	15.1	31.7	14
Tenmile Creek R2	7/7/2010	1.5	447.3	20.3	37.9	10.5
Lower Tongue HUC						
Pumpkin Creek R1	5/19/2010	5.4	1628.2	8.5	28.9	11.9
Pumpkin Creek R1	10/19/2010	3.1	928.6	5.5	70.4	5.4
Pumpkin Creek R2	5/21/2010	4.5	1336.4	24.6	65.6	37.9
Pumpkin Creek R2	10/19/2010	3.9	1156.4	16.2	98.2	14.3
Pumpkin Creek R3	5/19/2010	3.5	1063.6	14.7	90.5	23.2
Pumpkin Creek R3	10/20/2010	1.8	552.3	5	25.2	5.2
Pumpkin Creek R4	6/8/2010	4.5	1347.3	10.2	65	11.6
Pumpkin Creek R4	10/20/2010	4.3	1281.8	9.6	48.1	6.2
Lower Yellowstone HUC						
Cedar Creek R1	7/13/2010	4.1	1243.6	13.8	38.5	15.5
Cedar Creek R2	6/23/2010	4	1189.1	15.7	36.6	16.3
Cedar Creek R2	9/22/2010	3.5	1052.7	8.6	35.7	11.4

Cedar Creek R2a	7/1/2010	5.1	1527.3	31	45.7	24.3
Cedar Creek R2a	9/22/2010	4.6	1371.8	21.3	44.6	33.5
Cedar Creek R3	6/24/2010	3.4	1033.6	23.1	54.6	43.5
Cedar Creek R3	9/21/2010	3.2	970.9	15.5	48.7	23.3
Cedar Creek R4	6/28/2010	5.4	1628.2	11.6	31.3	7.8
Cedar Creek R4	9/21/2010	5.1	1521.8	9.1	40.5	8.3
Cedar Creek R5	9/20/2010	1.4	409.1	15	41.6	7.5
Cherry Creek R1a	6/16/2010	5.3	1581.8	1.9	6.3	1.7
Cherry Creek R1a	9/23/2010	7.3	2178	2.6	6.6	2.8
Cherry Creek R1b	6/22/2010	5.6	1693.6	9.1	13	3.5
Cherry Creek R1b	9/23/2010	4.6	1390.9	2.4	16.8	2.4
Cherry Creek R2	6/21/2010	4.9	1475.5	5.4	34.1	5.5
Lower Yellowstone-Sunday HUC						
Deadman Creek	5/26/2010	9.4	2816.2	0.4	1.6	0.2
O'Fallon Creek HUC						
Pennel Creek R1	8/2/2010	6	1800	9.6	63	8.5
Pennel Creek R2	7/14/2010	1.5	436.4	32.2	45.4	18.1
Pennel Creek R3	7/14/2010	2.1	643.6	16.7	51.8	12
Redwater River HUC						
Redwater River R1	8/25/2010	9.3	2784.5	2.9	21.7	3
Redwater River R2	8/25/2010	6.7	2012.7	11.7	30.5	4.8
Redwater River R3	8/25/2010	6.5	1944.5	7.3	24.5	2.3
Upper Little Missouri HUC						
Cottonwood Creek R2	9/7/2010	1.5	450	10.1	23.2	8.2
Little Beaver Creek R2	8/31/2010	7.3	2187.3	27.5	41.9	15.2
Little Missouri River R3	9/2/2010	11.3	3379.1	3.5	64.3	19.5
South Cottonwood Creek R1	9/7/2010	1.6	485.5	10.4	34.3	8.1
Clarks Fork Yellowstone HUC						
Bear Creek R1	7/28/2010	2.5	756.7	8.6	33.2	12.4
Middle Musselshell River HUC						
Willow Creek R1	7/29/2010	4.3	1298.2	8.8	25.8	7.3
Shoshone River HUC						

Sage Creek R2	7/28/2010	2.2	670.9	5.8	15.5	5.2
Upper Yellowstone River HUC						
Fly Creek R1	7/29/2010	5.1	1538.2	46.9	97.5	29.5
Upper Little Missouri River HUC						
Big Gumbo Creek R1	9/14/2010	1.4	422.7	1.5	7.3	2
Kid Creek R1	9/9/2010	3	902.7	11.5	27.8	10.5
Little Missouri River R1	9/8/2010	26.5	7953	11	41.4	10.6
Skull Creek R1	9/15/2010	3.5	1044.5	12.5	28.6	14.9

Appendix D. Water quality characteristics of sites arranged alphabetically by HUC. n=not sampled, due to technical difficulties.

	Date	Conductivity (µS/cm)	DO (% sat)	Air temp (F)	Water temp (C)	pH
Big Muddy Creek HUC						
Big Muddy Creek R2	8/24/2010	2810	68.3	n	20.8	n
Fort Peck Reservoir HUC						
Big Dry Creek R1	7/19/2010	2017	103.3	72	21.1	9
Big Dry Creek R2	7/20/2010	2067	73.7	70	18.1	9
Big Dry Creek R3	7/21/2010	2239	31.7	62	18.6	9
Hart Creek R1	8/10/2010	1092	53.9	89	25.7	9
Hell Creek R1	8/13/2010	1275	88.2	70	20.8	9
South Fork Rock Creek R1	8/23/2010	1674	24.9	58	18	n
Lower Musselshell HUC						
Calf Creek R1	8/11/2010	6840	48.6	98	28.8	9
Calf Creek R2	8/11/2010	1540	92.5	79	21.2	10
Lower Powder HUC						
Tenmile Creek R1	7/13/2010	45.3	90	94	26.5	9
Tenmile Creek R2	7/7/2010	1548	60	77	19.5	9
Lower Tongue HUC						
Pumpkin Creek R1	5/19/2010	2208	87.7	77	20.8	9
Pumpkin Creek R1	10/19/2010	3782	62.3	42	5.9	9
Pumpkin Creek R2	5/21/2010	1556	90	60	16.9	10
Pumpkin Creek R2	10/19/2010	3379	56.8	70	10.3	9
Pumpkin Creek R3	5/19/2010	3260	90.2	73	20.1	9

Pumpkin Creek R3	10/20/2010	1891	57.2	70	7.2	9
Pumpkin Creek R4	6/8/2010	3513	98.5	84	21.3	9
Pumpkin Creek R4	10/20/2010	2894	62.9	71	10.8	9
Lower Yellowstone HUC						
Cedar Creek R1	7/13/2010	4030	93.3	90	27.4	9
Cedar Creek R2	6/23/2010	1051	99.4	81	24	8
Cedar Creek R2						
Cedar Creek R2a	7/1/2010	2488	97.9	92	27	9
Cedar Creek R2a						
Cedar Creek R3	6/24/2010	1538	100.5	91	25.9	8
Cedar Creek R3						
Cedar Creek R4	6/28/2010	1127	94.1	94	26.5	8
Cedar Creek R4						
Cedar Creek R5	9/20/2010	3870	100.1	74	20.7	9
Cherry Creek R1a	6/16/2010	3828	48.9	73	18.9	9
Cherry Creek R1a						
Cherry Creek R1b	6/22/2010	4461	55.5	73	18	9
Cherry Creek R1b						
Cherry Creek R2	6/21/2010	4811	113.2	82	24.2	9
Lower Yellowstone-Sunday HUC						
Deadman Creek	5/26/2010	1450	105	76	10.9	9
O'Fallon Creek HUC						
Pennel Creek R1	8/2/2010	3782	65.1	90	26	9
Pennel Creek R2	7/14/2010	3249	96.4	74	21.4	9
Pennel Creek R3	7/14/2010	8230	77.3	71	19.3	8
Redwater River HUC						
Redwater River R1	8/25/2010	2007	51.6	n	14.9	n
Redwater River R2	8/25/2010	2511	53.7	n	20	n
Redwater River R3	8/25/2010	2929	58.8	n	23.1	n
Upper Little Missouri HUC						
Cottonwood Creek R2	9/7/2010	1290	36.5	66	18.7	9
Little Beaver Creek R2	8/31/2010	1150	41.6	67	15.5	9

Little Missouri River R3	9/2/2010	1930	42.7	68	17.1	9
South Cottonwood Creek R1	9/7/2010	1448	34.5	66	13	9
Clarks Fork Yellowstone HUC						
Bear Creek R1	7/28/2010	524	98.9	83	18.1	9
Middle Musselshell River HUC						
Willow Creek R1	7/29/2010	638	70.3	89	21.5	8
Shoshone River HUC						
Sage Creek R2	7/28/2010	641	103.7	72	19.3	9
Upper Yellowstone River HUC						
Fly Creek R1	7/29/2010	456	106.4	96	22.8	8
Upper Little Missouri River HUC						
Big Gumbo Creek R1	9/14/2010	6740	32.7	85	19.6	7
Kid Creek R1	9/9/2010	836	18.1	62	14.8	8
Little Missouri River R1	9/8/2010	1083	38.1	70	14.3	8
Skull Creek R1	9/15/2010	877	37	54	14	9